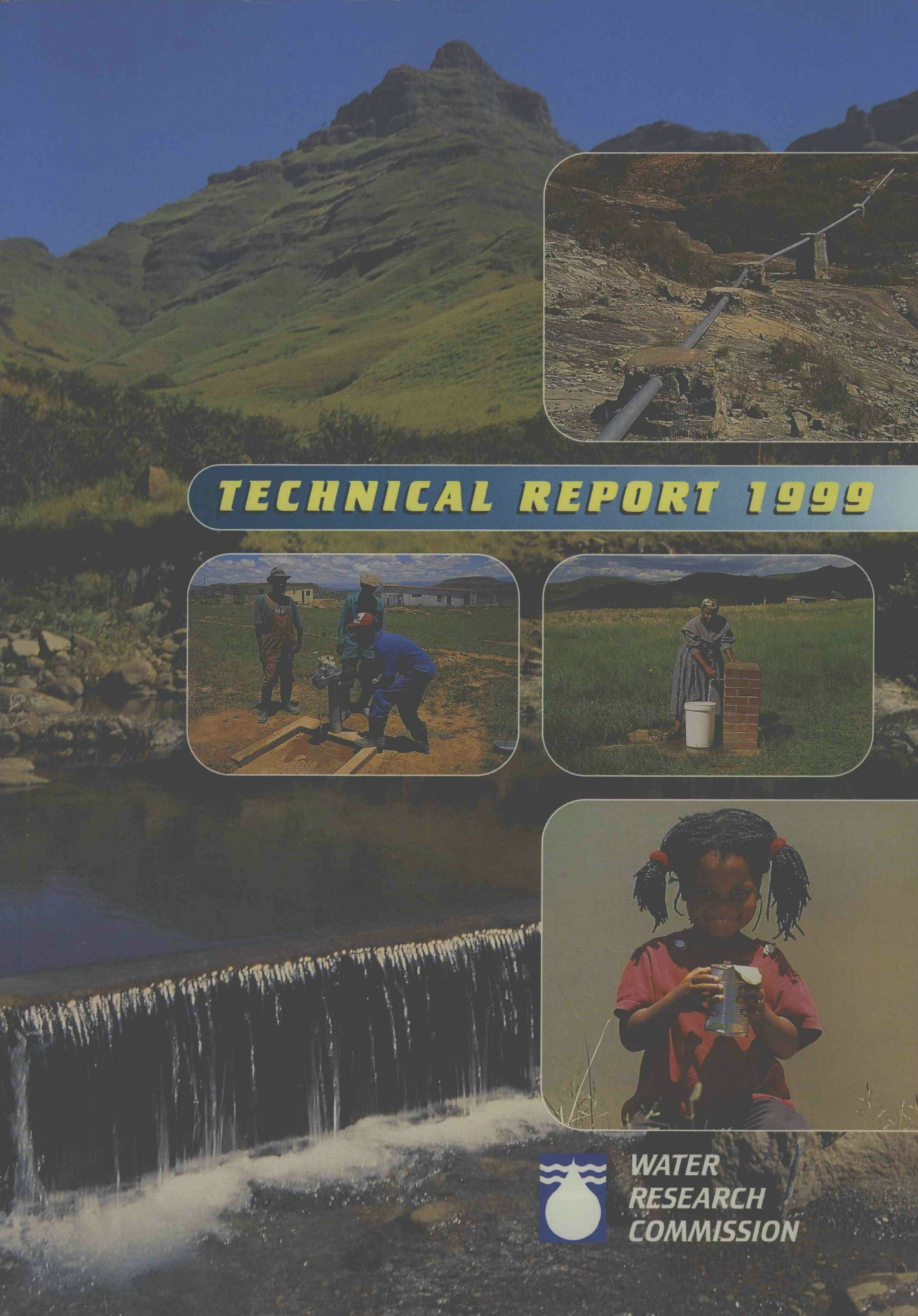

TECHNICAL REPORT 1999

WATER RESEARCH COMMISSION

1999 TECHNICAL REPORT

WATER RESEARCH COMMISSION

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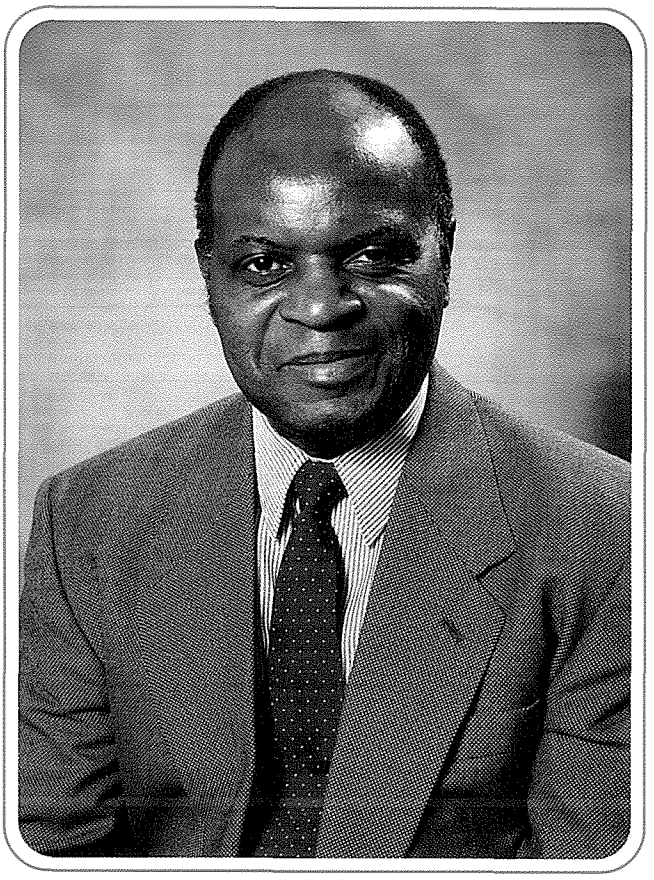

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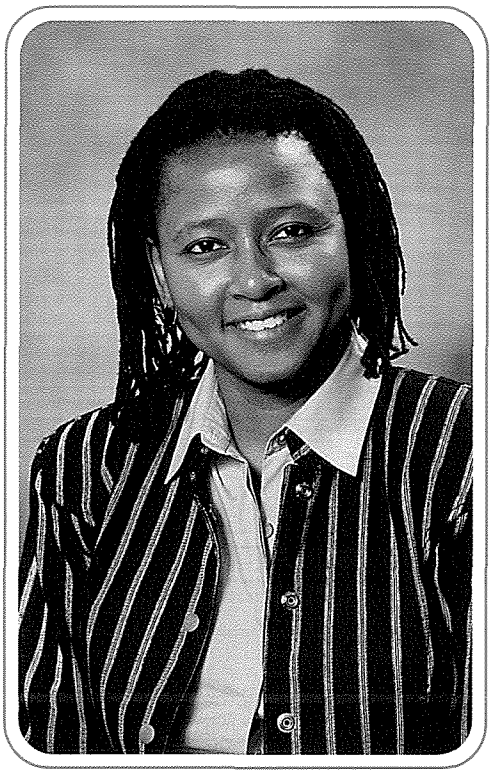

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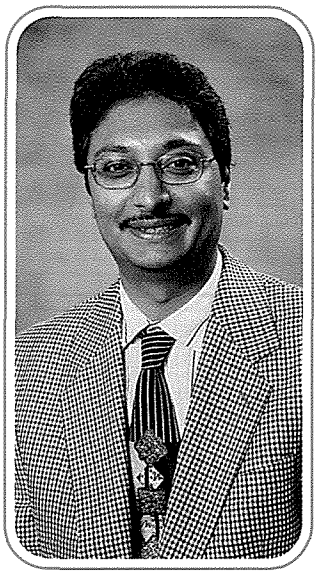

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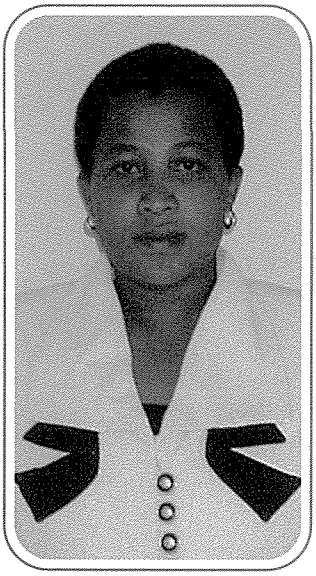
1999



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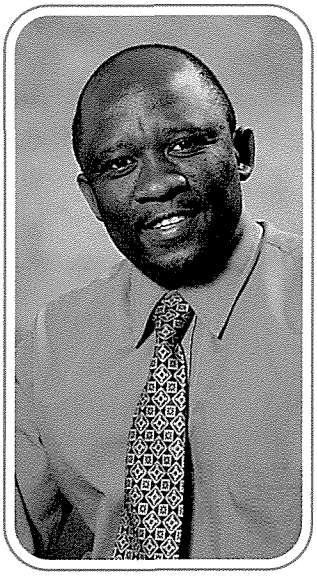

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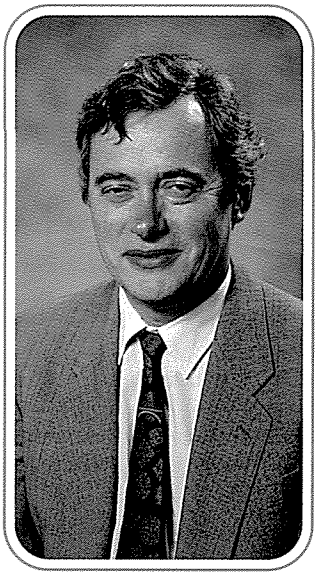

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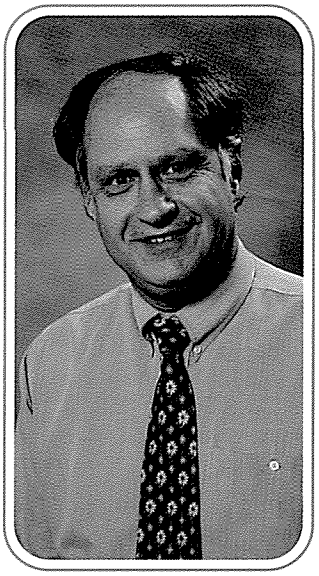

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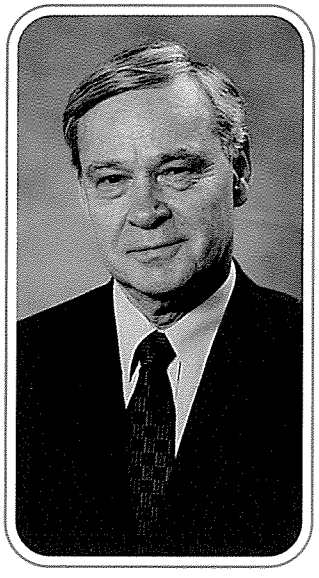
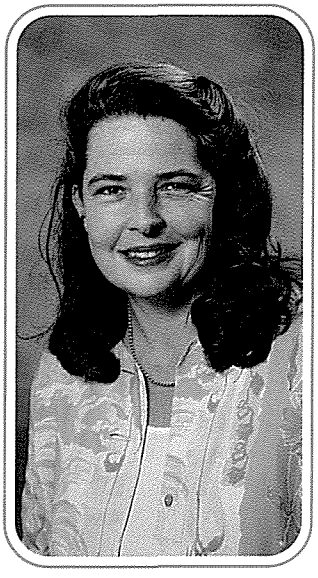


Mr PE Odendaal

Executive Director: WRC



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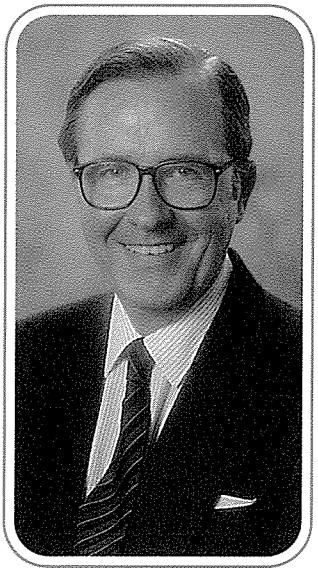

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Absent: Mr MN Nene

Nceduluntu Atech
Systems Inc., Empangeni

Professional

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Mr DS van der Merwe

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Deputy Executive Director

Dr GC Green

(Surface- and groundwater resources; water resource management; drinking water; water treatment technology; water pollution; mine water; hydroclimatology)

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Dr G Offringa
Mr GN Steenveld

Research managers

Mr HM du Plessis
Mr H Maaren
Mrs APM Oelofse
Dr IM Msibi
Mr K Pietersen

Administrative

Director: Administration

Mr JA Venter

Contents

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 1999 are indicated in Figure 1.

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.

From the figures it is evident that universities are involved in 51.59% of the total number of contracts. In 1999 the WRC financially supported 314 projects at a budgeted amount of R53 056 635. In addition to the direct funding of contractual research projects, the WRC also finances the Computing Centre for Water Research (CCWR), a research support service, and the development of the WATERLIT database.

Table 1

Research sector	Number of times involved	%
Universities	162	51.59
Consultants	69	21.97
CSIR	34	10.83
Water boards	16	5.1
ARC	13	4.14
Government departments	6	1.91
Other	3	0.96
Technikons	10	3.18
Local authorities	1	0.32
TOTAL	314	100

WRC Board reconstituted

The term of office of WRC Board members lapsed on 31 May 1999. After nominations for appointment had been invited through a press advertisement, the Minister of Water Affairs and Forestry appointed the following members to the Board:

Prof K Nyamapfene (Chairperson), Deputy Vice-Chancellor, Vista University. He takes over from Dr CT Johnson, who remains a member of the Board.

Dr N Tsengwa (Vice-Chairperson), CSIR Corporate

Ms ER Hay, Umvoto Africa cc.

Dr CT Johnson, President, Agricultural Research Council

Dr HC Kasan, General Manager, Scientific Services, Rand Water

Ms MM Molala, Matshipsana Consultants

Dr MB Molope, Chief Director, National Department of Agriculture

Mr AM Muller, Director-General, Department of Water Affairs and Forestry

Mr RJC Nay, Johannesburg Eastern MLC

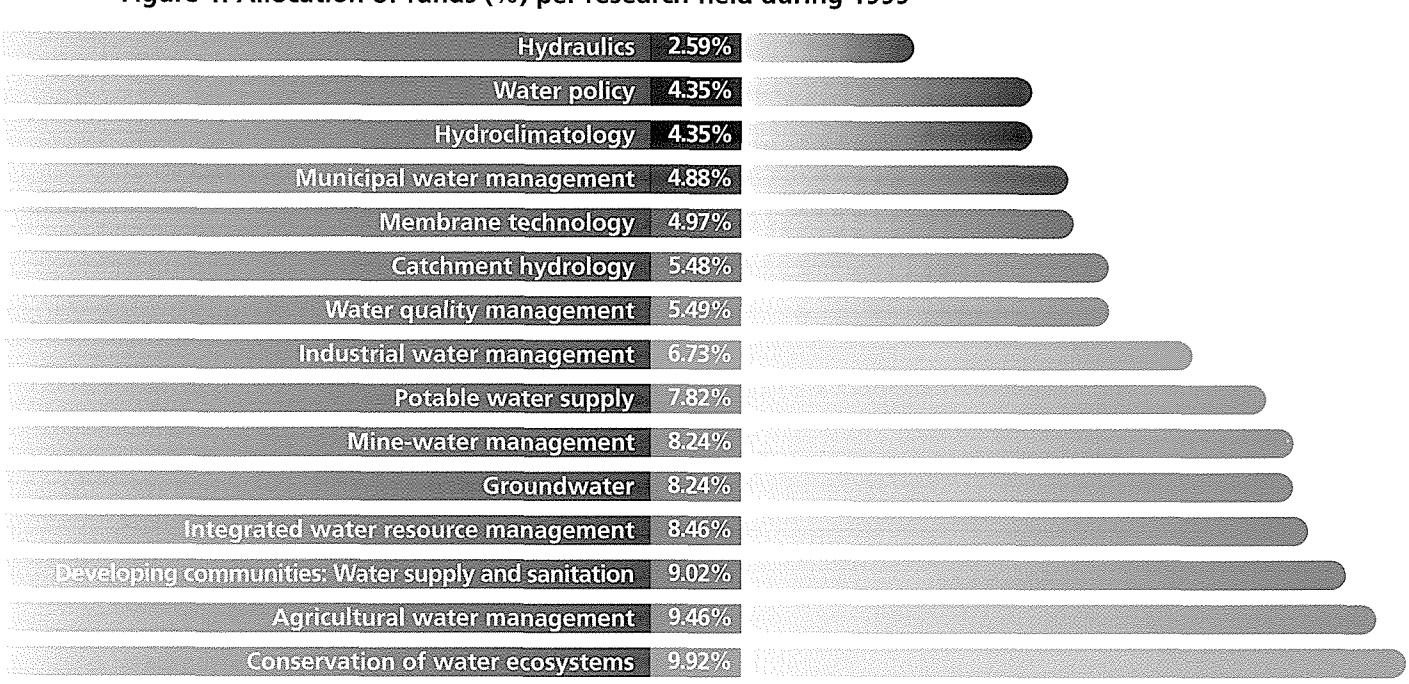
Mr MN Nene, Nceduluntu Atech Systems Inc.

Mr PE Odendaal, Executive Director, Water Research Commission

Dr CG Palmer, Institute for Water Research, Rhodes University

Prof PD Tyson, Director, Climatology Research Group, University of the Witwatersrand

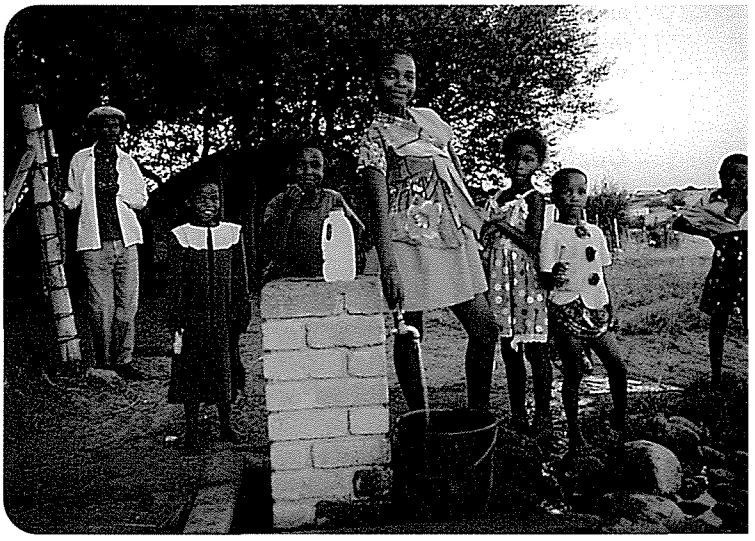
Figure 1: Allocation of funds (%) per research field during 1999



Community management of water supply schemes

Very interesting and important findings emanated from a WRC-funded study entitled **Case Study of a management system for rural water supply: Matatiele district**. The study emphasised the important role that community management can play in the sustainabilty of rural water supply projects. Using participatory techniques, the research teams captured the views of different stakeholders regarding community management, using projects in the Matatiele district as the basis. These projects include Presidential Lead Projects, projects implemented by NGOs and the Department of Water Affairs and Forestry (DWAF). The study indicated that the Water Services Act provides an appropriate framework for the management of rural water supply, that community-based water service providers are generally a most suitable option for stand-alone rural water schemes, and that cost-recovery levels need to be improved to sustain projects.

In complementing these findings, the research team developed various institutional models that would assist water service authorities in developing and supporting management arrangements with community water service providers. The water service authority in the Matatiele district has already benefited from the study, and will implement some of the study's recommendations.



Community managed stand-pipe scheme, Matatiele district.

Conference on appropriate practice in water supply and sanitation

Meeting water supply and sanitation backlogs has been one of the important activities of the new Government since 1995. It is also one of the most significant and challenging activities in the water sector. Extensive and pioneering work had been undertaken over the last few years, and it was deemed necessary to bring together practitioners engaged in this field, to share and disseminate their experience. This prompted the WRC, in association with DWAF, Mvula Trust, and the South African Institute of Civil Engineers to arrange an Appropriate Practice Conference in East London, March 1999.

The conference was attended by more than 550 participants representing local authorities, Government, NGOs, water boards, consultants and policy makers. As intended, the conference focused largely on the sharing of experience. It was possible to generate three conference outputs through a synthesis of the conference proceedings:

- Best practices document – Mvula Trust
- Policy implications document – DWAF
- Research needs and requirements documents – WRC

The intention with these outputs is to inform those active in the field of water supply and sanitation of areas of strength and of areas which need strengthening.

Simple test for assessing microbial water quality in small community water supplies

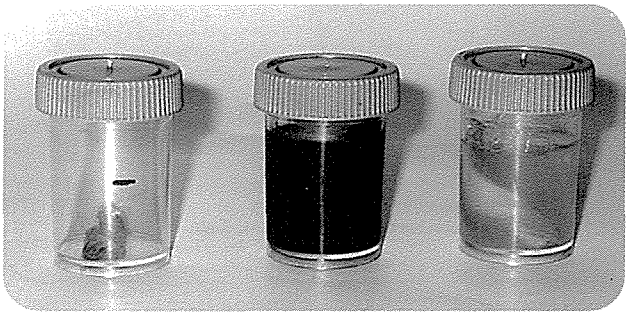
The CSIR, through its Division of Water, Environment and Forestry Technology, was contracted to test a novel H_2S strip method for its suitability as a water quality indicator. The H_2S strip test causes the contaminated water to turn black, thus providing a very effective visual mechanism for illustrating bacterial contamination of water supplies. The study showed that the H_2S strip test is very sensitive, being able to detect as few as two bacterial cells per sample in both pure and mixed cultures. The H_2S strip test is a simple, easy to use 'on-site' field test which can be used by rural communities to monitor the microbial quality of their water supply sources.

Fluorides and nitrates in rural water supplies

The WRC sponsored a two-day workshop on fluorides and nitrates in rural water supplies. The workshop was held in Mmabatho, 9 to10 March 1999. This well-attended workshop focused on the following issues:

- The extent of fluoride and nitrate problems in rural water supplies
- The health effects of fluorides and nitrates in drinking water
- Processes and techniques for the removal of fluorides and nitrates from water.

The first day consisted of presentations by various researchers and specialists in the field to establish the current status. During the second day the main focus was on group discussions towards the formulation of a strategy for a way forward



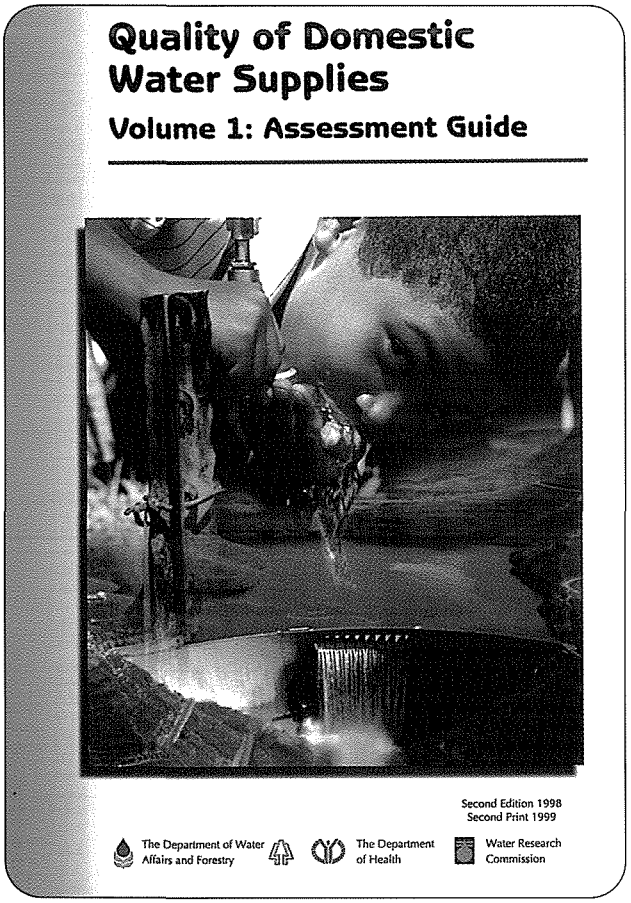
Novel H_2S strip test to assess microbial water quality in small community water supplies.

and establishing urgent research needs. One of the major outputs was the stimulation of research interest in this area, which has already resulted in the receipt of various research proposals.

Quality of Domestic Water Supplies – Volume 1: Assessment Guide

Volume 1: Assessment Guide, the first of a 5-volume series entitled *Quality of Domestic Water Supplies*, was jointly launched by the Minister of Health, Dr Nkosazana Zuma and the Minister of Water Affairs and Forestry, Prof Kader Asmal, during a press conference in Cape Town, February 1999. The Guide is the result of a joint initiative by the WRC, DWAF and the Department of Health.

The guide is in such demand that before the end of March, the first 4 000 copies had all been distributed and are in use at various levels of the South African population. Another 10 000 copies were printed of which 8 000 will, at the request of the then Minister of Water Affairs and Forestry, Prof Kader Asmal, be distributed to all high schools in the country. The Project Team was recently nominated for and subsequently awarded the South African Institution of Civil Engineers 1999 Water Engineering Award for its creative approach to a document of supreme importance to the health and well-being of all South Africans.



Quality of Domestic Water Supplies. Volume 1: Assessment Guide, awarded the SA Institution of Civil Engineers 1999 Water Engineering Award for its creative approach to a document.

Health-related research plan

The health-related research funded by the WRC is currently not integrated within a strategic plan. Experience with project proposals received during the previous years is that the health-related research proposals are lodged in any one of a number of research fields. Enquiries from researchers during the research proposal phase also made it clear that there are uncertainties concerning research needs.

It was, therefore, decided to develop a generic model for the health-related water research field. It is intended that the model should address research needs and provide guidance to the spectrum of users and researchers. Thereafter, specific objectives will be addressed through well-structured, cohesive, and easily updatable programmes. This will ensure that the ever-changing demands of user groups can be accommodated and specific needs identified in a pro-active way.

The first phase in the process to integrate health-related water research and to develop a generic model, took place on 5 and 6 October 1999.

Some of the specific research programmes of the generic model will be developed in parallel, in order to have these in place before the submission of research proposals in 2000. For instance, the first steps towards the consolidation of research on algae and endocrine disrupters into programmes, have already taken place by way of a special workshop. The WRC invited Dr Ian Falconer, a well-known Australian researcher in both fields, to the workshop. The research plans on algae which had recently been developed in Australia were discussed in order to identify similarities in the needs in South Africa and Australia, as well as possible co-operation.

A second phase workshop for development of the generic model is planned for January 2000, during which the programmes will be discussed and formalised.

Enhanced coagulation for the removal of organics in potable water treatment

Researchers at Umgeni Water found that removal of organic matter from water, using properly executed enhanced coagulation, was comparable or even better than those achieved with the more advanced treatment technology involving ozonation and granular activated carbon.

In general, conventional coagulation is identified with optimal turbidity removal, using coagulant alone, while enhanced coagulation is defined by the conditions that lead to optimal removal of organic matter or disinfection by-products. It was found that inorganic coagulants such as ferric chloride and alum were generally better than polymeric coagulants for the removal of natural organic matter, using enhanced coagulation. Using ferric chloride and alum for enhanced coagulation, it was possible to obtain removals of up to 40% in trihalomethane formation potential, up to 60% in total and dissolved organic carbon, between 70% and 90% in biodegradable dissolved organic carbon and between 70 and 90% in UV absorbance. Enhanced coagulation was also very effective for colour reduction and removal of algal cells, although not effective for removing micro-pollutants such as herbicides and taste and odour.

Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse

The CSIR's Division of Water, Environment and Forestry Technology, in collaboration with Enviro Options, completed a WRC-funded study to determine the viability of disposal of septic tank and pit latrine sludges through composting with municipal refuse. The study showed that composting of pit latrine and septic tank sludges with domestic refuse was a viable method for the disposal and recovery of useful products from these wastes. Co-composting served as both an environmentally friendly disposal method, as well as a method for recycling waste for useful purposes.

Shallow sewerage

The challenges in meeting sanitation backlogs in the country are many. In this context, one of the priority research areas identified is "intermediate sewerage technology". In meeting this need, the WRC initiated a desk study to assess – from a financial, technical and institutional perspective – the feasibility of applying shallow/simplified sewerage technology in South Africa. This concept, better known as the Brazilian Condominial System, has been extensively and successfully used in a number of developing areas in the world. In places such as Pakistan and Ghana, it is becoming a norm for sewerage provision.

The technology consists of relaxing some of the technical and construction requirements of conventional sewerage, resulting in smaller diameter pipes that are laid at shallow depths and flat gradients, away from street loads. The technology offers and requires community involvement in construction, operation and maintenance. Other advantages include materials saving, reduced water requirements and simple construction techniques. The technology could make water-borne sewerage an affordable option to many.

Findings from the study indicate that shallow sewer systems provide a viable intermediate sanitation alternative, with a total cost between that for VIPs and conventional sewerage. They may be preferable to VIPs in denser (greater than 35 dwellings/ha) formal and informal peri-urban settlements.

It provides a less expensive alternative to conventional sewerage in low- to medium-income formal urban residential areas. The capital costs of backyard shallow sewers are generally about 70% of the cost of conventional sewerage, dropping to as much as 50% in adverse geo-technical conditions. Operation costs with delegated management arrangements, is about 60% of that of conventional sewerage. Capital costs are 20% more than VIPs at medium densities (30 dwellings/ha), and about the same cost at high densities (greater than 50 dwellings/ha). However, operating costs are four times higher.

One of the main recommendations emanating from the study was that a pilot study be undertaken to evaluate the technology. Developments are underway in this regard, where Durban Metro has indicated interest in testing the technology, in partnership with Water Supply and Sanitation Africa, NaSCO (National Sanitation Committee) and the WRC. Successful application of the technology will herald a solution for the sanitation sector, as it will add a water-borne option to the basket of affordable sanitation technologies available to communities.

Guidelines for Operation and Design of Sewage Sludge Drying Beds

As a first for South Africa, much needed *Guidelines for Operation and Design of Sewage Sludge Drying Beds* have been published by the WRC. Although it was apparent that South African conditions are most ideally suited to the use of this sludge dewatering method, designers and operators needed guidance on the optimal use of the method. The guidelines are intended to meet this need.

The guidelines provide the user with fundamental principles to assist in the design and operation of sludge drying beds, including models for the physical design and detailing of the beds. Guidelines are also provided for the optimisation of drying bed operation.

Award for best paper at 6th International Landfill Symposium, Sardinia

A paper entitled *Graded Landfilling Standards – Taking Account of Waste Composition*, by AB Fourie, J Shamrock and GE Blight of the Department of Civil Engineering, University of the Witwatersrand, was awarded the Curi Award for best paper at the 6th International Landfill Symposium, Sardinia, 1997. The paper captures findings of a WRC-funded project entitled **Graded standards for landfilling in South Africa: Establishing appropriate affordable standards for disadvantaged communities**. Experiments done during the study, indicated that the quality of leachate generated from a low- and a middle-income community respectively, showed very little difference. This finding indicates that it may be possible to relax standards when low putrescible content waste is landfilled.

Demand management approach towards industrial water management

A demand management approach towards industrial water management is being promoted by WRC-funded research. New tools being refined in this context include:

- Pinch analysis (a mass balance technique for minimising the overall quantity of water used and pollutants generated in an inter-related series of industrial processes).
- Waste minimisation clubs.Two very successful clubs have already been launched and a methodology for sustaining this is currently being investigated.
- Cleaner production and clean technology. Industries currently receiving attention include pulp-and-paper processing, oil refining, textile processing, metal finishing and leather tanning.
- Life-cycle assessments for holistically and objectively analysing the total environmental impacts of alternative processes, either for production purposes, or for waste treatment.

Membrane strategic research plan reviewed

The *Strategic Plan for Water-Related Membrane Research in South Africa* has recently undergone its second review since its first release in 1994. The review was done as part of a workshop of the Membrane Technical Division of the Water Institute of Southern Africa, which was held from 26 to 29 September 1999 in the Drakensberg. Stakeholders in

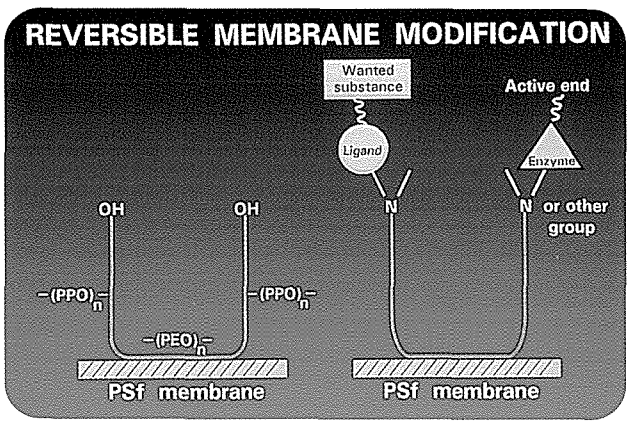
membrane research from both academia and industry took part in the review, which was facilitated by the Research Manager for Membrane Technology of the WRC. The current research goal structure was not changed fundamentally, but some important modifications and additions were made. In the same fashion, the list of research and development issues, i.e. more on a project level, was also reviewed and added to. These research and development issues have now been incorporated into the main *Strategic Plan for Water-Related Membrane Research*. This updated Strategic Plan can be accessed on the WRC's website at http://www.wrc.org.za.

New affinity separation membrane processes developed

An innovative new technology was developed under a recently completed WRC project: **Development, fabrication and production protocol for capillary and hollow fibre membranes and special modules for the low-cost treatment of contaminated water**. The inventors are Prof P Swart, Department of Biochemistry, and Dr EP Jacobs, Institute for Polymer Research, both from the University of Stellenbosch. The invention was patented by the WRC.

This innovation entails the non-chemical binding of the "foot" of a long-chain substance to the surface of an ultrafiltration membrane. The two "arms" of this molecule are hydrophilic and swing freely in the water phase. A carefully selected ligand (a chemical substance which is highly selective in binding specific compounds) is then attached to the active end of each of these "arms". The ligand is chosen such that it is able to "catch" certain high-valued substances from the effluent flowing through or across the membrane. At the same time the hydrophilic long-chained molecule prevents fouling of the membrane. The concept has been proven in the laboratory by selectively removing high-value bovine serum albumin while clarifying abattoir effluent.

The implication of this innovation is that various high-value products can be harvested while treating either industrial or municipal effluents, thereby off-setting the relatively expensive membrane costs, or even generating a profit. The concept will be further developed in a new project to commence in 2000. A further suggested application of the technology is the concentration and analysis of low-concentration components in surface or drinking water, such as oestrogen or the oestrogen-mimicking compounds.



The principle of the affinity separation membrane process.

Launch of software for water loss management

Two important WRC outputs in the field of water loss management, SANFLOW (the South African Nightflow Analysis Model) and WAR (Water Audit Reporting Model), were launched during the year.

The models emanate from years of research in this important field, with the aim of convincing practitioners and communities of the need for efficient water use in a water-stressed country like South Africa. This drive culminated in the launch of the SABS Code of Practice 0306, *The Management of Potable Water in Distribution Systems*, in September 1999. The Code builds on a series of WRC research outputs. The standard covers the managerial, administrative and operational functions required by water services authorities, in order to account for potable water within distribution systems and to apply corrective actions to reduce and control unaccounted-for water (UAW). The WAR software is exclusively made available with the Code and is a simple tool that will assist users in meeting the requirements of the Code. A water audit is now a requirement in terms of the Water Services Act, 1997 (Act 108 of 1997). WAR generates a standardised report for users' water audit.

Complementing the water auditing process is the tool SANFLOW, which is user-friendly software designed to help water suppliers to determine the level of leakage in a particular zone metered area (ZMA), from the analysis of recorded minimum nightflows. It is a very simple and straightforward model requiring minimal data and will help water suppliers to identify key problem zones quickly and effectively.

Because of the importance placed on the UAW control and efficient use of water – also emphasised by the new water legislation – many new initiatives have been embarked on during the year to assist water suppliers in addressing these issues. These include development of tools for water demand management and planning, economics of leakage management, and pressure management.

National productivity award for financial model emanating from WRC research

The computerised financial model for local authorities, called the Combined Services Model (CSM), earned the Development Bank of Southern Africa (DBSA) a gold award in the 1999 National Productivity Awards competition. The CSM emanates from a WRC-financed study undertaken in 1992 by Palmer Development, involving an institutional and financial review of water supply and sanitation services in the urban areas of South Africa. The financial model developed from this study was extended by the DBSA to include other services undertaken by local authorities. The model was extensively tested by Durban Metro Water Services. DBSA was instrumental in popularising and promoting the use of the model.

In this partnership approach between WRC, Durban Metro and DBSA, the model was upgraded to accommodate new legislative requirements for services provision, culminating in the Water Supply Services Model and the Sanitation Services Model (which are components of the CSM). The concept of the model stimulated the development of similar models for other tiers of government. The model assists local government to assess the level of services to be provided to their customers and the setting of tariffs for these services.

In using the model, DBSA staff were able to increase funding to projects by up to 80% within a period of four years, as well as turn-around time in approving a project. The model was applied widely to test the infrastructure plans of up to 70 municipalities and in the process building the capacity of local authorities, as well improving the understanding of DBSA staff of problems at local authority level. The success of the models and the improvements in productivity through their use were clearly demonstrated.

Research programme on the surface water Ecological Reserve

The inclusion of an Ecological Reserve in the National Water Act means that implementation strategies and methodologies need to be established on a sound scientific base. In consultation with the research community and DWAF, the framework for a research programme to address these needs was established. The programme will focus on capacity-building and on developing, refining and verifying methods to aid in the implementation of the Ecological Reserve.

Rapid biological assessment of water quality impacts in streams and rivers

World-wide it has long been known that the composition of communities of aquatic organisms is responsive to the nature of the physical and chemical environment in which they live. Many attempts have been made to use this fact in detecting water pollution and managing water quality. Most of these attempts have been unsuccessful, mainly on account of the fact that they are unaffordable in terms of time and the highly skilled manpower required to apply the biological knowledge.

In England a simplified method of summarising the meaning of the composition of the aquatic invertebrate community has been developed. The method was adapted to South African conditions by Dr FM Chutter, and applied widely to confirm its applicability. It has been re-named SASS (South African Scoring System).

After a number of iterations, Version 4 (SASS4) has been accepted as the standard method. The method is based on the fact that certain invertebrate taxa are more sensitive to environmental change than others. These more sensitive taxa are scored at a higher value than the tolerant species. Samples are taken in a standard way, and the invertebrates collected in the sample are then scored, with higher scores indicating higher water quality.

The method has been widely adopted in South Africa, and now forms the basis of the River Health Programme, a programme designed to monitor the ecological health status of South African rivers.

The building-block methodology for instream flow assessment

In response to a general deterioration in the condition of South African rivers, largely due to the increasing manipulation of flow regimes during the mid to late 1980s, DWAF, together with the WRC, supported the development of expertise in the field of instream flow assessments.

Researchers at the University of Cape Town successfully developed the building-block methodology to determine instream flow requirements (IFR) for maintaining ecological processes. Existing methods could not be used in South Africa as they relied on long and detailed data sets which are non-existent in this country. The building-block method will, in data-poor situations, give an estimate of the flow regime needed to maintain ecological processes.

The requirement for the ecological reserve in the National Water Act (Act 36 of 1998) requires that the reserve be determined for all significant water resources, and the building-block method has been adopted to determine the quantity component of the reserve. It has been widely used by DWAF, and this implementation of the method contributed substantially to its further development. The method has also been used in Australia where it has worked well, even though the rivers have a different character. Using this method as a basis, the IFR of the rivers in Lesotho has been assessed ahead of the construction of Phase IB of the Lesotho Highlands Development Scheme.

Workshop on algal toxins

The incidence of blue-green algal toxins appears to be on the increase in South Africa. However, this is difficult to quantify, as there is no co-ordination of information on the subject. Such co-ordination is a first step in the development of a national strategy for managing the problem.

During a two-day workshop, three aspects were addressed:

- The international perspective on the problem
- The South African perspective
- The limnological background to the problem and the impact on human and animal health.

Professor G Codd from the UK, a scientist with broad international experience, was the guest speaker for providing an international perspective, and also addressed the workshop on the various facets of detecting and monitoring the toxins within a co-ordinated programme.

Further sessions and discussions focused on the design of a programme for the co-ordination of data collection in South Africa, analytical methods, experience in running monitoring programmes, and the establishment of a central facility to store information. The workshop was attended by some 70 people from 1st and 3rd tier government, water boards, medical and veterinary researchers, limnologists and laboratory equipment suppliers.

During this workshop it was decided to constitute a Toxic Algal Forum to better co-ordinate a thrust for managing the problem.

Development of a framework for a research programme on eutrophication in South Africa

Eutrophication remains one of the major water quality problems of South Africa. Although extensive studies were conducted more than a decade ago, relatively little research, capacity building, or reporting on the status of the problem, or the effectiveness of management policies took place during the past 10 years. The WRC has commissioned a consultancy to develop a framework for eutrophication research that can be used to guide future research support and capacity development. This will be achieved by:

- Conducting an international scan of countries and organisations to establish the most recent management and policy

approaches and research that are in position to support these approaches
- Establish the concerns and opinions of local stakeholders and specialists
- Proposing a framework for eutrophication research for debate and modification at a workshop of key local stakeholders and specialists.

A framework for implementing non-point source directed measures under the National Water Act

Under the National Water Act, DWAF is authorised to implement source-directed controls for the management of both point and non-point source pollution, in order to achieve a desired level of resource protection. DWAF will develop appropriate tools in the form of guidelines and procedures to facilitate the implementation of such source-directed measures.

The WRC undertook a consultancy to examine a number of considerations related to the implementation process for non-point sources which had to be dealt with in addition to those covered in the *Guide to Non-point Source Assessment to Support Water Quality Management of Surface Water Resources in South Africa* (which is being prepared as part of a current WRC project). Considerations included, *inter alia*, the requisite structured linkages between resource and source-directed measures and the process of catchment management, and the role of national standards for land-use management practice. The framework which has been prepared should make it possible for DWAF to develop a set of guidelines/procedures for non-point source pollution and initiate the national non-point source management strategy.

Water quality management of South Africa's major port-catchment systems

Over the last decade the harbours along South Africa's coastline have become of increasing importance as recreational, ecotourism and general commercial areas. As a result they and their water quality are receiving increasingly high-profile public exposure. Harbours are more at risk of being polluted than the rest of the marine environment, since they are the receiving water bodies from adjoining urban and industrial areas which are mostly highly developed, with relatively poor water quality. A recently completed study of the water quality management in catchments of South African harbours:
- Evaluates the situation in South African harbours with water pollution management in three international ports
- Describes each of the six major South African ports and their catchment areas, gives an outline of their current environmental and water quality problems, how these are managed and records the scientific knowledge on each system
- Discusses and compares the general status of water pollution management for the ports and their associated catchment systems
- Lists actions which are required to improve the situation.

The development of a philosophy and methodology for the implementation of "the polluter pays" principle

Experience in many countries and earlier research by the WRC indicated that the traditional command-and-control (CAC) approach to regulate water pollution often fails to provide cost-effective solutions for water quality management. Economics-based measures were proposed to achieve the same environmental benefits with simpler administration and at lower cost. A WRC-initiated project investigated the philosophy behind, and the implementation of the "polluter pays" principle (PPP) for pollution control under South African conditions. The philosophy underlying the PPP was found to be both ethical and economically sound. Internationally the trend was found to combine CAC-based systems with PP-based pollution charge systems.

The Witbank Dam catchment and the pollutant sulphate were selected for a theoretical case study of pollution charges. A charge system with cost covering and incentive components (consisting of an administrative charge, a waste load charge and a non-compliance charge) was designed and tested on data from the Witbank Dam catchment. It was concluded that pollution charges are a viable water quality management tool for implementation in South Africa and that it should be implemented in a phased approach.

Protocols for assessing groundwater pollution impacts

Although the vulnerability of soils and aquifers to pollution has been studied in South Africa, the question of risk associated with various land-use practices has received little attention. There is a need to consolidate local research with the much larger body of research done overseas. Research can then be directed in a strategic manner towards the most desirable objectives.

A project was started in 1999 to formulate a research strategy for developing protocols to assess groundwater pollution deriving from land-use management practices. Land-use and groundwater contamination are closely linked, which brings land-use planning in focus as a means of preventing groundwater contamination. The project aims to:
- Summarise the current status of methodologies for determining groundwater pollution impacts from anthropogenic activities
- Summarise current approaches used in South Africa and identify limitations
- Define a suitable methodology and formulate a research strategy.

The use of saline water for irrigation purposes

DWAF endeavours to provide irrigators with water of a quality which should not affect crop production negatively. In setting salinity targets to which irrigation water should comply, agriculturists mostly rely on research findings from abroad. A project was undertaken to test the validity of irrigation water salinity criteria used by DWAF to guide their management of water quality in the Breede River. A 15-year old experimental vineyard in Robertson was irrigated over a 5-year period with six water qualities increasing in salinity from 25 to 500 mS/m.

The first full effect of the salinity treatments on yield and berry growth was recorded in the third season. A yield decrease of 60% was observed at the 500 mS/m salinity level. The interpretation of yield data was complicated by the fact that plant vigour and size were key determinants which influenced the response of grapes to salinity. The results of the study indicate that grapevines are more sensitive to salinity than previously accepted. The threshold salinity of 150 mS/m reported in the USA based on vegetative growth is too high. This investigation's results are more in line with a threshold value of 100 mS/m reported in Australia.

Impact of agricultural practices on groundwater quality

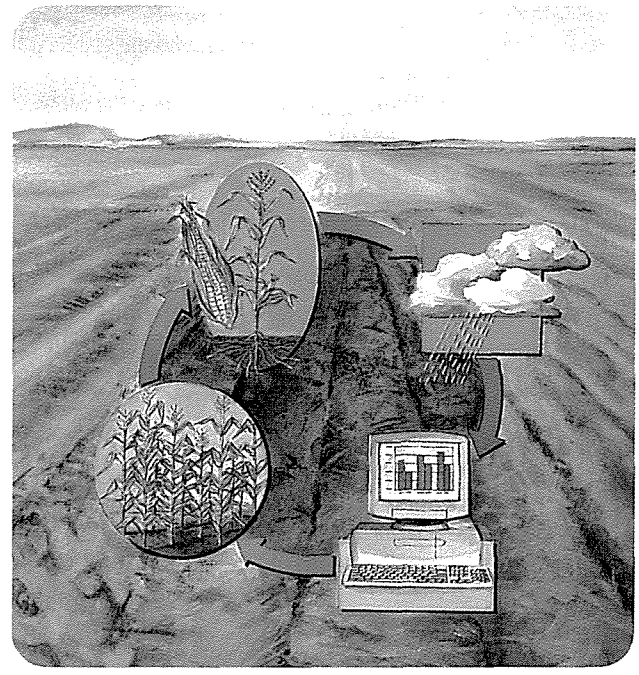
It is recognised world-wide that the agricultural sector contributes to diffuse pollution. Problems derive from irrigation practices, animal feedlots and the use of fertilisers, pesticides and herbicides. The impact of certain agricultural activities on groundwater quality was studied by researchers from the CSIR, University of Stellenbosch and University of Pretoria. The activities investigated were: intensive animal husbandry (IAH); use of sewage sludge as a fertiliser; use of inorganic fertilisers; irrigation; and pesticide application.

Groundwater quality was affected at all field sites with shallow, unconfined or semi-confined conditions. Nitrate was the most common agricultural contaminant evident in the groundwater sampled. Nitrate distribution and isotopic analysis of NO_3-N indicated that the most important sources were sludge, manure and soil biota. Elevated levels of dissolved organic carbon (DOC) were associated with sludge application and IAH. Potassium, orthophosphate and microbiological indicators of faecal pollution manifested in groundwater as a result of IAH practices.

A handbook illustrating good farming practices is being prepared. The handbook will give an introduction to groundwater, its occurrence, vulnerability, and the implications of deterioration in groundwater quality. Details of good farming practices to minimise contamination will be included.

Computerised tool for water management in rainfed agriculture

Over a period of 22 years, the WRC has funded several research projects at the Department of Soil Science, University of the Orange Free State. This has now culminated in a

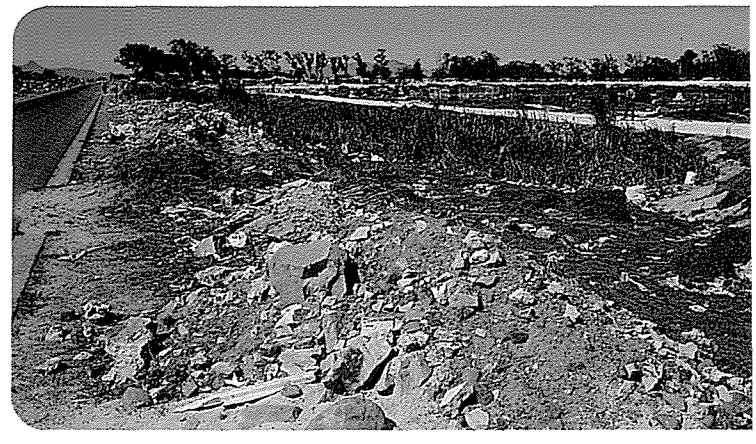


Use of computer models for agricultural water management at ecotope level.

consolidated report, under the leadership of Prof ATP Bennie, entitled *Use of Computer Models for Agricultural Water Management at Ecotope Level*. The report integrates information on the water balance for agricultural land in the semi-arid regions of South Africa.

The research focused on the need for a practical computer program, that can be run by farmers or agricultural advisers, for specific fields on a farm. Procedures were developed to estimate the evaporation of water from the soil surface, runoff, water uptake by crops at specific target or actual yields, and water loss by drainage below the deepest roots. Applying these procedures requires information that is readily available like soil depth, texture, rainfall, an estimation of soil wetness and target or actual yield. The amount of rain stored in the soil from harvesting of the previous crop, to planting of the present crop can be calculated. This information, in conjunction with an input of the expected precipitation, estimates

Uncontrolled land-use activities may result in groundwater pollution.



the obtainable yield. This can therefore serve as an aid to the farmer in making decisions, based on the economic viability and risk involved, on whether to plant or not.

The separate estimation procedures, for each of the components of the soil-water balance, were linked in a single computer program. This software package is available to individual farmers and agricultural advisers under the title SWAMP (Soil Water Management Programme). During 1999 the computer program was upgraded within the Windows environment and can be obtained directly from the Department of Soil Science, University of the Orange Free State.

International expert on decision models for water management visits South Africa

Dr Norman Dudley, Honorary Research Fellow at the Centre for Water Policy Research, University of New England, Australia, was a visiting professor in die Department of Agricultural Economics, University of the Orange Free State (UOFS) during the second semester of 1999. He is an authority on computer-based multi-stage decision models for economic problems in which uncertainty is paramount. The main aim of his visit was to present lectures and courses to various audiences on capacity sharing and stochastic dynamic programming. Dr Dudley was accompanied by his wife, who assisted in the specialised tutoring required. A second aim was to transfer technology on his research expertise to researchers. The visit was sponsored by the WRC, the NRF and the UOFS.

Dr Dudley also presented seminars on his research to the CSIR, University of Pretoria, University of Lesotho, University of Natal and the Institute for Groundwater Studies at UOFS. Dr Dudley invited Dr Helmut Lang from the German Ministry of Economic Co-operation and Development stationed in Zimbabwe, to visit the UOFS for discussions on suitable institutional arrangements for water management in Zimbabwe.

Community participation in natural resource management

When the WRC made funding available to the Farmer Support Group, University of Natal, for the development of a framework for community participation in catchment management, it could not have foreseen the far-reaching impacts this research would have. The scientifically sound approach is well reflected in Dr Raymond Auerbach's Ph.D. thesis entitled: *Design for Participation in Ecologically Sound Management of South Africa's Mlazi River Catchment* submitted to the Agricultural University of Wageningen, the Netherlands.

Through the research, numerous platforms for community participation have been created in the upper Mlazi catchment, such as subcatchment committees, conflict management groups, school environmental action clubs and community gardens and craft groups. Even large commercial concerns such as Mondi Forest and Umlaas Irrigation Board have actively participated. In Metropolitan Durban the importance of integrated catchment management has started to gain recognition.

The research also clearly highlighted that future water resource management will be a process of life-long learning and discovery.

International drought conference

The WRC together with the Department of Environmental Affairs and Tourism and DWAF, organised an International Conference on Drought Management with the theme: *"Lessons for Sub-Saharan Africa"*. The conference took place under the auspices of the International Hydrological Programme of UNESCO, and was sponsored by the UNESCO regional office in Nairobi. Some 150 delegates from 26 different countries, mostly from Africa, attended the conference.

The fundamental message of the conference was:

People on the continent of Africa have to live with high climate variability, but the risk of drought can be managed. One cannot manage climate variability, but appropriate intervention of man to reduce his vulnerability to drought can compensate nature's erratic behaviour. Two clear focus areas exist:

- *Mitigatory actions to create resilience to drought*
- *Improved capacity to identify early and respond appropriately to intense drought conditions.*

It was also identified that in Africa the national and regional development plans must include drought management planning.

Evaporation losses from open water revisited

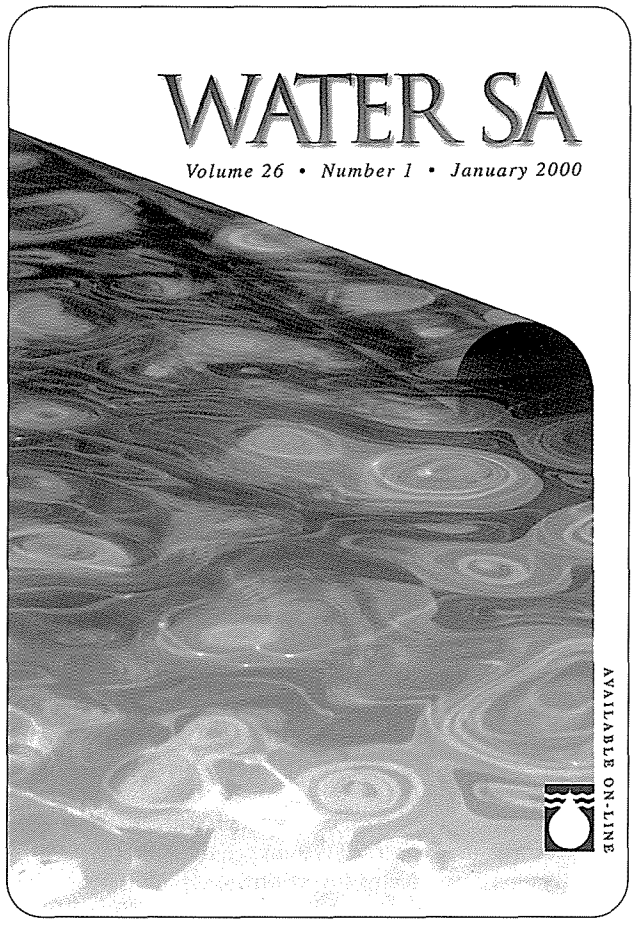
It has been known for a long time that evaporation losses from open water form a considerable component in our national water balance. A study on losses in the lower Orange River has shown that evaporation losses are of the same order of magnitude as the gross net yield from Phase 1 of the Lesotho Highlands Water Project (i.e. Katse, Mohale and Martsoku Dams).

In the past, considerable research effort has gone into finding ways to suppress evaporation but for various practical reasons no sustainable solutions have been found. Recent research in the Orange River between the Vanderkloof Dam and the river mouth showed that releases from a dam can be managed in a more efficient manner to prevent excess water simply evaporating or unnecessary spilling into the ocean. This is especially true when river flows are low and environmental releases to support a river mouth are required. A more accurate determination of evaporation losses has therefore become a necessary element in the future planning and management of available water resources.

Extended use of weather radar for rainfall measurement

The fruits of WRC-funded research by the Weather Bureau into the use of weather radar as a rainfall-measuring device have now, for more than a year, been displayed continuously as real-time rainfall maps on the website of the SA Weather Bureau. Coverage was originally confined to the Vaal Dam catchment. However, as more of the Weather Bureau radars have been suitably equipped, upgraded and included in the rainfall-measuring network, the extent of areal coverage has steadily been broadened to include large parts of the country. Although displayed products are already impressive, research and development goals have by no means yet been fully achieved.

A joint WRC-Weather Bureau research and development programme seeks to increase both the precision of rainfall measurement with radar and the reliability of radar networks for continuous rainfall monitoring. Country-wide monitoring is a further objective, with the filling of gaps in radar coverage to be achieved through the real-time integration of radar data with rain-gauge and satellite-derived data. The eventual outcome will be the production of real-time digital rainfall maps for the whole of South Africa from these merged data types. These maps will have sufficiently high time and space resolution to meet the growing needs for real-time rainfall information, not only of the water resource sector, but of the agricultural and disaster mitigation sectors as well.

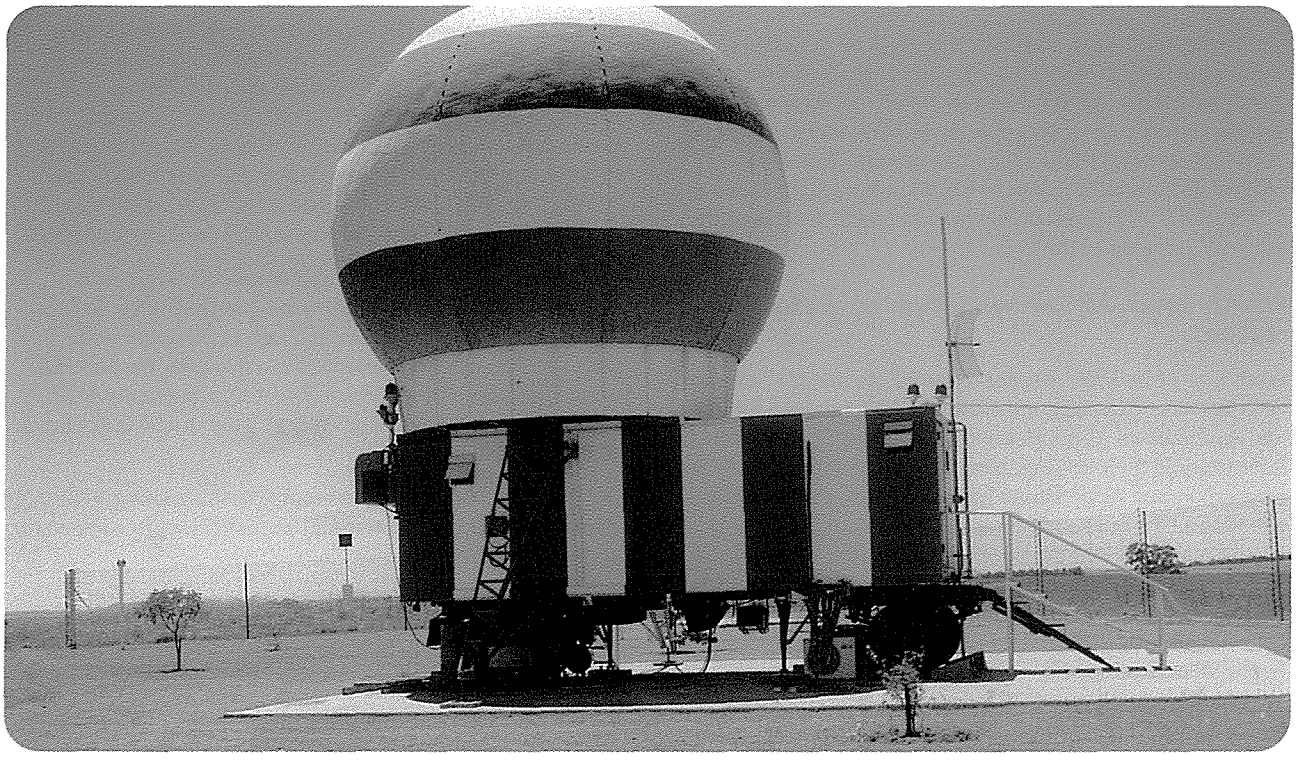


WATER SA – 25 YEARS

Shortly after the establishment of the WRC, it was recognised that a suitable medium would be required to publish the research results of the local water research community, as no other journal dealing exclusively with water existed at the time. It was therefore decided to establish a peer-reviewed scientific water journal *Water SA*, which would appear quarterly. Its appearance in 1975 created a forum for South African scientists and engineers to present their research results both nationally and internationally.

Water SA continues to serve the South African research community in this way, but in recent years it has also had increasing support from overseas authors as far afield as the Ukraine, Spain, Argentina, Finland, Korea, Turkey, Australia, Belgium, Canada, Thailand, Denmark and the USA.

The first edition was published in April 1975 and the three issues for that year averaged 48 pages and seven articles per



The WRC's MRL-5 research radar, used by the Weather Bureau to develop techniques for real-time monitoring and mapping of rainfall.

issue. Since then this volume has increased steadily and in 1999 the average stands at 135 pages and 16 articles per issue. *Water SA* has an extensive local as well as overseas readership. Currently there are 3 418 subscribers to *Water SA* of whom 895 are abroad. It is covered by all the major international abstracting services, who publish and distribute summaries of the articles which appear in *Water SA*.

Over a span of 25 years *Water SA* has moved from the paper era to the electronic era, employing the most advanced publication technologies currently available. Since the beginning of 1997 the full text version of the journal is also available on the Internet via the WRC website (http://www.wrc.org.za). It is of interest to note that this particular section of the website has attracted the most visitors and over the past few months *Water SA* articles have been the most popular file downloads for the site.

Collaboration with the Foundation for Water Research, UK

During 1999 the WRC entered into an agreement with the Foundation for Water Research (FWR) in the United Kingdom, providing for an exchange of research reports published individually by the two organisations. The FWR has set aside part of their website to list new research reports issued by the WRC, and has also added an electronic order form to forward orders for WRC reports directly to the responsible person at the WRC.

To draw attention to their co-operation with international research organisations, the FWR invited the WRC to share an exhibition space during the 3rd Ministerial Conference on Environment and Health which was held during June 1999 in London. The theme of the conference was "Action in Partnership" and the event was attended by some 70 ministers and over 1 000 participants from 51 countries of the World Health Organisation's European region. A set of posters, illustrating the functions and activities of the WRC were developed locally and couriered to the UK, together with WRC brochures and copies of selected WRC research reports. The FWR also exhibited at the International Water and Effluent Treatment Exhibition (IWEX) in Birmingham, 19 to 21 October 1999, again using the same set of promotional material provided by the WRC.

French-South African workshop on water research

From 5 to 7 July 1999, France (through the Centre National de la Reserche Scientifique – CNRS – and the French Embassy) and South Africa (through the CSIR, WRC and NRF), joined forces to hold their first combined workshop on water research issues. Approximately 50 delegates, with roughly equal numbers from each country, first explored common ground and reviewed the status of research in both countries, focusing mainly on the two broad fields of water treatment and hydrology. The latter included hydroclimatology, land-use hydrology, eco-hydrology and hydrogeology. This was followed by the identification and consideration of joint research projects having the potential to be co-funded by France and South Africa.

The final outcome of the workshop was the recommendation of a total of 16 potential projects for further consideration and development by designated research teams consisting of French and South African partners.

Subsequently, invitations were issued to research team conveners to submit letters of intent concerning the envisaged projects. Depending on the receipt and content of these letters, team conveners will be given the green light to proceed with the submission of formal proposals, which will then be channelled by the workshop co-ordinators to appropriate funding agencies.

All indications are that the workshop has stimulated research partnerships which promise to yield considerable benefit for both France and South Africa.

Co-operative agreement with Australian research centre

In July 1999, a research co-operation agreement was signed between the WRC and the Australian Co-operative Research Centre (CRC) for Waste Management and Pollution Control. The occasion was a workshop at the University of Stellenbosch, involving representatives of the WRC and the CRC, as well as a group of researchers working on relevant WRC-funded projects. The objective of the workshop was to identify areas of mutual interest between the WRC and the CRC, and which held potential for collaborative research. The workshop successfully identified areas in which researchers could work together to mutual benefit. Collaborative research initiatives in the fields of membrane technology and sewage treatment have already been launched.

News concerning senior staff and board members

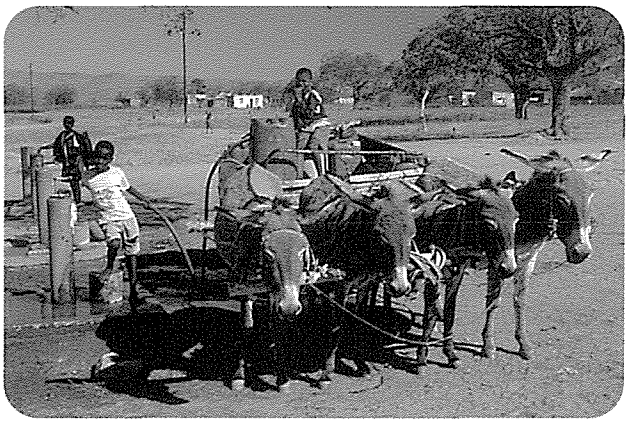
Mr Piet Odendaal, Executive Director of the WRC, and Mr Vincent Bath, Chief Executive of Rand Water, were elected co-presidents of the newly formed International Water Association (IWA). IWA resulted from a merger between the International Association on Water Quality (IAWQ) and the International Water Services Association (IWSA). Mr Odendaal was President of IAWQ at the time of the merger, and Mr Bath the incoming president of IWSA.

Dr Carolyn Palmer, newly appointed Board member, was awarded the Silver Medal of the South African Society of Aquatic Scientists at its conference in Swakopmund, Namibia, June 1999. The award was made for the part she played in formulating the new Water Law, particularly for the recognition accorded in the legislation to the importance of aquatic ecosystems.

Mr Kevin Pietersen was promoted to the position of Research Manager, responsible for the WRC's groundwater research portfolio.

Ms Martha Pretorius,Head: Information Management Division, has been elected as secretary of IAMSLIC, the International Association of Aquatic and Marine Science Libraries and Information Centers for a two-year period from 1999-2001.

2 Developing communities:
Water supply and sanitation



As we prepare to enter the 21st century, there is a growing realisation that the present approaches of delivering basic services to the poor are not sustainable. If the goal of providing basic services to all is to be achieved during the next century, there is a need to develop innovative ways of delivering sustainable services to the millions of people who currently lack access to these services. There is alarming evidence on the ground that large infrastructure projects that are based exclusively on technical merits without taking cognizance of the real needs as identified by target communities continue to fail. The traditional approaches used to plan these projects put emphasis on externally determined "needs" rather than the communities' "demand" for services and the selection of the level of services and technologies to be used is usually based on external perceptions of affordability, rather than on the communities' needs and willingness to pay.

The World Bank Water and Sanitation Programme (WSP) is advocating the delivery of basic services by using a demand-driven approach. This approach seeks to empower communities to take responsibility for their own development. Demands for community water supply and sanitation services are local demands, therefore, managerial decisions about levels of service, location of facilities and cost-sharing should be made locally. Experience shows that schemes implemented with full community participation, community contribution to capital and operation and maintenance costs ensure ownership and sustainability of water and sanitation projects.

South Africa is faced with the challenge of delivering basic services to the millions who currently lack access to these services; delegates at the Rural and Peri-Urban Water Supply and Sanitation Appropriate Practice Conference, held in March 1999, concluded that traditional approaches of delivering services were not meeting the expectations of the target communities. There is therefore an urgent need to initiate research to evaluate the demand-responsive approach for its suitability for South Africa. This approach could contribute to reducing the current dependency on Government to provide financial investments for infrastructure projects. There is a need to investigate models for community-based approaches to implementing water supply and sanitation projects, and this should include an investigation of alternative financing mechanisms for water and sanitation projects.

Completed projects

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

(No 346) Department of Hydrology, University of Zululand

The Zululand coastal region and the adjacent Natal midlands are important water-source areas. These regions are presently experiencing rapidly increasing pressure from rural settlement and small-scale agricultural development.

The water quality in the streamflow is generally good and preliminary studies have shown that water quality characteristics can be linked to hydrological processes. An understanding of this relationship is important for future management of the water environment in this relatively water-rich region.

The study focused on comparing two neighbouring catchments of equal size and natural conditions. However, the one catchment remained rather undisturbed while the other is characterised by increasing population and dryland agriculture, especially small-scale sugar-cane farming.

The most consistent observation during storm events was the immediate drop in electrical conductivity with the onset of the flow, which is assumed to indicate a dilution effect on the total dissolved salts in the system. Many of the storm events showed the nitrate concentration rising with the discharge followed by a similar recession assumed to indicate an association with new rainfall and surface flow. However, in some cases the nitrate peak lagged several hours behind the flow peak, indicating that in some cases this is associated with older water or subsurface flow. Sediment delivery from the two catchments was not consistently different, which was somewhat of a surprise.

The results have confirmed that conditions in a given stretch of river during a storm event can be very site-specific and variable depending on the spatial and temporal characteristics of the rainfall event. The precise connectivity between certain source areas of pollutants and the river can play a major role and lead to a need to map such land uses rather accurately if water quality is a sensitive issue in that river. It must be realised that in terms of pollution loads these study areas are very much on the "clean" side of the spectrum but as human settlement increases and especially if

dense industrial development is involved, the need for detail in the management of local streams is indicated. At the same time it appears somewhat premature to expect this level of detail to be implemented in the present level of water management in the country.

Cost: *R651 363*
Term: *1991-1996*

Groundwater contamination as a result of Third-World type urbanisation

(No 514) Division of Water, Environment and Forestry Technology, CSIR

Aquifers underlying informal and semi-formal settlements act both as a source of cheap, readily available drinking water and as a repository for wastes emanating from the sanitation systems and waste disposal activities associated with these settlements. A study was undertaken to ascertain the magnitude of any possible groundwater contamination originating from Third-World type urban catchments in South Africa and thereby providing the scientific input necessary to develop guidelines for the protection of groundwater resources within these urban catchments.

Case studies were undertaken in three areas, namely, Cape Town (Spandua Camp and Khayelitsha), Durban (Bester's Camp) and Northwest Province (Winterveldt). DWAF in turn agreed to undertake similar studies in Gauteng (Botleng and Poortjie). The case studies showed that the complex array of human activity found in these areas, coupled with the general lack of infrastructure and sanitation, creates the potential for a multitude of pollution sources. The major source of pollutants is domestic waste (liquid and solid) and excreta (human and animal faeces). Therefore, the most significant pollutants would be nutrients, pathogenic micro-organisms and organics. The type of human activity taking place within the informal settlements was similar throughout the country, with the result that the same types of potential pollution sources occur everywhere. What did differ was the impact that these had in the different hydrogeological environments.

Strategies to contain further groundwater contamination will depend on local hydrogeological conditions and strong local government (political) support.

Cost: *R540 000*
Term: *1993-1996*

Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse

(No 599) Division of Water, Environment and Forestry Technology, CSIR

The disposal of domestic wastes is a costly and economically draining activity for municipalities, with virtually no economic benefit other than community health. The main objective of this study was to determine the viability of disposal of septic tank and pit latrine sludges through composting with municipal refuse.

The study showed that composting of pit latrine and septic tank sludge with domestic refuse was a viable method for the disposal and recovery of useful products from these wastes. Co-composting served as both an environmentally friendly disposal method, as well as a method of recycling waste for useful purposes. Application of this technology in rural areas will depend on the availability of sufficient sludge and refuse to make it viable with regards to the investment required. However, in view of the unfavourable capital and operating costs for alternative sewage and/or sludge treatment systems for small communities, co-composting of sludges could be the most viable method for the disposal of sludge from on-site sanitation systems.

Cost: *R210 000*
Term: *1994-1996*

Occurrence and survival of protozoan parasites in source water and drinking water used by unserved rural communities

(No 685) Division of Water, Environment and Forestry Technology, CSIR

The protozoan parasites, *Giardia* and *Cryptosporidium*, are recognised causes of diarrhoea in man and can cause acute, sporadic gastroenteritis in otherwise healthy individuals and could have serious consequences for the immune-compromised.

In South Africa, informal settlements with no infrastructure have become common, resulting in increased levels of pollution of drinking-water sources.

The research team selectively sampled water used as drinking water by unserved rural communities and the indication is that the water was contaminated with *Giardia* cysts and *Cryptosporidium* oocysts.

Giardia was continually detected at the sampling sites during the study period, while *Cryptosporidium* occurred seasonally with high counts during summer and after rainfalls. Damaged pumps or taps as well as poor operation and management of purification plants resulted in high protozoan counts in fully treated water.

It was also confirmed that chlorination did not have an effect on the *Giardia* cysts and *Cryptosporidium* oocysts, but boiling or moderate heat of 65°C for 2 min could provide drinking water free of these protozoan parasites and viable cysts.

Cost: *R300 000*
Term: *1995-1996*

Pilot study for the development of a GIS database on water and sanitation in South Africa

(No 710) Division of Water, Environment and Forestry Technology, CSIR

The study was undertaken to investigate methods of improving the flow of information relating to water supply and sanitation infrastructure in rural areas of South Africa. The specific aim of the project was to develop a pilot GIS database on community water and sanitation provision and investment in the Northern Province. The database would assist decision-makers to plan and prioritise the water and sanitation needs of the region. The research showed that there was a need for the development of a water and sanitation monitoring management tool which could provide relevant decision support. Data analysis for the pilot study area showed that additional skills development was needed to enable communities to operate and maintain water systems adequately. All the villages (120) in the study area were found to have below RDP level of water and sanitation services.

Cost: *R451 000*
Term: *1995-1998*

Biological processes in on-site low-flush volume sanitation systems

(No 712) Division of Water, Environment and Forest Technology, CSIR

This study was undertaken with the aim of providing a better understanding of the biological processes taking place in the low-flush volume sanitation systems. Users of these systems have complained of several problems such as odour development and soakaway failure. These problems have led to a general dislike of low-flush volume sanitation systems by the end-user communities.

The following conclusions were drawn from this research:

- Biological activity appeared to be inhibited by the high ammonia concentrations and settling also appeared to be inhibited by the low flush volume.
- Although the concentrations of all measured parameters were high, the nutrient load exported from the system appeared to be comparable to septic tanks receiving conventional flush volume.
- The high concentrations of ammonia in all systems surveyed could possibly be inhibiting anaerobic degradation.

The results of this study did not provide adequate information which could assist manufacturers to design sanitation systems that would be more acceptable to the end users. There is a need to conduct further research on biological processes in low-flush volume sanitation systems. These studies should be done with appropriate controls and better analyses of microbiological processes are also necessary.

Cost: *R296 200*
Term: *1995-1996*

Case study of a management system for rural water supply: Matatiele district

(No 895) Matcomm

In the present context of rural water supply in South Africa there is a strong drive for implementation of projects that is not yet being matched by supporting considerations for operation and maintenance. Research into O&M management arrangements has only started to emerge and has been limited to broad guideline considerations. A large gap presently exists between communities, emerging local government and national policy-makers. There is therefore a need for consultation with and input from community levels in order to ensure that the emerging policy for rural water supply management is effective, appropriate and applicable on the ground. A detailed case study provides for a better understanding of financial issues associated with rural water supply schemes. Furthermore, there is a need for experiences in the field to be documented so that others involved in rural water supply (administration or implementation) may learn from this. Based on this approach and using projects in the Matatiele district, the following findings emerged from the study:

- There is a very strong preference by rural customers that the money from their tariffs remains in their community.
- Cost-recovery levels by water committees from community households are generally very low.
- Cost recovery is the most difficult challenge facing community-based water service providers. The challenges of cost recovery increase with the population and geographic size of projects as well as with the level of conflict within project areas.
- Cost recovery with a pre-paid system is remarkably better than any other project in the district. The pre-paid system ensures that water services are paid for before they can be accessed, centralises the collection arrangements and puts the onus on customers to pay, and not on the water committee to collect.
- Relying on volunteer committee members or staff for water tariff collection appears inadequate for achieving sustainable and sufficient levels of cost recovery.
- Post-project support, or mentorship, is required to assist community-based water service providers in developing and operating their financial and management systems.
- Committees are reluctant or unable to enforce policies dealing with non-payment at household or village levels. Committees feel that they presently lack the necessary authority or official mandate to implement punitive actions.
- There is overwhelming support for Village Water Committees to act as water service providers.
- Paid staff (albeit 'informally employed') are far more effective and active in carrying out their responsibilities than volunteer committee members, especially with the difficult task of tariff collection.
- The activities of project management and staff management by water committees are presently not well implemented. Group schemes are particularly badly effected by weak management.
- Community technical operators appear technically competent to conduct daily operation and maintenance of projects.
- Report-backs to communities with regard to technical issues and problems assist in building community awareness and ownership.
- A broad sense of ownership of projects appeared to be exhibited by both committees and communities.
- While there is general customer satisfaction with the operation of projects, there is also a clear demand for mixed levels of service, e.g. some private tapstands.

Findings of this study are most interesting and once again raise the issue of community ownership and management. Based on these experiences, the report also provides guidelines and models towards effective partnership between local government and communities that should contribute towards sustainability.

Cost: *R184 000*
Term: *1998-1999*

A tool for assessing the microbial water quality in small community water supplies: An H_2S strip test

(No 961) Division of Water, Environment and Forestry Technology, CSIR

It has become increasingly necessary to develop simple and visual methods for assessing the microbial quality of drinking water in rural areas. The preferred methods should be simple so that they can be performed by local communities without any special technical skills. During this study, the H_2S (hydrogen sulphide) strip test was evaluated for its suitability as a water quality indicator. The H_2S strip test causes the contaminated water to turn black, thus providing a very effective visual mechanism for illustrating bacterial contamination of water supplies.

This research has shown that the H_2S strip test is very sensitive; it can detect as few as two bacterial cells per sample in both pure and mixed cultures. Correlations between the H_2S strip test and indicator organisms were statistically significant, with faecal coliforms showing the best correlation with the H_2S strip test after 48 h of incubation. It was shown that when samples were incubated at room temperature, positive results were detectable after 48 h of incubation. However, when samples were incubated at 35°C, positive results could be detected within 24 h of incubation.

This study has indicated that the H_2S strip test could be employed as a simple, easy-to-use on-site field test for rural communities to monitor the microbial quality of their water supply sources.

Cost: *R100 000*
Term: *1998*

Applicability of shallow sewer systems/simplified sewerage systems for dense urban communities in South Africa – An economic and technical study

(No 983) Palmer Development Group

The Government is proceeding rapidly with its programme to provide adequate services to all. Sanitation, because of the major impact it has on health and quality of life, is a service with a high priority. The level at which such sanitation services are provided, and the arrangements for implementing the associated projects, are possibly the most debated and contentious issues in the field of urban service provision. The importance of looking at sanitation options between on-plot systems and full water-borne systems is evidenced by the results of a survey of local authority research needs commissioned by the WRC where it was identified as of high priority. In this endeavour the WRC initiated a desk study to establish the applicability of shallow sewerage technology for South African conditions. The technology has been widely and successfully applied in many countries and has become a norm in Brazil and Pakistan. The technology is very community-orientated and requires innovative management and institutional arrangements. The findings of the study have been most encouraging and will generate great interest amongst local authorities. Some of these are:

- Shallow sewer systems provide a viable intermediate sanitation alternative, with a total cost between that of VIPs and conventional sewerage. They may be preferable to VIPs in denser (greater than 35 dwelling units(du)/ha) formal and informal peri-urban settlements.
- They are unlikely to be a viable alternative to VIPs in rural settlements, because densities in these areas are generally too low. Shallow sewerage also provides a less expensive alternative to conventional sewerage in low- to medium-income formal urban residential areas. A significant advantage is that shallow sewer systems are appropriate where water use is between 30 and 60 *l*/capita·d (i.e. pour flush toilets with yard tanks or yard taps), which may be too high for VIPs and too low for conventional sewerage.
- The technical characteristics of shallow sewer systems require a relaxation of traditional design and construction standards, in particular the use of smaller diameter sewers (i.e. less than 150 mm), shallower block sewer depths (i.e. only 400 mm cover), flatter sewer gradients with small diameter pipes (i.e. 1:167 slope for 100 mm pipes) and less stringent access requirements (i.e. inspection chambers rather than manholes) and an associated education of the technical personnel who are responsible for their implementation and management. Building codes for household fittings and house connections should be relaxed, allowing local construction of fittings and connections, with less stringent connection requirements, albeit with quality control on trunk sewer access. The relaxation of design standards for shallow sewer systems is based on the assumption of high connection rates. Therefore, shallow sewers should not be implemented in blocks where less than 75% of the residents have agreed to connect under the proposed financing and management conditions.
- For a shallow sewer programme in a particular local authority to be effective, with dedicated personnel being appointed, a relatively large number of shallow sewer connections are required (i.e. at least 5 000 connections to allow economies of scale). This level of implementation may take time to develop, particularly during the initial implementation of these systems in South Africa.
- The capital costs of backyard shallow sewers are generally about 70% of the cost of conventional sewerage, dropping to as much as 50% under adverse geotechnical conditions. Operating costs for backyard shallow sewer systems with delegated management arrangements should be about 60% of those for conventional sewerage systems. Together this implies a total annualised cost for backyard shallow sewers which is about two thirds of conventional sewerage. The capital and operating cost savings for front-yard shallow sewerage are not as high (i.e. only 80% to 95%).

The capital costs of backyard shallow sewer systems are only about 20% more than VIPs at medium densities (30 du/ha) and are about the same cost at high densities (greater than 50 du/ha). However, the operating costs (even with delegated management) are about 4 times higher, which equates to a 100% increase in total annualised cost for shallow sewer systems over VIPs. If the operating costs for bulk and connector infrastructure are not included, this annualised cost is only 50% of that of VIPs.

Cost: *R115 500*
Term: *1998-1999*

New projects

Computerised human-resource planning system for water service institutions

(No 993) Stewart Scott (Pty) Ltd.

There is a need for innovative approaches to address the existing shortage of high-level and middle-level manpower in South Africa, especially in the scientific, engineering and technical fields. The growth in personal skills and productivity can be augmented by management and decision-support systems. Computerised management systems lessen the need to depend on direct supervision. Computer-based information systems allow managers to handle more subordinates, thus leading to wider spans of supervision and reduced staff and, consequently flatter organisations.

The enhancement of knowledge with regard to the eventu-

al application of a computerised human-resource planning system specifically for water service institutions in South Africa will be achieved through the incorporation of human-resource modelling techniques that have in the past only been applied to organisations overseas not generally involved with the water industry.

The project aims to develop this management tool to help managers undertake integrated human-resource planning of water service institutions that focuses on the human resources required to support the infrastructure as well as organisational structure requirements of various sizes of water service institutions. As these organisations are dynamic institutions due to the fact that there is a growth in the demand for their services, as well as a continuous movement of staff into and out of the organisation, a dynamic computerised human-resource planning system is required. The tool will enable those water service institutions who have limited resources to meet the requirements of the Water Services Act in the preparation and implementation of business and development plans and its operation in a sustainable manner.

Estimated cost: *R160 000*
Expected term: *1999*

Monitoring leachate and biogas emissions from existing experimental field cells

(No 995) Department of Civil Engineering, University of the Witwatersrand

Municipal solid waste disposal sites often pose a major potential risk to underlying groundwater resources. The large volumes of degrading waste may generate a highly noxious liquid, termed leachate, which migrates under gravity and has the potential to contaminate the subsoil and associated water resources. However, recognising that in the semi-arid parts of South Africa the infiltration of rain water may be insufficient to generate significant volumes of leachate, a guideline document for the design of waste disposal facilities has been developed that takes cognizance of the local climate when defining leachate collection and control facilities that are required for a particular landfill.

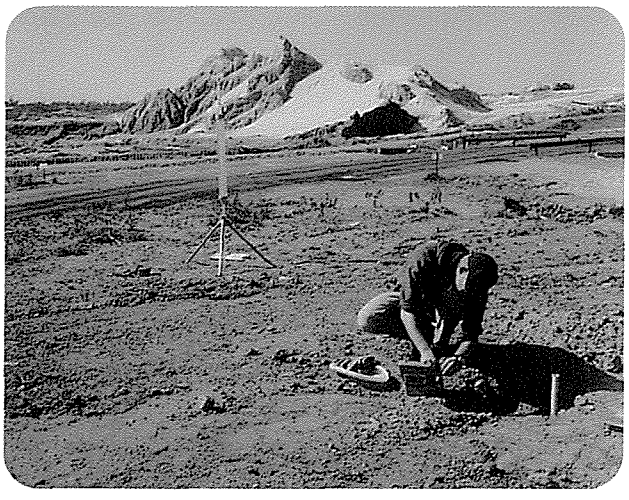
Adherence to the current guidelines document may nevertheless still entail the incurrence of a very large cost for many municipalities. The dangers of this are twofold: municipalities may ignore the fact that their landfill poses an environmental and health risk and choose to continue using existing, unlicensed sites way beyond their design capacity, or, if they attempt to adhere to the new guidelines, may find that the costs are prohibitive and provision of other essential services is compromised.

This project forms part of ongoing research to refine the existing guidelines to make them more affordable, without compromising environmental integrity. Specifically, it sets out to determine whether differences in waste composition between affluent and poor communities may enable the relaxation of leachate control measures. The first two components were completed relatively easily and a great deal of data has already been produced and reported (Project No 670). The third phase – the field work – was delayed by severe summer rainfall and the test cells were only completed late in 1997. The amount of data, in terms of leachate and biogas emissions from these cells, has to date been very limited.

The aims of this project are thus to:

- Continue to monitor the emissions from the field test cells (at Weltevreden municipal landfill) in order to obtain full advantage of the money already spent on construction of the cells
- Monitor changes in the moisture content of the waste with time and relate this to ambient climatic conditions
- Use these data, together with those already obtained, to refine and improve current landfilling standards to increase affordability for disadvantaged communities.

Estimated cost: *R118 000*
Expected term: *1999-2000*



Jeremy Morris, a Ph.D. student in Civil Engineering at Wits University, doing temperature and moisture content measurements on Weltevreden landfill site. In the background is a Guelph permeameter, which is being used to measure the hydraulic conductivity of the cover soil.

Ms Pratibha Mistry, a civil engineering student at Wits University, measuring biogas emissions at Weltevreden landfill site.

Community management of natural, human and financial resources relating to basic water supply projects

(No 996) Lynette Dreyer and Associates

There is currently a major national initiative to supply everyone in the country with potable water. The drive is led by DWAF and implemented through a number of agencies. It is well known that projects to provide a basic water supply currently experience an unacceptably high failure rate. A previous research project financed by the WRC (i.e. *The Dynamics of Community Non-Compliance with Basic Water Supply* (Report No TT 93/98)) investigated reasons for this high failure rate.

Besides finding reasons in a variety of factors on the societal as well as community level, the research raised a number of other questions that call for in-depth investigation into aspects of community management. At the same time the national institutional environment is changing with new legislation on water and local government being put in place and water delivery institutions and communities are required to comply.

The proposed research will investigate conventional community management of resources and provide guidance on how these can be reconciled with the demands of the emerging institutional arrangements to ensure sustainability in water supply. Conventional community management of resources refers to systems that are already being used, i.e. stokvels, burial committees, créche committees, etc. The project will identify why these arrangements are functional and successful, and how they can be adapted or made compatible for water supply projects.

The project aims to provide guidelines on achieving compatibility between conventional community management of natural, financial and human resources and the demands of the emerging national institutional environment (new legislation in regard to water and local government) to ensure sustainability in village water supply. This will enable better project design to improve the effectiveness and efficiency of water supply projects. All the stakeholders in the community water supply sector will benefit from the research.

Estimated cost: *R140 000*
Expected term: *1999*

Typical pre-paid water meters.

Development of generic and sectoral competencies in the water supply and sanitation training sector

(No 1020) National Community Water and Sanitation Training Institute (NCWSTI)

DWAF has expressed a need for better co-ordination of training activities for the water and sanitation sector. This need stems from the current lack of training standards within this sector. There are currently no formal methods for assessing the quality of training programmes offered. There is, therefore, a need for generic and sectoral training competencies which will help to avoid the present situation where numerous training consultants develop their own competencies which are based on their own assumptions and criteria.

The main objectives are to:

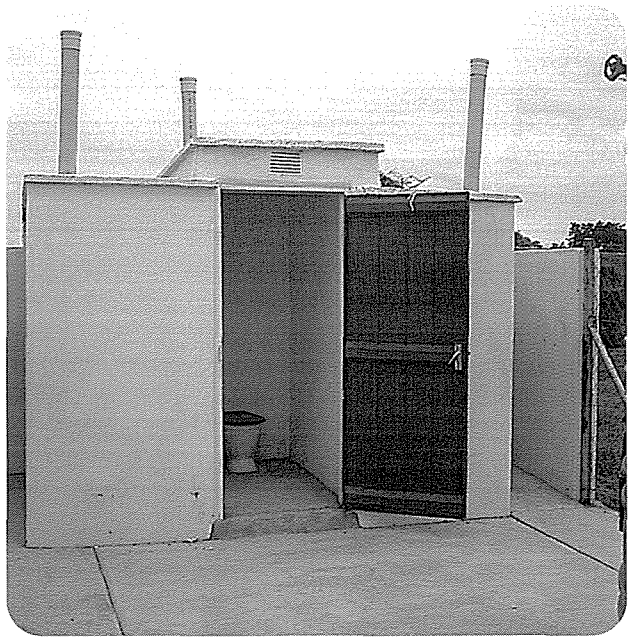
- Generate generic, sectoral and target modular-based competencies
- Develop a model which is believed to be able to facilitate co-ordination and standardisation of training
- Design and develop modular-based competencies which are appropriate to and in accordance with sectoral needs and the National Qualification Framework.

Estimated cost: *R295 000*
Expected term: *1999-2000*

Cost improvement of solar still units for general use by rural communities in remote Southern African locations

(No 1032) McCracken Solar Stills (Pty) Ltd.

Internationally the use of solar stills for the desalination of brackish water has been investigated for a considerable period. In South Africa it has great potential in large areas of the country, but has found limited commercial application, mainly due to its relatively high up-front cost. Market research has



Ventilated improved pit latrine (VIP) demonstration units in the Mpumalanga Province.

concluded that the imported price of R4 500/2 m^2 still unit was unacceptable to communities in South Africa. To make solar stills commercially viable, such units should cost about R500 each. At that price, households and small communities, with a daily pure water requirement of up to 500 *l* can be serviced at less than R10/m^3. Experimental and costing investigations on alternative substitute plastic materials have shown that this price might be achievable, but attention should be paid to the environmental durability of such a still.

This project therefore aims to develop and demonstrate affordable and durable solar still desalination batteries for the provision of sufficient freshwater to smaller sized remote communities. A comprehensive materials audit on inexpensive commercially available construction materials will be carried out, followed by accelerated ageing and intensive field testing of an integrated solar still battery in a developing community environment.

Estimated cost: *R338 000*
Expected term: *1999-2001*

Assessment of the attended coupon-operated access-point cost-recovery system for community water supply schemes

(No 1052) Lima Rural Development Foundation

The most severe constraint to sustainability of water supply and sanitation schemes is poor cost recovery. Cost recovery includes paying for services, that is capital costs and operation and maintenance costs of schemes. The effects of poor to inadequate cost recovery are that:

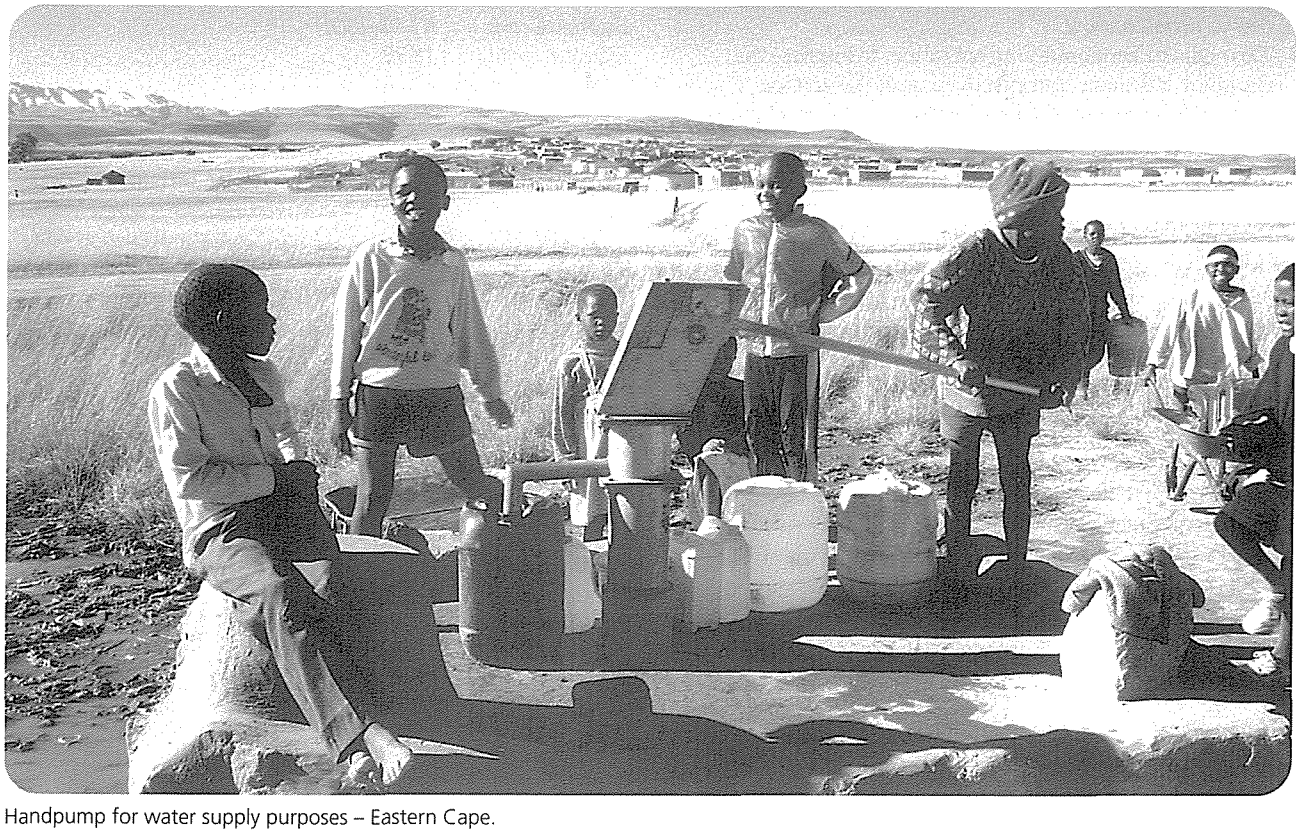
- More pressure is put on the limited resources of central government
- Scarce resources are not valued
- There is very little ownership by recipients
- Systems have short lifespans.

When there is adequate cost recovery, a relationship between the water service provider and its customers is developed. Since services are paid for by the community, more reliable services are provided. Poor cost recovery is a common problem in South Africa and, in order to improve this, a number of techniques and systems have been developed and applied. These range from tariffing, billing, prepayment systems through to the Masakhane Campaign. Prepaid systems (both mechanical and electrical), and many other systems have been applied as a quick-fix solution to non-payment. Many of these systems have had limited success and one of the reasons for this is that they were not well researched before implementation. The conventional modern technology prepayment systems have received greater support from local authorities, than from the consumer or communities.

Hence, this study aims to assess mechanical systems, in the form of the attended coupon-operated access-point cost-recovery system, for community water supply schemes. The objectives are to:

- Assess the adequacy of the system
- Determine parameters for its efficient operation
- Understand social parameters which will render the technology appropriate.

Estimated cost: *R165 000*
Expected term: *1999-2000*



Handpump for water supply purposes – Eastern Cape.

Benchmarks and key performance indicators in water and wastewater services

(No 1053) P Pybus Consulting Engineer cc

This project is a follow-up on the previous study on the above topic (Project No 984) to establish the level of benchmarking in the sector, findings of which indicated that:

- Of the local authorities interviewed, not one was practising any benchmarking activities
- Most were unaware of the practice of benchmarking
- They were also interested in recommendations concerning key performance indicators that would be comparable from one local authority to another, as a measure of their effectiveness and efficiency.

Benchmarking is a process of continuous improvement based on a comparison of the methods of operation and performance achieved by different organisations, known as benchmark partners, carrying out similar operations. By comparing the methods used by the different organisations, the good features of each can be identified and promoted in practice. In the South African context, a system of benchmarking will prove useful for emerging local authorities, who can be mentored by the more formal local authorities. Benchmarking is seen as an integral part of the improvement process and the key performance indicators will assist in the measurement of the performance. This will facilitate progression towards best practice in the water and wastewater sector.

The project aims are:

- To stimulate local authority officials engaged in providing water and sanitation services to monitor and improve those services
- To enable them to examine critically the operations that are cardinal to the success of the provision so that these can be benchmarked
- Through the benchmarking operation, to improve the standard, efficiency and effectiveness of the service
- To establish the methodology for the calculation of standardised key performance indicators for water and wastewater service and provide a tool for ongoing improvement.

Estimated cost: *R303 000*
Expected term: *1999-2000*

Development of small-scale ultrafiltration systems for the provision of potable water at point source

(No 1070) Department of Chemical Engineering, ML Sultan Technikon

In many instances small communities, schools and clinics are dependent on surface water of inadequate quality for potable use, giving rise to health problems. Ultrafiltration is an established membrane filtration operation that has found acceptance in potable water treatment in both America and Europe. However, development to date has mostly focused on larger scale, more sophisticated and expensive systems. Small-scale, simple and robust systems are required that would not need any skilled operator input and which would operate reliably with minimal maintenance and energy requirements.

This project aims at providing such systems. A membrane cleaning protocol will also be evaluated whereby the membranes are not chemically cleaned in place, but rather at a central location which will allow simple soak-type cleaning strategies to be adopted. Economics of the system will be investigated, as well as minimisation of electrical power requirements, and the use of alternate power sources, e.g. natural heads. As a positive spin-off, the country's skills base in terms of membrane technology in potable water provision will be expanded by training staff and students at the collaborating Technikons.

Estimated cost: *R630 000*
Expected term: *1999-2000*

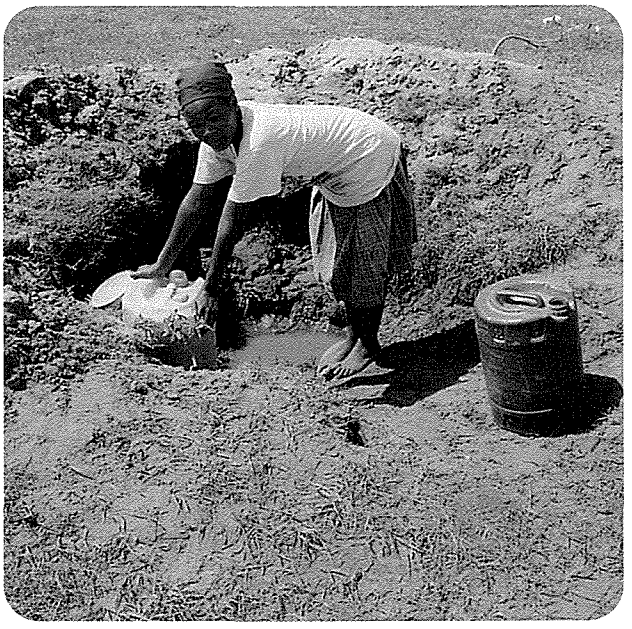
Assessing the impact of gender in water and sanitation provision and maintenance

(No 1087) Networks for Development

Water supply and sanitation projects are implemented as community projects and, therefore, their success depends on the participation of both men and women. According to a report on the evaluation of the Community Water Supply and Sanitation Programme of DWAF (1997), the involvement of women in most projects evaluated was found to be minimal. This resulted in specific problems such as communal standpipes being placed according to the instructions of men in places that were not suitable for the users who are mainly women. The report recommended that extensive gender awareness programmes should precede the implementation of new water and sanitation projects.

The proposed research will assess the impact of gender in water and sanitation provision and maintenance. The findings of the assessment will be used to develop gender-sensitive approaches which will contribute to the implementation of gender-balanced approaches within the water and sanitation sector.

Estimated cost: *R150 000*
Expected term: *1999*



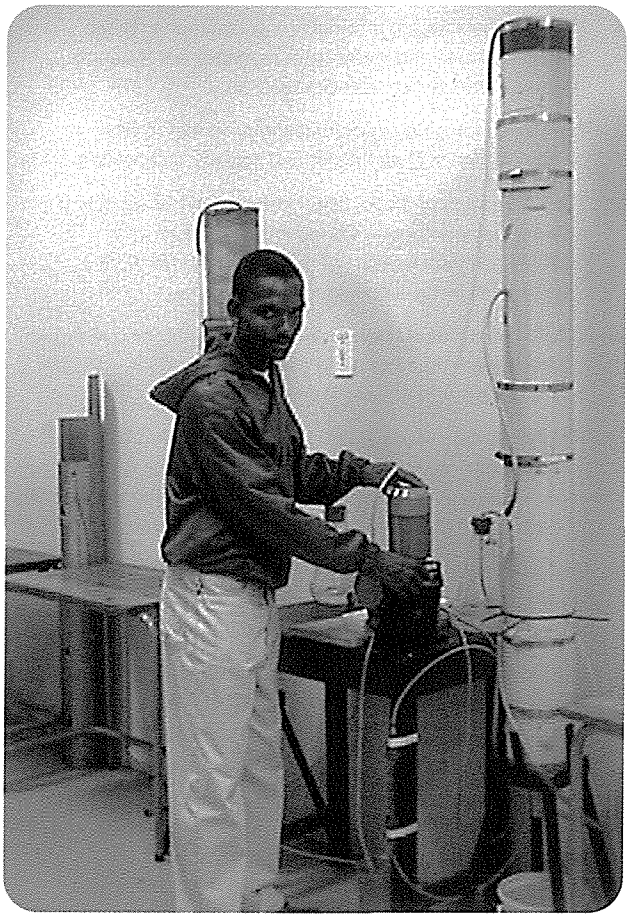
A woman collecting untreated water from a traditional source for household purposes in Northern KwaZulu-Natal – 1993.

Developing guidelines and methodology to implement operation and maintenance in rural water supply programmes

(No 1099) In-Touch Community Development and Project Management

In terms of policies of the past, inadequate attention was given to the capacity of people to control and manage development projects on a sustainable basis. Infrastructure development, and even water provision was seen as a financial and technical issue. The social component was relegated to that of communities as the ultimate target and beneficiaries of projects, and not as the vehicle and engine of the development process. This has left a legacy of non-involvement, non-payment and neglect in service provision, especially operation and maintenance.

Current initiatives have attempted to address these problems. However, it is evident that not much change in the situation has been achieved. The problem generally rests in the technocratic nature of dealing with problems that are socially orientated. The top-down approach (planning to implementation) is evident in many projects, with softer issues being given lip-service, especially when it is these issues that are critical for the sustainability of projects. One of these critical components is the ongoing operation and maintenance of schemes.



Laboratory set-up for the investigation into the removal of nitrogen from ventilated improved pit latrines (Mathews Mmomotsa – laboratory assistant).

The objectives of the research programme cover two broad themes with regard to operation and maintenance in community water supply, and are as follows:

Institutional development

- Investigate the strengths and weaknesses of the Community Water Supply and Sanitation (CWWS) institutional delivery systems towards ongoing operation and maintenance, and its implications.
- Evaluate the implications on operation and maintenance of the Water Service Act – Act 108 of 1997.

Capacity-building

- Identify possibilities for women and youth involvement in operation and maintenance
- Identify methods for local role-players to play a facilitating role in the capacity-building process
- Identify capacity needs and requirements at water committee level.

Although many research products provide limited solutions to community participation in operation and maintenance, most are based on face-value information. The study intends to concentrate on the more effective (although time-consuming) methods such as interviewing, participatory observation and using various participatory techniques where relevant.

Estimated cost: *R200 000*
Expected term: *1999-2001*

Research projects

Completed

- **346** Study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region (University of Zululand – Department of Hydrology)
- **514** Groundwater contamination as a result of Third-World type urbanisation (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)
- **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)
- **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)
- **895** Case study of management systems for rural water supply: Matatiele district (Matcomm)
- **961** A tool for assessing the microbial water quality in small community water supplies: An H_2S strip test (CSIR – Division of Water, Environment and Forestry Technology)

- **983** Applicability of shallow sewer systems/simplified sewerage systems for dense urban communities in South Africa – An economic and technical study (Palmer Development Group)

Current

- **384** Water resources and sanitation systems sourcebook with special reference to KwaZulu-Natal (University of Natal – Department of Economics)
- **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)
- **520** Guidelines on appropriate technologies for water supply and sanitation in developing communities (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)
- **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)
- **631** Assignment of a financial cost to pollution from on-site sanitation, with particular reference to the PWV (University of the Witwatersrand – Department of Civil Engineering)
- **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 sewage treatment using the advanced algal high rate oxidation pond (AHROP) (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)
- **698** Land-based effluent disposal and use: Development of guidelines and expert-systems-based decision-support (CSIR – Division of Water, Environment and Forestry Technology)
- **709** Preparation of standard engineering drawings, specifications and guidelines for ventilated improved pit (VIP) latrines in South Africa (CSIR – Division of Building 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 Bophuthatswana – 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 North West – Departments of Nursing Science, Chemistry and Agriculture)
- **727** Effects 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)
- **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 technologies (University of Stellenbosch – Institute for Polymer Science)
- **767** Sustainability and affordability of community based integrated waste and wastewater 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** An 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 applications technology in South Africa: Building the capacity of local communities in urban development (University of Cape Town – Department of Civil Engineering)
- **792** Solar still batteries in arid rural sites without electricity supply to provide potable water from brack, salty water (McCracken Solar Stills Company (Pty) Ltd.)
- **817** Development of strategies for empowerment of women in water supply and sanitation projects (CSIR – Division of Water, Environment and Forestry Technology)
- **818** Development and evaluation of sanitary surveillance methods for rural communities' water supply and sanitation system maintenance (CSIR – Division of Water, Environment and Forestry Technology)
- **819** Hygiene education to support water supply and sanitation interventions in developing communities (CSIR – Division of Water, Environment and Forestry Technology)

- **828** Field evaluation of alternative disinfection systems for small water supply schemes (CSIR – Division of Water, Environment and Forestry Technology)
- **830** Level of communication between communities and engineers in the provision of engineering services (Philip Pybus CE)
- **837** Guidelines for the development of rural water supply schemes – Further development of a decision-support system (Rhodes University – Institute for Water Research)
- **859** Reliability of small spring water supply systems for community water supply projects, and the enhancement of flows from springs (CSIR – Division of Water, Environment and Forestry Technology)
- **861** Development of guidelines for the management of rural groundwater resources (CSIR – Division of Water, Environment and Forestry Technology)
- **875** Development of an appropriate, low-cost, solar-powered Stirling motor for water pumping (Wagner Systems (Pty) Ltd.)
- **880** Development of standards and mechanisms for quality management in the water and sanitation training sector (National Community Water and Sanitation Training Institute)
- **885** Removal of nitrogen from ventilated improved pit latrines (VIP) systems by nitrification and denitrification processes (Technikon Pretoria, and NRF)
- **886** Development of a framework for the calculation of a monthly tariff payable in stand-alone community water supply schemes (Mvula Trust)
- **902** Fog water collection: Implementation of an operational prototype system (University of the North – Department of Geography)
- **925** Assessing the causes and pathways of water-borne disease in rural settlements with limited formal water supply and sanitation (Umgeni Water)
- **958** Institutional structure for the management of a rural water and sanitation supply scheme involving five local authorities (Association for Water and Rural Development (AWARD))
- **959** Institutional arrangements and support facilities required for sustainable community water supply (Water Systems Management)
- **960** Improving water use, sanitation practices and hygiene education for primary-school children in South Africa – Phase II (University of the Western Cape – Public Health Programme)
- **962** Water-supply management for small communities: Development of expert-systems-based decision-support software and a guidelines manual (CSIR – Division of Water, Environment and Forestry Technology)
- **976** Continuous-flow air lift groundwater pump for rural applications (Green Energy Systems cc)
- **981** Incorporation of water, sanitation, health and hygiene issues into Soul City, a multimedia edutainment vehicle (Soul City)
- **982** Development of a rapid capacity-building programme for management of water and waste services at district council and local authority levels (University of Port Elizabeth – Institute for Development Planning and Research)
- **991** Capacity-building and training needs of district councils and transitional rural councils in the management of community water and sanitation services in the Eastern Cape (University of Fort Hare – Department of Development Studies)

New

- **993** Computerised human-resource planning system for water service institutions (Stewart Scott (Pty) Ltd.)
- **995** Monitoring leachate and biogas emissions from existing experimental field cells (University of the Witwatersrand – Department of Civil Engineering)
- **996** Community management of natural, human and financial resources relating to basic water supply projects (Lynette Dreyer and Associates)
- **1020** Development of generic and sectoral competencies in the water supply and sanitation training sector (National Community Water and Sanitation Training Institute (NCWSTI))
- **1032** Cost improvement of solar still units for general use by rural communities in remote Southern African locations (McCracken Solar Stills (Pty) Ltd.)
- **1052** Assessment of the attended coupon-operated access-point cost-recovery system for community water supply schemes (Lima Rural Development Foundation)
- **1053** Benchmarks and key performance indicators in water and wastewater services (P Pybus Consulting Engineer cc)
- **1070** Development of small-scale ultrafiltration systems for the provision of potable water at point source (ML Sultan Technikon – Department of Chemical Engineering)
- **1087** Assessing the impact of gender in water and sanitation provision and maintenance (Networks for Development)
- **1099** Developing guidelines and methodology to implement operation and maintenance in rural water supply programmes (In-Touch Community Development and Project Management)

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3 Potable water supply

As the quality of source water is continually deteriorating, there is increased emphasis on cost-effective treatment methods for the best water quality production while minimising risk from treatment processes. Enhancement of operating treatment systems through use of new chemicals and improvement of the chemical dosing environment, development of better processes for the removal of natural organic matter, application of activated and powdered carbon, optimisation of current sedimentation practice through the use of particle counting and evaluation of alternative approaches to disinfection are current high-priority research topics. Attention is increasingly being given to understanding the relationship between water quality and public health outcomes. Current research also focuses on a range of microbial and chemical constituents of drinking water, with relevance to both urban and rural water. The occurrence of substantial changes to drinking-water quality in distribution systems and reservoirs is also receiving due attention. There is a need to understand the mechanisms by which water flow, biofilms, and pathogens interact in pipes and reservoirs to affect health-related and aesthetic dimensions of water quality at consumers' taps.

Supplying safe water to rural communities will continue to be of top national priority for some time. Issues such as high fluorides and nitrates in rural water supplies are being addressed. There is also an increased focus on suitable technical interventions and more emphasis is placed on the social aspect of implementing a community water supply project.

Research on potable water treatment and supply has therefore developed into three main areas: **Water Treatment and Reclamation, Drinking Water Quality and Health Aspects** and **Rural and Urban Water Supply**. There are a fair number of projects addressing each of these major areas whilst capacity-building initiatives are continually being integrated into our projects.

Completed projects

Development of guidelines for toxicity bioassaying of drinking and environmental waters in South Africa

(No 358) Division of Water, Environment and Forestry Technology, CSIR

The report is in three parts. The first deals with the development of guidelines for toxicity testing, during which the following acute toxicity tests were evaluated: fish and water flea lethality tests; protozoan oxygen uptake test; algal and bacterial growth inhibition tests; urease and acetylcholinesterase inhibition tests and a mammalian cell colony formation test. The Ames *Salmonella* mutagenicity test and the toad embryo teratogenicity test were evaluated as chronic toxicity tests. Each test was evaluated using raw water from various sources, treated water and a range of toxicants at known concentrations.

Certain treated water samples registered low toxicity with most of the tests. Some mutagenicity was detected in some of the raw surface water samples, but teratogenicity was not detected in these samples. The groundwater tested showed considerably higher toxicity than the surface water, and the water flea lethality test was particularly sensitive to this.

An annexure using chemical equilibrium modelling to interpret the toxicity of the borehole water comprises the second part of the report.

The final part of the report presents the guidelines for toxicity bioassaying of waters and effluents. This document gives details of test organisms, the ten tests mentioned in the first paragraph, data analysis, reference chemicals and the application of the tests (Report No 358/1/98).

Cost: *R374 000*
Term: *1991-1993*

Development and evaluation of small-scale potable water treatment equipment

(No 363) Department of Chemical Engineering, University of Natal and Scientific Services, Umgeni Water

In planning extensions to a potable waterworks or in optimising the operation of an existing waterworks, trials are frequently carried out. These trials are usually undertaken sequentially with the assumption that the water quality

remains reasonably constant. In this evaluation it was advantageous to have small-scale waterworks processes so that side-by-side trials could be undertaken. Typical changes which were investigated included: different blends of raw water; different flocculants and coagulants; the effect of pre-ozonation on chlorine dioxide addition; and the need and efficiency of granular or powdered activated carbon processes. Regarding the use of small-scale systems, it was found that small-scale processes which will operate similarly to a full-size process, can be constructed with the help of a flow model. Trials, carried out when planning extensions to processes or modifications of processes, may then be performed on a small scale.

A user-friendly, interactive computer program, IMPULSE, was written to perform residence time distribution analyses from tracer tests. It allows easy modelling of systems using curves obtained from tracer response tests. The user assumes a flow model for the system; the program allows determination of the response curve for the model, and adjustment of the estimated parameters of the model to fit the experimental curve by minimising the sum of squares error (regression on the data). IMPULSE takes flow-rate variation (and therefore velocity) into account.

Cost: *R560 000*
Term: *1991-1995*

Application of health risk assessment techniques to microbial monitoring data

(No 470) Division of Water, Environment and Forestry Technology, CSIR

The task of formulating water quality criteria and guidelines for the protection of public health has always been complicated by the difficulties of relating levels of micro-organisms in water to health effects in the exposed population. The research team investigated monitoring requirements for risk assessment and current microbial risk assessment models.

It was found that the use of enteric viruses as a general group of micro-organisms for water quality monitoring and estimation of possible health risks adds to the uncertainty in risk calculation.

A main concern is that microbial risk assessment techniques could not be used and applied in South Africa because of a lack of available and reliable data.

Cost: *R85 000*
Term: *1992-1993*

Biodegradable organic compounds and microbiological regrowth in drinking water

(No 541) Scientific Services, Rand Water

During the treatment of potable water, most but not all of the organic compounds contained in the raw water are removed. Biodegradable and/or assimilable organic carbon can be mineralised by heterotrophic micro-organisms and could therefore give rise to bacterial regrowth in the distribution network.

Available methods to determine the biodegradable organic carbon in water were evaluated. The methods of Van der Kooij and Werner were found to be reliable and were used to determine the extent of the problem in the Rand Water distribution system.

Possible seasonal effects on biodegradable organic carbon in water, during the conventional treatment process at Rand Water, were investigated.

The effects of different treatment processes such as silica/lime vs. lime/ferric chloride, high ferric chloride/low lime vs. low ferric chloride/high lime and pre-chlorination vs. pre-ozonation on the concentration and availability of biodegradable organic carbon were also evaluated.

The presence of biodegradable organic carbon directly after treatment (ozonation and/or chlorination) vs. the possible formation in the distribution network was investigated. The use of granular activated carbon (GAC) for the removal of biodegradable organic carbon was assessed.

The methods evaluated could therefore be used to predict bacterial regrowth in the distribution network and to recommend possible adjustments to the treatment process.

Cost: *R465 000*
Term: *1993-1997*

Evaluation of water pipe leaks in the Johannesburg municipal area

(No 587) Division of Materials Sciences and Technology, CSIR

Significant water losses due to leaks and other causes are experienced by the Johannesburg City Council. In fact, the unaccounted-for water (UAW) losses for 1991 amounted to an unacceptably high 23% of the bulk water purchased. The aims of the study were to critically examine the reasons for leaks from water pipes in Johannesburg and to classify the causes of leaks. Although corrosion is accepted as being responsible for the bulk of the leaks occurring in water pipes, no detailed systematic evaluation has been undertaken to classify the corrosion mechanisms responsible for failure. This aspect is considered to be critically important if correct remedial measures are to be implemented. Findings from the investigation indicated that:

- Unprotected mild steel pipelines in potable waters are susceptible to microbially induced corrosion (MIC), both internally and externally.
- Sulphate reducing bacteria (SRB) play a major role in the corrosion process.
- The majority of corrosion failures of the potable water pipelines sections studied were external.
- Preferential weld corrosion was prevalent.
- Stray currents are active and contributed to 7% of the total failures.
- The level of cathodic protection in the Johannesburg municipal area was generally ineffective or non-existent which indicates that active corrosion of metallic pipelines is occurring.
- Of a total of 126 pipe samples tested in the Johannesburg:
  - 41% failed due to external corrosion damage
  - 25% failed due to internal corrosion damage
  - 32% failed due to both external and internal corrosion damage.
- External corrosion failures accounted for 57% of all bulk water reticulation corrosion failures.
- The presence of electric railways, direct current generators and electric cables is a common feature of a highly developed city like Johannesburg, contributing to 7% of all failures due to stray currents. This illustrates the importance of cathodic protection to minimise the problem.

- The effects of galvanic corrosion were noted on some pipelines where two dissimilar metals were joined together due to either ignorance or irresponsibility.

Cost: *R162 800*
Term: *1993-1996*

Design and analysis package for air saturation systems used in dissolved air flotation

(No 872) Department of Civil Engineering, Rand Afrikaans University

Dissolved air flotation was introduced to the drinking-water field about 30 years ago. Initially, the emphasis was mainly on empirical development of the process. South Africa, in particular, played a leading role during these years. This was documented in the WRC-sponsored *A South African Design Guide for Dissolved Air Flotation*, published in 1993. During the past few years, there has been renewed interest in this field, but now more directed towards the development of a solid theoretical, rational basis. This study was aimed at consolidating both new and older information and guidelines into a single electronic document. The resulting report will be made available exclusively through the WRC website. The approach followed resulted in:

- The development of a computer software program called DESDAF which provides a comprehensive and easy-to-use design and analysis tool for packed saturators used in dissolved air flotation. With only a few inputs from the user, the program either designs a new saturation system from scratch or analyses an existing saturator in terms of air transfer efficiency. The end result in both cases is the amount of air supplied by the saturator to the flotation unit for the formation of microbubbles. The program requires a minimum understanding of the underlying calculations for its successful use.
- DESDAF is supported by a comprehensive help component, which not only serves as a support tool for the design and analysis part of the program but can also be read as a stand-alone documentation. The latter is important for those users,who are looking for a consolidated text on the subject, which has not been available in a single source to date.

This electronic report and its accompanying software are now available on the WRC website at http://www.wrc.org.za/software/desdaf.htm

Cost: *R75 000*
Term: *1997*

Investigation into total organic halogen information after disinfection of drinking water by chlorine

(K8/132) Scientific Services, Rand Water

Chlorinated organic chemicals containing a carbon-to-chlorine bond are man-made and called halogenated compounds which contribute to total organic halogens. This bond is rarely encountered in nature and is difficult to break down.

The potential danger to public health posed by organic halogens has been the subject of attention for some time now by, among others, the World Health Organisation.

The halogenated organic complexes may be produced during the chlorination of drinking water and it is important to assess the situation with regard to their occurrence in potable water from local purification plants.

Rand Water investigated the determination of the concentration levels of toxin organic halogen (TOX). The research team found TOX measurement to be an inexpensive and useful method for screening large numbers of samples before using specific and more complex analyses to monitor the breakthrough of some synthetic organic compounds in the water treatment process and estimating the level of formation of chlorinated organic by-products after disinfection with chlorine.

Cost: *R85 000*
Term: *1994*

New projects

Water leakage: Pressure management model

(No 997) WRP (Pty) Ltd.

Water demand management is rapidly becoming a major issue in South Africa as the country's water resources become fully utilised. The options of new water infrastructural developments and major water transfers are becoming limited and in all cases more expensive. In the last two years it has become apparent that South Africa must look to better water-use efficiency in order to curb the growing demands and in so doing, reduce the need for new water transfer schemes or postpone such developments as long as possible through greater water-use efficiency and proper water demand management.

Considerable work is being undertaken in the field of leakage reduction and management. The approach basically involves four main components which are:

- Water audit process
- Nightflow analysis
- Economic analysis
- Pressure management.

Software models and guidelines for the first three components have already been produced or are in the process of being developed for the WRC. The fourth component on pressure management has yet to be developed in South Africa and is basically the missing link to the full leakage management approach as used elsewhere in the world.

The aim of the proposed project is to produce a user-friendly Windows-based software package to assist water suppliers in evaluating whether or not they can reduce water consumption through pressure management. The proposed pressure management model will complement the nightflow analysis and financial analysis models. A comprehensive user guide will accompany the model and include several actual examples from South Africa where pressure management has been used to reduce water consumption. The model will provide a simple and easy-to-use tool to enable water suppliers to evaluate the savings in water consumption and reduction in burst and background losses that can be achieved through pressure reduction. It will provide information that can be used in conjunction with the economic model to indicate the overall cost or saving associated with pressure reduction.

Estimated cost: *R319 000*
Expected term: *1999-2000*

Modelling of flocculation, thickening and sedimentation in water treatment

(No 998) School for Mechanical and Materials Engineering, Potchefstroom University for CHE

South Africa is a semi-arid country running out of water for all its needs. The problem of decreasing availability and increasing cost of water can be addressed in a number of ways. The first order of priority should be to make the best possible use of what is available, i.e. to effect a significant saving in water consumption. One method to attain this is to optimise water treatment processes. A significant loss of water occurs during treatment due to inefficiencies in the sedimentation/clarification and filtration processes. The reason for the losses in the sedimentation process is the lack of a comprehensive understanding and model of the process itself that can be used to optimise design and operation. Availability of such a tool will improve the technique considerably.

One reason for this lack of a comprehensive model is the nature of the material that is removed from the water during sedimentation. It varies from low concentrations of organic material (micro-organisms), with a density very close to that of the water, to very dense inorganic compounds in crystalline form. The flocculent used can also cause formation of flocs with very different characteristics, from gel-like to dense.

The project aims to:

- Collate the information available in literature on the characteristics of floc and models of floc settling
- Develop and improve the available models of floc settling by incorporating information about the characteristics of different types of floc
- Integrate the information and models about floc settling into models describing sedimentation basin dynamics
- Use the sedimentation models to simulate and investigate the sedimentation process in order to obtain a better understanding of the physical processes involved
- Develop a set of guidelines for the design and operation of sedimentation basins.

The intended output will be a set of guidelines for operation and design of clarifiers and thickeners, and computational fluid dynamics (CFD) models for design and operation of clarification and thickening for research, design and remedial purposes. The project will increase knowledge of the operation of clarifiers and thickeners.

Estimated cost: *R269 000*
Expected term: *1999-2001*

Inhibition of biofilm regrowth in potable water systems

(No1023) Department of Biochemistry and Microbiology, University of Fort Hare

The degradation of the bacteriological quality of water in distribution systems is one of the main problems facing suppliers of potable water. The major water quality objectives in water supplies consist of the removal of micro-organisms which cause "water-borne disease" and the prevention of contamination of drinking water by these organisms during distribution. A recent study by Muyima and Ngcakani (1998) (*Water SA* **24** (1) 29-34) showed that Alice drinking water is of poor quality. The regrowth of heterotrophic bacteria, total and injured coliforms in the chlorinated water between 15 and 23°C was recorded, and all indicators were above acceptable guidelines. Potable water purification in Alice involves sedimentation, sand filtration, and chlorination, using chlorine gas. Although chlorine has been reported to be an efficient disinfectant in the treatment of drinking water, it has also been reported that bacterial regrowth occurred in water when chlorine residual disappeared. It has also been shown that the maintenance of chlorine residual does not eliminate all bacteria in water distribution systems. In another study it was shown that greater persistence of monochloramine residuals inhibits bacterial regrowth.

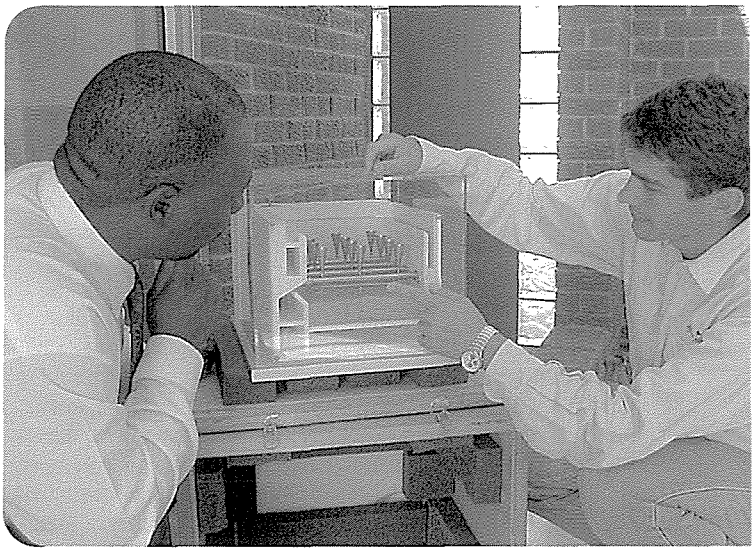
This project is expected to investigate the inhibition of bacterial regrowth and biofilm regrowth, especially that of coliform bacteria in Alice drinking-water systems. The use of chlorine as the primary disinfectant followed by monochloramine as a secondary disinfectant will be investigated, and where necessary, laboratory-scale units will be used.

Estimated cost: *R180 000*
Expected term: *1999-2000*

Evaluation of phase removal processes at SA water treatment plants in terms of particle size and number

(No 1024) Department of Civil and Urban Engineering, Rand Afrikaans University

The removal of particulate matter is one of the most important goals of water treatment. Determining the amount of particles in the raw water, what happens to the particles during treatment and how many particles remain in the effluent are all critical to optimising water treatment plant performance. A number of studies have been performed by the American Waterworks Association (AWWA) where mention is made



Mr Mias van der Walt (Magalies Water) explaining a finer point to Dr Innocent Msibi (WRC) on a model of the proposed dissolved air flotation plant being constructed at the Vaalkop Water Treatment Plant. The WRC has contributed greatly to the development of DAF through numerous projects over the years.

specifically of the use of particle counters for optimising water treatment. Most data in the literature point to the use of particle counters for control of sand filtration, but mention has been made of the optimisation of coagulation and other processes.

This project will specifically look at the available particle counters, configuring of the counters and standardising reporting procedures. It will also establish the baselines in terms of general performance using particle counters and further study the effect of the flocculation regime on final water quality. A full evaluation of filter performance under various hydraulic regimes will be done.

Estimated cost: *R261 000*
Expected term: *1999-2000*

Investigation into the use of particle size analysis for monitoring and optimising plant performance for the production of potable water

(No 1025) Process Facility Department, Umgeni Water

Streaming current and zeta potential are often used as a measure of the destabilisation of particles during coagulation in water treatment. These are also used as control parameters to set chemical dosages. This study complements Project No 1024 and will further look at using the monitoring of particle counts to establish the accuracy of turbidity measurements. The project will also investigate the relationship between particle size and *Cryptosporidium* and *Giardia* in filtered waters from water treatment plants. Studies on the effects of pretreatment processes such as ozonation on the clarity of filtered water by measuring the particle size after filtration, including the use of particle size analysis together with computational fluid dynamics for the optimisation of water treatment equipment will crown this project.

Estimated cost: *R250 000*
Expected term: *1999-2000*

Consolidation and transfer of limestone-mediated stabilisation technology for small- to medium-scale water users

(No 1026) Cape Water Programme, CSIR

It is estimated that 40% of surface waters of South Africa characteristically have low alkalinity, calcium and pH levels. The affected area includes most of the Western Cape and the southern and eastern seaboards, including the Durban region. Furthermore, virtually all the groundwaters of the southern and eastern fringes of South Africa have similar characteristics. The waters described are aggressive to cement-type materials and are corrosive to metals, attacking conduits, fittings and appliances. For the many cities, towns and small communities utilising soft, acidic waters for domestic supplies, this can have significant financial consequences.

The WRC report *Stabilisation of Soft Acidic Waters with Limestone* (Report No 613/1/98) documents the process of identifying a suitable limestone deposit, describes the designs of various small-scale stabilisation systems and presents the results of trials with these systems. This project will therefore continue this work by focusing on the effective transfer of this technology and implementation of limestone-mediated stabilisation. It will also focus on groundwater stabilisation and iron removal, colour limit of feed water and protection afforded by partial stabilisation. Guidelines will be produced and workshops for technology transfer will also be arranged.

Estimated cost: *R275 000*
Expected term: *1999-2000*

Development and assessment of the limestone-mediated sidestream stabilisation process, with emphasis on use thereof by Rand Water for stabilisation of Lesotho Highlands Scheme water

(No 1027) Division of Water, Environment and Forestry Technology, CSIR

Rand Water is in the process of considering options for transport and treatment of the Lesotho Highlands Scheme water. To date Rand Water has abstracted some 95% of its raw water from the Vaal Dam. However, it is expected that by 2008, 50% of raw water will be Lesotho Highlands water. This water is chemically very different to the Vaal Dam water. In particular it is relatively soft and acidic, requiring conditioning to prevent attack on cement and metal structures. The sidestream stabilisation process (SSP) offers a potentially attractive alternative to conventional lime and carbon dioxide mediated stabilisation.

This project will focus on developing a calibrated mathematical model describing the aqueous, gaseous and solid phase chemistry of the carbonate weak/acid system and influencing parameters. Also the desirability and suitability of the SSP for the various Lesotho Highlands water treatment/transfer scenarios will be determined. Further motivation for industrialisation and full-scale implementation will be assessed.

Estimated cost: *R300 000*
Expected term: *1999-2000*

Protocol for surveillance and prospective epidemiological studies of gastro-intestinal health effects due to consumption of drinking water

(No 1028) Scientific Services, Rand Water

The notion that coliform-free water is pathogen-free is being seriously questioned as is the value of current water quality indicators for safe-guarding against water-borne diseases. World-wide, several outbreaks of gastroenteritis, hepatitis, giardiasis and cryptosporidiosis in communities supplied with water meeting current regulations have brought to public attention the fact that current standards may not provide complete protection. In a recent study conducted in Canada with tap water meeting North American regulations, it was estimated that 35% of the reported gastrointestinal illnesses among tap-water drinkers were attributable to the tap water and thus preventable. The rate of disease increased with the amount of tap water consumed and with distance of the household from the treatment plant. Bacterial regrowth in tap water was suggested as an explanation.

The situation in South Africa is not known, therefore the aim of this project is to develop a protocol and expert system (in a user-friendly computer program format) that can be used to guide water suppliers in water-related health investigations.

Estimated cost: *R225 000*
Expected term: *1999-2000*

Evaluation of alternative disinfection processes for the removal of protozoan oocysts and cysts and other micro-organisms, in the treatment of final wastewater effluents

(No 1030) Umgeni Water

Wastewater effluents are routinely chlorinated prior to discharge to river or sea. However, low concentrations of chlorine residuals are toxic to aquatic life and some chlorination by-products have been shown to be mutagenic.

Obviously more effective disinfection of wastewater effluents is required than can be achieved using chlorine under the present DWAF residual chlorine standards. Monitoring of the microbiological quality of such effluents needs to be extended beyond the usual bacterial indicator organisms such as *E. coli*, faecal *Streptococci* and coliform organisms. A number of alternative disinfectants warrant investigation, including ultraviolet irradiation (UV) and ozone, UV/chlorine and UV/ozone and membrane filtration prior to disinfection by any of the above approaches.

The overall aims of this project are to evaluate different disinfectants for adequate disinfection of wastewater effluents in terms of parasitic cysts, viruses and bacterial indicator organisms and to provide design and operational guidelines for simple and effective disinfection of wastewater effluents.

Estimated cost: *R207 000*
Expected term: *1999-2000*

Occurrence of emerging viral, bacterial and parasitic pathogens in source and treated water in South Africa

(No 1031) Department of Microbiology and Plant Pathology, University of Pretoria

Several pathogens could be responsible for water-borne disease. Among them are a number of disease-causing agents that have been gaining importance in the last decade or have recently been identified. These emerging pathogens are not restricted to a specific group of organisms and include viruses, bacteria and parasites.

Little information is available on the presence of these emerging pathogens in South Africa but there are indications that these pathogens are present in source and treated water. An urgent need, therefore, exists for the detection and quantification of these emerging pathogens in order to be able to control and minimise their risk to human health.

The aims of this project are to verify these emerging pathogens and establish techniques for the specific detection and quantification thereof in source and treated water of South Africa, as well as to formulate future research needs and management strategies regarding those organisms that are of concern for South Africa.

Estimated cost: *R400 000*
Expected term: *1999-2000*

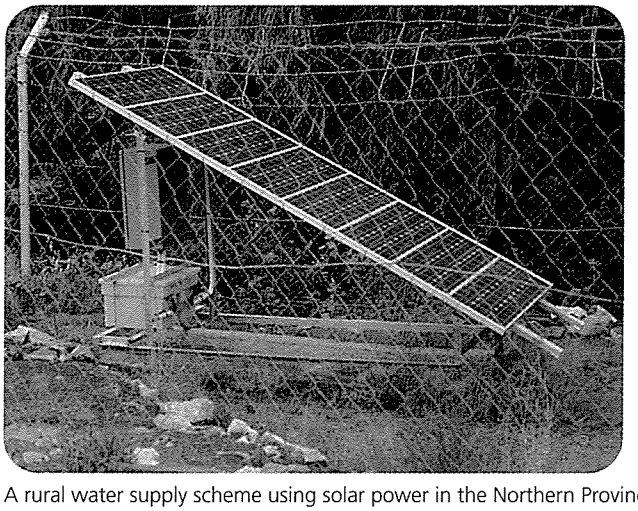
Support, maintenance and debugging of WATREX – Expert System for Water Treatment Plant Design

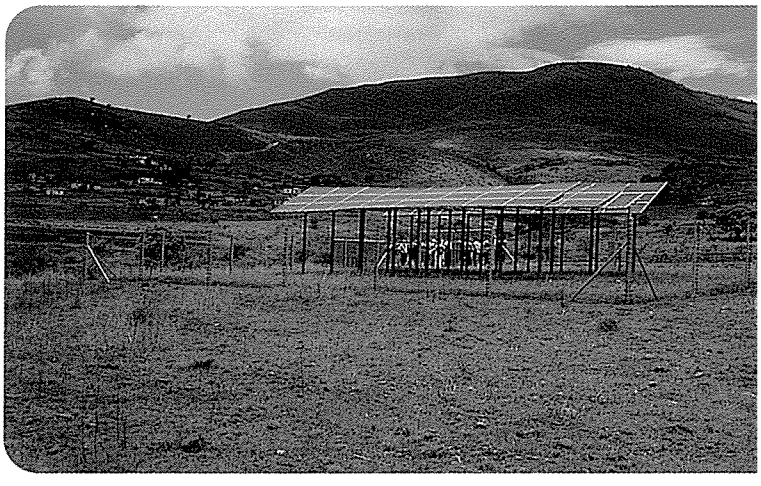
(No 1041) Sutherland Associates

The WATREX program, or Expert System for Water Treatment Plant Design, is a program for the computer-assisted design of drinking-water treatment plants. It is in the final stages of evaluation before it is to be distributed. This program has excellent potential to elicit a great deal of interest – both locally and abroad. However, after distribution has commenced, it is of the utmost importance that a user service for the program be maintained, at least for the initial period until most of the "bugs" discovered and reported have been sorted out. Feedback from the users can be used to refine the operation of the program and this will lead to both the expansion and refinement of the knowledge base behind the program. Specific aims of the project include the following:

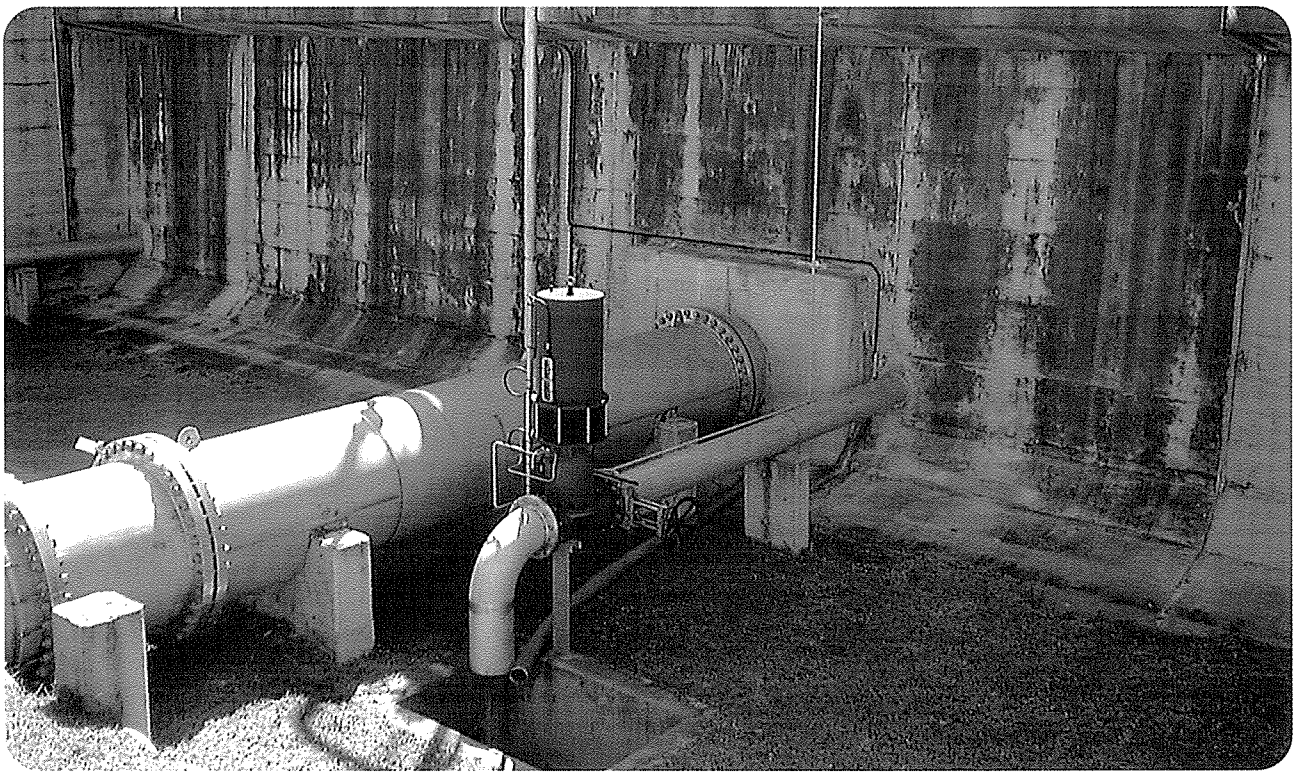
- Compilation and distribution of the WATREX program to interested users
- Continued improvement of the operation and integrity of WATREX (debugging)
- Refinement and expansion of the knowledge base behind WATREX
- Provision of on-line support to WATREX users in order to enhance usage and obtain direct feedback.

Estimated cost: *R84 000*
Expected term: *1999*

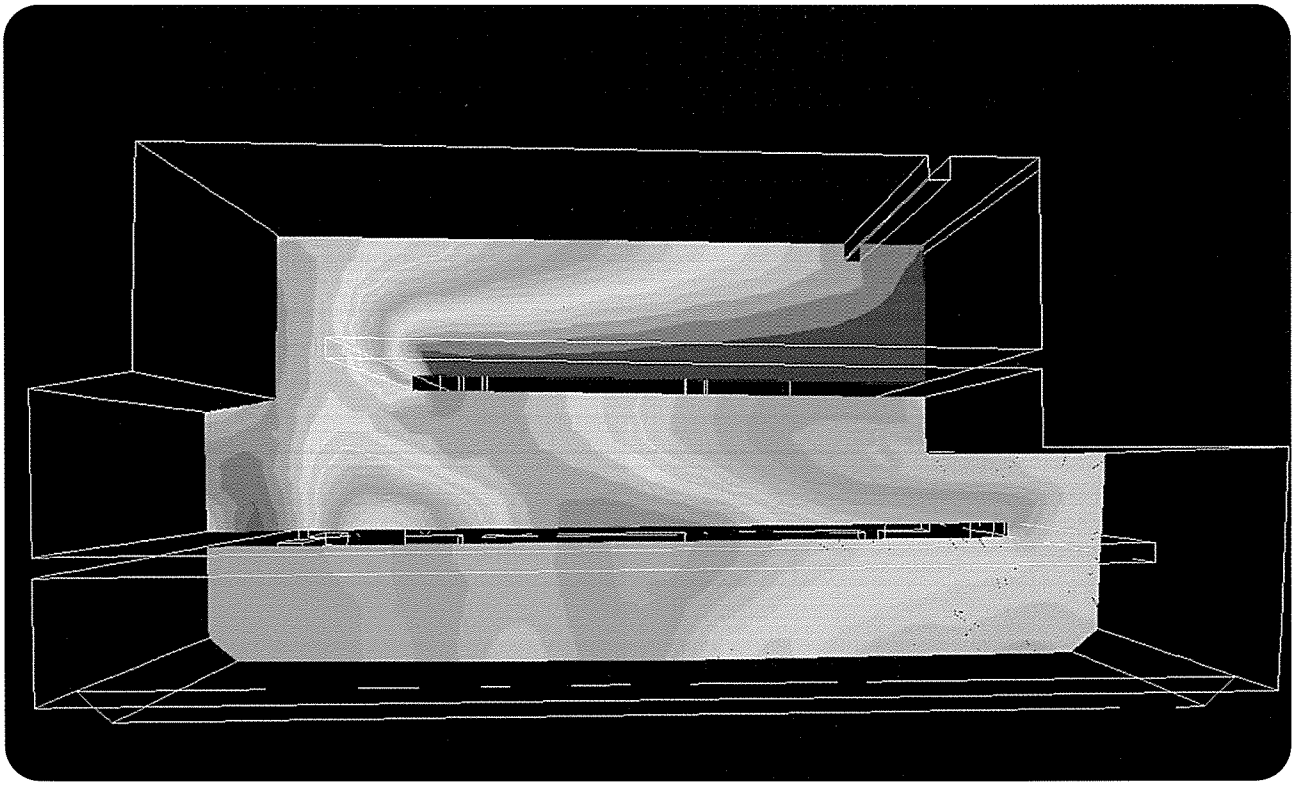




A rural water supply scheme using solar power in the Northern Province.



An outside view of part of one of the contactors, showing the static mixer where ozone is mixed with water before being introduced to the contactor, which is the concrete structure visible in the picture.



This picture is plotted from a CFD simulation of a tracer test on the contactor, in which a pulse of coloured tracer is suddenly introduced through the static mixer, which is located at the bottom left of the diagram. The coloured contours indicate concentrations of tracer distributed on a vertical section through the contactor, at 3.5 minutes after the tracer was introduced, just as it is about to appear for the first time at the contactor outlet, which is located at the top right of the diagram.

Determination of cytotoxicity and invasiveness of heterotrophic plate count bacteria isolated from drinking water

(No 1069) Scientific Services, Rand Water

Naturally occurring micro-organisms in drinking water are of great concern to suppliers of potable water. Microbiological guidelines for drinking-water quality are used to assess the health risks that treated water could pose to the consumer.

The current SABS standard plate count (SPC) or heterotrophic plate count (HPC) guidelines for treated drinking water in South Africa are often exceeded by water suppliers.

Therefore, whenever this guideline is exceeded, water suppliers add more chlorine to comply with the SABS standard which may be excessively stringent. A literature survey of guidelines revealed only one proposed HPC guideline which was fivefold higher than the South African guideline.

According to overseas studies the association between HPC bacteria in drinking water and gastroenteritis could not be proven. This has financial implications both for the supplier and consumer.

The overall aim of this study is to assess the health risk posed by virulent heterotrophic plate bacteria using various methods and re-evaluate current microbiological water quality guidelines for South African conditions.

Estimated cost: *R500 000*
Expected term: *1999-2000*

Research projects

Completed

- **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 – Scientific Services)
- **470** Application of health risk assessment techniques to microbial monitoring data (CSIR – Division of Water, Environment and Forestry Technology)
- **541** Biodegradable organic compounds and microbiological regrowth in drinking water (Rand Water – Scientific Services)
- **587** Evaluation of water pipe leaks in the Johannesburg municipal area (CSIR – Division of Materials Sciences and Technology)
- **872** Design and analysis package for air saturation systems used in dissolved air flotation (Rand Afrikaans University – Department of Civil Engineering)
- **K8/132** Investigation into total organic halogen information after disinfection of drinking water by chlorine (Rand Water – Scientific Services)

Current

- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (Orange Free State Gold Fields Water Board)
- **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)
- **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 – Scientific Services)
- **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)
- **611** Development of procedures for biodegradability testing of organic chemical compounds (CSIR – Division of Water, Environment and Forestry Technology)
- **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 wastewater 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 – Scientific Services)
- **737** Additional treatment requirements of water abstracted from the Vaal River system following the importation of Lesotho Highland 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)
- **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)
- **825** Preparation and testing of kits for the detection and quantification by developing countries of *Cryptosporidium* oocysts and *Giardia* cysts in water supplies (Umgeni Water – Scientific Services, and University of Natal – Department of Microbiology and Plant Pathology)

- **829** Systems for the abstraction of surface water through river sand-beds (Chunnett, Fourie and Partners (CE))
- **831** Development and implementation of gas and liquid chromatographic organic water profiles as a management tool (Rand Water – Scientific Services)
- **832** Application and efficiency of "mixed oxidants" for the treatment of drinking water (Rand Water – Scientific Services)
- **833** Measurement of COD (organics) in drinking waters and tertiary effluents (University of Cape Town – Department of Civil Engineering, Water Quality Group)
- **834** Photocatalytic purification of drinking water (University of Stellenbosch – Chemistry Department)
- **836** Evaluation and development of physical water treatment processes for the reduction of scale in heating and cooling circuits (Rand Afrikaans University – Departments of Chemistry and Mechanical Engineering)
- **873** Chemical and microbiological evaluation of the performance of commercially available home treatment devices (Rand Water – Scientific Services)
- **898** Economic model for leakage management (BKS (Pty) Ltd.)
- **919** Optimisation of an automatic backwashing filter for the cost-effective production of potable water for rural areas (Umgeni Water – Scientific Services)
- **920** Evaluation of a filter washwater recovery plant to establish guidelines for design and future operation (Rand Water – Scientific Services)
- **921** Water quality deterioration in potable water reservoirs relative to chlorine decay (Rand Water – Scientific Services)
- **922** STASOFT IV – A user-friendly computer program for use in the treatment of municipal water supplies (University of Cape Town – Department of Civil Engineering)
- **923** Supercritical fluid regeneration of activated carbon applicable to water fraternity (Potchefstroom University – Centre for Separation Technology)
- **924** Characterisation and chemical removal of organic matter in South African coloured surface waters (Chris Swartz Engineering)
- **948** Water meters: Influence of various fittings and installation configurations on accuracy (SABS)
- **963** Trouble-shooting guide for the domestic consumer (Rand Water – Scientific Services)
- **984** Benchmarks and cost parameters in water and wastewater treatment (Philip Pybus (CE))

New

- **997** Water leakage: Pressure management model (WRP (Pty) Ltd.)
- **998** Modelling of flocculation, thickening and sedimentation in water treatment (Potchefstroom University for CHE – School for Mechanical and Materials Engineering)
- **1023** Inhibition of biofilm regrowth in potable water systems (University of Fort Hare – Department of Biochemistry and Microbiology)
- **1024** Evaluation of phase removal processes at SA water treatment plants in terms of particle size and number (Rand Afrikaans University – Department of Civil and Urban Engineering)
- **1025** Investigation into the use of particle size analysis for monitoring and optimising plant performance for the production of potable water (Umgeni Water – Process Facility Department)
- **1026** Consolidation and transfer of limestone-mediated stabilisation technology for small- to medium-scale water users (CSIR – Division of Water, Environment and Forestry Technology)
- **1027** Development and assessment of the limestone-mediated sidestream stabilisation process, with emphasis on use thereof by Rand Water for stabilisation of Lesotho Highlands Scheme water (CSIR – Division of Water, Environment and Forestry Technology)
- **1028** Protocol for surveillance and prospective epidemiological studies of gastro-intestinal health effects due to consumption of drinking water (Rand Water – Scientific Services)
- **1030** Evaluation of alternative disinfection processes for the removal of protozoan oocysts and cysts and other micro-organisms, in the treatment of final wastewater effluents (Umgeni Water)
- **1031** Occurrence of emerging viral, bacterial and parasitic pathogens in source and treated water in South Africa (University of Pretoria – Department of Microbiology and Plant Pathology)
- **1041** Support, maintenance and debugging of WATREX – Expert System for Water Treatment Plant Design (Sutherland Associates)
- **1069** Determination of cytotoxicity and invasiveness of heterotrophic plate count bacteria isolated from drinking water (Rand Water – Scientific Services)

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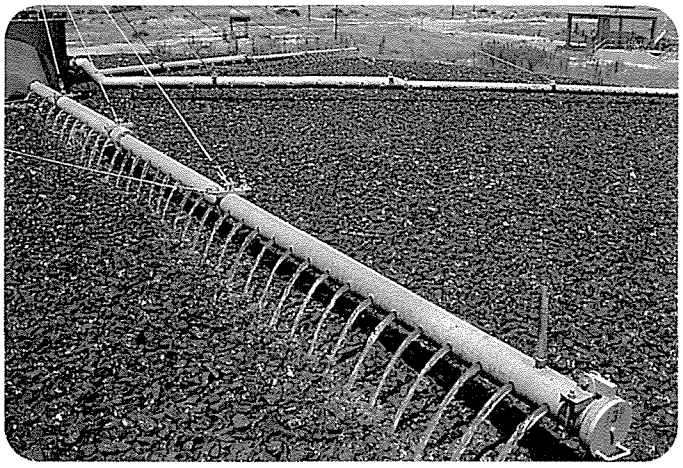
4 Municipal wastewater management



All South African citizens have recently-acquired constitutional rights to a minimum quantity of good-quality water. As service provision of housing, water supply and sanitation progresses, there will be a corresponding increase in the volumes of domestic wastewater produced. The increasing wastewater loads will be discharged in varying proportions regionally both as point loads reticulated to metropolitan or smaller sewage works and as diffuse sources from dense peri-urban settlements. This scenario presents the current challenge to the effective management of domestic (municipal) wastewater treatment practice in the RSA.

Sewage purification

Historically, in the field of sewage purification in the RSA over the past few decades, the simultaneous threats of increasing salinisation and eutrophication of water supplies were cost-effectively met by the development of biological nutrient removal (BNR) processes which removed the nutrients (variously, nitrogen and phosphorus) from treated wastewaters discharged to water-courses without adding to inorganic salt loads as occurs in chemical nutrient removal. Current research into BNR processes is aimed largely at further elucidating the fundamental chemical, biochemical and microbiological mechanisms that govern their functioning in the engineering mathematical models that are now routinely employed for purposes of design and operational control. In this regard, the WRC has launched a research programme to synergistically combine the respective engineering and multi-disciplinary scientific understandings of BNR processes, to improve the security of design and operating procedures used. A particular priority in this programme is to define the active fraction of the heterotrophic and autotrophic biomass responsible for the removal of organic matter (measured as COD) and nutrients (nitrogen and phosphorus compounds) from wastewater during sewage treatment processes.

In the context of new (more stringent) standards for wastewater discharge being imposed by DWAF in terms of the National Water Act, both highly-engineered sewage treatment systems (such as in metropolitan areas, involving sophisticated trains of unit processes) and relatively low-cost sanitation facilities (such as pond systems) will face further pressure to meet the required wastewater discharge quality. As demand management spreads from the industrial sector to the management of domestic water use, an exacerbating factor is that the concentrations of pollutants in raw sewage flows could increase as the volume/mass load ratio varies. Research attention being given to these aspects is essentially aimed at improved understanding/manipulation of the mechanisms and unit processes involved, for designing new works and retro-fitting existing works to meet such demands. Specific research projects in this respect are:

- Continued investigations into external nitrification in trickling filters to enhance the overall treatment capacity of sewage treatment works
- Development of algal improved pond systems (AIPS) and pond-enhanced treatment operations (PETRO) processes to include nutrient removal
- The incorporation of low-cost fixed-film reactor elements into sewage treatment trains to improve nutrient removal
- The co-digestion of refractory wastes from industrial sources with domestic sewage
- Continued research into the use of computational fluid dynamics for the optimisation of individual unit processes is also being supported
- Seminal research into the life-cycle assessment of the overall environmental impacts of alternative wastewater disposal options, specifically adapted to RSA conditions and requirements.

Sewage sludge treatment and disposal

The two most significant directions of current WRC-funded research into sewage sludge treatment and disposal are, firstly, the WRC programme launched into critically re-appraising and possibly modifying the *Sludge Management Guidelines* published by DWAF in 1997, and, secondly, the innovative use of sewage sludges as a carbon source for the remediation of high-volume, long-term wastewaters from mining and industrial sources. In the former (*Sludge Management Guidelines*) context, the strategic aims of the WRC programme are the

preparation of an addendum to the 1997 Guidelines (in the short term), a renewed focus on research needs (in the medium term) and the drafting of a second edition of the Guidelines (in the longer term).

Regarding the second aspect, exciting preliminary results from the use of sewage sludge to provide a carbon source for treating industrial wastewaters from tannery and other industries indicate an accelerated hydrolysis of sewage sludge solids in the presence of anaerobic sulphate-reducing bacteria. The promise indicated is being promoted by the WRC in terms of collaborative full-scale projects with ERWAT (East Rand Water Care Company), supported by more fundamental laboratory- and pilot-scale research projects at Rhodes University (microbiology/enzymology/process development) and the University of Cape Town, Departments of Civil Engineering and Chemical Engineering (aquatic and gaseous sulphur chemistry/kinetic modelling of sulphate-reduction and sulphur-recovery biodesalination processes).

Completed projects

Causes and control of A/A filament bulking in nutrient removal activated sludge systems

(No 542) Department of Civil Engineering, University of Cape Town

Two surveys of filamentous bulking in South African biological nitrogen (N) and nitrogen and phosphorus (N&P) removal plants indicated that bulking caused by low food/micro-organism (F/M) filaments, is the major solid/liquid separation problem through poor sludge settleability in these plants. The main aim of this research was to establish the cause of low F/M bulking and to develop strategies for the control of the low F/M bulking in N and N&P removal plants. The research has shown that the promoted specific control method of selectors which stimulate removal of influent readily biodegradable COD in anaerobic, anoxic or aerobic selectors by metabolic or kinetic selection is not successful for controlling bulking in biological N&P removal plants. It was found that the conditions that stimulate biological N removal are conducive to bulking on nutrient removal plants, i.e. if denitrification is not complete at the time conditions switch from anoxic to aerobic, then proliferation of low F/M (renamed anoxic-aerobic (A/A) to accurately describe the conditions under which they proliferate) filaments takes place.

Cost: *R398 000*
Term: *1993-1996*

High-rate recirculation and solids contact optimisation of biological filtration plants

(No 569) Wates, Meiring and Barnard (CE) Inc.

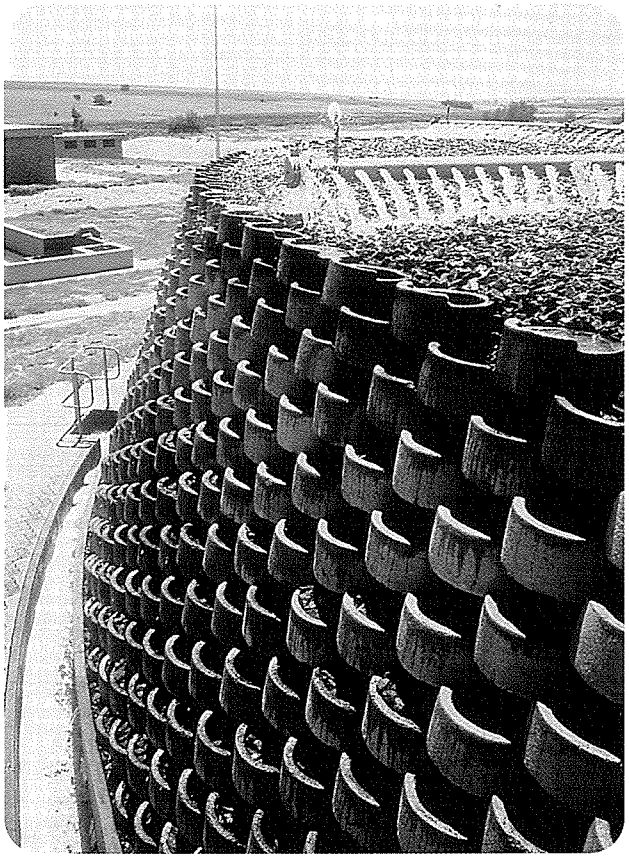
The biofiltration solids contact-process modification was investigated to establish the influence of different process parameters on the final effluent suspended solids concentration. The liquid retention, hydraulic residence time and residence time distribution in biofilters were investigated at different hydraulic loading rates. The carbon removal characteristics of biofilters were compared by using different organic loading rates, media sizes and recirculation.

Existing full-scale intermediate-rate biofilters were found to have substantially under-estimated treatment capacity in terms of carbon removal, as the two treatment plants that were monitored exceeded the design criteria.

An economic analysis confirmed that high-rate biofiltration was an efficient and cost-effective approach. Although the capital construction cost in combination with polishing activated sludge was higher than other process technologies, the operating and maintenance costs were lower. Existing biofilters may be upgraded at relatively low cost to high-rate applications which could increase the reliable treatment capacity and life of an existing plant.

Cost: *R170 000*
Term: *1993-1996*

The Klipspruit Water Care Works (Witbank) utilising the latest biofiltration technology.



Wastewater distribution across a modern biofilter.

Technology adaption for successful application of septic tank systems in the coastal zone

(No 597) Division of Water, Environment and Forestry Technology, CSIR

Septic tank and soak-away systems are widely used for wastewater disposal in South African coastal resort areas. In view of the highly variable loading linked to holiday seasons, few resorts have conventional water-borne sewerage and newer developments rely on conservancy tanks and centralised wastewater soak-away systems. The design and management of these systems vary from area to area and even within single municipalities, as different design criteria have been applied over the years. As a result, septic tank and soak-away systems have developed the reputation of being pollution hazards, involving contamination of groundwater, stormwater runoff and ultimately the local lagoon, estuary or bay.

The aims of the study were to adapt internationally known technology of septic tank systems to the South African coastal environment and to develop a standard and user-friendly set of guidelines for the management of such systems by local authorities. The findings from field studies and tests indicated that:

- The septic tank system is the most commonly used method of domestic wastewater treatment in the coastal zone. The design and management of these systems vary greatly within the region. Differences even occur within single local authority areas.
- Wastewater disposal by means of septic tank systems is a well-established technology and a wealth of technical information is available on design criteria. There is, however, a general lack of technical knowledge at the user level. This is reinforced by a lack of legislation pertaining specifically to septic tank systems.
- The majority of septic tank problems is caused by blocked or inadequate drainage fields and may be attributed to poor location, poor design and lack of maintenance. Greater emphasis should be placed on the land capability assessment and on-going maintenance. Local hydrogeological conditions invariably play a major role in the regional variation of the same generic problem.
- There is an urgent need for greater control in the use of septic tank systems within the coastal zone. Greater attention must be given to the drainage field component of septic tank systems, as this currently receives minimal attention and is the cause of most pollution problems.
- The disposal of septic tank/conservancy tank effluent at communal sites, either by surface spreading or trench infiltration, must be closely monitored. Such operations should require a permit from DWAF and routine groundwater quality maintenance.
- The septic tank system remains the most cost-efficient means of domestic wastewater disposal for the coastal zone. The system must, however, be correctly designed, constructed and maintained.

Two reports emerged from the study, firstly providing information on the status of septic tanks in coastal areas and, secondly, user-friendly guidelines to assist users and practitioners (WRC Report Nos 597/1/99 and TT 114/99).

Cost: *R190 300*
Term: *1994-1996*

Compilation of guidelines for the design and operation of sewage sludge drying beds

(No 604) GFJ (CE) Inc.

The need for efficient handling of waste sewage sludge and drainage liquors has recently been attracting great attention. The climate in most parts of South Africa makes waste sludge treatment in drying beds a very attractive option for smaller authorities. The cost of sludge treatment and disposal forms a large part of the total capital and operational costs of a sewage works. Any optimisation of the design and/or operation requirements for sludge drying beds will result in *pro rata* capital and operational cost savings. As sludge drying beds are generally cleaned and maintained by manual labour, there is the added advantage of job creation.

Current information and guidelines for the design and operation of sewage sludge drying beds in the RSA are very limited. The design data available are largely empirical and give almost no insight into the effect of climate, sludge concentration, loading rates, sludge volume index, filter media, etc. on the drying bed area required. The absence of design and operational data for wastewater sludge drying beds was identified by the Sludge Management Division of the Water Institute of Southern Africa as a major gap in the effective management of sludge. The study emanated from a request by the Sludge Management Division to the WRC to address this problem.

Based on the research and support of experimental work done, as well as information obtained from literature, the study produced a guideline that is specific for South African conditions called *Guidelines for the Design and Operation of Sewage Sludge Drying Beds* (WRC Report No TT 107/99). Based on questionnaire surveys, site visits and interviews held with operators of sewage plants and designers, the study also produced the following findings indicating problem areas:

- A lack of formal training of operators
- Poor design guidelines
- Low productivity and labour difficulties.

Cost: *R178 000*
Term: *1994-1996*

Practical application of special waste co-disposal with municipal refuse at the Coastal Park Landfill bioreactor

(No 606) City Engineer's Department, Cape Metropolitan Council

The conclusions of the study were that a wide array of special wastes with undesirable characteristics produced by industry can be co-disposed together with municipal refuse in the landfill if the site is operated as a bioreactor and controlled application of the special waste is practised.

The City Engineer's Department of the Cape Metropolitan Council has existing infra-structure at the Coastal Park Landfill to conduct this type of research which is unique to South Africa.

The team improved the design, materials and mode of construction of the pilot-scale columns. They applied chemical engineering techniques of reactor design and transport phenomena to determine the behaviour of heavy metals in a landfill environment.

The data collected at the Coastal Park Landfill included

rainfall and leachate outflow and thus enabled the team to construct a water balance and to develop models to predict water flow and leachate generation.

Cost: *R334 400*
Term: *1994-1996*

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. The project aimed to elucidate the metabolism of microbial communities in activated sludge plants by characterising metabolic zones in a typical activated sludge reactor, as well as in different designs of activated sludge plants. The research indicated that the protein fingerprinting method was a sensitive tool for the determination of the bacterial population structure in activated sludge plants. Differences in system design and the type of wastewater treated did not alter the protein profile of bacterial proteins. This indicates that activated sludge systems are not dominated by any specific group of bacterial species, but different bacterial species co-exist and function together in a complex microbial community.

Cost: *R154 000*
Term: *1996-1997*

New projects

Critical appraisal of guidelines for sewage sludge disposal

(No K8/361) Sludge Consult

World-wide, sludge disposal poses an ever-increasing problem to wastewater treatment authorities. Disposal options such as sea disposal, sacrificial land disposal and incineration are increasingly falling out of favour because of environmental and cost considerations. Agricultural utilisation, on the other hand, is gaining in popularity because of its recycling and environmentally sustainable characteristics. The acceptable metal content of the recently issued South African guidelines for sludge utilisation appear to be very restrictive to land application of sludge. This consultancy is being undertaken with the co-operation of the major sludge producers and the Government Departments concerned as part of a phased process to:

- Prepare an addendum to the present guidelines containing explanatory notes on the way in which the present guidelines should be interpreted and implemented
- Identify and initiate research and other actions which should culminate in the drafting of a second edition of the guidelines based on local experience.

Estimated cost: *R100 000*
Expected term: *1999-2000*

Extension of applications and optimisation of operational performance of algal integrated ponding system (AIPS) technology in appropriate low-cost treatment of industrial and domestic wastewaters

(No 1073) Department of Biochemistry and Microbiology, Rhodes University

The algal integrated ponding system (AIPS) technology brought to South Africa from the USA by the WRC promises to be a low-cost alternative wastewater treatment technology eminently suitable for South African conditions. To demonstrate the feasibility of the process, the WRC funded Project No 651 entitled **Appropriate low-cost sewage treatment using the advanced algal high-rate oxidation pond**. The main aim of this project was to construct a demonstration plant, proving the underlying principles of the AIPS process and to effect technology transfer.

This phase has been successfully achieved and the investment substantiated by an increasing number of both potential users and engineering consultants interested in utilising the technology. Furthermore, the official opening of the plant at Grahamstown by the Minister of Water Affairs and Forestry, focused the attention of decision-makers on the potential application of AIPS in the Government's RDP programme.

The second phase of AIPS technology transfer involved a monitoring programme to collect operational data after the commissioning phase and to undertake a first-order assessment of both potential problems and opportunities for process improvement under South African operating conditions (WRC Project No 799). This project has demonstrated both a number of shortcomings in the current design (such as unreliable operation of the fermentation pit in the primary facultative pond under shock loading conditions and low anaerobic digestion rates due to poor sludge retention characteristics) and significant opportunities for extending the applications of AIPS, including the potential use of AIPS technology as a free-standing tertiary treatment process for nitrogen and phosphate removal, for rapid alkalisation of acidic industrial effluent, and for effective odour control on anaerobic waste stabilisation pond installations.

The aims of the project include the following:

- To undertake scale-up evaluation of laboratory findings relating to the improved performance of the AIPS anaerobic pit digester utilising UASB-type configurations
- To develop the application of the AIPS high-rate algal pond as a free-standing tertiary treatment unit operation for the removal of nitrates and phosphates from conventionally treated sewage effluents.

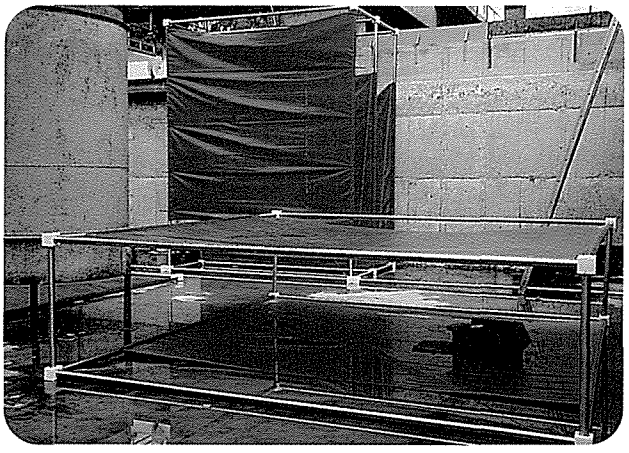
Estimated cost: *R942 000*
Expected term: *1999-2001*

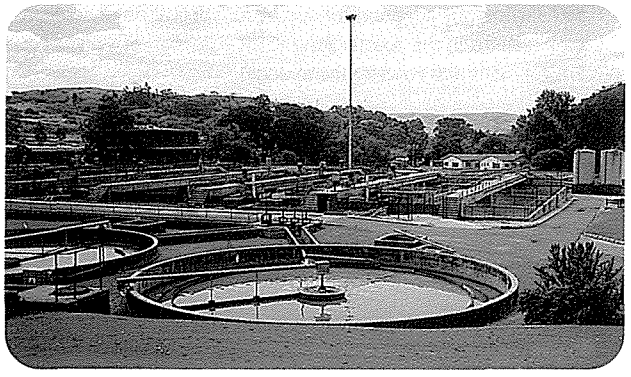
Computational fluid dynamic support to water research projects

(No 1075) Pollution Research Group, University of Natal

Computational fluid dynamics (CFD) is a numerical procedure to calculate the properties of moving fluid as occurs in most water treatment processes to provide insight into processes which otherwise would not have been possible. A previous WRC project (No. 648) indicated the value of CFD modelling of clarifiers and an anaerobic reactor. This project proposes to extend and build on the lessons and skills obtained. The reliability of user-friendly commercial computer software has brought this tool within the reach of consultants and water authorities. In order to promote its use in the RSA, the benefits must be shown and people trained in its use. The overall aim of the project is to provide a service to water researchers by undertaking modelling exercises on proposed and existing equipment so that they may design more efficient experimental equipment and to better interpret their experimental results. Thereby it is hoped to promote the use of CFD by water authorities, consultants and water researchers. In addition, training assistance will be provided to academics and students in the practical use of computational fluid dynamics.

Estimated cost: *R795 000*
Expected term: *1999-2001*





The early stages in the construction of a novel anoxic reactor insert before baffle tightening for pilot trials at Daspoort Sewage Treatment Works.

Development of a novel reactor insert to upgrade anoxic reactors in biological nutrient removal wastewater treatment plants

(No 1076) Division of Water, Environment and Forestry Technology, CSIR

In the operation of South African biological nutrient removal (BNR) plants, a common problem is that optimal recycle flows are difficult to achieve due to variations in the TKN/COD ratios of the plant feed. When nitrate enters the anaerobic unit, the phosphorus-removal efficiency drops, and a lower quality effluent is released. More robust techniques/structures need to be developed to ensure that recycled flows are completely denitrified.

This project will develop, build and test a novel reactor insert that can be retrofitted to domestic wastewater treatment plants, or used as the core of new low-capital treatment units. The proposed technology is based on the theory that biofilms have lower energy requirements than free- swimming organisms and that biofilms can thrive at low nutrient concentrations.

Estimated cost: *R163 000*
Expected term: *1999-2000*

Use of life-cycle assessments in the selection of water treatment processes

(No 1077) Department of Chemical Engineering, University of Natal

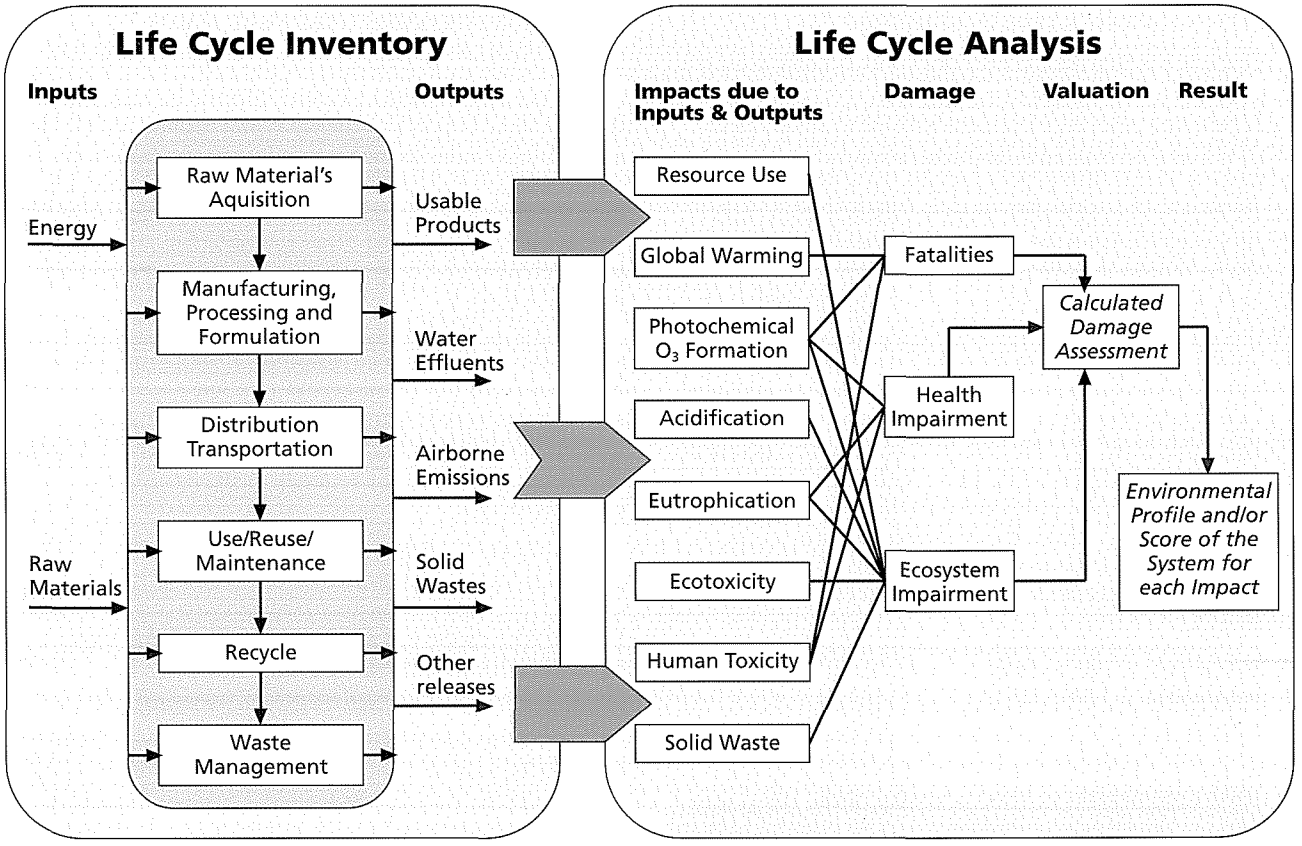
Life-cycle assessment (LCA, also known as life-cycle analysis) is one of the tools of "cleaner production" that can be used to calculate the overall environmental burden of products, processes and services. It can be undertaken in increasing degrees of detail. After an LCA exercise on two or more processes has been completed, the differences in the environmental burden of the processes can be quantified. The LCA of a complex system is the sum of the impacts of the components of the subsystems. The LCA is only a tool in making an informed decision, it does not replace informed decision-making. It does, however, provide a logical basis for making informed decisions about the environmental consequences of design decisions.

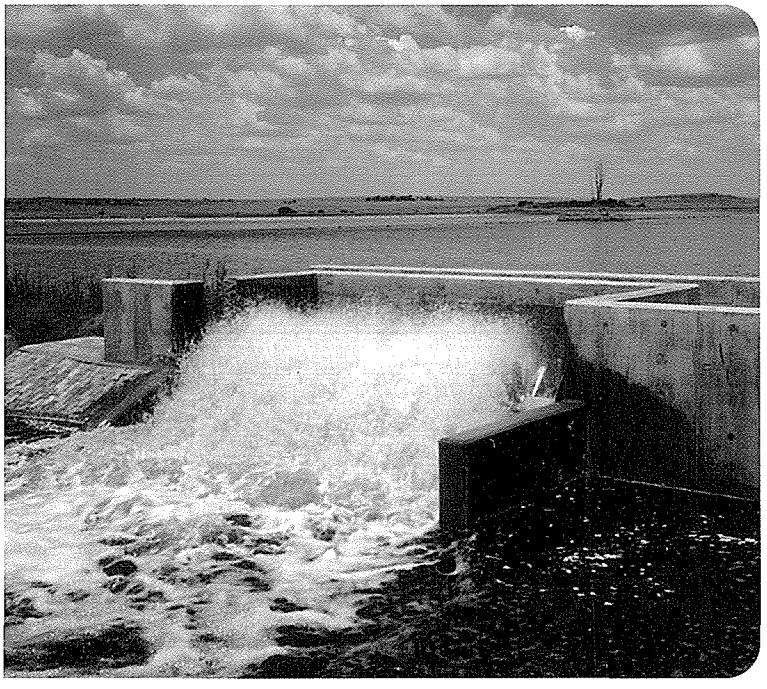
International trade is starting to require information on the environmental impact of products, processes and services. Water and wastewater treatment is a component of most economic activities. Thus it makes a contribution to the total life-cycle environmental impact of that activity. South African exports will be at a disadvantage unless this information is available, since, in the absence of data, international worst case estimates will be used to the possible detriment of exporters of commodities, goods and technology.

The project aims to improve the total environmental performance of selected water and wastewater treatment processes, and to guide designers and owners of water and wastewater treatment facilities on the full-life cycle environmental consequences of selected treatment processes.

Estimated cost: *R520 000*
Expected term: *1999-2000*

Life Cycle Assessment: An Overview





A key factor for the low-tech generation of readily biodegradable organics in the envisaged BNR PETRO concept: Algae-rich recycle provided to the surface of the primary pond (Bloemfontein).

Research projects

Completed

- **542** Causes and control of low A/A filament bulking in nutrient removal activated sludge systems (University of Cape Town – Department of Civil Engineering)
- **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)
- **604** Compilation of guidelines for the design and operation of sewage sludge drying beds (GFJ (CE) Inc.)
- **606** Practical application of special waste co-disposal with municipal refuse at the Coastal Park Landfill bioreactor (Cape Metropolitan Council – City Engineer's Department)
- **776** Fingerprinting of activated sludge systems using PAGE analysis of total protein extractions for the optimisation of biological phosphorus removal (University of Pretoira – Department of Microbiology and Plant Pathology)

Current

- **248** Chemical augmentation of biological phosphate removal (Greater Johannesburg Metropolitan Council (GJMC))
- **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)
- **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)
- **560** Development of a cross-flow microfiltration unit to improve the performance of anaerobic digesters at wastewater treatment works (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **620** Modelling, design and operation of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **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)
- **692** Treatment of wastewaters with high nutrients (N and P) but low organic (COD) contents (University of Cape Town – Department of Civil Engineering)
- **713** Removal of algal and other biomass from treated wastewaters employing the PETRO® process (Wates, Meiring and Barnard (CE) Inc.)
- **739** Disinfection of purified effluent (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **775** Development of strategies for amelioration of bulking by anoxic-aerobic filamentous organisms in nutrient removal activated sludge systems (Stewart Scott (CE) Inc.)
- **799** Development and monitoring of integrated algal high-rate oxidation pond technology for low-cost treatment of sewage and industrial effluent (Rhodes University – Department of Biochemistry and Microbiology)
- **820** Production and biodegradation of organic carbon from sewage and biological sludge for denitrification (University of Natal – Pollution Research Group)
- **822** Investigation and comparison of microbial contribution to nutrient removal in activated sludge and trickling filter wastewater treatment processes (Technikon Natal – Department of Biotechnology)
- **823** Full-scale demonstration of specific filamentous bulking control in a biological nutrient removal activated sludge plant at Mitchells Plain wastewater treatment plant (University of Cape Town – Department of Civil Engineering)
- **835** Hydrodynamic modelling of secondary settling tanks (University of Cape Town – Department of Civil Engineering)
- **848** Water Institute of Southern Africa *Operators Handbook* (Philip Pybus (CE))
- **929** Investigation into optimisation of high-rate biological filtration for wastewater treatment (Wates, Meiring and Barnard (CE) Inc. – Water Engineering Division)
- **933** Biological application in microbial diversity studies of activated sludge (University of Pretoria – Department of Microbiology and Plant Pathology)
- **934** Bio-augmentation of activated sludge for enhanced biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **970** External nitrification with the aid of fixed media trickling filters (TF) to increase the capacity of biological nutrient removal (BNR) suspended medium activated sludge (AS) systems (University of Cape Town – Department of Civil Engineering)
- **971** Transforming the PETRO® process to provide for biological nutrient removal (PGJ Meiring Konsult)

New

- **K8/361** Critical appraisal of guidelines for sewage sludge disposal (Sludge Consult)
- **1073** Extension of applications and optimisation of operational performance of algal integrated ponding system (AIPS) technology in appropriate low-cost treatment of industrial and domestic wastewaters (Rhodes University – Department of Biochemistry and Microbiology)
- **1075** Computational fluid dynamic support to water research projects (University of Natal – Pollution Research Group)
- **1076** Development of a novel reactor insert to upgrade anoxic reactors in biological nutrient removal wastewater treatment plants (CSIR – Division of Water, Environment and Forestry Technology)
- **1077** Use of life-cycle assessments in the selection of water treatment processes (University of Natal – Department of Chemical Engineering)

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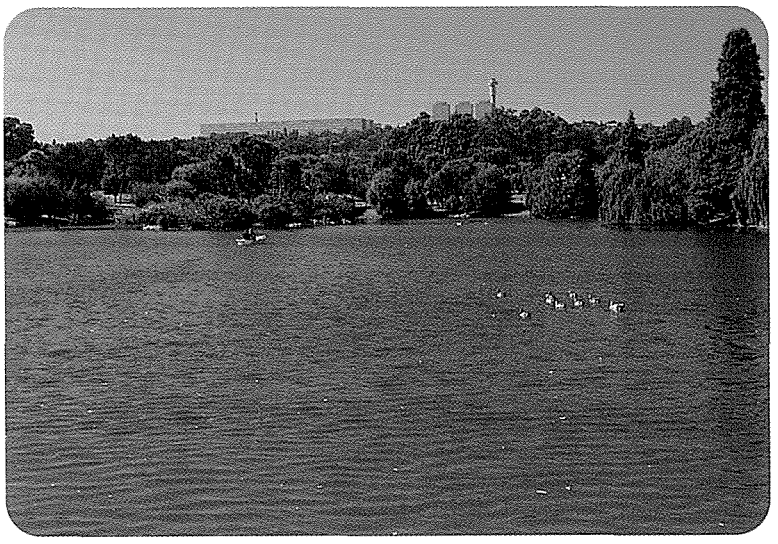
5 Water quality management



Impaired water quality has a negative impact not only on potable use, but on practically all water uses. It is further an unfortunate fact that most water uses are accompanied by a deterioration in water quality. In a water-scarce country such as South Africa with a diminishing surplus dilution capacity, water quality might therefore deteriorate rapidly if a high level of water quality management is not maintained. This will not be easy and experts warn that in the longer term it may be more difficult to sustain the provision of water of an acceptable quality, than merely ensuring an adequate supply.

The research projects funded by the WRC in the field of water quality management are aimed at ensuring that the quality of our water resources is maintained and, where possible, improved for the benefit of all our people and the water environment. A number of projects analyse the current water quality situation, establishing causes, extent and impact of poor quality on users. Other projects aim to improve our ability to predict system response to natural driving forces, disturbances, pollution incidents and management interventions, or to obtain a better understanding of the processes which operate in nature. Increasing attention is being devoted to the use of biological methods of water quality assessment.

Poor water quality manifests itself in several ways:

Salinisation remains one of the consequences of water pollution which is most widespread in South Africa. With increasing salinity water becomes less fit for most users, who consequently have to incur additional costs. Because its effect is creeping and incremental, negative impacts may 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 connected with development.

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 excrete toxins.

Microbiological pollution and organic contamination result from areas with inadequate provision for sanitation (especially high-density settlements), overloading or improper operation of wastewater treatment plants and the use and disposal by industry, agriculture and households of an ever-expanding range of organic chemicals. They are closely linked to health-related water quality issues and are commanding increasing attention.

Completed projects

Hydrosalinity studies in the Eastern Cape

(No195) Institute for Water Research, Rhodes University

Since crops use water consumptively the concentration of salts in irrigation water is increased manyfold in the drainage emanating from irrigated land. The possible use of the Sundays River as conduit for the supply of Orange River water to Port Elizabeth thus gave reason for concern and led to this study being undertaken in order to gain a better understanding of the hydrosalinity process in the lower Sundays River valley, and to select and evaluate hydrosalinity models appropriate to irrigation management. On a macro-scale, irrigation was found to be associated with a marked rise in the groundwater table which gave rise to an increase in the base flow of the river. The irrigation drainage was significantly less saline than the natural groundwater. Water flow through larger soil pores was found to play a significant role in explaining the observed salt and water balances within an orchard. Since existing hydrosalinity models largely ignore macro-pore flow they proved to be inappropriate to model irrigation drainage in the study area. This demonstrated the need for research on and development of models suitable for macro-pore flow dominated drainage.

Cost: *R1 394 400*
Term: *1987-1992*

Coastal pollution: Pathogenic micro-organisms

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

The fundamental objective of this project was to establish South African water quality guidelines to protect the health of those who use the marine environment for either recreation or as a source of food. The approach followed in formulating realistic guidelines was to base them on correlations between the quality of seawater/seafood and the incidence of related infections among bathers/consumers. For this purpose the research team developed a practical and efficient procedure for the recovery of viruses and indicators in shellfish. Methods for more reliable indicators of viral depurination and faecal pollution were also investigated and are described in the final report. The project team furthermore formulated a protocol for the microbiological analysis of shellfish and recommended limits for the microbiological quality of shellfish intended for human consumption. The *Water Quality Guidelines for the South African Coastal Marine Water* (Volumes **1** and **3** dealing with Recreational Use and Mariculture, respectively), published in 1996 by the DWAF, was another product based on the information emanating from this project.

Cost: *R310 000*
Term: *1991-1994*

Relationship between atmospheric deposition and water quality in a small upland catchment

(No 421) Division of Water, Environment and Forestry Technology, CSIR

Earlier studies indicated that only about 10% of the sulphate load (largely emanating from sulphur dioxide released by burning of coal) in rain falling in the Vaal Dam catchment can be accounted for in the inflow into the Dam. This implies that sulphate is being immobilised in soil and that Vaal Dam salinity may increase significantly in future once a new equilibrium between sulphate input and output has been established in its catchment. The WRC launched a programme to investigate the assumptions underlying the anticipated increase in salinity. This project investigated the sulphate input component. Wet deposition was measured using a standard automatic wet sampler, while a number of techniques were used to estimate dry deposition in a small undisturbed catchment in the Suikerbosrand. The ratio between wet and dry deposition was related to the amount of rainfall. Dry deposition as a fraction of total deposition varied between 39% (during an "above normal" rainfall summer season) and 91% (during the dry winter season). The total output of sulphate from the catchment as recorded at a weir at the catchment outlet, varied between 9% and 17% of the total sulphate input. This indicate that most of the sulphate deposited, was most likely being retained within the catchment.

Cost: *R462 400*
Term: *1992-1993*

Validation of the modified MINLAKE model on Roodeplaat Dam

(No 785) Stewart Scott (CE) Inc.

Earlier research on the use of hydrodynamic reservoir models (Project No 304) demonstrated their potential to simulate hydrodynamic reservoir processes such as mixing, within reservoir flow and stratification/destratification. MINLAKE was one of the models which was evaluated. Although being only one-dimensional, MINLAKE uses routines to predict water quality and growth of different algal classes, which are more advanced than those used by the other models tested. It thus has the potential to predict the longer-term consequences of water quality management options aimed at eutrophication control. After incorporating modifications to account for chemical processes which are important in the warmer waters of South African reservoirs, MINLAKE succeeded in simulating the water quality behaviour of Roodeplaat Dam remarkably well. During follow-on testing it simulated the change in phosphate concentration that occurred from the calibration to the validation period as a result of the implementation of the 1mg phosphate standard. Prediction of changes in algal concentration, ammonia and nitrate was less successful. This significantly reduces the potential for using the model to predict future trophic conditions in an impoundment.

Cost: *R83 000*
Term: *1996-1997*

Holistic water quality management in catchments of South African harbours

(No 794) SRK (CE) Inc.

Over the last decade the harbours along South Africa's coastline have become of increasing importance as recreational, ecotourism and general commercial areas. As a result they and their water quality are receiving increasingly high profile public exposure. Harbours are more at risk of being polluted than the rest of the marine environment, since they are the receiving water bodies from adjoining urban and industrial areas which are mostly highly developed, with relatively poor water quality. The final report of this study:

- Evaluates the situation in South African harbours with water pollution management in three international ports
- Describes each of the six major South African ports and their catchment areas, gives an outline of their current environmental and water quality problems, how these are managed and records the scientific knowledge on each system
- Discusses and compares the general status of water pollution management for the ports and their associated catchment systems
- Lists actions which are required to improve the situation.

Cost: *R141 000*
Term: *1997-1998*

Framework for implementing non-point source-directed measures under the National Water Act

(K8/352) Department of Civil Engineering, University of Stellenbosch

Under the National Water Act, DWAF is authorised to implement source-directed controls for the management of both point- and non-point source pollution, in order to achieve a desired level of resource protection. DWAF will develop appropriate tools in the form of guidelines and procedures to facilitate the implementation of such source-directed measures. This consultancy was undertaken to examine a number of considerations related to the implementation process for

non-point sources which had to be dealt with in addition to those covered in the *Guide to Non-point Source Assessment to Support Water Quality Management of Surface Water Resources in South Africa* (which is being prepared as part of WRC Project No 696). Considerations included *inter alia* the requisite structured linkages between resource and source-directed measures and the process of catchment management, and the role of national standards for land-use management practice. The framework which has been prepared should make it possible for DWAF to develop a set of guidelines/ procedures for non-point source pollution and initiate the national non-point source management strategy.

Cost: *R96 000*
Term: *1999*

New projects

WQ90: Development of a set of surface water quality manuals for South Africa

(No 950) Stewart Scott (CE) Inc.

In a water-stressed country such as South Africa, increasing development leads to an increasing susceptibility to salinisation and other forms of degradation of the country's water resources. Sustained development of the country will, *inter alia*, require early anticipation of water quality problems which, if not properly countered, could lead to the development of inappropriate water resource schemes which may later have to be abandoned or rectified at great expense to obviate harmful impacts of poor water quality. However, the budgets available for the numerous necessary investigations are constrained, as are the available professional manpower resources. This raises the need for a tool that will enable planners to make rapid low-cost, but realistic, initial assessments of salinity impacts at the earliest planning stage. The proposed interactive system which will be developed as part of this project, is aimed at providing just such a planning tool.

Estimated cost: *R775 000*
Expected term: *1999-2001*

Evaluation of predictive models for pesticide behaviour in South African soils

(No 999) Plant Protection Research Institute, Agricultural Research Council

Research has shown that pesticides often behave differently in South African soils compared to behaviour experienced in the country from which the pesticides originate. The majority of South African soils are highly weathered with a low organic matter content and low microbial activity, when compared to e.g. European soils. Organic matter constitutes the major soil component onto which a pesticide can be absorbed or adsorbed. Most of the newly developed pesticides are, furthermore, reliant on microbial activity for their degradation. South African soil conditions are thus conducive to prolonged persistence of a pesticide. This project will evaluate existing computer-based mathematical models in terms of their efficiency and applicability in predicting pesticide behaviour under South African conditions. The evaluation is aimed at recommending the use of the most suitable model by pesticide registration authorities. This is expected to lead to reduced risk of pesticide contamination of ground- and surface waters from pesticide application.

Estimated cost: *R357 000*
Expected term: *1999-2000*

Algal scum near a stormwater culvert.

Scope and dynamics of toxins produced by cyanophytes in the freshwaters of South Africa and the implications for human and other users

(No 1029) Department of Botany and Genetics, University of the Orange Free State

Microcystis (cyanophytes, blue-green algae) contain non-toxic and toxic strains. Toxic strains have been responsible for serious losses of livestock and could pose a threat to human health as well. Toxicity is affected by various environmental factors and it has been found that concentrations of the microcystin toxin, are usually higher under stress conditions. Reduction of microcystins is of importance in South African waters. This project is aimed at determining the scope and degree of toxicity of cyanophytes in the freshwaters of South Africa. The project will also address the growth and cultivation of toxic and non-toxic cyanophytes and control of peptide synthesis as a prelude to determining genetic control. Determination of the correlation between *Microcystis* blooms and environmental conditions in natural systems will also be addressed in order to establish a protocol for predicting the outbreak of toxic *Microcystis* blooms in natural systems.

Estimated cost: *R372 000*
Expected term: *1999-2000*

Assessing potential health risks related to the use of treated wastewater for various agricultural and aquacultural activities

(No 1039) Department of Environmental Science,Technikon Free State

The increasing demand for substantial quantities of agricultural water in the immediate vicinity of marginalised communities, has led to several discussion fora in the Free State on the use of treated/semi-treated wastewater. Although an

Algae in Zoo Lake due to pollution.

Blue-green algal scum in reedbed.

interest in utilising these waters has been expressed, environmental health authorities are generally not keen to permit the use of such water because of the uncertain risk that may be posed by treated/semi-treated wastewater. Present guidelines are not flexible enough to allow practical discretionary decision-making when permitting wastewater reuse in agriculture and recreation. Safe levels for treated wastewater use on crops, for livestock grazing and for aquaculture need to be established to provide updated guidelines for health authorities. The aim of this project is therefore to assess the applicability of the existing 1979 South African guidelines and to compile new draft guidelines by identifying possible shortcomings. A feasibility study will be done to address the extent and level of research necessary for the apparent shortcomings.

Estimated cost: *R80 000*
Expected term: *1999*

Water quality monitoring programme to fulfil the needs of integrated catchment management in a densely populated rural catchment

(No 1067) Department of Chemistry, University of Fort Hare

A catchment management plan is a prerequisite for integrated catchment management (ICM). Information on water quality in the catchment is needed both for the development of a sound management plan and for monitoring the outcomes of implementing ICM. The nature of the monitoring programme required will depend on land utilisation in the catchment and riparian zones, the susceptibility of the rivers to degradation, water quality requirements of ecosystems and users, and existing sources of water quality data. The Umtata River catchment is representative of one class of river catchment which, for the demands of catchment planning have created associated demands for water quality monitoring. The aim of this research project is to design and initiate a water quality monitoring programme which will meet the requirements of catchment management in the Umtata River catchment and serve as a guide for related activities in similarly impacted catchments.

Estimated cost: *R450 000*
Expected term: *1999-2000*

Occurrence of E. coli 0157:H7 and other pathogenic *E. coli* strains in water sources intended for direct and indirect human consumption

(No 1068) Department of Virology, University of Pretoria

South Africa lacks important epidemiological information on pathogenic *E. coli*. Most *E. coli* strains are microbiological inhabitants of the intestinal tract of humans and other warm-blooded animals, but some are known to have the ability to cause diarrhoeal disease, e.g. traveller's diarrhoea. The presence of pathogenic *E. coli* in contaminated surface, recreational and drinking water poses a human health risk and could cause a large outbreak of water-borne haemorrhagic colitis such as experienced in 1992 in Swaziland. KwaZulu-Natal and other parts of Africa have lately experienced outbreaks of a disease thought to be shigellosis, but which may, in fact, have been due to pathogenic *E. coli*. A complicating factor is the shiga-like toxin produced by enterohaemorrhagic *E. coli* organisms. Traditionally *E. coli* strains are regarded as harmless indicator organisms for other pathogens and are widely used as such.

This study will provide information on the health risk of direct and indirect consumption of contaminated water. The intention is also to develop a rapid identification method for potentially pathogenic *E. coli* in surface water used by communities for various purposes.

Estimated cost: *R150 000*
Expected term: *1999*

Development of a framework for a research programme on eutrophication in South Africa

(No K8/360) Mzuri Consultants

Eutrophication remains one of the major water quality problems of South Africa. Although extensive studies were conducted more than a decade ago, relatively little research, capacity building, or reporting on the status of the problem, or the effectiveness of management policies has taken place during the past 10 years. This consultancy is being undertaken to develop a framework for eutrophication research that can be used to guide future research support and capacity development. This will be achieved by:

- Conducting an international scan of countries and organisations to establish the most recent management and policy approaches and research that is in position to support these approaches
- Establishing the concerns and opinions of local stakeholders and specialists
- Proposing a framework for eutrophication research for debate and modification at a workshop of key local stakeholders and specialists.

Estimated cost: *R60 000*
Expected term: *1999-2000*

Research projects

Completed

- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University – Institute for Water Research)
- **411** Coastal pollution: Pathogenic micro-organisms (University of Pretoria – Department of Medical Virology)
- **421** Relationship between atmospheric deposition and water quality in a small upland catchment (CSIR – Division of Water, Environment and Forestry Technology)
- **785** Validation of the modified MINLAKE model on Roodeplaat Dam (Stewart Scott (CE) Inc.)
- **794** Holistic water quality management in catchments of South African harbours (SRK (CE) Inc.)
- **K8/352** Framework for implementing non-point source-directed measures under the National Water Act (University of Stellenbosch – Department of Civil Engineering)

Current

- **266** Extension of the management-orientated models for eutrophication control (CSIR – Division of Water, Environment and Forestry Technology)
- **369** Completion of research relating to the DISA model – A daily irrigation and salinity analysis system model (Ninham Shand (Cape) Inc.)
- **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)
- **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)
- **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 I: Development of a generic model (DWAF – Division for Water Quality Management and its Directorate for Project Planning, and Urban-Econ)
- **696** Development of a guide to assess non-point source pollution of surface water resources in South Africa (Sigma Beta (CE) Inc. and DWAF – Institute for Water Quality Studies)
- **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.)
- **717** Impact of urbanisation and industrialisation on the environment (Vista University – Department of Chemistry (Mamelodi Campus))
- **784** Rapid quantitative evaluation of water quality using a modified biological test – Phase II (University of the Witwatersrand – Department of Microbiology)
- **795** Assessment of the quality of water supplies in the rural Western Cape with regard to agrichemical pollutants (University of Cape Town – Department of Community Health)
- **796** Feasibility of using low-cost modelling techniques to relate river water quality and diffuse loads to a range of land uses (Stewart Scott (CE) Inc.)
- **814** Identification of diatoms and their use in the assessment of water quality (University of Port Elizabeth – Department of Genetics and Botany)
- **815** Use of *Daphnia* spp. and indigenous river invertebrates in whole effluent toxicity testing in the Vaal catchment (Rhodes University – Institute for Water Research)
- **824** Selection of procedures for faecal pollution monitoring to describe health risks (CSIR – Division of Water, Environment and Forestry Technology)
- **926** Assessment of the extent of oestrogenic activity in Western Cape water resources (University of Stellenbosch – Department of Zoology)
- **927** Occurrence and source of *Cryptosporidium* and *Giardia* in catchment areas and wastewater works (Umgeni Water)
- **928** Molecular characterisation of F-RNA coliphages in South African water sources (University of Pretoria – Department of Virology)
- **951** Water quality information systems for integrated water resource management: The Riviersonderend-Berg River system (University of Stellenbosch – Department of Civil Engineering and Department of Soil and Agricultural Water Science)
- **952** Biomarker assays for the detection of chronic toxicity in the aquatic environment (CSIR – Division of Water, Environment and Forestry Technology)

New

- **950** WQ90: Development of a set of surface water quality manuals for South Africa (Stewart Scott (CE) Inc.)
- **999** Evaluation of predictive models for pesticide behaviour in South African soils (Agricultural Research Council – Plant Protection Research Institute)
- **1029** Scope and dynamics of toxins produced by cyanophytes in the freshwaters of South Africa and the implications for human and other users (University of the Orange Free State – Department of Botany and Genetics)
- **1039** Assessing potential health risks related to the use of treated wastewater for various agricultural and aquacultural activities (Technikon Free State – Department of Environmental Science)
- **1067** Water quality monitoring programme to fulfil the needs of integrated catchment management in a densely populated rural catchment (University of Fort Hare – Department of Chemistry)
- **1068** Occurrence of *E. coli* 0157:H7 and other pathogenic *E. coli* strains in water sources intended for direct and indirect human consumption (University of Pretoria – Department of Virology)
- **K8/360** Development of a framework for a research programme on eutrophication in South Africa (Mzuri Consultants cc)

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6 Groundwater

The overall goal of groundwater research at the WRC is to promote the optimal and sustainable utilisation of groundwater resources of South Africa through a series of co-ordinated geohydrological research projects. To meet the above goal, various research programmes have been formulated over the past few years.

The development of methodologies for the determination of the groundwater component of the Reserve is an urgent and high priority issue. The National Water Act requires that water be allocated to the Reserve before water is allocated to other users in a particular catchment. Thus, the National Water Act No. 36 of 1998 provides a "new" approach to water resource management and, for the first time, groundwater is considered to be an integral part of the hydrological cycle. To meet these challenges, a multifaceted research programme aimed at developing sound and widely acceptable protocols for the **Comprehensive Determination of the Groundwater Component of the Reserve** was started in 1999. These protocols that need to be developed must be acceptable to both water resource managers and to catchment stakeholders, who are to become increasingly involved in allocation of water resources through catchment management agencies.

A research programme that has been on-going for several years focuses on better understanding of groundwater resources in fractured-rock aquifers, 90% of aquifers found in South Africa occur in these domains. The **Fractured-Rock Aquifer** research programme attempts to characterise various geological provinces in terms of groundwater occurrence and developmental potential; develop techniques and protocols for groundwater exploration; estimate aquifer parameters using innovative techniques; and develop systems for better resource management.

The semi-arid to arid areas of the Northern Cape are characterised by aquifers which have been classified mainly as poor (negligible to low-yielding with poor water quality), or at best as minor (moderate-yielding with variable water quality). Notwithstanding this, local communities are virtually totally reliant on this resource. Although consumption of groundwater provides the means of survival for many in the region, there are strong suggestions that the insufficiency of supply and substandard quality of much of the groundwater currently being utilised impacts heavily on quality of life and health. A research programme **Sustainable Groundwater Management and Utilisation in the Semi-arid and Arid Northern Cape** is being conducted by the University of the Western Cape in the region. There is ample scope for improving the situation by first gaining better insight into the spatial variation and long-term exploitability (yields and rates of recharge) of the aquifers within the region, the links between groundwater quality and human well-being, the vulnerability of aquifers to contamination, and the availability of affordable groundwater treatment options. Based on these insights, it would then be possible to conceptualise improved groundwater supply and management scenarios which can subsequently be tested for affordability, acceptability, assurance of supply and sustainability among communities.

Another important research programme is the **Community Groundwater Supply and Sanitation** programme. The overall aim is the optimisation of groundwater utilisation for all communities through an integrated management approach. This is because lack of basic services, such as water supply and sanitation, is the norm in the underdeveloped rural areas in South Africa. Groundwater has been identified as a strategic resource to meet basic human needs for potable water, in especially arid zones. The implications of inadequate

water supply and sanitation facilities in these areas are increased health costs, financial losses due to illness, reduced life expectancy and high infant mortality rates.

Rapid urbanisation and economic development goals in South Africa are causing increasing pressure on natural resources. This is particularly true of groundwater which is prone to pollution because of indiscriminate disposal of harmful substances and inadequate protection measures. In order to address groundwater vulnerability to pollution, a programme on **Groundwater Quality and Protection** has been formulated. The overall aims being the determination of the occurrence, degree and potential of groundwater contamination and the development of suitable techniques for groundwater protection.

A programme to assess the water resource potential and management requirements of the Table Mountain group of aquifers is in the planning stage. The first step will be to assess and consolidate all available information to serve as the foundation for further investigations.

Completed projects

Geochemistry and isotopes for resource evaluation in the fractured-rock aquifers of the Table Mountain Group

(No 481) Division of Water, Environment and Forestry Technology, CSIR

Reliable resource evaluation in fractured-rock aquifers is a developing science not only in South Africa, but world-wide. This project was undertaken to assess the applicability and usefulness of hydrochemical time-series and isotope time-series monitoring as a tool in fractured-rock resource evaluation. The aims were firstly to relate hydrochemical variations and hydrographs to recharge and resource evaluation of the Table Mountain Group. The second aim was to relate groundwater isotopes to hydrochemical variations and hydrographs for the estimation of groundwater residence time and groundwater source areas.

Two study sites were selected, one in the Agter-Witzenberg, a mountain valley northwest of Ceres; and Struisbaai, a coastal aquifer near Cape Agulhas on the Cape South Coast. In the Agter-Witzenberg valley, both shallow and deep boreholes were established to sample the Table Mountain Group quartzite and Bokkeveld shale. The monitoring programme began in October 1993 and continued until January 1996. It became evident from analysis of the results from the first year that the Struisbaai aquifer was not suited for the aims of this project. There were no meaningful seasonal variations in any of the isotopic or hydrochemical parameters.

Recharge sources to the Agter-Witzenberg aquifer could be distinguished using hydrochemistry and isotopes. However, the techniques used only produced qualitative insight into flow patterns and groundwater movement. The main flow component consists of recharge in the mountains (to the extent of 50% of the rainfall) which discharges at the base of the mountain and drains away in streams, with some ponding as well. Some isotope enrichment occurs during ponding. Recharge from surface water occurs mainly in summer, when farmers draw down water levels in neighbouring boreholes substantially. The isotope differences between the mountain recharge and the evaporated stream water provides a useful tracer, with chloride and alkalinity, to follow the movement of this water.

Cost: *R512 537*
Term: *1992-1996*

Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone

(No 572) Division of Water, Environment and Forestry Technology, CSIR and Department of Soil and Agricultural Water Science, University of Stellenbosch

Soil and the unsaturated zone provide the first line of natural defence against groundwater pollution by providing a favourable environment for pollution attenuation or elimination. This assimilative capacity is often built into estimates of groundwater impacts without a proper understanding of our ability to quantify the attenuation capacity of soils or the unsaturated zone. This project made a start by addressing these issues for South African conditions by carrying out a number of interrelated tasks. The project:

- Reviewed the scientific knowledge on attenuation processes, with special emphasis on chemical processes
- Conducted laboratory studies to determine the potential for contaminant attenuation in selected soil materials
- Conducted field studies to confirm that the processes indicated by literature and laboratory studies operate at field scale
- Evaluated and demonstrated solute transport modelling as a means to further extrapolate findings
- Demonstrated the feasibility of generating regional-scale maps indicating vadose zone attenuation characteristics for use by planners, by making use of GIS techniques and the information locked up in land-type maps
- Developed a prototype decision support system for assessing the contaminant attenuation potential of soils.

Cost: *R985 900*
Term: *1993-1998*

Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa

(No 641) Division of Water, Environment and Forestry Technology, CSIR

The agricultural sector has been identified as the largest consumer of groundwater in South Africa. It is estimated that 78% of all groundwater abstracted is used for irrigation. It is recognised world-wide that the agricultural sector contributes to diffuse contamination. To determine the extent of groundwater pollution from agricultural practices, research focused on certain agricultural activities, namely: intensive animal husbandry; use of sewage sludge as a fertiliser; use of inorganic fertilisers; irrigation; and use of pesticides.

The contribution of each of these practices to groundwater contamination was evaluated separately, thereby consolidating knowledge on the impact of agricultural practices on groundwater quality. An impact on groundwater quality was seen at all the field study sites with vulnerable, shallow, unconfined or semi-confined conditions. Nitrate was the most common agricultural component evident in groundwater sampled. Nitrate distribution and isotopic analyses of NO_3-N

indicated the most important sources to be sludge, manure and soil biota. Elevated dissolved organic carbon (DOC) levels were associated with sludge application and intensive animal husbandry practices. Potassium, orthophosphate and microbiological indicators of faecal pollution, contaminated groundwater as a result of intensive animal husbandry activities. Limited impacts on groundwater quality were found to be associated with the application of inorganic fertilisers. Although inorganic fertilisers are believed to contribute to high nitrate levels, other activities such as the application of organic fertilisers and deep-rip ploughing play a significant role in elevating nitrate levels.

Significant salinisation has been reported in groundwater underlying the irrigated lands of the Great Fish-Sundays River basin. At the Vaalharts Irrigation Scheme irrigation water recharging the aquifer resulted in increased groundwater salinity, a rise in the water table and some waterlogging of soils.

The outcome of the research was a series of recommendations for good farming practices, which should significantly reduce the agricultural contribution to groundwater pollution.

Cost: *R838 117*
Term: *1994-1997*

Investigation into a GIS-based methodology to determine the sustainable exploitability of South African aquifers

(No 840) Division of Water, Environment and Forestry Technology, CSIR

The sustainable utilisable potential (SUP) of aquifers is defined as the volume of groundwater that can be abstracted on a sustainable basis after the requirements of the reserve have been met.

The methodology developed during this research was applied to three test areas for which there are extensive groundwater data. The three aquifers studied were: a sandy porous aquifer in Atlantis, a dolomitic aquifer in Zeerust and a fractured-rock aquifer in Beaufort-West. The key parameters required by the methodology are:

- Physical parameters (recharge and storage potential)
- Anthropogenic and ecological parameters (the reserve, inaccessible areas)
- Cost parameters (number of boreholes, depth to water and water quality considerations).

The resource potential is quantified in mm/a (or the equivalent $m^3/km^2 \cdot a$). Where the resource potential is solely based on physical parameters, recharge and storage, the actual measured abstractions in the three case studies would be slightly higher than the sustainable potential. Although the research identified clear limitations to the methodology it could nevertheless, as a first approximation, be considered useful.

Cost: *R 200 000*
Term: *1998*

Artificial recharge: A technology for sustainable water resource development

(No 842) Division of Water, Environment and Forestry Technology, CSIR

South Africans are faced with the daunting task of supplying an ever-increasing population with water from a very limited water resource. Artificial recharge and the principles of conjunctive use offer a valuable tool for augmenting the rather limited natural recharge.

The two main factors which determine the potential for artificial recharge in South Africa are the availability of raw water and the ability of the aquifer to physically receive surplus water. Because most of South African aquifers are located in fractured-rock environments, it will be necessary to test artificial recharge in these environments. Secondary aquifers with high permeability and storativity are most suitable for receiving additional water. Such aquifers include the dolomitic aquifers in the Northwest Province and the intensely weathered fractured aquifers which are found in various parts of the country.

The aim of artificial recharge for water supply purposes is to rapidly replenish aquifers with water that would otherwise be lost through evaporation and stream flows. The subsurface conservation of water is of special significance in semi-arid and arid areas. Borehole injection schemes seem to be the most appropriate technology given South African conditions. Injection schemes require relatively advanced management. With the advent of the National Water Act and the proposed formation of catchment management agencies and water-use associations, the institutional framework is being created which can facilitate a phased and multidisciplinary approach to planning and implementing artificial recharge schemes. This project developed guidelines for establishing such artificial recharge schemes.

Cost: *R186 000*
Term: *1997-1998*

New projects

Decision tool for establishing a strategy for protecting groundwater resources: Data requirements, assessment and pollution risk

(No 969) Institute for Groundwater Studies, University of the Orange Free State

Current research on fractured-rock aquifers is leading to new insights regarding the spreading and retention of contaminants. These insights will strongly influence the selection of appropriate protection and remediation strategies. Contaminants could for instance, diffuse from water in flow channels to immobile volumes of water in fractures from where they diffuse into the microscopic cracks in the rock and into the rock matrix itself. This process implies that remediation could be extremely difficult and coupled to very long time scales, possibly hundreds of years.

New insights into aquifer characteristics together with information obtained from extensive tracer tests, would form a sound basis for an objective, cost-effective, risk-based approach to groundwater protection and remediation. The aim of the project, therefore, is to develop a decision tool for establishing local groundwater resource protection strategies.

To achieve this aim, it will *inter alia* be necessary to:
- Develop a framework for early stage risk assessment, considering both the probability and economic consequences of contamination, prior to undertaking more detailed studies
- Provide a basis for cost-effective decision-making regarding groundwater protection and management options
- Perform tracer studies at a number of sites to obtain information on parameters such as matrix diffusion and dispersivity and on the potential for remediation.

Estimated cost: *R650 000*
Expected term: *1999-2001*

Enhancement of the WISH software package to meet current requirements of geohydrologists

(No 1006) Institute for Groundwater Studies, University of the Orange Free State

The WISH (Windows-based Interpretation System for Hydrogeologists) software package resulted from a 3-year project completed at the end of 1997. WISH has powerful data-processing capabilities and links to groundwater models (including management and risk assessment models) developed at the Institute for Groundwater Studies over many years. Currently a one-year project is under way to link WISH to the modern groundwater database developed during the recently completed MuniWater project, further enhancing its capabilities.

Although WISH has been extensively tested in the mining and power-generation arenas (particularly for evaluating groundwater quality in the vicinity of mines and slimes dams), it has still to be accepted as the standard throughout the hydrogeological community. It has, however, become evident that WISH needs to be enhanced in two further areas in order to ensure its wide-spread acceptability. This project aims to introduce these enhancements and actively continue with the promotion of WISH among hydrogeologists and professionals in related disciplines. The enhancements envisaged will:
- Ensure compatibility with spatial data sources stored in various GIS and map files. Since there is no generally-accepted standard format, the ability to read a wide range of formats will greatly increase the usefulness of WISH
- Extend the processing capabilities of WISH to accommodate interdisciplinary processes and associated data sources, e.g. river baseflow-groundwater interactions, vegetation-groundwater interactions, irrigation requirement-assured borehole-yield relationships, rainfall-groundwater recharge relationships, etc.

Estimated cost: *R250 000*
Expected term: *1999*

Development of a Windows-based interactive 3-D visualisation computer program for geohydrological data

(No 1007) Institute for Groundwater Studies, University of the Orange Free State

Archived geohydrological data and geohydrological model outputs can produce a flood of unconsolidated information, far in excess of what can be grasped by the human brain. Visualisation offers a means whereby important information hidden in the data or model output can be effectively extracted. Interactive visualisation, whereby the user's point of view is manipulated and optimised to provide an integrated mental image, is especially powerful in progressing towards a better understanding of geohydrological states and processes. Such an understanding forms a sound base for selection of management practices or from which to undertake further groundwater investigations.

At present there is no visualisation software which can be economically linked to, and thereby further the use of, the geohydrological models and interpretative software packages already available, or soon to become available to South African geohydrologists.

This project, therefore, aims to provide the software tools for visualising:
- Outputs from two- and three-dimensional groundwater models and parameter estimation programs
- Those aquifer characteristics important for management purposes, such as surface contours, groundwater levels, geological logs and geophysical data.

Estimated cost: *R273 000*
Expected term: *1999-2000*

Protocols for assessing groundwater pollution impacts – Formulation of a research strategy

(No 1008) Division of Water, Environment and Forestry Technology, CSIR

Given the heavy reliance of many communities on groundwater supplies, it is essential that aquifers, which are also coming under increasing pressure, be afforded the best possible protection from contamination. On the one hand, the vulnerability to groundwater pollution is directly linked to soil-aquifer sensitivity factors (i.e. the hydraulic accessibility of the saturated zone to mobile contaminants and the capacity of the unsaturated (vadose) zone to retain or react with pollutants). On the other hand, vulnerability is linked to the characteristics of the pollutants themselves and the extent and magnitude of pollutant loading, which is a function of land-use practice and human activity.

Although some attention has been given in South Africa to the issue of soil-aquifer vulnerability characteristics, the question of risk associated with various land-use practices has received little attention. There is a need to consolidate the research done locally with the much larger body of research done overseas and direct further research in a strategic manner towards the most desirable end result. In this instance, this will be a set of protocols which will enable the impacts of particular land-use practices on particular groundwater systems to be soundly assessed.

This project, accordingly, aims to formulate a research strategy for developing the necessary protocols for assessing groundwater pollution impacts associated with various land-use management practices.

Estimated cost: *R199 000*
Expected term: *1999*

Evaluation of groundwater resources in fractured-rock aquifers at a catchment scale using evidence of mixing of groundwater from CFC and isotope data

(No 1009) Division of Water, Environment and Forestry Technology, CSIR

Knowledge of the age of recharged groundwater and of recharge rates is important for evaluating groundwater resources in terms of sustainable exploitability. Chlorofluorocarbon (CFC) levels in groundwater have been shown to provide a means of accurately estimating the age of unmixed younger groundwaters (less than 50 years). However, unlike primary aquifers, fractured-rock aquifers might experience a considerable degree of mixing of young and old groundwaters which could make the interpretation of CFC data extremely difficult. Nevertheless, it was also shown that by combining CFC and C-14 data, it became not only possible to explain anomalously low CFC values in terms of mixing of young and old waters, but there also seemed to be a real potential for expanding the technique to determine the actual mixing ratios of groundwater of different ages. If this potential could be confirmed and exploited, then the use of these mixing ratios will present opportunities for improving our understanding of groundwater recharge and refining groundwater flow models for these fractured-rock aquifers. In turn this will enable water resource managers to evaluate groundwater reserves with greater confidence than is possible with current knowledge and tools.

The aims of the project are to:

- Develop a method of integrating and analysing groundwater age data provided by C-14, CFC-11, CFC-12, CFC-13, tritium and other isotope analyses so that groundwater mixing ratios can be determined
- Investigate the application of these mixing ratios to groundwater resource evaluations so that the reliability of these evaluations can be refined.

Estimated cost: *R354 000*
Expected term: *1999-2000*

Hydrogeological evaluation of groundwater in fractured-rock aquifers using trace elements and stable isotopes at Loxton, Central Karoo

(No 1037) Department of Geology, University of Stellenbosch

Groundwater composition in the Karoo is often highly variable with depth in boreholes and from borehole to borehole over short distances. Little is known about the reasons behind the variability although the semi-arid climate, geology and topography play an important role. Variability could also be attributed to different groundwater flow systems. Trace elements and isotopes can, therefore, be used as a tool to distinguish between the different groundwater systems and for the development of new groundwater resources in the Karoo basin. To identify the origin of groundwaters in the Central Karoo, the following key issues will be investigated:

- The presence of a deeper flow system that may be influenced by deep-seated connate water and to what extent mixing of meteoric and connate waters occurs
- The geochemical elements that are best suited to investigate groundwater origin in the Central Karoo
- The influence of structural features (lineament type and orientation) and geological features (dolerite intrusions, kimberlite fissures and sediments) on the groundwater chemistry
- The influence of physiography and climate on groundwater salinity
- The occurrence of low temperature rock-water interaction and the effect it has on groundwater chemistry.

Estimated cost: *R63 000*
Expected term: *1999*

Nitrate and associated groundwater hazard quantification and strategies for protecting rural water supplies

(No 1058) Division of Water, Environment and Forestry Technology, CSIR

Groundwater exploitation in many respects forms the cornerstone of water supply to rural communities in South Africa. A problem frequently being faced by developers of rural water supply schemes is that of high nitrate concentrations in groundwater. Such water does not conform to fairly stringent potable water standards and is therefore perceived by many to be unsafe.

The high nitrate levels could derive from either one, or a combination of two processes, namely natural accumulation (where climate, soil and vegetation are important factors) and anthropogenic accumulation (associated with human activity and land use). A previous survey of the nitrate problem (done at a coarse scale) as well as recent experience, make it clear that many areas of South Africa (particularly in the north) either already are, or are very likely to be, more seriously affected than others. The degree to which such areas are affected or susceptible depends on the levels of natural nitrate accumulation and the susceptibility to anthropogenic accumulation. In the case of anthropogenic nitrate pollution associated with rural settlements, there may also be microbiological contamination of groundwater leading to health risks which overshadow those associated with high nitrate levels only.

The objectives of the proposed project are to:

- Determine the extent and severity of high nitrate in groundwater (and associated anthropogenic pollution) in selected study areas in the community water supply context
- Identify and interpret environmental conditions aggravating the situation
- Map out potentially affected and vulnerable areas
- Develop strategies, where feasible, for diminishing the accumulation of nitrate and associated pollutants
- Communicate the outcomes of the research to water resource planners and community representatives in appropriate ways.

Estimated cost: *R450 000*
Expected term: *1999-2000*

A modelling decision-support system for the groundwater reserve (A component project of the Research Programme on the Determination of the Groundwater Reserve)

(No 1090) Institute for Groundwater Studies, University of the Orange Free State

This project forms an essential and integral part of the **Research Programme on the Determination of the Groundwater Component of the Reserve**, within the context of the National Water Act. The analytical and modelling capabilities needed to address the complex groundwater-surface water-environment interactions which come into play in the determination of the Reserve, have yet to be developed. Furthermore, existing models have not yet been refined, adapted and integrated in a manner which will allow them to be used as tools for Reserve determination. Finally, there is need for a user-friendly decision-support system which will enable decision-makers to interact with stakeholders in reaching decisions concerning the groundwater component of the Reserve and the allocation of accessible groundwater resources. The aims of the project are thus to:

- Develop and refine the concept of the groundwater component of the Reserve, required in terms of the National Water Act (1998)
- Determine a procedure for groundwater reserve determination, in an interactive way with stakeholders
- Develop a coupled surface water/groundwater flow model for the estimation of total accessible water resources
- Introduce a stochastic concept into the coupled surface water/groundwater model
- Develop software tools for the quantification of the comprehensive groundwater reserve
- Develop a comprehensive protocol for catchment managers to enable use of new tools and products to quantify and allocate accessible groundwater resources.

Estimated cost: *R732 000*
Expected term: *1999-2001*

Groundwater reserve: Delineation, reference conditions and classification (A component project of the Research Programme on the Determination of the Groundwater Reserve)

(No 1091) Division of Water, Environment and Forestry Technology, CSIR

This project forms an essential and integral part of the **Research Programme on the Determination of the Groundwater Component of the Reserve**. Detailed research is necessary to understand the groundwater reserve, within the framework of the requirements of the National Water Act (1998) which include the determination of a national water balance and the risk-based classification of water resources. In order to
do this, it is first of all important to delineate geographical boundaries of regions within which groundwater conditions are relatively homogeneous. Within such regions, it will be necessary to establish the groundwater reserve reference situation describing the natural, un-impacted groundwater

Groundwater exploration in dolerite ring structures in the Karoo, near Victoria-West.

conditions. Finally, the groundwater resource will have to be classified on the basis of the importance of the resource (socio-economic and ecological) and its sensitivity to the impacts of abstraction and land use.

Accordingly, the project will focus on:

- Determining the best method of delineating geographical boundaries of the Groundwater Reserve
- Determining reference conditions for aquifers
- Reviewing and determining an appropriate classification based on a qualitative risk assessment process, which takes into account aquifer importance, sensitivity and economic value.

Estimated cost: *R627 000*
Expected term: *1999-2001*

Classification of critical groundwater dependent terrestrial ecosystems (A component project of the Research Programme on the Determination of the Groundwater Reserve)

(No 1092) Division of Water, Environment and Forestry Technology, CSIR

This project forms an essential and integral part of the **Research Programme on the Determination of the Groundwater Component of the Reserve**, within the context of the National Water Act. Critical terrestrial ecosystems include those which are most sensitive to changes in the availability of groundwater. Their groundwater requirements need to be determined as a matter of urgency.

A comprehensive, multidisciplinary, integrated approach is required to examine the dynamics of water use of selected critical terrestrial ecosystems in the field. This will give a better understanding of the importance of the water environment and the role of groundwater in these natural systems. The results should supplement parallel projects investigating the importance of groundwater supply to aquatic and riparian ecosystems. This project aims to establish a practicable methodology for uniformly determining groundwater requirements of selected, representative terrestrial ecosystems.

This project will:

- Make a preliminary identification and classification of critical terrestrial ecosystems dependent on groundwater
- Identify suitable tools to be used to determine the groundwater reserve for terrestrial ecosystems
- Propose a methodology to determine the groundwater reserve necessary to sustain these critical terrestrial ecosystems
- Examine an example site in the field and gather 'hard' field data supporting an integrated assessment of groundwater dependency in a comprehensive multi-disciplinary case study.

Estimated cost: *R485 000*
Expected term: *1999-2001*

Groundwater recharge to basement aquifers (A component project of the Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape)

(No 1093) Department of Earth Science, University of the Western Cape

An important facet of sustainable management of groundwater resources, and therefore of the **Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape**, is the quantification of recharge. The quantification of the rate of groundwater recharge is a basic requisite for efficient groundwater resource management or sustainable management of groundwater resources. Investigating recharge is important not only on

Successful siting of a borehole in the dolerite ring structures in the Karoo, near Victoria-West.

account of the small storage capacity of basement aquifers, but also to obtain a better understanding of the processes and quantities involved which increases knowledge of the aquifer potential.

The project will assist in developing "innovative" methodologies for the estimation of recharge in basement aquifers. The lessons learnt will be compiled in guideline documents(s), which may be applied in other areas of similar terrain in South Africa and other parts of Africa. Groundwater recharge estimation is an iterative process, with hopefully increasing precision following successive iterations. The approach to the study will be:

- Identifying catchment(s) for recharge studies
- Identifying the probable flow mechanisms and important features influencing recharge for a given locality
- Application and comparison of a number of independent approaches for recharge estimation
- Modelling to quantify localised recharge and its variation in space and time
- Producing a practical guideline document(s) on estimating localised recharge in basement aquifers.

Estimated cost: *R1 701 000*
Expected term: *1999-2003*

Fluoride in drinking water and its effects on human health and nutrition (A component project of the Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape)

(No 1094) Faculty of Dental Science, University of the Western Cape

Contributing to the poor domestic water supply and quality in the Northern Cape are high fluoride levels. The high fluoride levels pose a health risk to the community. It is therefore essential to address this aspect within the **Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape**.

This component project will undertake a systematic analysis of the impact of poor water quality, high in fluoride, and the potential for low-cost treatment.

The objectives of the study are therefore to:

- Determine the levels of fluoride in the groundwater supply used for human consumption
- Use GIS to map the following parameters:
  - Fluoride levels in the drinking water
  - Population distribution and water utilisation
  - Socio-economic status of the population
- Determine the nutritional status of selected samples of children in terms of outcomes related to high and low fluoride levels
- Initiate a pilot project with appropriate and inexpensive technology for providing safe and sustainable drinking water supply in households with special reference to:
  - De-fluoridation of excessive fluoride in the drinking water
  - Improving the quality of drinking water by applying simple measures.

Estimated cost: *R318 000*
Expected term: *1999-2001*

Research projects

Completed

- **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)
- **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)
- **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)
- **840** Investigation into a GIS-based methodology to determine the sustainable exploitability of South African aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **842** Artificial recharge: A technology for sustainable water resource development (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **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)
- **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)
- **653** Regional characterisation and mapping of Karoo fractured aquifer systems – An integrated approach using a geographical information system and digital image processind (DWAF – Directorate of Geohydrology and the Council for Geoscience)
- **676** Preparation of a monograph on South Africa's groundwater resources (JR Vegter Esq. (Private Consultant))
- **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 (WISH) (University of the Orange Free State – Institute for Groundwater Studies and 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)
- **729** Modelling of groundwater flow in the Table Mountain Sandstone fractured aquifer in the Little Karoo region of South Africa (DWAF – Directorate Geohydrology, and SRK (CE) Inc.)
- **731** Chlorofluorocarbons (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)
- **821** Bacterial pathogens in groundwater (University of Durban-Westville – Department of Microbiology)
- **838** Critical evaluation of groundwater monitoring in water resources evaluation and management (Water Resources Evaluation and Management cc and DWAF)
- **841** Assessment of ambient groundwater quality on a national scale in the Republic of South Africa (Hydromedia Solutions and DWAF)
- **860** Preparation of a handbook on the hydrogeology of the Karoo Supergroup (DWAF)
- **862** Integrated multidisciplinary approach to groundwater development in granitic aquifers (University of Pretoria – Department of Geology)
- **935** Evaluation of nuclear magnetic resonance (NMR) as a new geophysical technique for groundwater exploration in fractured rocks (CSIR – Division of Water, Environmentek and Forestry Technology)
- **936** Flow and transport characteristics of groundwater in Karoo formations (University of the Orange Free State – Institute for Groundwater Studies)
- **937** Influence of dolerite ring-structures on the occurrence of groundwater in Karoo fractured aquifers: A morphotechtonic approach (The Council for Geoscience)
- **966** Groundwater development for rural water supply in complex and problematic terrain: An assessment of geological controls, geophysical exploration methods and the quantification of exploitation potential (The Council for Geoscience)
- **967** Pilot artificial recharge schemes: Testing sustainable water resources development in secondary aquifers (CSIR – Water Quality Programme)
- **968** Amalgamation of MuniBase and WISH software into a user-friendly software package to be used by South African geohydrologists (University of the Orange Free State – Institute for Groundwater Studies)

New

- **969** Decision tool for establishing a strategy for protecting groundwater resources: Data requirements, assessment and pollution risk (University of the Orange Free State – Institute for Groundwater Studies)
- **1006** Enhancement of the WISH software package to meet current requirements of geohydrologists (University of the Orange Free State – Institute for Groundwater Studies)
- **1007** Development of a Windows-based interactive 3-D visualisation computer program for geohydrological data (University of the Orange Free State – Institute for Groundwater Studies)
- **1008** Protocols for assessing groundwater pollution impacts – Formulation of a research strategy (CSIR – Division of Water, Environment and Forestry Technology)
- **1009** Evaluation of groundwater resources in fractured-rock aquifers at a catchment scale using evidence of mixing of groundwater from CFC and isotope data (CSIR – Division of Water, Environment and Forestry Technology)
- **1037** Hydrogeological evaluation of groundwater in fractured-rock aquifers using trace elements and stable isotopes at Loxton, Central Karoo (University of Stellenbosch – Department of Geology)
- **1058** Nitrate and associated groundwater hazard quantification and strategies for protecting rural water supplies (CSIR – Division of Water, Environment and Forestry Technology)
- **1090** A modelling decision-support system for the groundwater reserve (A component project of the Research Programme on the Determination of the Groundwater Reserve) (University of the Orange Free State – Institute for Groundwater Studies)
- **1091** *Groundwater reserve: Delineation, reference conditions* and classification (A component project of the Research Programme on the Determination of the Groundwater Reserve) (CSIR – Division of Water, Environment and Forestry Technology)
- **1092** Classification of critical groundwater dependent terrestrial ecosystems (A component project of the Research Programme on the Determination of the Groundwater Reserve) (CSIR – Division of Water, Environment and Forestry Technology)
- **1093** Groundwater recharge to basement aquifers (A component project of the Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape) (University of the Western Cape – Department of Earth Science)
- **1094** *Fluoride in drinking water and its effects on human health* and nutrition (A component project of the Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape) (University of the Western Cape – Faculty of Dental Science)

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7 Agricultural water management

Agriculture is an activity of people, which is primarily undertaken for the purposeful production of food and fibre by means of crop cultivation and animal husbandry within constraints of available resources. People involved in irrigated agriculture comprise an estimated 40 000 small-scale farmers, 15 000 medium- to large-scale farmers, 120 000 permanent labourers, variable numbers of seasonal labourers and their dependants. Irrigation operations take place on 1.3×10^6 ha, i.e. 10% of the cultivated area, and use an average of 10.7×10^9 m^3 of water, i.e. 53.6% of currently utilisable water resources. Under normal conditions a substantial contribution of between 25 to 30% is made to gross agricultural production. Although the contribution of agriculture to the gross domestic product is relatively small at 4 to 5%, backward and forward linkages and the multiplier effect of irrigated agriculture, are of considerable importance for economic activities in rural areas. In this context both the intensive nature and stabilising effect of irrigation farming regarding food production, labour absorption and earning of foreign exchange are noteworthy.

Utilisation and development of natural resources in general and water resources in particular must be analysed in relation to the needs of people. According to the Strategic Research Plan for Agricultural Water Management, the point of departure of applied research is, therefore, the real-life problems experienced by users of water for livestock watering, rainfed agriculture, irrigation and aquaculture. These problems may vary from non-existence of knowledge; doubt regarding applicability of existing knowledge; and deviation of empirical observations from some relevant theoretical optimum; to unclear outcome of possible alternative directions of decisions and actions. Overall objectives are increased household food security and farming profitability as well as improvement of long-term efficiency and equity of the economy as a whole. The most important goals which are quantified and must be reached over the medium term are as follows:

- Reduction of obstacles for, or optimisation of technical, biological and economic efficiency of water use and allocation
- Alleviation and reduction of poverty of human resources
- Rehabilitation, protection and reclamation of waterworks and water resources.

These goals must be achieved through creation of knowledge by means of research and influencing decisions and actions of individuals and groups through training and extension. Focus areas are mainly rural sociology, resource economics, engineering, climatology, hydrology, soils and crops. The emphasis in these specialist research areas is first and foremost capacity enhancement of users of agricultural water in order to improve livelihoods by own efforts. Clients include women and men active in small-scale or large-scale, subsistence or commercial and part-time or full-time farming. In all these cases the challenge for funding and management of research projects on a priority basis is to appropriately combine both farmer participation in on-farm trials and laboratory or research station trials. Performing needs-driven, problem-solving research also requires a balance between addressing issues of immediate concern and anticipating issues which are expected to be of concern in the future. To achieve this, existing channels of communication with representatives of the farming communities and with researchers themselves will continue to be used to promote co-operation and co-ordination of research.

Completed projects

Use of saline water for irrigation purposes and an assessment of salt tolerance criteria of crops

(No 303) Department of Soil and Agricultural Water Science, University of Stellenbosch

DWAF endeavours to provide irrigators with water of a quality which should not affect crop production negatively. In setting salinity targets for irrigation water, agriculturists mostly rely on research findings from abroad. This project set out to test the validity of irrigation water salinity criteria used by DWAF to guide their management of water quality in the Breede River. A 15-year-old experimental vineyard in Robertson was irrigated over a 5-year period with six water qualities increasing in salinity from 25 to 500 mS/m. The first full effect of the salinity treatments on yield and berry growth was recorded in the third season. A yield decrease of 60% was observed at the 500 mS/m salinity level. The interpretation of yield data was complicated by the fact that plant vigour and size were key determinants which influenced the response

of grapes to salinity. The results of the study indicate that grapevines are more sensitive to salinity than previously accepted. The threshold salinity of 150 mS/m reported in the USA based on vegetative growth is too high. This investigation's results are more in line with a threshold value of 100 mS/m reported in Australia.

Cost: *R1 320 600*
Term: *1990-1995*

Molecular approach to drought tolerance

(No 479) Roodeplaat Vegetable and Ornamental Plant Institute, Agricultural Research Council

In South Africa, where drought is a severe problem, the value of drought tolerance in economically important crops cannot be underestimated. Since most plants can only survive limited drought, an understanding of how water stress affects their growth, metabolism, development and yield is of practical value. Little attention has been paid to plants with a high degree of drought tolerance. For economic reasons, it is important to explore the mechanisms of drought tolerance. The general aim of the project was to identify and characterise the genes, which are involved in drought tolerance in plants, and to transfer such genes to drought-sensitive plants. Different approaches were followed with different crops, namely tobacco, potatoes, cotton and maize. It was found that there are no genes for drought tolerance as such, only genes for traits that contribute to drought tolerance. Thus, the traits involved in drought tolerance offered the opportunity to develop a screening method.

From the results it can be deduced that the mechanisms of drought and heat tolerance involved a series of anatomical and physiological traits, but that the importance of these traits differs between species and stresses. In tobacco, the proline pathway is crucial in sustaining drought tolerance. A balanced antioxidative enzyme ratio was found to be important in sustaining drought tolerance in potatoes. The levels of the enzymes involved in the antioxidative pathway, Cu/Zn superoxide dismutase, glutathione reductase and ascorbate peroxidase, must all be high to achieve the maximum advantage for the cultivar during drought tolerance. With cotton it was observed that the dehydrogenases involved in the triphenyltetrazolium chloride reduction assay play a vital role in the drought- and heat-tolerance mechanisms. It was also observed that proline metabolism cannot be used as an indicator of heat tolerance. The maize study established that the tolerant cultivar responded by growing a greater amount of roots in the deeper, wetter soil and was thus able to maintain a higher transpiration rate for longer than the sensitive cultivar.

It is thus evident that physiological and anatomical screening methods can be used in distinguishing between sensitive and tolerant cultivars. Screening for different traits involved in tolerance has enhanced the knowledge of genes contributing to the tolerance of the cultivars tested and is of great economic importance in terms of benefits to the breeding programme and predicting the optimum locality for a specific cultivar.

Cost: *R871 200*
Term: *1992-1998*

Facilitating irrigation scheduling by means of the soil water balance model

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

The interest in scheduling irrigations with crop growth computer models is rapidly increasing, particularly since personal computers have become accessible to crop producers. Most of the existing models, however, either are crop-specific or do not simulate daily crop water use. Some models are relatively simple to use for planning purposes, but do not allow real-time scheduling. Other models accurately describe the complexity of natural processes. This makes them suitable for research purposes, but they are generally not applicable in practice due to the large amount of input data required and lack of a user-friendly interface.

The soil water balance (SWB) model is a mechanistic, real-time, generic crop, soil water balance, irrigation scheduling model. SWB gives a detailed description of the soil-plant-atmosphere continuum, making use of weather, soil and crop management data. It thus largely overcomes the problems of other models for irrigation scheduling as indicated above. However, since SWB is a generic crop growth model, parameters specific for each crop have to be determined.

Calibration and validation of SWB with independent data sets of relevance for irrigation scheduling were required in order to establish the reliability of the model in representing the real-world system.

Data sets for the validation of SWB were therefore sought for two types of models:

- Crop growth and SWB model making use of specific crop growth parameters
- FAO-based model making use of FAO crop factors.

Severe difficulties were encountered in the attempt to obtain complete, reliable and usable data sets for the validation of SWB. In most cases, available data sets were incomplete, in others potential collaborators were reluctant to make data available. In the absence of useful data sets for vegetables, a field trial was set up at Roodeplaat in co-operation with the Department of Agriculture, Pretoria. The objective was to determine specific crop growth parameters for several irrigated vegetable species, and include them in the database of SWB. A field trial was also carried out at Hatfield in order to determine FAO crop parameters for peach trees. Specific crop growth parameters for peaches were not determined as it was not possible to carry out growth analysis due to the limited number of trees and limited time available.

Simulations were carried out for agronomic, vegetable and tree crops, using both the crop growth and FAO-type model. Reasonable predictions of soil water deficit, root depth, leaf area index, total above ground and harvestable dry matter were obtained with SWB. Differences in crop water use and growth were observed for different cultivars. The crop growth model proved to be suitable for deficit irrigation simulations. Soil water deficit predicted with the FAO-type model was generally higher than that calculated with the crop growth model under water stress conditions, as the FAO model does not account for smaller canopy size. Caution should be exercised against blind acceptance of the FAO parameters as local conditions, management and cultivars are likely to influence crop growth periods and basal crop coefficients. They should, how-

ever, give a reasonable first estimate of the behaviour of the system.

The user-friendly interface, on-line help tool, range and error checking, as well as comprehensive output graphs should allow the user to easily make real-time use of the output results. The context-sensitive help tool describes how to operate the model (enter input data, run simulations, and print or create results and recommendations) and most of the technical procedures used by SWB to estimate crop growth and calculate the soil water balance. Recommended ranges for input data and general information are also given.

Cost: *R526 200*
Term: *1996-1998*

Evaluation of the performance of two types of sprinkler irrigation emitters

(K8/321) Institute for Agricultural Engineering, Agricultural Research Council

The need for the investigation became necessary in view of the claims made regarding the superior application efficiency of Floppy sprinklers in comparison with conventional impact sprinklers. In the interest of potential users it was considered advisable to have an evaluation of these claims, since, if proven valid, it amounts to a very important development from a water conservation point of view.

The Floppy sprinkler on a permanent layout and two impact sprinklers on dragline systems were evaluated in-field at Silverton. Tests were performed during the day to establish the variation in sprinkler system performance due to changing climatic conditions.

The uniformity evaluations showed that the permanent Floppy sprinkler yields a smaller range of CU and DU values (CU = Christiansen's coefficient of uniformity; DU = distribution uniformity), and a higher mean CU and DU than the dragline impact sprinkler system over the entire data set. This indicates that the Floppy sprinkler obtains a higher degree of uniformity.

The Floppy system achieved lower scheduling coefficient values than the impact sprinklers on a dragline system indicating that the regions within the test block with the lowest application are less critical for the Floppy than for impact sprinklers. (The scheduling coefficient is used as a multiplier to determine the length of time that a sprinkler system should be operated to achieve a target application in that part of the wetted area receiving the least water). The mean scheduling coefficients for the impact and Floppy systems were respectively 1.5, 1.8 and 1.3. These values indicate that the crop should be irrigated 50%, 80% and 30% longer with each of the systems to ensure that the portion of the field receiving the lowest application will have an application equal to the target application.

The permanent Floppy system consistently achieved higher application efficiencies than the impact sprinklers on a dragline layout. The importance of incorporating application efficiencies in the design of sprinkler systems was highlighted where the impact sprinklers were evaluated on both permanent and dragline systems. Permanent impact sprinkler systems also consistently achieved higher application efficiencies than dragline efficiencies (in the same order of magnitude as the Floppy when compared to dragline systems). Microclimate formation in the case of permanent systems is the apparent explanation for these observations. Since Floppy sprinklers are only used in a permanent system set-up, the advantage of high application efficiency is obtained as an integral characteristic of this type of sprinkler.

Utilising a cost analysis of a permanent Floppy and a dragline impact system, it was demonstrated that capital cost of a system cannot be isolated and utilised to compare these systems. Capital cost was, therefore, reviewed in conjunction with labour requirements, maintenance, life expectancy, pumping costs and water tariffs. It was determined that the running cost of a permanent Floppy system was less than that of a dragline impact system. This is due to lower labour costs and a reduced pumping head since the Floppy is operating at a lower pressure. Fewer pumping hours result since the Floppy system applies the water more efficiently, and due to its higher application efficiency, Floppy systems utilise less water. A cost analysis along the above-mentioned lines indicated a result in favour of permanent Floppy systems in the ratio 1:1.2 when compared to dragline impact systems.

Cost: *R99 700*
Term: *1998-1999*

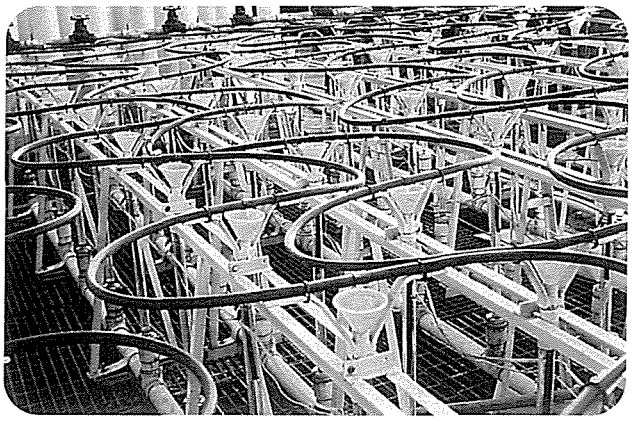
New projects

Performance of drip irrigation systems under field conditions

(No 1036) Institute for Agricultural Engineering, Agricultural Research Council

It is being estimated that 250 000 ha are currently micro-irrigated in South Africa. The term "micro-irrigation" refers to two types of systems i.e. micro-sprinklers and drip irrigation. On about two thirds of the above-mentioned area micro-sprinklers are being utilised and on the remaining third drip irrigation is practised. Furthermore there are indications that irrigation in South Africa is more and more moving in the direction of drip irrigation, therefore necessitating a re-evaluation of facets of this irrigation technique.

Drip irrigation certainly has the potential to make a significant contribution to water conservation. Although considered to be the most efficient system in terms of water utilisation, there are also a number of investigations indicating the opposite. It is suspected that management and maintenance problems are the main reasons for these observations. For



Test bench for drip irrigation emitters (Institute for Agricultural Engineering, ARC).

various planning and design activities, however, reliable values for attainable micro-irrigation efficiencies are required. Utilising too low values results in over-designed systems and associated over-irrigation, and utilising too high values results in systems with insufficient capacity, unable to meet peak water requirements. The need for typical South African efficiency values and guidelines on dripper selection and system management is, therefore, very urgent.

In addition to the investigation regarding efficiencies, the project also intends producing guidelines for dripper selection and management of drip irrigation systems. Both of these, based on a project of this nature, will be significant contributions to irrigation practice in SA.

Against the above background, the aims of the project are as follows:

- To determine the extent to which water quality and age of the emitter affect the performance and efficiency of various drip irrigation emitters (d.i.e.'s) under typical South African conditions
- To develop guidelines for the selection of d.i.e.'s with due allowance to soil type, water quality and maintenance
- To develop operational guidelines for drip irrigation in South Africa.

Estimated cost: *R459 000*
Expected term: *1999-2001*

Quantification of the water use of four tree crops in the Lowveld of Mpumalanga

(No 1046) Institute for Tropical and Subtropical Crops, Agricultural Research Council

According to a recently completed comparative study of the economic efficiency of water use in the Crocodile River catchment of the Lowveld, subtropical fruit orchards perform better than forest and sugar-cane plantations. Based on the area under cultivation, the most important of these tree crops are citrus, mangos, bananas, avocados, nuts, papayas and litchis. A shortcoming is that very little is known about the water use of in particular avocados, mangos, macadamias and litchis. The only available information is based on one-year pilot studies and extrapolation from overseas research results. Furthermore, field observations indicate that over-irrigation occurs more regularly than under-irrigation. Efficiency gains are clearly achievable through better management of water allocation and utilisation, but this will require information on water use of tree crops over different growth stages.

The research products that will be forthcoming from this project directly address the gaps in knowledge that exist at present. These are measurement of the water use of tree crops:

- In different age groups from establishment to maturity
- For homogeneous climate zones
- Subject to the same method of irrigation, namely micro-irrigation
- In relation to various elements of fruit quality
- In order to adjust SWB, an existing generic soil water balance model, which will allow extrapolation of results to any production area.

The testing and refinement of such a model will fulfil a major need within the subtropical fruit industry. Research on this subject has also been identified as a high priority by the Co-ordinating Committee for Agricultural Water Management. Applying the model to irrigation scheduling has important benefits since scheduling is the one aspect of crop management which has the biggest impact on yield and fruit quality, which in turn leads to higher profits for crops with a market potential. This project will therefore make a valuable contribution to improved water management of high-value, labour-intensive crops of which a major proportion is exported.

The main aims of the research are to:

- Quantify the seasonal water use of four selected tree crops over different age groups
- Evaluate the effect of irrigation on fruit size and quality
- Provide crop parameters and other inputs for modelling of water use by means of the SWB model.

Estimated cost: *R726 000*
Expected term: *1999-2003*

Evaluation of competition from trees for light (as in this photo) and water is a critical factor in alley-cropping systems.

Water-use efficiency of multi-crop agroforestry systems, with particular reference to small-scale farmers in semi-arid areas

(No 1047) Department of Plant Production and Soil Science, University of Pretoria

Much of the landscape in rural areas with a semi-arid climate has been denuded of indigenous trees and is prone to erosion. Under these circumstances, agroforestry can contribute towards stabilising production of forage or staple food crops and also production of fuelwood. Because of difficulties in propagating indigenous trees and due to the slow growth cycles, it is necessary to utilise exogenous trees for agroforestry which are nonetheless adapted to a semi-arid climate. Not only rainfall, but also minimum temperatures and soil conditions are important considerations. In order to achieve efficient water use and nutrient uptake, more information is required on e.g. tree spacing and appropriate crop selections.

Studies on different multi-purpose trees, such as *Leucaena leucocephela* (leucaena) and *Sesbania sesban* (sesban), are being

conducted currently. There are indications that these trees can be incorporated successfully into small-scale enterprises. Leucaena is reportedly suited to alley cropping systems and provides adequate amounts of fodder, firewood and poles. The incorporation of woody species into agricultural systems occurs in many traditional systems which often include different multi-crop systems. However, little is known about the effect of such systems on the efficiency of water use.

In this project the generic, mechanistic soil water balance (SWB) model will be adjusted for agroforestry crops on the research farm. The model will be used to assist with the establishment of agroforestry systems in co-operation with small-scale subsistence farmers and in different rainfall zones of semi-arid areas. In this way research station and on-farm research will be effectively combined to obtain practically applicable information.

The aims of this research are to:

- Evaluate locally adapted crops that may be incorporated into an agroforestry system, with emphasis on water requirements
- Determine the quality and quantity of resources available for a target group of small-scale farmers by means of participatory rural appraisal
- Develop an applicable agroforestry system that satisfies the objectives of the target group
- Assess the agronomic, economic and ecological sustainability of the agroforestry system.

Estimated cost: *R1 001 000*
Expected term: *1999-2003*

Analysis of the social, economic and environmental direct and indirect costs and benefits of water use in the irrigated agriculture and forestry sectors

(No 1048) Division of Water, Environment and Forestry Technology, CSIR

In the White Paper on a National Water Policy for South Africa it is stated that a system for allocation of water resources must be set up to achieve the "best possible use" of water. This concept involves more than productive use of water since it explicitly provides for weighing up of social, economic and environmental objectives to promote equity, efficiency and sustainability. It is therefore important to quantify direct and indirect benefits and costs to allow a fair comparison of water use within and between water-use sectors. Differences must be recognised between net benefits of:

- Water use at a primary level
- Value adding through e.g. processing at a secondary level
- Differential impacts on the natural environment.

It is also necessary to determine backward and forward linkages in the economic activity of different water users within and outside the boundaries of catchment areas.

These types of comparisons between the efficiency of water use of subtropical fruit trees, pine and eucalypt trees and sugar-cane were attempted in a project which is currently being finalised (No 666, Chapter 11). While relying on the best available information, more questions have been raised than answers provided. These questions refer specifically to accuracy of water-use measurements, analysis of total private costs and quantification of external social and environmental costs and benefits. The proposed research addresses these deficiencies and although the derived comparative values will only be applicable to the Crocodile River catchment, the principles and procedures developed will have wider application. The findings will therefore potentially provide decision support for private and public management of water allocation within other river catchments.

This project aims to broaden the findings of the previous project, and to put its findings into the broader context required to make the results useful in guiding water policy decisions.

The specific aims are to:

- Refine the data on water use and economic returns derived during the first phase of the project
- Quantify the forward and backward economic linkages in the forestry and irrigated agricultural sectors investigated in the past project

Leucaena leucocephala, a leguminous fodder tree being utilised increasingly in alley-cropping systems by small-scale farmers.

- Quantify the environmental costs and benefits of water use in the two sectors.

Estimated cost: *R558 000*
Expected term: *1999-2001*

Application of rainfall intensity-runoff relationships to water harvesting from micro-catchments to stabilise food production in rural and peri-urban settlements

(No 1049) Department of Agrometeorology, University of the Orange Free State

In most parts of South Africa where rural and peri-urban settlements take place, rainfall is low and variable, so that water is often the limiting factor for cultivation of food crops. However, if the storm water, including runoff from roofs, roads and surrounding natural areas can be channelled to adjacent high potential land, then crops could be grown, despite the low rainfall. These types of water harvesting techniques have been successfully used in rural areas in other African countries, but an operational model needs to be developed for local conditions. For this purpose data which have, amongst others, been collected in WRC-funded research undertaken by the Agricultural Research Council (Project No 878), and theoretical relationships developed by the University of Natal (Project No 681), will be further analysed and tested. In particular the simulated relationships between daily rainfall and rainfall intensity have to be refined in order to generate expected runoff through application of the ACRU model.

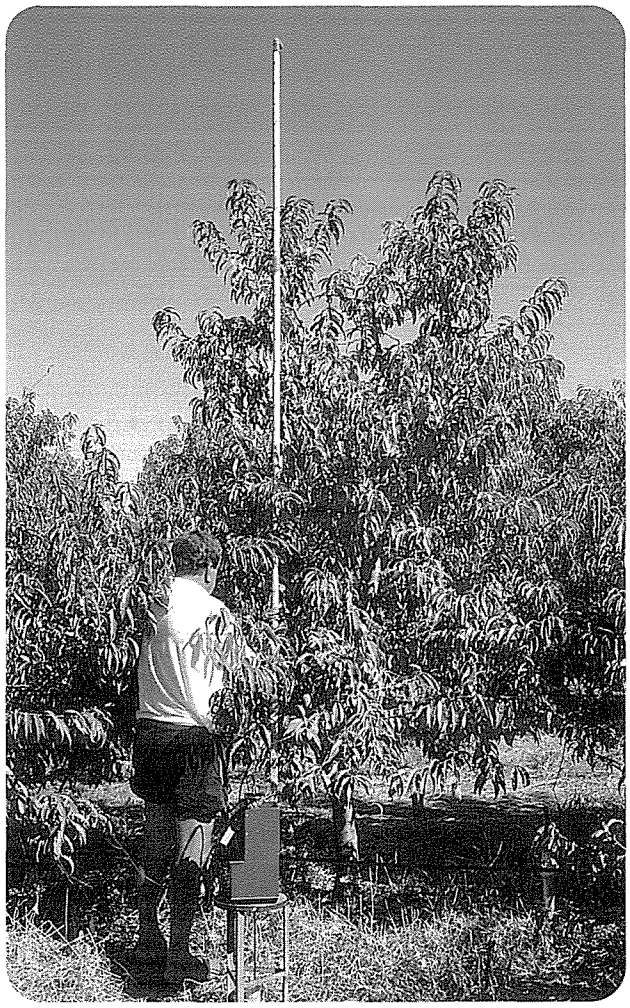
Information on expected runoff is required to determine the area of micro-catchments that will be necessary to harvest water for different field or community garden sizes. Because of rainfall variability, the long-term potential to stabilise or increase food production will also be evaluated by using crop models. Thereby this project will contribute towards practical implementation of previous research work and will support livelihood opportunities in micro-scale rural and peri-urban agriculture. These have been identified as areas for serious investigation by the report on Poverty and Inequality in South Africa (May 1998), prepared for the Office of the then Executive Deputy President and the Inter-Ministerial Committee for Poverty and Inequality. The focus has to be on gaining access to natural resources and obtaining sources of income through agricultural activities.

The aims of this project are to:

- Do a complete analysis of the rainfall intensity and runoff data already collected
- Test various theoretical relationships identified as appropriate for South African conditions
- Generate rainfall intensity data from the historic record of daily rainfall at selected benchmark ecotopes and use the ACRU model to simulate runoff
- Conduct a risk analysis for water harvesting techniques at selected rural and peri-urban sites using climate-crop models.

Estimated cost: *R521 000*
Expected term: *1999-2001*

Measurement of photosynthesis plays an important role in the evaluation of irrigation-induced stress in the plant.



Measurements of tree dimensions were done to correlate growth with water use. In the foreground is the neutron moisture probe used to measure soil water changes.

Sustainable local management of smallholder irrigation

(No 1050) Faculty of Agriculture, University of the North

Up until the mid-1980s the development approach for small-scale farmer irrigation schemes was mainly one of conceptualising, planning and implementing schemes on behalf of farmers. This type of development was based on the mistaken premise that available natural resources and technological innovations themselves would be sufficiently attractive for farmers to participate. It has resulted in farmers effectively being labourers with little decision-making powers, and being overdependent on Government or management agencies for technical and financial assistance, for operation and maintenance of schemes and for extension or training. Furthermore, the bureaucratic, centralised approach has tended to discourage local initiative and endeavour. Although farmer organisations do exist, they lack leadership, managerial competence, responsibility and accountability.

In the Northern Province over 160 smallholder irrigation schemes have been established with the objective to improve the livelihood of rural people. These schemes have been managed in a top-down manner with the emphasis on food self-sufficiency. Various constraints and a lack of incentives have led to low productivity and incomes which are below subsistence levels. However, commercially oriented farmers are also emerging on some of these schemes. The Provincial Government is now considering the transfer of management of these schemes, where feasible, to local communities. To date little research has been done on the local managerial capacities, existing organisational structures and the potential for improvement. The appropriate mechanism for this transformation needs to be determined through consultation and active involvement of stakeholders by undertaking participatory action research. The advantage of this approach is that it combines three principal activities namely research, education and action.

The main aim of the research is to contribute to poverty alleviation through improving productivity, profitability, gender equity and environmental sustainability in smallholder irrigation. The specific aims include the following:

- To identify cropping and irrigation management practices for improved water-use efficiency and productivity
- To assess the productivity and profitability of a sample of irrigation farming systems by applying specific measures of performance
- To determine the extent to which poverty alleviation and empowerment of smallholder farmers can be achieved through self-management of smallholder irrigation systems.

Estimated cost: *R863 500*
Expected term: *1999-2001*

Research projects

Completed

- **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)
- **479** Molecular approach to drought tolerance (Agricultural Research Council – Roodeplaat Vegetable and Ornamental Plant Institute)
- **753** Facilitating irrigation scheduling by means of the soil water balance model (University of Pretoria – Department of Plant Production and Soil Science)
- **K8/321** Evaluation of the performance of two types of sprinkler irrigation emitters (Agricultural Research Council – Institute for Agricultural Engineering)

Current

- **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)
- **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)
- **573** Water-use efficiency of cultivated subtropical forage and pasture crops (University of Pretoria – Department of Plant Production and Soil Science)
- **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.)
- **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 and Soil Science)
- **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)
- **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)
- **740** Effect of water quality on irrigation farming along the lower Vaal River: The influence on soils and crops (University of the Orange Free State – Department of 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)
- **798** Quantification of the water balance on rehabilitated mine soils under rain-fed pastures on the Highveld of Mpumalanga (Agricultural Research Council – Institute for Soil, Climate and Water)
- **816** Use of triploid grass carp for the biological control of excessive growth of water weeds in irrigation schemes (Rand Afrikaans University – Department of Zoology)
- **857** Extension to and further refinement of a water quality guideline index system for livestock watering (University of Pretoria – Department of Animal and Wildlife Sciences)
- **858** Influence of irrigation with gypsiferous mine water on soil properties and drainage water in Mpumalanga (Chamber of Mines)
- **878** Optimising rainfall-use efficiency for developing farmers with limited access to irrigation water (Agricultural Research Council - Institute for Soil, Climate and Water)
- **891** Guidelines for rehabilitation of small-scale farmer irrigation schemes in South Africa (Prof emeritus TJ Bembridge, Private Consultant)
- **892** Evaluation of a model for water use in deciduous fruit orchards and scheduling of irrigation with the aid of meteorological data (Agricultural Research Council – Infruitec)
- **893** Factors which influence the acceptance of irrigation scheduling with specific reference to scheduling models (University of Pretoria - Department of Agricultural Economics, Extension and Rural Development)
- **894** Implementation of the FARMS (firm-level agricultural risk management simulator) system for management of decision-making in irrigated farming (University of the Orange Free State – Department of Agricultural Economics)
- **918** Investigation into the use of pathogenic organisms for the biological control of the troublesome alga *Cladophora glomerata* (Agricultural Research Council – Plant Protection Research Institute)
- **944** Selection for drought tolerance in the germplasm of *Vigna unguiculata* (cowpea), *Vigna subterranea* (bambara groundnut) and *Amaranthus* spp. (marog) (Agricultural Research Council – Vegetable and Ornamental Plant Institute)
- **945** Two-dimensional water balance and energy interception model for fruit trees (University of Pretoria – Department of Plant Production and Soil Science)
- **946** Development of an integrated information system using the WAS, SWB and FARMS computer models (NB Systems)
- **947** Economic impact of changing water quality on irrigation farming in the Lower Vaal River (University of the Orange Free State – Department of Agricultural Economics)
- **974** Economic efficiency of irrigation systems for large- and small-scale farming enterprises (University of the Orange Free State - Department of Agricultural Economics)

New

- **1036** Performance of drip irrigation systems under field conditions (Agricultural Research Council – Institute for Agricultural Engineering)
- **1046** Quantification of the water use of four tree crops in the Lowveld of Mpumalanga (Agricultural Research Council – Institute for Tropical and Subtropical Crops)
- **1047** Water-use efficiency of multri-crop agroforestry systems, with particular reference to small-scale farmers in semi-arid areas (University of Pretoria – Department of Plant Production and Soil Science)
- **1048** Analysis of the social, economic and environmental direct and indirect costs and benefits of water use in the irrigated agriculture and forestry sectors (CSIR – Division of Water, Environment and Forestry Technology)
- **1049** Application of rainfall intensity-runoff relationships to water harvesting from micro-catchments to stabilise food production in rural and peri-urban settlements (University of the Orange Free State – Department of Agrometeorology)
- **1050** Sustainable local management of smallholder irrigation (University of the North – Faculty of Agriculture)

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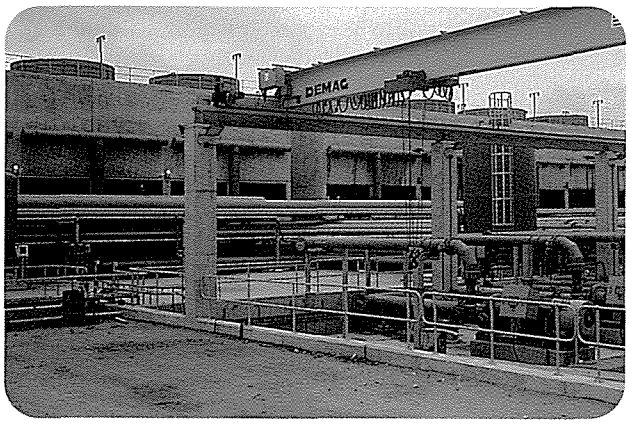
8 Industrial water management



Under the provisions of the Constitution, the Water Services Act and the National Water Act, increasing downwards pressure will be placed by DWAF on water services (local) authorities to meet appropriate waste discharge standards, and this will directly and indirectly devolve to industry in terms of increasing reluctance by the authorities to accept intractable waste loads and/or to impose very high levies on such discharges.

Industry has a crucial role in the RSA to provide the base for national socio-politico-economic development. This is counter-balanced, and indeed enforced in recently-enacted water-related legislation, by the responsibility to improve and then sustain the aquatic environmental standards necessary for the provision of basic human needs such as the security of adequate and acceptable-quality water supplies. In the water-source RSA context, where indirect water reuse is a necessary fact of life, the contradictions of this paradigm are most logically met by source reduction of industrial demand in terms of water use and waste/pollution generation, with associated cost-savings to industry and concomitant reductions in the impacts on the aquatic environment.

Accordingly, in ascribing priorities to research in the field of industrial water management, attention continues to be given to balancing preventative, "reduction-at-source" approaches with "end-of-pipe" treatment technologies. In the latter scenario, it is recognised that reduction in industrial water use without an equal or greater reduction in pollutant loss to drain will result in more concentrated (although lower-volume) effluents, which could require the development of different or modified treatment technologies. Increasing emphasis continues to be placed on the former approach, aimed at achieving sustainable industrial development which is at the same time environmentally acceptable in terms of the overall impacts on the aquatic environment and other water users.

The "demand management" approach towards industrial water management has been promoted by WRC-funded research over a period of decades. New tools for assisting in progress towards this objective include:

- Pinch analysis (a mass balance technique for minimising the overall quantity of water used and pollutants generated in an inter-related series of industrial processes)
- Waste minimisation (two very successful clubs have been launched and a methodology for sustaining this is currently being investigated)
- Cleaner production and clean technology (industries currently receiving attention include pulp and paper processing, oil refining, textile processing, metal finishing and leather tanning)
- Life-cycle assessments (for holistically and objectively analysing the total environmental impacts of alternative processes either for production purposes, or for waste treatment).

Regarding treatment technologies, research work has continued on biological effluent treatment in the edible oil industry, biosorption of heavy metals from metal finishing wastes, and new work has commenced on innovative bio-technological and chemical approaches to the removal and recovery of metals and salts (in particular sulphate) from both industrial and mining wastewater sources.

Completed projects

Dewatering of compressible cakes

(No 241) Pollution Research Group, University of Natal

The aim of this study was to identify and develop methodology that would enable the characterisation of compressible cakes and predict performance of large filters from laboratory tests and the basic equations. It was found that the performance of filters may reasonably be predicted from basic sludge characterisation data. The effects of hydraulic compression on cake properties and filter performance were shown. Methods to characterise the compression-permeability-voidage relationships for a cake have been investigated and evaluated. The basic equations for planar, internal cylindrical and external cylindrical filtration are presented together with a solution algorithm. However, it was recommended that methods to make these techniques more accessible to workers in the filtration field be developed.

Cost: *R561 000*
Term: *1991-1993*

Evaluation of various methods for the forming of free radicals for the oxidation of molecules in industrial effluents and potable water

(No 388) Pollution Research Group, University of Natal and Watergroup Africa (Pty) Ltd.

The emphasis of this project was to investigate hydrodynamic cavitation as a method for the production of free radicals for oxidation in potable and industrial water treatment – without the necessity for further chemical addition. The effects of ultrasonic cavitation on organic pollutants in industrial effluents were also investigated. It was found that hydrodynamic cavitation without the use of chemicals was not effective in either the oxidation of pollutants or for the inactivation of bacteria. On the other hand, the degradation of a model organic compound by ultrasonic cavitation indicates the potential of sonochemistry as an oxidation process for the treatment of industrial effluents. The sonochemical formation of hydroxyl radicals by ultrasonic cavitation can be enhanced by the addition of hydrogen peroxide and oxygen.

Cost: *R833 000*
Term: *1991-1995*

Development and implementation of biological cleaning techniques for ultrafiltration and reverse osmosis membranes for industrial effluents with a high organic content

(No 660) Department of Biochemistry, University of Stellenbosch

The project aimed to investigate and ameliorate the fouling of polysulphone ultrafiltration membranes used in the treatment of Cape brown waters, pulp and paper effluent, and abattoir effluent. The water and effluents were characterised and enzymes and other cleaning methods investigated for the cleaning of fouled membranes. In respect of the brown water and pulp and paper effluents, surface active and fouling prevention agents were evaluated and successfully applied. In the case of ultrafiltration membranes fouled in abattoir effluent, it was found that a blend of lipase and protease enzymes was effective as a cleaning agent to restore the membrane flux.

Cost: *R176 000*
Term: *1995-1998*

Enhanced granulation in upflow anaerobic sludge-bed digesters (UASB) by process induction and microbial stimulation

(No 667) Department of Food Science, University of Stellenbosch

One of the problems with the application of the UASB process is the long start-up period. The objective of this study was to enhance granulation in UASB systems and to promote a more rapid start-up procedure.

A hypothesis for enhanced granulation was developed and validated against experimental observations. This hypothesis was used to develop a biological model for the simulation of the process and to compare results from both batch- and laboratory-scale anaerobic systems. The research showed that the response of the anaerobic consortium was strongly dependent on specific carbon source, suitable nitrogen source and presence of necessary growth factors. The condition of the inoculum sludge such as type, age and concentration was found to be extremely important in the enhancement of the granulation process.

Cost: *R148 700*
Term: *1995-1996*

Membrane-based biotechnological systems for the treatment of organic pollutants

(No 687) Department of Biochemistry and Microbiology, Rhodes University

This project was aimed at the development of two approaches to the bioremediation of organic water pollutants, viz.:

- Non-specific oxidative degradation of organic compounds utilising the peroxidase activity of white rot fungi
- Removal and conversion of phenolic compounds using an isolated polyphenol oxidase enzyme system.

Locally developed capillary membranes were utilised as bioreactor in these studies.

A range of biological agents was identified and characterised with respect to their potential for bioremediation. Significant progress was made in developing several novel systems which had not been reported or characterised in such detail previously. Progress was also made in the innovative development of membranes and bioreactor modules suited to the biological systems selected. The modules developed could now be usefully produced for evaluation and general application in many fields. An immobilised enzyme bioprobe was successfully developed and patented, using polyphenol oxidase as the biocatalyst. This technology can now usefully be transferred for commercialisation.

Cost: *R292 500*
Term: *1995-1997*

New projects

Mass culturing of granules for use in upflow anaerobic sludge blanket (UASB) bioreactors by process induction and microbial stimulation

(No 1022) Department of Food Science, University of Stellenbosch

In 1995, the WRC funded the University to investigate the granulation processes. This study was based on the hypothesis that when sudden stress conditions were applied to UASB systems under controlled environmental conditions, an enhancement of the granulation process took place. The research has successfully enhanced granule production in a small batch reactor.

In this follow-up research project the project team aims to investigate the mass culturing of granules, analyse the microbial consortium within granules and include selected microbes into granules in order to enhance degradation of specific waste waters. The granules will be produced in a larger scale bioreactor. The successful cultivation of granules in a larger scale bioreactor has important economic implications for the optimisation of biological treatment processes in terms of faster start-up, and independence of South African industries from importation of granules from overseas.

Estimated cost: *R231 000*
Expected term: *1999-2001*

Caustic management and reuse in the beverage bottling industry

(No 1033) Department of Chemical Engineering, ML Sultan Technikon

Sodium hydroxide solution (caustic) is widely employed as a cleaning agent in the food industry. It is estimated that 35% to 40% of the water that enters bottling plants is discharged as a caustic effluent. Bottling plants are now giving serious consideration to caustic management and reuse/recycling. Previous attempts at developing caustic recycling processes usually consisted of neutralisation, followed by membrane processes to clean up the stream and recover sodium hydroxide – at high expense to the caustic users. However, recent advances in membrane technology may result in a significant decrease in membrane costs as well as membranes more suited to operations at high pH. Of special note is the development of improved local membranes suitable for the recovery of sodium hydroxide. Therefore, the aims of the project are to develop a viable membrane-based process for the reuse and/or recovery of sodium hydroxide; demonstrate the process to potential users; develop a commercialisation strategy for the proposed process, and develop a human resource skills base that is capable of implementing such processes in industry.

Estimated cost: *R370 000*
Expected term: *1999-2000*

Isolation of microbial extracellular enzymes for possible use in dairy cleaning-in-place applications

(No 1040) Department of Biochemistry and Microbiology, University of Port Elizabeth

Processing of dairy products is very complex with respect to production requirements. Unlike some other industries, a dairy plant is concerned with the processing of a highly perishable product for supply to the consumer who is becoming increasingly aware of nutritional requirements and has an increasing desire for high-quality, value-for-money products. In order to produce such high-quality, value-for-money products, the dairy industry has to concern itself with issues such as labour and its increasing costs, the cost of operation and maintenance of equipment, the cost of cleaning and maintaining hygienic conditions on the plant, pressures from regulatory agencies with regard to product specifications and the discharge of effluent and the rising cost of fuels.

The hypothesis for this study is that if it is possible to harness the enzymes which cause the unwanted degradation of milk constituents and modify them to be used as possible cleaning agents in the dairy industry, the total cost of cleaning in dairies could be significantly decreased.

Estimated cost: *R82 000*
Expected term: *1999-2000*

Optimisation of protein recovery in treatment of organic effluents: Feeding trials on biomass from pilot plant

(No 1081) DB Thermal (Pty) Ltd.

Replacement of the conventional settling tank in an activated sludge system with a fine screen resulted in the possibility of growing filamentous organisms (mainly fungi) as a near-monoculture in an open reactor, without any sterilisation, while simultaneously purifying the water. The WRC has already funded three projects where filamentous organisms were successfully used for the purification of industrial effluents, while simultaneously producing single-cell protein with good amino acid profiles. However, unless a value can be fixed to the biomass, i.e. whether it can be used as animal feed and at what cost, the risk is too high for industry to invest money in further optimisation and full-scale implementation of the process. In order to finalise the work that was sponsored so far by the WRC, animal feeding trials have to be done on the biomass to assess its applicability as animal protein and its commercial value. The aims of the project are therefore to:

- Determine the value of the biomass as protein source in the diets of pigs and broilers, and ascertain that the fungal protein is not toxic or cause growth deficiencies
- Determine a market value for the biomass produced, to enable the final introduction of the process into industry
- Continue with proper monitoring of the existing pilot plant in order to accumulate enough data for the design of a full-scale plant.

Estimated cost: *R196 000*
Expected term: *1999*

Further development of a biotechnological approach to the management of effluents from the pulp and paper industry

(No 1082) SAPPI Biotechnology Laboratory, University of the Orange Free State

Bleach plant effluents from the pulp and paper industry are highly coloured and contain chlorinated organic materials (which pose serious environmental problems because some of these compounds are in part toxic and mutagenic) and also, high concentrations of chlorides (which contribute to their corrosiveness). In response to these environmental concerns and increasingly stringent emission standards, the pulp and paper industry is making efforts to reduce the chloro-organic/chloride discharges by the introduction of more environmentally-benign bleaching methods. These include extending the cooking time for additional lignin removal, the use of oxygen as a prebleaching step, elemental chlorine-free and totally chlorine-free bleaching. Physico-chemical methods of removing chloro-organics (e.g. membrane treatment), although quite effective in decolorisation of pulp and paper mill effluents, are unattractive for industrial applications because of the high costs.

Work carried out to date on WRC Project No 763, entitled **Biotechnological approach to the management of effluents from the pulp and paper industry** (1996-1998) has shown considerable progress in providing viable bio-bleaching alternatives to the use of chlorine bleaching in the pulp and paper industry in the RSA, as well as environmentally friendly bio-decolorisation, biodegradation and bioremediation of the industry's effluents. Such "process substitution" steps are a necessary but often neglected aspect of shifts towards cleaner production. The present project (No 1082) aims at furthering this work towards practical implementation, and also expanding this into the production of commercially exploitable enzymes from pulp and paper effluents. The research work is being conducted at the SAPPI

Biotechnology Laboratory in close collaboration with the pulp and paper industry. Practical implementation of these bioprocesses in terms of bleaching chemical and effluent loads will result in cost-effective savings to the industry as well as reducing the environmental impact.

The aims of the project therefore include development of a modern biobleaching technology to improve the existing chemical bleaching processes of pulp and paper production in an environmentally-friendly and cost-effective way; utilisation of effluents from the pulp and paper industry to obtain valuable products such as enzymes (xylenases), single-cell protein and/or high-value fatty acids (gamma-linoleic acid); and reduction of the environmental impact of effluents from the pulp and paper industry by employing micro-organisms with special emphasis on effluent biodecolorisation, biodegradation and bioremediation.

Estimated cost: *R400 000*
Expected term: *1999-2001*

Assessment and application of the latest technology available for the bioremediation of heavy metal effluents

(No 1083) Centre for Water and Wastewater Research, Technikon Natal

The major industrial sources of metals in wastewaters in South Africa are from the metal-plating industries, mines and paint manufacturers. Inadequately treated metal-laden effluents which are discharged into rivers are toxic to the aquatic environment, including informal settlements using such water sources for potable purposes. In addition, heavy metal effluents affect the efficient functioning of wastewater works.

Current technologies for the treatment of heavy metal effluents are costly and are considered as ecologically-unfriendly. Global trends have recently shifted towards the use of bioremediation as an alternative cleaner technology which also appears to be economically feasible. A number of commercial biosorbents for heavy metal removal claim to be environmentally friendly and cost-effective when compared to current chemical treatment technology. The overall aim of the project is therefore to conduct a comprehensive global search to identify effective biosorbents for the local industries and to test these in laboratory- and pilot-scale trials so that guidelines for their appropriate application can be developed for local industrial users. The latest bioremediation technology for treatment of heavy metal effluents will be transferred to postgraduate students and personnel from industry. There is considerable potential for synergy with other current programmes involving industrial heavy metal discharges, such as the Waste Minimisation Club for the Metal-Plating Industry established by the Pollution Research Group, University of Natal, the National Waste Management Strategy (DWAF/DEAT) and the Cleaner Production Project (DANCED).

Estimated cost: *R 350 000*
Expected term: *1999-2000*

Development of biological treatment technology for the remediation of edible oil effluent

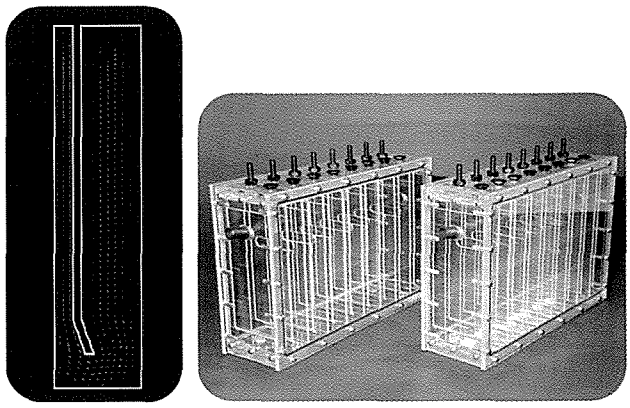
(No 1084) Centre for Water and Wastewater Research, Technikon Natal

The South African vegetable oil industry uses approximately 2×10^6 m^3 of water per year and about 40% of the water taken in is discharged to sewers. The quantity and physico-chemical characteristics of the effluent produced vary for different refineries, but in general the effluent has a high pollutant profile based on pH and high concentrations of COD, greases and phosphates. There are three distinct types of effluents emanating from the vegetable oil production cycle: from crude oil production, oil-refining and packaging (washing and spillages from bottling).

South African oil industries generally use two methods for effluent treatment: pH control and physical separation of oil and greases by using a DAF unit. Even after application of these methods the remaining emulsified greases tend to clog sewer pipes and pumps and the high COD and phosphates create shock-loading problems for the receiving wastewater treatment plant. Due to increased pressure from local authorities and wastewater treatment plants to increase the efficiency of in-house effluent treatment, some vegetable oil industries are taking steps toward implementation of biological methods in addition to the existing physico-chemical treatment. Although biological methods of treatment are used for treatment of palm oil effluents, information on biological treatment of other vegetable oil effluent is scant. The advantage of using aerobic treatment is primarily nutrient removal (particularly phosphates in the case of edible oil effluents). The overall aim of the project is to develop multi-stage anaerobic/aerobic processes so that, firstly, COD in the effluent can be removed anaerobically with minimum biomass (waste) production and secondly, the phosphates can be removed aerobically, thus producing a good quality effluent.

Estimated cost: *R 350 000*
Expected term: *1999-2000*

Assessment of a baffled (compartmentalised) anaerobic digester for the treatment of high-strength and toxic organic industrial effluents. The picture shows a computational fluid dynamic simulation of one compartment (left) of a proposed design for the anaerobic baffled reactor (right).



Upgrading of the WRC/LIRI wastewater treatment pilot plant for industrial effluent treatment and training of wastewater treatment personnel

(No 1085) LIRI Technologies

The LIRI/WRC wastewater treatment research/training/demonstration plant has already over the past few years been used for in-service training of over 100 employees from the leather processing industry. The LIRI/WRC plant is being extended in this project to include anaerobic digestion and high-rate algal ponding as a stand-alone treatment system for any high-load organic effluent such as from the tannery industry. The method of construction is to combine the two systems in a double-deck chamber, simultaneously reducing the cost of construction and the possibility of hydrogen sulphide air pollution. The anaerobic unit will be operated as a trench digester in a horizontal plug flow fashion and a plastic membrane will segregate the high-rate oxidation pond on top, operated in typical raceway fashion.

The aims of the project are thus:

- To extend and continue the operation and monitoring of the LIRI/WRC wastewater treatment plant to fulfil the objectives of incorporating an anaerobic/aerobic treatment stage by means of a combined double-deck trench digester/high-rate algal pond unit
- Researching and optimising the performance of the extended pilot-plant treatment process for treatment of tannery effluents
- Effecting transfer of successful technology to industry
- Studying the effects of various tanning chemicals on the wastewater treatment plant performance in terms of biodegradability and the reuse potential of treated water
- Training students, operators and managers in the design, operation and monitoring of these industrial wastewater treatment systems.

Estimated cost: *R 420 000*
Expected term: *1999-2001*

CONTACT PERSON

- **Mr GN Steenveld** (Industrial Water Management and Municipal Wastewater Treatment)
  E-mail: greg@wrc.org.za
  ☎ **(012) 330-0340**

Research projects

Completed

- **241** Dewatering of compressible filter cakes (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **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 and Watergroup Africa (Pty) Ltd.)
- **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)
- **667** Enhanced granulation in upflow anaerobic sludge-bed digesters (UASB) by process induction and microbial stimulation (University of Stellenbosch – Department of Food Science)
- **687** Membrane-based biotechnological systems for treatment of organic pollutants (Rhodes University – Department of Biochemistry and Microbiology)

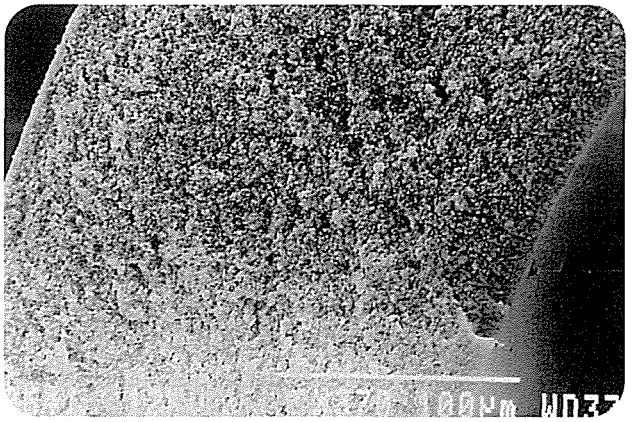
Current

- **308** Recovery of water and chemicals from ion-exchange regeneration effluents (University of Natal – Department of Chemical Engineering)
- **331** Improved oxygen transfer for high biosludge concentrations (University of Pretoria – Department of Chemical Engineering)
- **455** Anaerobic digestion of dairy factory effluents (Agricultural Research Council – Irene Animal Production Institute)
- **457** Monitoring and optimisation study of high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery wastewater (Rhodes University – LIRI Technologies)
- **495** Biotechnological approach to the removal of organics from saline effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **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 wastewater (University of Stellenbosch – Department of Chemistry)
- **616** Use of algal and yeast biomass to accumulate toxic and valuable heavy metals from wastewater (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 wastewater 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)
- **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)
- **759** NATSURV: Water and wastewater 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 – Department of Chemical Engineering, Pollution Research Group)
- **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 – Department of Chemical Engineering, 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)
- **826** Operation and monitoring of the WRC/LIRI wastewater treatment pilot plant for industrial effluent research and training of wastewater treatment personnel (Rhodes University – LIRI Technologies)
- **827** Detection methods for studying the ecology of *Legionella* in cooling-water systems (University of Pretoria – Department of Microbiology and Plant Pathology)
- **845** Development of bioreactor systems for the treatment of heavy metal containing effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **851** Application of pinch technology as a strategic tool in the rational management of water and effluent in an industrial complex (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **853** Assessment of a baffled (compartmentalised) anaerobic digester for the treatment of high-strength and toxic organic industrial effluents (University of Natal – Department of Chemical Engineering, Pollution Research Group)
- **869** Biological sulphate desalination and heavy metal precipitation in industrial and mining effluents using the algal integrated ponding system (AIPS) (Rhodes University – LIRI Technologies)
- **939** Development of bioreactor systems for the conversion of organic compounds in industrial effluents to useful products (Rhodes University – Department of Biochemistry and Microbiology)
- **940** Electrochemical treatment removal of phosphates and *sulphates from sewage and acid mine drainage respectively* (Anglo Operations Ltd. – Anglo Coal)
- **941** Research and development of electronic distance-learning methodology for the education and training of industrial wastewater treatment personnel (Rhodes University – LIRI Technologies)
- **942** Solid stabilisation of soluble wastes from the ferro-alloys industry (Council for Mineral Technology, Mineralogy and Process Chemistry)
- **972** Process development and system optimisation of the integrated algal trench reactor process for sulphate biodesalination and heavy metal precipitation in mining and industrial effluents (Rhodes University – Department of Biochemistry and Microbiology)
- **973** Waste minimisation and effluent treatment clubs – Phase 1: Initial assessment and pilot study (University of Natal – Department of Chemical Engineering, Pollution Research Group)

New

- **1022** Mass culturing of granules for use in upflow anaerobic sludge blanket (UASB) bioreactors (UASB) by process induction and microbial stimulation (University of Stellenbosch – Department of Food Science)
- **1033** Caustic management and reuse in the beverage bottling industry (ML Sultan Technikon – Department of Chemical Engineering)
- **1040** Isolation of microbial extracellular enzymes for possible use in dairy cleaning-in-place applications (University of Port Elizabeth – Department of Biochemistry and Microbiology)
- **1081** Optimisation of protein recovery in treatment of organic effluents: Feeding trials on biomass from pilot plant (DB Thermal (Pty) Ltd.)
- **1082** Further development of a biotechnological approach to the management of effluents from the pulp and paper industry (University of the Orange Free State – SAPPI Biotechnology Laboratory)
- **1083** Assessment and application of the latest technology available for the bioremediation of heavy metal effluents (Technikon Natal – Centre for Water and Wastewater Research)
- **1084** Development of biological treatment technology for the remediation of edible oil effluent (Technikon Natal – Centre for Water and Wastewater Research)
- **1085** Upgrading of the WRC/LIRI wastewater treatment pilot plant for industrial effluent treatment and training of wastewater treatment personnel (LIRI Technologies)



New ultrafiltration membrane developed by the Institute for Polymer Science, University of Stellenbosch.

Membranes are increasingly being accepted as cost-effective unit processes for a wide range of applications, including desalination of sea water and brackish water, the purification of surface and polluted waters for potable use, and the treatment of industrial and municipal effluents. Membrane separation processes are not only relevant to First-World conditions, but also have great potential for water supply to rural and peri-urban communities. In research and development projects funded by the WRC and DWAF, this potential is being demonstrated. Innovative research, which has resulted in a number of new patents, is continuing on the following aspects:

- Using the new sponge-type ultrafiltration membrane developed by the Institute for Polymer Science, University of Stellenbosch, small water treatment systems are being developed for community water supply. The capabilities of the membrane for micro-organism removal are being addressed under a separate project.
- The affordable purification of groundwater for community use is also being addressed in two solar-power related projects. In the one project, solar-powered reverse osmosis is being evaluated, whereas in the other project the accent is on cost-engineering an expensive imported solar still to under R700 in order to render it affordable for use by households, schools and clinics.
- An innovative affinity separation membrane system has been developed for the highly selective removal of wanted and valuable chemicals from water and effluents, thereby affording the possibility of offsetting treatment costs – or even showing a profit.
- Noteworthy results in membrane fouling control are being obtained with electromagnetic, physical, membrane surface modification, *in situ* enzymatic, and "defouling-on-demand" enzymatic methods. A suite of projects is addressing the removal of unwanted organics, metals and other contaminants from water and effluents. These include the following:
  - Removal of organics using micro-organisms and membrane bioreactors
  - Employing innovative electromembranes with catalytic and ion-separation capabilities
  - Membrane-based catalytic generation of mixes of ozone and hydrogen peroxide
  - Using environmentally friendly chitosan-based materials for the adsorptive removal of heavy metals
  - Membrane-based recovery of caustic used for bottle washing and chemical cleaning by the removal of contaminants and subsequent concentration of the caustic for reuse.

The technical achievements have been made possible to a great extent by the establishment of an empowered manpower base in the membrane field. Joint research and general co-operation between the Universities of Stellenbosch, Rhodes, Western Cape, South Africa, and the Technikons ML Sultan, Cape, Peninsula and Northern Gauteng have created a core of knowledgeable scientists and technologists in this field. Co-operation with private membrane manufacturing and supplying organisations has resulted in increased local and foreign application of local membrane research and development.

During a membrane technology conference and workshop of the Membrane Technical Division of WISA, held from 27 to 29 September 1999, a strategy planning session was held by the WRC, at which some specific research and development needs were elicited, with a view to supplementing and updating the Strategic Plan for Water-related Membrane Research in South Africa. The updated Strategic Plan is available on the WRC's website.

Completed projects

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

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

A need exists for students of membrane technology to understand the internal workings of a membrane and its flows. To provide an initial product in this regard, a CD ROM-based computer program for the simulation of membrane treatment and capillary membrane design for potable water production was compiled. The program provides for an animated and multimedia presentation of the design. The first part gives a brief overview and introduction to potable water manage-

ment, as well as the advantages of using membrane modules for the production of potable water. Subsequently, the following design information and functioning of components may be obtained from a few required input parameters:

- Provides the module area and packing density of the capillaries
- Shows animated flows of the basic feed stream, permeate and concentrate circuits
- Explains plant components when one clicks on the specific component.

Sound has been added to some of the simulation aspects to make it more realistic. The program can be down-loaded from the WRC website.

Cost: *R42 000*
Term: *1996-1997*

Defouling of ultrafiltration membranes

(No 791) Department of Biochemistry and Microbiology, Rhodes University

The consequences of membrane fouling include loss in throughput (flux), high cleaning costs, and damage to the membranes due to harsh chemical cleaning agents. The project therefore aimed to develop self-cleaning membrane filtration systems by the attachment of biodegradative enzymes to the active layer of membranes so that they may degrade the forming gel layer from the surface of the membrane upon activation by the membrane operator. After normal fouling of the membranes, which took place over time, it was shown that the fouling layer could be removed by activating the enzyme at will of the operator, using an oxidising activator. The enzymes manganese peroxidase and horseradish peroxidase showed the best results. Activating agents found to work best to activate these two enzymes were the manganous ion and hydrogen peroxide respectively.

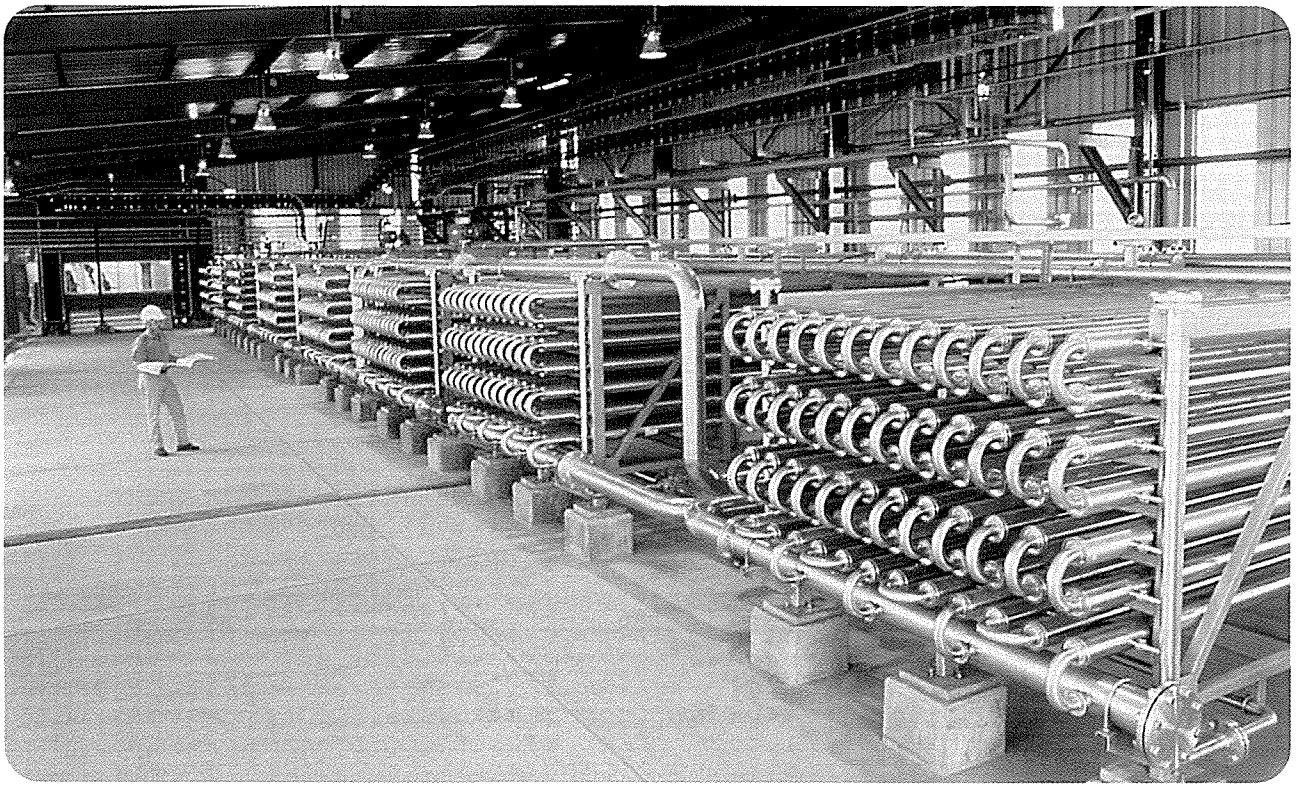
Cost: *R48 000*
Term: *1997-1998*

New projects

Microbiological assessment of membrane technology in water treatment

(No 1034) Biological Sciences, ML Sultan Technikon

Membrane technology potentially offers the water industry a barrier to micro-organisms with a high level of resistance to chemicals used in water disinfection, including *Cryptosporidium, Giardia, Cyclospora, Mycobacteria*, as well as the rugose form of *Vibrio cholerae* or *Legionella pneumophila* which multiply in amoebae where they lie protected from disinfection processes. The University of Stellenbosch has developed low-cost capillary membranes which show great potential for the small-scale treatment of potable water in developing countries. To complement this technology, simple, reliable methods to test and set microbiological performance criteria for these membranes are needed. This project aims to develop bio-assessment criteria to evaluate capillary ultrafiltration systems for the production of potable water and to determine the efficacy of the membranes in the removal of pathogens largely implicated in enteric infections, such as *E. coli, Shigella, Salmonellae, Campylobacter jejuni, Vibrio cholerae, Cryptosporidium, Giardia* and viruses. The use of a simple



Enzymatic cleaning of RO membranes for the pulp and paper industry.

method that can be applied in a field situation to indicate membrane performance during, after, and before cleaning operations will also be investigated.

Estimated cost: *R360 000*
Expected term: *1999-2001*

Implementation of membrane cleaning and pretreatment techniques for membranes fouled during the filtering of pulp and paper effluent

(No 1035) Department of Biochemistry, University of Stellenbosch

The most challenging obstacle in the way of full implementation of membrane filtration processes, is the fouling phenomenon, an inherent consequence of any high-pressure effluent or polluted water filtration process. In a previous WRC project (No 660, **Enzymatic cleaning of membranes used in high organics effluents**) methods for effluent and foulant characterisation, membrane cleaning and membrane pretreatment were developed. These methods were successfully applied under laboratory-scale conditions for membranes fouled by paper and pulp effluent and are now available for implementation on a larger scale.

Therefore, the aims of the project include the following:

- Development of a pilot-scale filtration unit and filtration of pulp and paper effluent under the same conditions as in the industry
- Implementation of membrane cleaning techniques developed under laboratory-scale conditions in the pilot plant
- Implementation of cleaning and non-covalent membrane pretreatment techniques on a pilot scale and evaluation of the cost-efficiency thereof
- Transfer of this technology to the industry for large-scale implementation.

Estimated cost: *R123 000*
Expected term: *1999-2000*

Development of a solar-powered reverse osmosis plant for the treatment of borehole water

(No 1042) Weir Envig (Pty) Ltd.

The development and implementation of a solar-powered reverse osmosis (RO) unit are seen as being of great potential benefit to communities in rural areas, especially in terms of the cost-effective supply of safe drinking water from brackish groundwater sources. The cost of solar energy panels for power generation for the RO system is very low when compared to conventional electrification of a household, rendering this an attractive water supply option under certain circumstances. However, the combined system consisting of solar panels, solar-powered pump and RO system still needs further development and evaluation under typical field operating conditions. Therefore, the project aims to design and construct a practical, cost-effective unit capable of producing potable quality water from brackish groundwater to small and isolated communities. The operation of such units will be demonstrated in structured field trials.

Estimated cost: *R85 000*
Expected term: *1999-1999*

Electrochemical generation of high-concentration ozone in compact integrated membrane systems

(No 1071) Dinax Technologies cc and Department of Chemistry, University of Stellenbosch

Ozone can be produced using either pure oxygen or air by means of the corona discharge method. Where air is used, the concentration of ozone is low and harmful nitrous oxides are formed. When oxygen is used, high capital costs are incurred and ozone production is not that easily accessible to everybody. The technology proposed will provide approximately 18% ozone concentration at lower costs than the current technology, which only delivers 3% ozone. It could potentially replace the corona discharge method of ozone generation.

It is expected that the availability of ozone at high concentrations will allow significant improvements to be made in the design and use of ozone technology for the disinfection and treatment of water and effluent streams. Two components only will be consumed, i.e. electricity and a liquid electrolyte, such as deionised water or specially selected solutions of inorganic compounds. Potentially this technology should enable one to combine the production of hydrogen peroxide and ozone in a single reactor and in a single electrochemical process.

Estimated cost: *R809 000*
Expected term: *1999-2001*

Development of environmentally friendly biopolymeric heavy metal adsorbing membrane materials for industrial wastewater treatment

(No 1072) Department of Chemical and Mineral Engineering, Potchefstroom University for CHE

South African freshwater increasingly suffers from pollution by heavy metal wastes from the mining, plating and metal fabrication industries. Polysaccharide biopolymers isolated from aquatic organisms are a new class of potentially inexpensive and environmentally benign solid adsorbents which exhibit a high specificity towards metal ions. Specifically, chitosan, a deacetylated poly-glucose amine derived from the exoskeletons of shellfish, has been shown to demonstrate an exceptionally high affinity for cadmium, copper, zinc, chromium, mercury, manganese and nickel. In addition to chitosan, poly-gamma-glutamic acid is a second potential metal chelator which will be considered as a potential adsorbent.

The aims of the project are, therefore, to investigate the metal removal efficiency employing the biologically-derived polymers of chitosan and poly-gamma-glutamic acid. The mechanism of adsorption and desorption processes will be established, and the performance of the complete membrane process in which biopolymers are used for heavy metal removal will be established and compared with other appropriate complexation agents.

Estimated cost: *R894 000*
Expected term: *1999-2002*

Research projects

Completed

- **728** Computer program for cross-flow module and potable water plant design (University of Stellenbosch – Institute for Polymer Science)
- **791** Defouling of ultrafiltration membranes (Rhodes University – Department of Biochemistry and Microbiology)

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)
- **723** Designed functionalised polymers by anionic macro-molecular engineering for membrane development (Vista University – Department of Chemistry (Port Elizabeth Campus))
- **769** Development of a fabrication protocol for the production of capillary membranes and special modules for the low-cost treatment of contaminated water (University of Stellenbosch – Institute for Polymer Science)
- **844** Polymeric and ceramic-based membranes for use in electromembrane reactors (University of the Western Cape – Department of Applied Chemistry)
- **846** Development of a continuous-flow membrane bioreactor (University of the Western Cape – Department of Microbiology)
- **852** Use of tolerant membranes for preparing drinking water as well as for water reuse, using solar-power and electro-induced driving forces (University of Stellenbosch – Institute for Polymer Science)
- **930** Water desalination and clarification by electronically enhanced membrane defouling (Mineral Water Development (Pty) Ltd.)
- **931** Transverse-flow module fabrication technology development (University of Stellenbosch – Institute for Polymer Science)
- **932** Development of a "defouling on demand" strategy for the operation of bio-active membranes (Rhodes University – Department of Biochemistry)
- **964** Electromembrane reactors for desalination and disinfection of aqueous solutions (University of the Western Cape – Department of Chemistry)
- **965** Capillary ultrafiltration membrane process systems R and D (University of Stellenbosch – Institute for Polymer Science)

New

- **1034** Microbiological assessment of membrane technology in water treatment (ML Sultan Technikon – Biological Sciences)
- **1035** Implementation of membrane cleaning and pretreatment techniques for membranes fouled during the filtering of pulp and paper effluent (University of Stellenbosch – Department of Biochemistry)
- **1042** Development of a solar-powered reverse osmosis plant for the treatment of borehole water (Weir Envig (Pty) Ltd.)
- **1071** Electrochemical generation of high-concentration ozone in compact integrated membrane systems (Dinax Technologies cc and University of Stellenbosch – Department of Chemistry)
- **1072** Development of environmentally friendly bio-polymeric heavy metal adsorbing membrane materials for industrial wastewater treatment (Potchefstroom University for CHE – Department of Chemical and Mineral Engineering)

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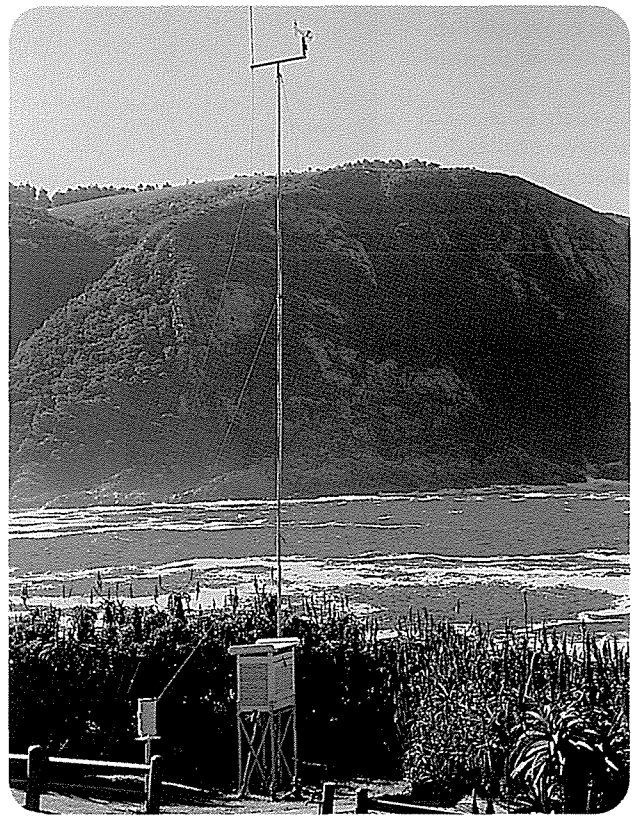
10 Hydroclimatology



Hydroclimatology focuses on that part of the hydrological cycle where atmospheric processes dominate. It seeks a sounder understanding of short- and long-term climate variability. Results of hydroclimatological research provide the foundation for better climate and water resource prediction methods and point the way to possible management strategies for avoiding impacts of adverse climatic conditions and profiting more from favourable conditions.

In September 1999 the Co-ordinating Committee for Research Hydroclimatology (CCRH) adopted a revised research plan which will guide WRC-supported hydroclimatological research over the next two to five years. The plan highlights six research programmes which encapsulate the research needs in this field. These are:

- The generation and beneficial use of weather and climate predictions in support of water resources management. An essential element is the achievement of a level of understanding of climate variability across temporal and spatial scales, and of atmospheric and oceanic mechanisms, which will enable necessary refinements of forecasting techniques and models.
- The impacts of global atmospheric and climate change on water resources.
- The development of integrated precipitation monitoring systems for water resource assessment, development and management in South Africa.
- The impact of aerosols of natural and anthropogenic origin on the hydroclimatology of Southern Africa.
- Methodologies for the monitoring of evaporation (transpiration included) from land surfaces and water bodies.
- Harvesting of cloud water.

Many of the current hydroclimatological research projects already contribute substantially to these programmes, the goals of which are spelled out in greater detail in the hydroclimatology research plan which can be viewed or downloaded via the WRC's website.

Completed projects

Fog collection as a supplementary water resource for small rural communities

(No 671) Department of Geography, University of the North

The objective of this project was to assess the amount and quality of fog water available in relation to needs of rural communities in various parts of South Africa. Spatial and temporal characteristics of fog occurrence were deduced from measurements made along the West Coast and in the mountainous and escarpment regions of the Northern Province and Mpumalanga. Pilot fog collectors in the form of either 1 m^2 or 3.6 m^2 screens were installed and tested at several sites in each of these areas. Both area characteristics and site characteristics conducive to high fog-water yields were identified. At the better escarpment sites with altitudes well in excess of 1 000 m, average daily water yield over all seasons was between 10 and 20 l/m^2 of collector surface,

with even the dry winter months having average daily yields of approximately 2.5 l/m^2. Yields along the West Coast were considerably lower but nevertheless comparable to those obtained in a successful fog-water supply project in Chile. Water-poor communities in the Northern Province who might be potential beneficiaries of fog-water collection schemes were identified and a fog-water collection unit for potential large-scale implementation was provisionally designed.

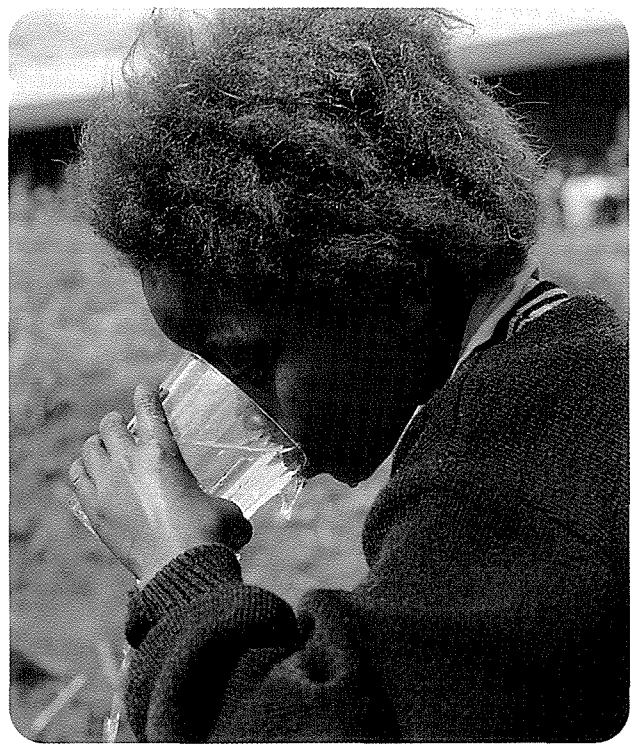
Cost: *R305 800*
Term: *1995-1998*

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

The issue of global climate change has become a widely accepted probability, if not already a fact. Such 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.

This follow-on project aimed to further refine the scenario-generating methodologies for regional precipitation in order to permit the impacts of climate change on water resources to be assessed.



Schoolgirl drinking fog water.

Prototype fog collector in the Soutpansberg.

This project produced two main results, the first of which is a sophisticated down-scaling methodology incorporated into a stable software package. Important features of the methodology are the following:

- It employs the direct transfer approach, transfer functions being derived by means of artificial neural nets (ANNs), a non-linear procedure analogous to multiple regression
- It incorporates three primary sources of forcing which are important in determining the manner in which local climates derive from the general circulation-based climate
- It has been validated against observational data and shown to effectively capture the spatial and seasonal attributes of precipitation over South Africa from general circulation data.

The second result comprises a set of provisional climate-change scenarios for South Africa, based on global GCM projections. These provisional scenarios have been derived through applying the methodology developed to the output from one leading GCM only. Similarly, the methodology could easily be applied to the outputs of other GCMs in order to generate a range of scenarios, which would converge as greater agreement among currently disparate GCM projections is achieved.

Cost: *R137 100*
Term: *1996-1998*

Spatial and temporal modelling of rainfields using fractals

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

It is well-recognised that the greatest limiting factor to the effective use of distributed models for hydrological applications is the quality of the rainfall input information. This is especially true in predominantly convective (thunderstorm) rainfall regimes in which point measurements made with isolated rain-gauges are notoriously unreliable. The aim of this project was to address this shortcoming by developing a parsimonious model capable of simulating rainfields having the same properties with respect to both space and time as might be observed by radar. In the interest of parsimony, the fractal approach originally envisaged had to be relinquished. The research has resulted in a model which is becoming widely known as the string-of-beads model. This name derives from the characteristic nature of sequences of dry "string" and wet "bead" events.

The one-dimensional process of alternating wet and dry periods is modelled satisfactorily by a three-state Markov chain. The real space-time variation within a "bead" is well represented by a time sequence of radar determined rain-rate images called "constant altitude plan position indicators" or "CAPPIs," in practice typically captured at 5 min intervals by a radar. Each observed CAPPI consists of 9 000 data points or pixels. By fitting a log-normal distribution to these pixels and determining, with the aid of the Fast Fourier transform, the two-dimensional power spectrum in order to define the spatial correlation structure, it is possible to derive the values of three parameters which together form adequate statistical descriptors of the "bead" characteristics. By reversing the analysis process, both simple and complex rainfall events can be simulated and represented pictorially by means of a sequence of simulated CAPPIs which preserve the statistical characteristics of real CAPPIs. Animation of real and simulated CAPPIs has shown the evolution of real and simulated wet events over an area to be visually indistinguishable in terms of typical growth, decay and movement of rain-producing cells and their clustering behaviour.

Cost: *R247 000*
Term: *1996-1997*

Modelling extreme rainfall over Southern Africa

(No 805) Climatology Research Group, University of the Witwatersrand

For sound planning and adequate warning, early recognition of conditions which give rise to heavy rainfall occurrences is vitally important. This project investigated the modelling of extreme rainfall over a range of temporal and spatial scales in Southern Africa. Firstly, with the help of the well-known CSU RAMS mesoscale model and the Wits University CRG kinematic trajectory model, new insight was gained into moisture sources and transport associated with widespread heavy rainfall periods such as the one which affected almost the entire summer rainfall region of South Africa in February 1996. Secondly, the CRG trajectory model was used to investigate air mass transport and moisture sources associated with tropical cyclone Demoina (January 1984), revealing that the primary moisture source was highly localised and associated with the vortex itself. Thirdly, in examining the difficulties experienced by some models in forecasting recent wet seasons, it appeared that premature northward progression of the westerly winds during autumn, was being simulated, resulting in too early an end to the rainfall season. Finally, a step towards overcoming problems of poor spatial resolution in GCM usage for simulating rainfall variation at inter-annual and climatological time scales, was taken with the successful nesting of the CSIRO limited area model (DARLAM) within the CSIR09 GCM output.

Cost: *R538 000*
Term: *1997-1998*

New projects

A real-time flood forecasting model using radar and satellite data

(No 1005) Department of Civil Engineering, University of Natal

There is an urgent need to put in place improved, efficient and easily calibrated flood forecasting systems in order to anticipate serious, life and property-threatening flooding. These improved systems should have the capacity to use powerful new data sources (radar, satellite) to supplement rain-gauge data.

This project therefore aims to provide a research shell which can be used for testing model constituents and training hydrologists in the area of flood forecasting, using modern technology and new data sources. There is evidence to suggest that catchment models used in real-time flood forecasting are easier to calibrate and run faster if they are of the transfer type than if of the conceptual/physical type. Calibration can be made automatic and independent of the modeller, thus facilitating model use by many different people. For these reasons, the use of transfer-type models will be a focus of

the proposed research, which has the following aims:

- Devise a computer model shell which incorporates easily calibrated components for the modelling of catchment and channel characteristics and which can accept satellite, radar and rain-gauge data as inputs
- Incorporate within the shell the facility to accept real-time streamflow data for updating forecasts
- Further incorporate the space-time stochastic rainfall model (the outcome of WRC Project No 752) as a means of generating areal rainfall input for the production of simulated floods to be used for testing and improving operating rules for flood mitigation
- Make the model shell available to flood forecasting practitioners as a training tool
- Use the research and its products for training engineers to Masters level and thereby increase the pool of personnel understanding the intricacies of real-time flood forecasting and management.

Estimated cost: *R200 000*
Expected term: *1999-2000*

Space-time modelling of rainfall using the string-of-beads model: Integration of radar and rain-gauge data

(No 1010) Department of Civil Engineering, University of Natal

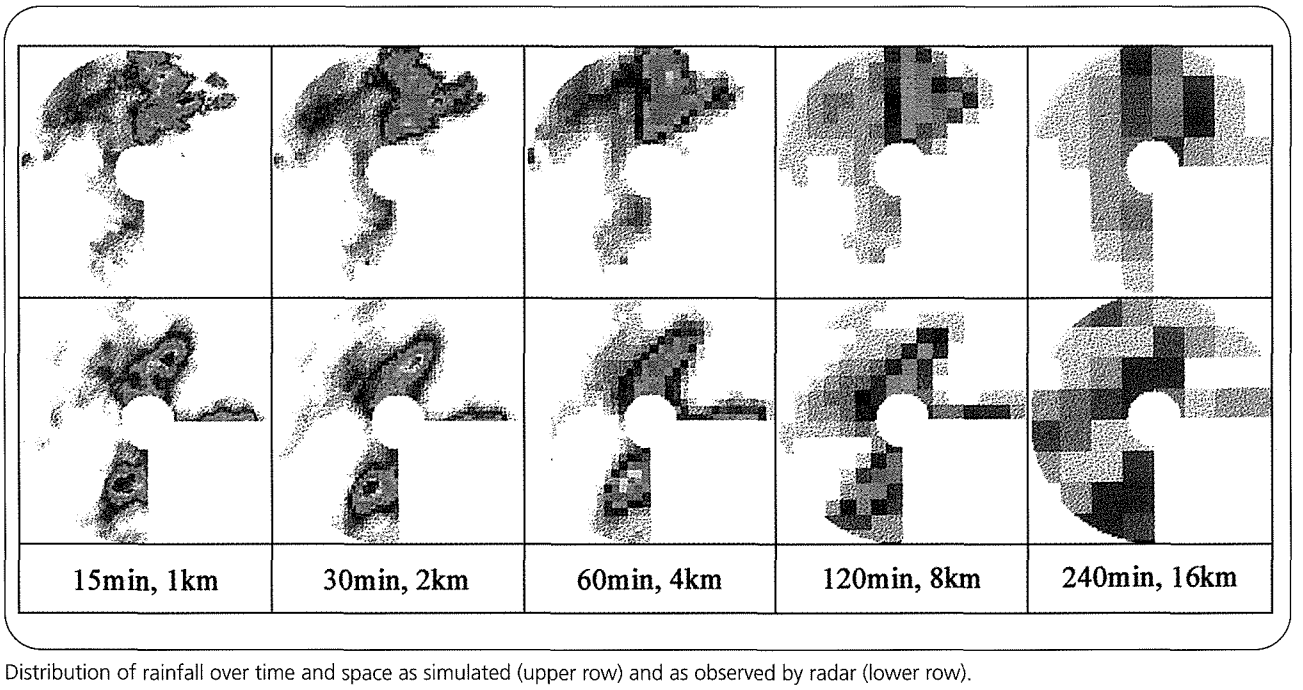
The manner in which rainfall gets distributed in time and space is a complex process, as observers of thunderstorm behaviour will know. However, recent research in the Department of Civil Engineering at the University of Natal, which utilised radar images of rainfields, has shown that within this apparently chaotic, turbulent behaviour, there exists a simplifying structure which can be exploited to model the main features of rain falling over space and time. In other words, the model would be able to produce simulated, sequential, radar images for a designated land area. At present real radar-rainfall images are available from only a few locations in South Africa and for, at most, the past two rainy seasons only. The use of a space-time rainfall model, together with available rain-gauge data, to simulate such images and generate simulated radar-rainfall climatologies, has important practical implications. For example, up to now, the lack of spatial detail in rainfall inputs into hydrological models has been the main factor limiting the usefulness of these models in real-time applications (e.g. flood forecasting) and short time-scale applications (e.g. simulating impacts of intense localised storms on streamflow, sediment transport, safety of structures, etc.).

The further development of a space-time (string-of-beads) rainfall model will fill a pronounced gap and greatly enhance the power of hydrological models for flood disaster management, as well as for land-use planning and hydraulic engineering design within the context of water resources.

The main aims of this project are, therefore, to:

- Validate the newly-developed model and refine model parameterisation
- Extend the model to areas where only historical rain-gauge network data are available and also to where a combination of rain-gauge and satellite data might exist
- Investigate the possibility of extending the model's capacity to make allowance for topographic features and large-scale weather systems
- Make the model available to the hydrological community as a working simulation tool.

Estimated cost: *R200 000*
Expected term: *1999-2000*



Distribution of rainfall over time and space as simulated (upper row) and as observed by radar (lower row).

Short-term weather forecasting techniques dedicated to flood management systems

(No 1011) Chair of Meteorology, University of Pretoria

Improvement of flood forecasting systems is a matter of urgency. Such systems can, however, only be as good as the information input into the system. At present the Weather Bureau is in a position to provide conventional qualitative (probabilistic) rainfall forecasts and is rapidly gearing itself to also supply radar and satellite-derived areally-distributed rainfall data in real time.

A gap which needs to be filled is the provision of quantitative rainfall forecasts with lead times of 6 to 48 h. This project, therefore, aims to facilitate the generation of quantitative rainfall forecasts for input into a river-flow forecasting model, by improving rainfall forecasting techniques and developing a new forecasting system for the period 6 to 48 h ahead.

To achieve this aim, a method of classifying weather systems into baroclinic, tropical or tropical-temperate will first be devised and then used to classify all past heavy rainfall events and associated systems accordingly. Past forecasts issued for these events will be evaluated and forecasting techniques for the different classes of event refined. The results should impact positively on the performance of flood forecasting systems in South Africa.

Estimated cost: *R239 000*
Expected term: *1999-2001*

Climatology of water vapour sources, sinks and transport in Southern Africa

(No 1012) Department of Environmental and Geographical Sciences, University of Cape Town

South Africa has a highly variable climate system and is prone to both drought and flood events. Many communities, both rural and urban, and sectors, such as water resources and agriculture, are highly vulnerable to such extreme climatic and weather events.

Despite fairly extensive recent research into the climate system, there are nonetheless still significant gaps in understanding of the processes involved. In particular, very little is known about the dominant sources and transport of moisture in the atmosphere. Initial investigations have been limited to case studies. There is, however, an urgent need to build on such case studies in order to confirm hypotheses regarding key moisture sources for Southern African precipitation and to develop a long-term climatology of moisture transport and of its intra- and inter-annual variability. Such information is fundamental to improving seasonal precipitation forecasts and to correctly interpreting outputs of global and regional climate models prior to their use in water-resource strategy or policy development. The research, therefore, aims to:

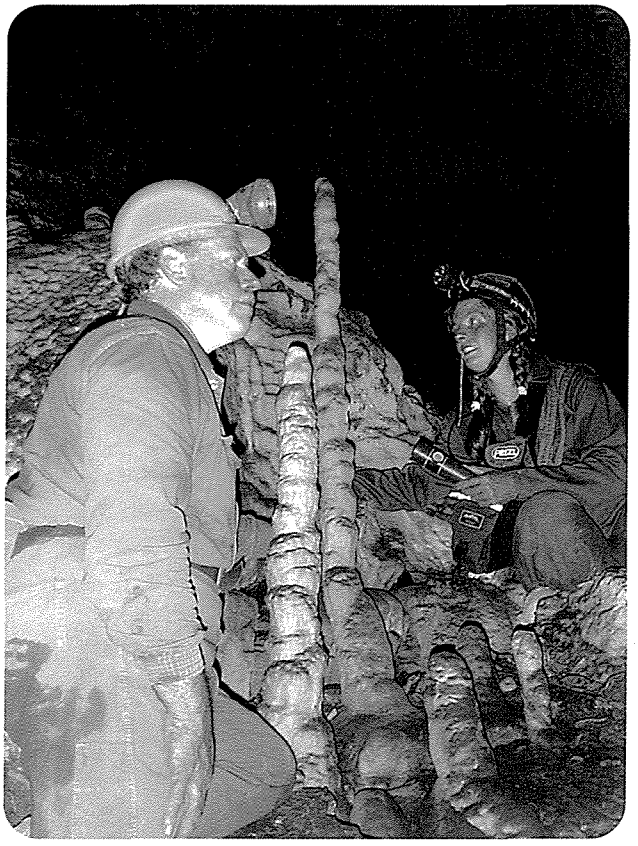
- Extend existing trajectory models to include aspects of diffusion and precipitation in the atmospheric transport of moisture
- Develop a long-term climatology of atmospheric water transport and analyse its variability, for different regions in Southern Africa
- Evaluate the atmospheric water transport characteristics of selected global climate models and global operational forecast models
- Perform a diagnostic analysis of the transport characteristics of available regional impact studies and seasonal forecasting.

Estimated cost: *R562 000*
Expected term: *1999-2002*

Reconstruction of long-term, high-resolution records of summer rainfall and its variability in South Africa from cave speleothems

(No 1013) Department of Archaeology, University of Cape Town

Climate change has occurred throughout history, but in recent times human activity has become a significant additional driving force for climate change. Climate change impacts on the environment, water resources as well as on countless facets of human endeavour and well-being. Unfortunately, knowledge of the direction, rate and "human component" of climate change is extremely difficult to come by. This is because of the relatively short length of record of objective hydroclimatic observations and the extremely pronounced inter-annual hydroclimatological variability which combine to mask climate change at the decadal and century scales. For this important reason and others, there has been a world-wide drive to reconstruct historical climate data using proxy data. The research aims to construct a unique



Tim Partridge and Karen Holmgren viewing the new stalagmite, T8, from Cold Air cave. The stalagmite is continuous throughout the Holocene (last 10 000 years) and goes back beyond the last glacial maximum, to about 27 000 years. The dating was done by Karen Holmgren in Bergen, Norway.

subdecadal-scale record of precipitation, temperature and vegetation response for periods during the past 10 000 years in the Northern Province region by the following:

- Validating growth and chemical signals in speleothems pertaining to moisture availability, distribution and amount of rainfall, to temperature and to vegetation response, in order to separate and elucidate these signals
- Extending existing speleothem records which have already produced exceptionally strong evidence that the sought-after information, at the desired time scales, is contained therein
- Improving the chronological resolution to achieve sub-decadal-scale (possibly even 5-year resolution) records
- Integrating data and interpreting them in terms of:
  - Variability of precipitation, temperature and vegetation
  - Amplitudes and rates of change
  - Quasi-periodicities at various scales
  - Modes of forcing
  - Occurrence and impact of extreme events.

Estimated cost: *R375 000*
Expected term: *1999-2001*

Research projects

Completed

- **671** Fog collection as a supplementary water resource for small rural communities (University of the North – Department of Geography)
- **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)
- **805** Modelling extreme rainfall over Southern Africa (University of the Witwatersrand – Climatology Research Group)

Current

- **596** Development of a real-time non-conventional rainfall mapping system for coastal zone cloud systems (University of Pretoria – Department of Civil Engineering)
- **693** Weather radar measurement of rainfall as well as hydrological applications of weather radar (University of Pretoria – Department of Civil Engineering)
- **804** Acquisition of off-shore marine sediment samples for palaeoclimatic and hydrological record reconstruction (University of the Witwatersrand – Climatology Research Group)
- **806** Dynamic modelling to investigate the regional climate response to global change (University of Cape Town – Department of Environmental and Geographical Science)
- **868** Modelling variability in the Agulhas Current system and its influence on South Africa's climate (University of Cape Town – Department of Oceanography)
- **903** Development of optimum statistical long-range forecast models of summer climate and hydrological resources over Southern Africa (University of Zululand – Department of Geography)
- **904** Seasonal climate predictions with a coupled atmosphere/ocean general circulation model: A contribution to water resource management over Southern Africa (University of Pretoria – Department of Civil Engineering)
- **938** Aerosols, recirculation and rainfall experiment (Arrex) (University of the Witwatersrand – Climatology Research Group)
- **953** The ocean's role in South Africa's rainfall (University of Cape Town – Department of Oceanography)
- **954** Integrated radar-based precipitation observing system for the Vaal Dam catchment to facilitate water resource operations and research (Department of Environmental Affairs and Tourism – Weather Bureau)

New

- **1005** A real-time flood forecasting model using radar and satellite data (University of Natal – Department of Civil Engineering)
- **1010** Space-time modelling of rainfall using the string-of-beads model: Integration of radar and rain-gauge data (University of Natal - Department of Civil Engineering)
- **1011** Short-term weather forecasting techniques dedicated to flood management systems (University of Pretoria – Chair of Meteorology)
- **1012** Climatology of water vapour sources, sinks and transport in Southern Africa (University of Cape Town – Department of Environmental and Geographical Sciences)
- **1013** Reconstruction of long-term, high-resolution records of summer rainfall and its variability on South Africa from cave speleothems (University of Cape Town – Department of Archaeology)

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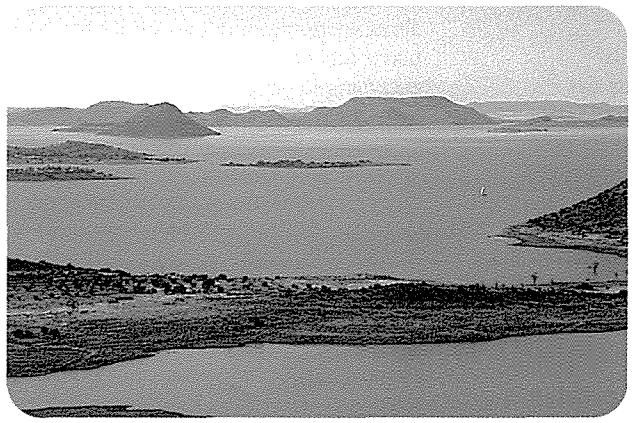
11 Integrated water resource management



Integrated water resource management (IWRM) is a process with biophysical and socio-economic dimensions. Maintaining the integrity of the eco-hydrological whole or unitary continuum of the hydrological cycle is essential to the sustainable use of the natural water resource system. Simultaneously, IWRM is about the fact that water is a natural resource that belongs to all people and management of the resource needs to ensure equity in access and equitable allocation of water for beneficial use in the public interest.

The WRC has embarked on the development of a strategic research plan for the field.

One of the keys to successful IWRM is the level of awareness and support achieved among all stakeholders in a water management area. At present the majority of people are not actively involved in this process, possibly as a consequence of low levels of awareness. In a democratic society the State has a clear responsibility to provide its citizens with relevant information in order to empower them, either as individuals or groups, to actively and meaningfully take part in the IWRM process. This was again highlighted in a seminar on public participation organised by the WRC and DWAF. At the same time the State cannot collect all the necessary data, and certain responsibilities in this regard will also have to be given to grassroot levels of the society. Research has clearly shown that communities, especially schools, can enthusiastically contribute to this activity.

Very briefly the IWRM process is characterised by the following sequence of events:

- Sharing a vision for the catchment
- Sharing information
- Sharing the water resources.

Research can support this process. A major challenge for research in this field is to demonstrate the advantages of certain institutional arrangements and identify failures in this regard.

In developing a framework for community participation in the Mlazi catchment, research has clearly identified that the building of subcatchment "platforms" is a useful stepping stone in the process of moving people from the physical world of "my place" to the social world of "our catchment". Platform-building is a process of exploring, interacting, planning and collective action. Research in IWRM can probably be most effective if it can assist in speeding up this process. For researchers, this often means the facilitation of a process of discovery learning, not only in their capacity as technical experts but also as true participants in the IWRM process. Unfortunately, "champions", i.e. researchers or facilitators with the appropriate interests, dedication and drive, who are urgently needed for the platform-building process, are still relatively rare.

Stakeholder's meeting to set up a water association.

Completed projects

Holistic, catchment-scale comparison of water-use efficiency of crops, focusing on the comparison between forest plantations and key irrigated agricultural crops

(No 666) Division of Water, Environment and Forestry Technology, CSIR

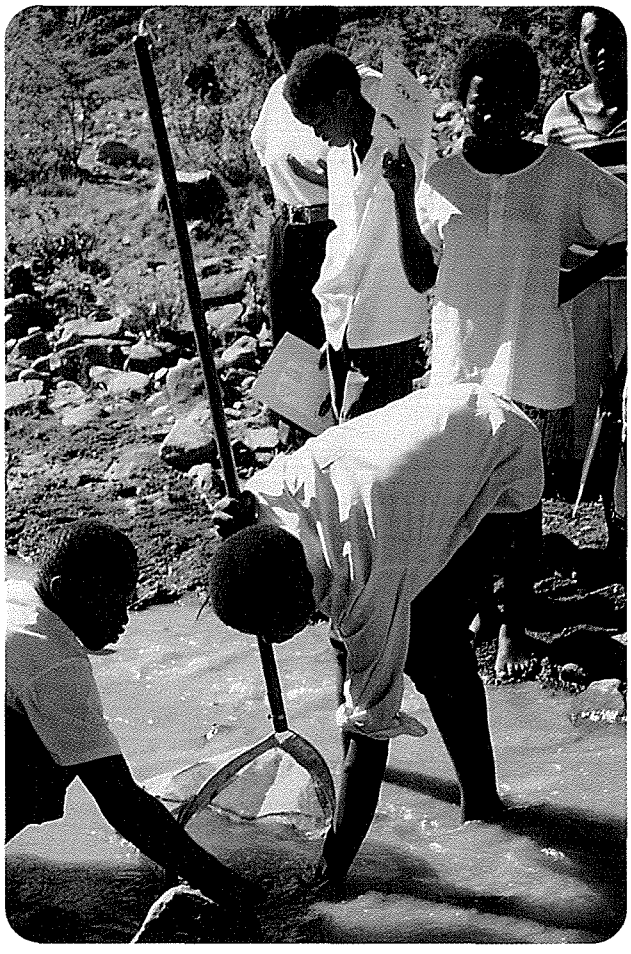
The allocation of water resources in the Crocodile River catchment has become a critical issue. A variety of sectors, such as industry, agriculture, forestry and domestic users, are demanding their fair share of the catchment's limited water. This particular investigation focused specifically on the irrigated agricultural and forestry sectors in the Crocodile River catchment of Mpumalanga Province. These two sectors have traditionally viewed each other as competing over the water resource. The objective of this project was to compare the direct economic returns, at the farm gate, which are realised from the use of water in these two sectors. This information will contribute to a basis for rational and equitable allocation of water in those parts of the country where there is a conflict between forestry and downstream agriculture.

The analyses show that in terms of the direct economic returns, irrigated subtropical fruit crops are more efficient users of the water resource in the Crocodile catchment than either sugar-cane or forest plantations. Also forestry in low productivity classes and low-rainfall zones generates lower direct economic gains, particularly when under pines, and hence has a weaker competitive advantage. Nevertheless, eucalypts for pulp and sawlogs performed better than sugar-cane in terms of economic efficiency.

It should be stressed here that the results are based only on the **direct** economic benefits derived from the various crops, and do not account for any of the forward or backward economic linkages in each of the crops. Also, while this investigation should be seen to reflect the current state of knowledge, it is not complete for the drafting of final water resource management policy. Rather, it should give direction to further studies in this area, but does provide first estimates of the economic efficiency of water use of plantations, irrigated sugar-cane and subtropical fruits.

The report also raises the possibility that while forest plantations and irrigation agriculture do not compete for land, trading of water rights or licences between the two sectors could take place through water markets. Therefore, the trade-off between development strategies based on increased afforestation upstream, and expanded food or fibre production under irrigation downstream, can be guided by water allocations either through quantitative measures (e.g. quota systems) or regulated markets.

Cost: *R204 700*
Term: *1995-1998*



Children undertaking biomonitoring using SASS4.

Continued research on flood-damage functions, models and computer programs for irrigation and urban areas in South Africa

(No 690) Department of Agricultural Economics, University of the Orange Free State

A new policy on disaster management is presently being developed for South Africa. Management of floods is an integral part of this policy and revision of the national flood management policy is also in process. The overall aim of the project was the development and adaptation of flood-damage functions, models and computer programs for irrigation and urban areas in South Africa. The floodplain between the Mfolozi and Msunduzi Rivers in KwaZulu-Natal was selected for development, adaptation and refinement of the irrigation-information base. For the urban research, the floodplains of Uitenhage and Despatch along the Swartkops River were chosen for research on the formal sector and the Soweto-on-Sea area in the floodplain of the Chatty River for the informal sector.

The flood management aids (computer programs and loss functions) that were developed during this research are indispensable for flood management. A stage is now reached that the flood management aids can be generally applied to different floodplains. Prior to floods actually occurring, it is possible to determine the extent of damage for various sized floods and to evaluate the benefits of different flood-damage control measures. All authorities and organisations that have a responsibility in effective flood and floodplain management, will benefit from the use of these aids.

It should be emphasised that the developed flood management aids can only be optimally used when applied within a holistic and sustainable integrated catchment management framework. For this to happen, an organisational network is

suggested for South Africa. Organisations that have specialist interests and that can contribute must be brought together as a multidisciplinary team to provide the required expertise and specialised services to national, provincial and local governments.

Cost: *R390 126*
Term: *1995-1997*

Econometric and institutional economic analysis of water use in the Crocodile River catchment, Mpumalanga Province, South Africa

(No 855) Cambridge Centre for the Study of Institutions

From a policy perspective, there is a strong need to increase the efficiency of water use and to implement policies that can effect this. Increasing water tariffs is one way to achieve this; however, the level to which tariffs should be increased is not clear as it is difficult to estimate the opportunity cost of water use. An efficient way of exposing water users to the opportunity cost of water is through the market and by encouraging the trading of water rights.

To improve economic efficiency in the allocation of water it is essential to know the economic value that users place upon water. The usual method for achieving this is to base valuation on the unit market price, which is often absent from most water allocation frameworks. However, substantial trading of water-use rights has occurred on the Crocodile River catchment, revealing the preferences of many farmers as to the value they attribute to water.

These trades were analysed in detail and it was found that significant, although not precisely quantifiable, efficiency gains have been made from water-use rights trading between farmers in the catchment. Efficiency gains could perhaps be enhanced by greater definition of the amounts of water used through metering, and in principle by extending trading to include other water users such as the municipality and the various mills in the area. Several technical and institutional barriers would have to be overcome for this to be achieved, especially analysis of potential external pollution costs would have to be undertaken. As water becomes relatively scarcer, and governmental priorities may also shift, water will have to go to its highest economic use if conflict is to be avoided. Farming will have to demonstrate that high-value crops deserve water, and changes in the crops grown will probably have to occur. Farming does, however, compare favourably with forestry in economic terms.

The net back analysis demonstrates that under certain circumstances, in aggregate, some crops become uneconomic as the full economic cost of water is used to calculate the true net present value of crops. However, any conclusions drawn from this analysis are tentative, because it is very sensitive to changes in fixed cost allocations to crops grown, and assumed demand elasticities.

There is a need for further research to determine more accurately the benefits of water trading and to determine the institutional requirements for trading to take place on a wider basis. Policy makers and water users need to understand the benefits of trading and the role of market mechanisms and research that achieves this should be encouraged.

Cost: *R112 000*
Term: *1997-1998*

Scientists working with local people.

New projects

Development and co-ordination of catchment forums through empowerment of rural communities

(No 1014) Department of Geography, Rhodes University

It is to be welcomed when historically disadvantaged grass-roots people become aware of water-related catchment and environmental issues and begin to show an interest, and even demand a say, in how these issues are being addressed.

Through a WRC-supported Ph.D. thesis, rural communities in the Kat River valley have attained such a higher level of awareness and interest. They are indeed beginning to demand that water problems be addressed in a manner which will better meet their basic needs, but appropriate institutions to assist them in achieving satisfaction in this regard are not yet in place.

This project aims to make a contribution to the development of important institutional structures within the integrated catchment management framework. Hopefully, lessons learnt through this pilot attempt to develop a water-user association in the Kat River valley will be of value in drawing other rural communities into the integrated water resource management process.

The specific aims of the proposed project are to:

- Facilitate the development and co-ordination of a catchment forum in the Kat River valley (Mpofu District, Eastern Cape) through awareness building, learning and empowerment so as to enable the Kat River people to take a positive role in their catchment management.
- Ensure that the empowerment process already initiated by Motteux (1996-'97) and now driven by the community of Fairbairn will be positively channelled into a "Catchment Forum". This will enable the process to be sustainable and ensure that their new "power" does not make the community of Fairbairn worse off.
- Identify differences of interest and priorities among the different users, especially those who are disadvantaged, and to give them collective awareness and confidence to confront others and argue their case.
- Share ideas and experiences concerning principles, approaches and methods in the establishment of a Catchment Forum to outsiders and help to facilitate other national water-user projects.

Estimated cost: *R392 000*
Expected term: *1999-2000*

Use of grass species for rehabilitation after wattle control

(No 1016) Agricultural Research Council

The *Working for Water (WFW) Programme* is a long-term nation-wide initiative: up to 20 years of clearing operations are planned. The most dominant alien invasive species in many of the WFW projects are the Australian acacias: *Acacia mearnsii, Acacia saligna,* and *Acacia cyclops.*

There are active programmes involving the development of more cost-effective methods for the control of acacia species. However, the adjacent vegetation normally takes a long time to colonise the cleared areas. Thus rehabilitation is required. Different bio-climatic zones have different rainfall and temperature patterns and this determines which grass species can be used for rehabilitation in these areas. Sowing rates require investigation, so that optimum densities of grass seed can be applied after clearing the wattle, in order to provide an adequate ground cover to prevent loss of topsoil.

This project proposes an investigation of the impact of different sowing rates on establishment of a ground cover, using grass species adapted to selected bio-climatic regions of KwaZulu-Natal and the Eastern Cape. The information resulting from this project will be presented in booklet format for distribution to land users.

Estimated cost: *R214 000*
Expected term: *1999-2001*

Water resource systems analysis: Training and transfer of technology

(No 1038) BKS (Pty) Ltd.

The project will involve the preparation of training material in the field of water resources system analysis. This training material will accompany the new South African Water Resource Analysis Model (SAWRAM) currently being developed for DWAF. In the light of required international river system management the training material and courses in the use of the SAWRAM model can make a significant contribution to build a culture of Southern African approaches to water system management in the SADC region.

Estimated cost: *R40 000*
Expected term: *1999*

Development of models for economic evaluation of integrated management of quantity and quality of irrigation water within river catchments

(No 1043) Department of Agricultural Economics, University of the Orange Free State

Decisions by individual farming businesses to divert or withdraw water for cultivation and irrigation of different crops, has wide-ranging impacts on the natural environment. Changes in the type of land-use and cropping practices influence runoff while the choice of water distribution and irrigation methods as well as the efficiency of operations determines return flow. With intensive production methods the level of nitrates, phosphates and chemical residues of pesticides and herbicides in surface and underground water is an increasing problem. Legislative prescriptions have therefore been specified in the National Water Act to protect aquatic ecosystems as part of the Reserve, regulate stream-flow reduction activities and prevent pollution. Information on and tools to manage the quantity and quality of water are now clearly required to ensure sustainable use of water for irrigation in relation to all other use sectors.

In an on-going WRC-funded research project (No 645), dynamic stochastic decision models are being developed to analyse the influence of variable availability of water, and the requirement to maintain minimum instream flows, on the economic viability of irrigation farming. The obvious next step is to extend the procedures and models to include the water quality dimension. User-friendly adaptation of models in order to provide practical decision-support, will

furthermore assist with the implementation of water policy. This is in agreement with the shift in emphasis from formulation to implementation of policy as indicated by DWAF.

The aims of the research are to:

- Develop decision-making tools and evaluate the economic impact of policy strategies on the control of non-point pollution
- Apply agro-hydrological and economic models and assess the influence of a change in the allocation and use of water on integrated management of the quantity and quality of water resources and long-term profitability of irrigation farming.

Estimated cost: *R683 000*
Expected term: *1999-2001*

Impact of farming systems on sediment yields in context of integrated catchment management

(No 1059) Institute for Soil, Climate and Water, Agricultural Research Council

Sediment delivery to our water systems has always been considered a real threat to our sustainable water supply. Not only does it affect storage capacity of impoundments but it also acts as a transport mechanism for non-point pollution. It is important to note that the *Working for Water Programme* is starting to support the emerging "Land Care Movement" of the Department of Agriculture. This process will also give greater emphasis to water issues being addressed as part and parcel of Land Care, such as sediment delivery and groundwater recharge.

The project will also make a concerted effort to address commercial farming, subsistence farming and small-scale farming impacts in a single unified approach.

Specific aims are:

- Integrate and calibrate international and SA methodologies for quantitatively predicting the impact of subsistence and commercial farming systems on sediment yield from catchments
- Assess the impact of the following land-use types on sediment yield:
  - Subsistence farming systems: communal grazing, communal cropping, traditional settlement
  - Commercial farming systems: grazing, cropping (e.g. conventional tillage vs. minimum tillage, rotations, etc.)
  - Conservation areas.
- Assess the impact of quality, availability and the spatial distribution of input data on the accuracy of sediment yield prediction results
- Develop a methodology for auditing the impact of land-use and management practices and monitoring the change thereof on sediment yield.

Estimated cost: *R843 000*
Expected term: *1999-2002*

Developing protocols for integrated catchment management (ICM) based on current initiatives and techniques

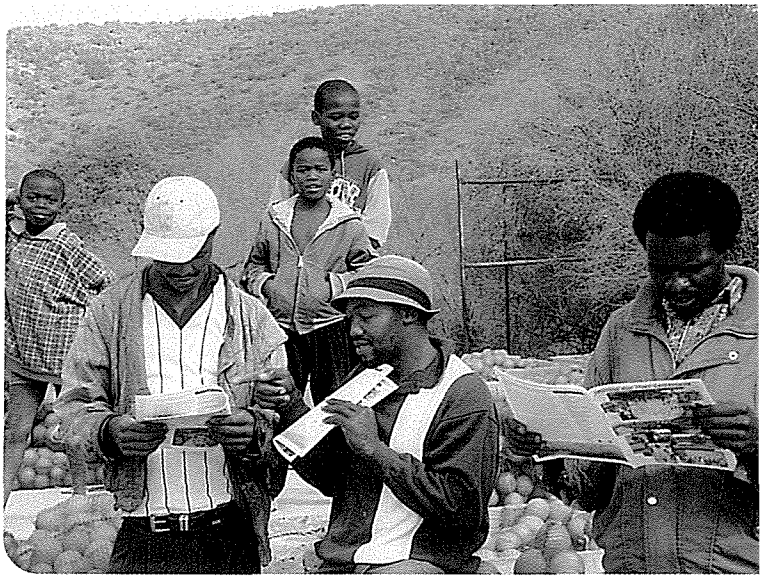
(No 1062) Division of Water, Environment and Forestry Technology, CSIR

The new Water Act has created the need for DWAF to develop strategic plans and procedures for the phased implementation of the new Act. The key concept upon which this process will rest is that of integrated water resource management on a catchment basis. A great number of techniques and methodologies have been developed to support integrated water management. These include Strategic Environmental Assessment, Cumulative Effects Assessment, the Afforestation Permit System, Geographical Information Systems applications, the National Biomonitoring Programme, etc. The protocols envisaged in this proposal will provide an overarching framework for such activities.

The project's overall aim, therefore, is to develop protocols for the management of river systems on a catchment basis, in line with the move towards integrated catchment management, using the establishment of catchment management agencies, and drawing on the range of related but presently unco-ordinated initiatives with similar objectives. The specific subgoals are to:

- Assess the present state of the environment in a catchment as a baseline for the study
- Describe the desired state of the environment, in terms that would be required to ensure the equitable and sustainable development of water resources
- Build capacity in all stakeholders and parties participating in the research project
- Develop a set of principles by which existing techniques can be integrated into the activities of catchment management agencies to ensure sustainable and equitable conservation of water resources
- Demonstrate through practical application how these principles can be implemented and to document the lessons learnt during the process, so that practical application can easily be extended to other catchment areas
- Provide a model for water resource management on a catchment basis for use and application by DWAF and other catchment management agencies.

Estimated cost: *R1 500 000*
Expected term: *1999-2001*



Fostering catchment awareness through newsletters and brochures.

Research projects

Completed

- **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)
- **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 DWAF)
- **855** Econometric and institutional economic analysis of water use in the Crocodile River catchment, Mpumalanga Province, South Africa (Cambridge Centre for the Study of Institutions)

Current

- **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)
- **749** Modelling benefits of integrated catchment management (University of Natal – Department of Agricultural Engineering)
- **807** Multi-level decision support for the control of alien invasive plants in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **863** *Development of group decision support methods to* facilitate participative water resource management (University of Cape Town – Department of Statistical Sciences)
- **864** Integrated catchment management in an urban context: The Great and Little Lotus Rivers, Cape Town (Abbott Grobicki (Pty) Ltd.)
- **865** Operational model of the Orange River (BKS (Pty) Ltd.)
- **866** Community-based integrated catchment management programme with special reference to sustainable resource use in the Mlazi catchment (University of Natal – Farmer Support Group)
- **888** Socio-economic impact of the Komati River basin development, with special reference to irrigation agriculture (Conningarth Consultants)
- **889** Aids for flood-damage assessment and flood-damage control planning in irrigation and urban areas (University of the Orange Free State – Department of Agricultural Economics)
- **890** Development of a hydrological economic model based on the Mvoti catchment (Umgeni Water)
- **905** Model for water demand management planning and monitoring (BKS (Pty) Ltd.)
- **906** *Development of a decision-support system for the* Mhlatuze catchment in Zululand (University of Zululand – Department of Hydrology)
- **907** Technique for modelling scenarios for alien plant control (CSIR – Division of Water, Environment and Forestry Technology)
- **913** Framework for state-of-the-catchment report for developing a catchment management plan using as basis Palmiet River, Western Cape (Groenland Irrigation Board (for the Palmiet River Catchment Management Steering Committee))
- **914** Feasibility of using a risk-based approach to setting integrated environmental objectives for protection of water resources (Rhodes University – Institute for Water Research)

New

- **1014** Development and co-ordination of catchment forums through empowerment of rural communities (Rhodes University – Department of Geography)
- **1016** Use of grass species for rehabilitation after wattle control (Agricultural Research Council)
- **1038** Water resource systems analysis: Training and transfer of technology (BKS (Pty) Ltd.)
- **1043** Development of models for economic evaluation of integrated management of quantity and quality of irrigation water within river catchments (University of the Orange Free State – Department of Agricultural Economics)
- **1059** Impact of farming systems on sediment yields in context of integrated catchment management (Agricultural Research Council – Institute for Soil, Climate and Water)
- **1062** Developing protocols for integrated catchment *management (ICM) based on current initiatives and techniques* (CSIR – Division of Water, Environment and Forestry Technology)

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12 Catchment hydrology

Measuring the impacts of afforestation in Ntabamhlope.

The primary goal of research on catchment hydrology is to provide a scientific explanation and adequate quantitative understanding of the soil water balance dynamics for any spatial and temporal scale and their relationships with the physical and chemical transport of matter in the soil zone and with ecology.

There is a growing understanding that the impacts of human interventions in the hydrological cycle are rather site-specific. Apart from broad statements of principles, generalisations seldom hold up in real-life situations. Therefore, we need to gain a quantitative understanding of those elements that modify generic catchment processes and result in such site-specific impacts. Human management skills are also becoming important modifiers of catchment hydrology where issues such as runoff-farming, the use of mulches, deep soil preparation, inter-cropping, the use of swales and contour banks, and fertilisers all affect the precise functioning of processes in the hydrological cycle. Apart from spatial and temporal distribution of rainfall and solar energy, the most significant influence is imposed by the depth of the weathering zone, the nature of the soil profile, the slope and aspect of the landscape and the conditions of the surface itself throughout the year. The nature of the interaction between groundwater in the saturated zone and streamflow is part of this site-specific process that needs further elucidation through future field studies. As a result of increasing vandalism and theft of scientific instruments, field studies are unfortunately becoming very difficult to execute.

One of the major methodologies in catchment hydrology research is the use of simulation models. Some of these models not only serve to encapsulate scientific understanding and stimulate further questions, but also function as decision tools. Therefore, a start has been made to develop some procedure to arrive at a set of accredited models which may be used for decision-support purposes. One of the criteria for a good decision-support model would be scientific credibility, reflecting sound understanding of the catchment hydrological processes. Another criterion could be the relevancy of the model outputs in terms of the water management process.

Completed projects

Hydrological systems modelling research programme: ACRU model development and user support

(No 636) School of Bioresources Engineering and Environmental Hydrology, University of Natal

The overall aim of this project was to further improve the understanding of hydrological processes and the modelling thereof in the ACRU modelling system.

In the past five years, innovations in graphically-based user-friendly programs have created many new options for integrating user knowledge and existing data into model-ready inputs. The package *ACRU 2000 Utilities* was developed with the specific purpose of integrating geographic information systems (GIS) databases and user-derived information into a flexible menu system for ACRU input.

The innovative appointment of an ACRU user consultant has supported a variety of researchers, industry consultants and stakeholder groups in the use of ACRU model. The increasing use of the model by consulting groups has provided the research team with invaluable feedback on practical issues surrounding the model usage.

The development of a modular framework for the model *ACRU 2000*, will assist in the ability of the model to incorporate the latest understanding of hydrological processes.

Cost: *R1 739 400*
Term: *1994-1999*

Studies on river losses: Phase 2

(No 638) BKS (Pty) Ltd.

Evaporation losses into the atmosphere from our open water bodies have always been regarded as an important factor in water management. However, now that water shortages are emerging almost everywhere in the country a renewed effort is being made to see if evaporation losses can be better quantified and managed. With this in mind, the Orange River was the subject of a case study.

Until recently, the water resources of the Orange River were well in excess of the various existing water requirements. Release from reservoirs could be made in excess of downstream requirements for generating hydroelectric power, and flows reaching the river mouth were often well in excess of the estuary needs. In times of water shortage, however, managing releases from Vanderkloof Dam is particularly difficult since the dam is located almost 1 400 km from the river mouth. It is now becoming increasingly important to accurately quantify the evaporation losses between Vanderkloof Dam and the river mouth.

Using A-pan equivalent evaporation rates and sophisticated hydraulic models, backed up with three sets of manual flow gaugings, it was estimated that as a result of reduced surface areas during lower flows (50 m^3/s) a reduction of 380 million m^3/a in evaporation could be achieved with careful releases. The study also confirmed the important role of riparian vegetation and the benefit of using hydraulic models to investigate the effect of different operational rules for dam releases.

Cost: *R350 000*
Term: *1994-1998*

Short-duration design rainfall estimates for Southern Africa

(No 681) School of Bioresources Engineering and Environmental Hydrology, University of Natal

Many thousands of engineering and conservation design decisions, contributing multi-millions of rands to construction, are made annually in South Africa. These require accurate short-duration design rainfall intensity information. Databases used in arriving at current depth-duration-frequency estimates only extend to the 1970s and were derived from manually extracted rainfall increments at 15, 30, 45 and 60 min intervals. This project processed all available digitised rainfall data up to 1996.

An analysis of 412 stations showed that only 12 had record lengths of more than 40 years. This is particularly pertinent in estimating design events with return periods of 50 to 100 years. Data analysis also led to the disappointing conclusion that the digitised data were generally not adequate for directly estimating design storms for durations less than 24 h. Instead the research developed indirect methods that use regional similarities and scaling properties of extreme events as well as stochastic simulation of rainfall series. For this, 15 relatively homogenous regions in South Africa were defined.

Cost: *R390 000*
Term: *1995-1998*

Evaporation from the Orange River: Quantifying open water resources

(No 683) Division of Water, Environment and Forestry Technology, CSIR

Estimates of evaporation losses from open water have usually been based on measurements with evaporation pans (A-pan and Symons pan). The data from these instruments are unfortunately very strongly influenced by the local conditions surrounding the pan, with resulting extreme scatter and variability in observed data. This project investigated the use of Bowen ratio equipment in measuring evaporation from flowing water in the Orange River.

Comparison between evaporation data derived from Bowen ratio measurements over stretches of the Orange River and from A-pan data indicated that pan data were approximately 8% lower than Bowen ratio-derived data.

The study concluded that energy balance models of evaporation (Priestley-Taylor and Penman equations) using standard weather data acquired over land along the extent of the river can be used to estimate evaporation losses from open water, even under conditions of extreme advection. The research also indicated that the use of thermal infra-red remote sensing to monitor surface water temperatures could provide a technique for direct measurement of evaporation from large open water bodies.

Cost: *R241 000*
Term: *1995-1998*

Experimentation and laboratory measurement for hydrological process research

(No 744) School of Bioresources Engineering and Environmental Hydrology, University of Natal

A long-term strategic project was initiated to observe and measure specific hydrological processes in order to contribute to our quantitative understanding of and ability to model such processes.

Specific processes included:

- Infiltration, redistribution and percolation of water in soil and the interaction with groundwater
- 2-Dimensional migration and accumulation of water on hill slopes
- Soil water budgeting in wetlands and vegetated riparian zones
- Contaminant fluxes from localised leaks or spills to groundwater or stream
- Rural community gardening.

During this research, specialised instrumentation was developed and tested. An initial evaluation of the results of measurements with such instrumentation was made to guide future hydrological process research. A unique laboratory has been established.

Cost: *R550 600*
Term: *1996-1999*

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

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

The research catchments at Cathedral Peak have 40 years of uninterrupted data on rainfall and streamflow. The Cathedral Peak data set represents a unique long-term time series from an unchanged catchment. Increasing evidence of climate change associated with global warming, increasing atmospheric pollution and repeated droughts are strong arguments to maintain the Cathedral Peak monitoring network. For various reasons the CSIR, the most recent custodian of the monitoring network, could no longer continue monitoring activities. The main objective of this project was to develop a proposal for alternative long-term maintenance of the hydrological monitoring sites.

The outcome of this project is that DWAF has negotiated

a contract with the KwaZulu-Natal Conservation Trust to continue monitoring, thereby ensuring an uninterrupted data set.

Cost: *R98 600*
Term: *1996-1998*

New projects

Modelling the impacts of land cover and land management practices on streamflow reduction

(No 1015) School of Bioresources Engineering and Environmental Hydrology (BEEH), University of Natal

The requirements of the new Water Act are that communities are empowered to "control" their water resources via catchment management authorities (CMA). Within each catchment different stakeholders will be competing for water and the CMAs will need to make decisions regarding the management of water resources in a catchment. These will be based upon the effects of different competing land covers (e.g. riparian zones, sugar-cane, forestry) and land management practices (e.g. site preparation, degree of tillage, conservation structures) on the hydrological response of the catchment in order to ensure an equitable distribution of water. Hence it is necessary to have a credible model, which has been widely verified in South Africa, to enable an objective assessment of the hydrological impacts of the competing land uses and management practices.

The CSIR is proposing a co-ordinated land-use hydrology research programme in the Natal midlands, which will integrate the efforts in this field by various organisations (e.g. CSIR, Institute for Commercial Forestry Research, School of BEEH). It is expected that the proposed CSIR programme will further the understanding of water use by various land covers and clarify the term "streamflow reduction activity" as used in the new Water Act. This project will contribute to the programme and provide a vital link between the process studies undertaken by the School of BEEH and other organisations, which are usually undertaken at a point, and the modelling of hydrological responses of a catchment. The project will thus verify and enhance the current, or possibly, establish new algorithms in ACRU for process modelling and thus attempt to scale understanding obtained from observations conducted at a point or transect, to a catchment scale for use in the modelling of integrated water resource management.

The ACRU model has the facility of enabling model variables to change within a simulation in order to model dynamic catchment changes. However, this facility is not easy to use and hence is not used as frequently as it should be. Hence the development of an easy-to-use method of modelling dynamic changes in a catchment using the ACRU modelling system will be one of the objectives of the project.

This research aims to provide an appropriate modelling framework and decision-support system, capable of modelling both historical and projected land-use changes, which will be recognised by different interest groups as the most appropriate tool for assessing the impacts of land cover and management practices on water resources in South Africa.

Estimated cost: *R571 800*
Expected term: *1999-2001*

Regionalisation of rainfall statistics for design flood estimation

(No 1060) School of Bioresources Engineering and Environmental Hydrology (BEEH), University of Natal

It is generally accepted that South African flood hydrology is in need of an update. Additional data have become available and new regionalisation techniques have been developed. The School of BEEH of the University of Natal, in co-operation with the Weather Bureau, has made significant progress in this regard. These new data and techniques need to be accommodated in an improved information base for flood hydrologists in South Africa.

When estimating design floods from a catchment it is necessary to convert point rainfall data to areal rainfall depths using areal reduction factors (ARFs). In the interests of reliability, these ARFs need to be re-investigated in the light of recent extreme events and the longer time series which have become available since they were last revised.

Regionalisation of short-duration rainfall, especially, also plays an important role in improving the accuracy with which the erosive power of rainfall and its expression in terms of erosion and sediment delivery can be determined. This aspect will be addressed as a secondary objective of the research. Having done this, regionalised rainfall can be beneficially linked to regionalised, observed floods in rivers in a next phase of research.

Specific aims are:

- Design storm estimation in South Africa
  - Linking techniques developed during Project No 681 (**Short-duration design rainfall estimates for South Africa**) to results from Project No 811 (**Long-duration design rainfall estimates for South Africa**), thus increasing spatial resolution of short-duration design rainfall estimates in South Africa
  - Development of new regionalised areal reduction factors for South Africa
  - Development of new regionalised design and actual hyetographs for South Africa
  - Development of a revised erosivity map for SA
  - Investigation into the effect of climate change on design storm estimates
  - Production of user manual/computer package for short- and long-duration design storm estimation in South Africa
- Design flood estimation in South Africa
  - Critical review of existing techniques
  - Further evaluation and development of techniques for design flood estimation using a continuous simulation modelling approach
  - Investigation into the effect of climate change on design flood estimates
  - Production of a comprehensive design flood hydrology manual for South Africa summarising existing and new techniques developed during the project.

Estimated cost: *R1 072 700*
Expected term: *1999-2001*

Field study of two- and three-dimensional processes in hillslope hydrology for better management of wetlands and riparian zones

(No 1061) School of Bioresources Engineering and Environmental Hydrology (BEEH), University of Natal

The major impediment to progress in land-use hydrology and scientific land management which, for example, impairs our ability to accurately predict the effects of land-use practices on streamflow reduction, has proved to be the lack of detailed hydrological process data in representative conditions of the South African landscape.

Representative hydrological situations, more often than not, are characterised by heterogeneous and layered soils of varying depth, variable slopes and frequently also preferential pathways for water movement. Such situations are not satisfactorily simulated with one-dimensional models, which up to now has been common practice. Beneficial use could be made of two- and three-dimensional approaches, provided that carefully planned field observational programmes are carried out in order to acquire the data and understanding needed to select the most appropriate modelling routines and configure them for typical South African situations. The ability to undertake such observational programmes is, however, also dependent on the expertise available.

The importance of this work is underwritten by the fact that Mondi Forests has decided to defer the planting of trees in one of the research catchments in the NE Cape until such time that the research team has gathered enough quantitative information of the hydrological process. After trees have been planted a detailed monitoring of the effect will then take place and hopefully lead to some highly significant guidelines for water management in similar landscapes.

Specific aims:

- Hillslope hydrology: To measure, define and model the dynamics of the hydrological cycle.
- Up-scaling hydrological processes: To define dominant hydrological processes at different scales (field, hillslope, catchment and basin) by observing the hydrological response at these scales.
- Wetland riparian processes: While significant studies have researched the dynamics of wetland and riparian zones *per se*, the objective of this part of the project is to define the interaction between hillslope hydrological processes and the wetland and riparian zones.

Estimated cost: *R1 809 000*
Expected term: *1999-2002*

Experimental and laboratory measurements of soil hydraulic properties for improved modelling of catchment processes

(No 1086) School of Bioresources Engineering and Environmental Hydrology (BEEH), University of Natal

Catchment management agencies and other stakeholders require accurate assessments of the perturbations in catchment water resources caused by changes in land use, including waste management aspects. The movement of water and solutes throughout the landscape is complex and to a large degree determined by two- and three-dimensional variability in soil hydraulic properties. The team proposing this research has over recent years made a large contribution to the development of soil physics laboratory methodologies and measurement expertise for use in the context of hydrology, groundwater pollution, leaching from waste sites and maintenance of wetlands. Techniques developed in the laboratory will be applied in research catchments whereafter the results will be used directly in modelling studies relevant to the specific field conditions in order to explore water resource management options. After further necessary improvement, laboratory and measurement techniques will also be used in a range of other WRC funded projects where such measurements are needed. The research proposed here will contribute to a sounder foundation for quantitative understanding and managing water in South African catchments.

The specific aims of this research are:

- Further develop a state-of-the-art soil water and solute dynamics laboratory. This laboratory is necessary to establish an acceptable standard of soil physical measurement.
- Develop and use specialised equipment for monitoring water and solute movement in the landscape and to make high quality *in situ* measurements of required soil physical variables.

Estimated cost: *R646 300*
Expected term: *1999-200*

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Research projects

Completed

- **636** Hydrological systems modelling research programme: ACRU model development and user support (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **638** Studies on river losses: Phase 2 (BKS (Pty) Ltd.)
- **681** Short-duration design rainfall estimates for Southern Africa (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **683** Evaporation from the Orange River: Quantifying open water resources (CSIR – Division of Water, Environment and Forestry Technology)
- **744** Experimentation and laboratory measurement for hydrological process research (University of Natal – School of Bioresources Engineering and Environmental Hydrology)

- **781** Long-term monitoring of streamflow and weather in the Cathedral Peak catchments (CSIR – Division of Water, Environment and Forestry Technology)

Current

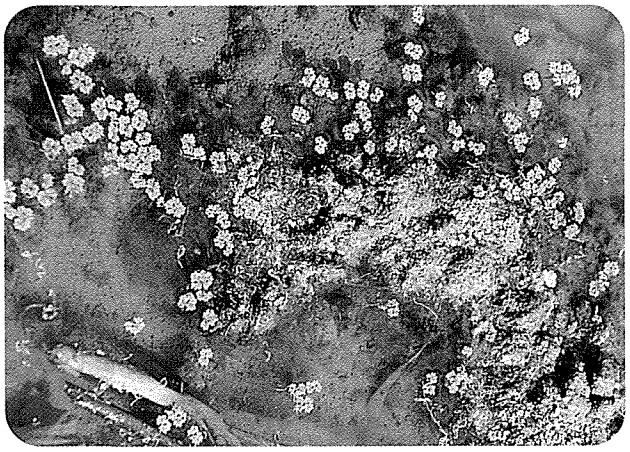
- **348** Root development and water usage of commercial timber species (University of Natal – Department of Agronomy)
- **637** Hydrological systems modelling research programme: Hydrological process research (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **746** 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)
- **808** Comparison of the water use of selected invasive and indigenous riparian plant communities (CSIR – Division of Water, Environment and Forestry Technology)
- **809** Feasibility of using trunk growth increments to estimate water use of *Eucalyptus grandis* plantations (CSIR – Division of Water, Environment and Forestry Technology)
- **810** Afforestation effects: A re-analysis of the South African catchment afforestation experimental data (CSIR – Division of Water, Environment and Forestry Technology)
- **811** Long-duration design rainfall estimates for Southern Africa (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **867** Integration and application of daily flow analysis and simulation approaches within Southern Africa (Rhodes University – Institute for Water Research)
- **908** Flood-forecasting system for Vaal Dam (DWAF)
- **909** Monthly multi-site streamflow model (BKS (Pty) Ltd.)

New

- **1015** Modelling the impacts of land cover and land management practices on stream-flow reduction (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1060** Regionalisation of rainfall statistics for design flood estimation (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1061** Field study of two- and three-dimensional processes in hillslope hydrology for better management of wetlands and riparian zones (University of Natal – School of Bioresources Engineering and Environmental Hydrology)
- **1086** Experimental and laboratory measurements of soil hydraulic properties for improved modelling of catchment processes (University of Natal – School of Bioresources Engineering and Environmental Hydrology)

Construction of the Bosboukloof weir by hand labour in 1937 in Jonkershoek near Stellenbosch. This catchment was planted to pines in 1940 (The data collected here are presently re-analysed in Project No 810).

13 Conservation of water ecosystems



The emphasis of the National Water Act (Act 36 of 1998) on the inclusion of aquatic ecological processes in the definition of the resource has continued to generate research needs in this field. In response to research needs around the determination of the surface water ecological reserve, a research programme was established based on the research needs identified during a workshop focused on the surface water ecological reserve and in consultation with the directorates of DWAF tasked with the reserve implementation.

A number of workshops were held during the year. In addition to the one identifying the research needs around the surface water ecological reserve described above, workshops were also held to define the methodologies to be used to determine the ecological reserve for the freshwater requirement for estuaries and wetlands. One further workshop was held to work on the future direction for South African estuarine research and the role of the Consortium for Estuarine Research and Management (CERM). Methods for determination of the estuarine freshwater requirement (EFR) have been developed over the last few years. The specific issues addressed during this workshop were how to integrate the EFR methodology with that used for the reserve determination in rivers, and the depth of detail required when determining the reserve at the various levels of certainty required by draft DWAF policy. The wetland reserve workshop focused on the reserve determination methodology to be used to fulfil the requirements of the various levels of certainty required by draft DWAF policy. It was noted that groundwater connectivity was likely to play a greater role in the sustainability of wetlands than other inland waters. In the CERM planning workshop, in addition to debating future research direction for estuarine research, there was discussion on impact of the promulgation of the Living Marine Resources Act (Act 18 of 98) on CERM. This includes estuaries in the marine resource, and so has changed the institutional arrangements for estuarine research in South Africa.

Following the working conference on the National Rivers Initiative (NRI) held in Pietermaritzburg during 1998, the WRC undertook to carry out a survey of national research needs on rivers. The first step was to invite identification of needs in a structured way from the end users of research. This document was then circulated to all who attended the NRI conference for comment. The findings are currently in the process of being incorporated in a strategic research plan. The institutional structure of the NRI is currently being developed to accommodate what will be a far-reaching initiative in inland water research in South Africa.

Completed projects

Overview of the pesticide and heavy metal levels present in populations of the larger indigenous fish species of selected South African rivers

(No 428) Division of Water, Environment and Forestry Technology, CSIR

Five of the selected rivers are east-flowing rivers in Mpumalanga (Crocodile, Sabie, Olifants, Letaba and Luvuvhu) which, together with the Berg River in the south-western Cape, were selected for the study. The findings show that the highest nutrient loads were carried by the Olifants and Luvuvhu Rivers, and that the Olifants River carried a high sulphate load from the mining activities in the catchment.

Not all fish species accumulated the same heavy metal contaminants at the same rate, but analyses showed that for all the fish analysed there were three tissue types that showed consistently higher accumulation than other tissues, and so should form the basis of any future monitoring programme. These are livers (metals accumulated: Fe, Cu, As, Cd, Co, Mg, Ni, Hg), gills (metals accumulated: Zn, Al, Mn) and testes (metals accumulated: Al, Cr). Similarly, pesticides accumulated at higher levels in certain tissues, specifically the fatty tissues (mesenteric fat and gonads) and livers.

The levels of pesticide contained in the fish, when expressed in terms of the danger to people eating them, showed that the maximum whole fish load of organochlorines reached high-risk levels in worst-case scenarios (fish eaten daily all year round). A cost-effective monitoring programme is proposed for the surveillance of rivers exposed to heavy metal or pesticide pollution.

Cost: *R324 900*
Term: *1992-1995*

Geomorphological classification system for South African river systems

(No 497) Department of Geography, Rhodes University

In order to address the aims of this project, an existing hierarchical model of river classification was taken as the basis from which to develop a model extending from catchment scale to morphological unit scale. However, to link geomorphology to ecology it was necessary to take the classification one step further to correspond with the ecological habitat. The term "hydraulic biotope" was coined for this step, as the term "habitat" does not distinguish between stable (e.g. bedrock) and temporally unstable (e.g. sandbanks) features, while the geomorphological-based definition of the hydraulic biotope does make this distinction. The habitat presented by a certain stretch of river will change with flow, e.g. a small pool at low flow will become a run at higher flows and the fauna will move. The geomorphological classification proposed here takes this into account.

The relationship between hydraulics and the instream environment was characterised, giving a measure of the conditions experienced by biota occupying a particular habitat.

Cost: *R666 100*
Term: *1992-1996*

Integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development

(No 627) Sigma Beta (CE))

During the course of this project, the research team addressed the establishment of a quantitative catchment modelling system as part of the aims of the decision support systems (DSS) Development and Management Subprogramme of the Kruger National Park Rivers Research Programme (KNPRRP). The intention was that this modelling system would serve to integrate the disparate predictive capabilities in hydrology, hydraulics, water quality, sediment production and transport, channel morphology and ecological functioning. This modelling system was tested on the Sabie River, demonstrating the utility of the modelling system and linking "what if" catchment development scenarios to protocols for evaluating the acceptability of predicted changes.

A number of local and internationally available DSSs were reviewed, followed by a decision to develop a local system known as WDM Guide. The system eventually became known as the Sabie integrated catchment information system (ICIS). It is not a static system, but one which is under constant development, thus continuously addressing the needs of the user community involved in its use.

The modelling system developed in this project incorporates both "traditional" modelling techniques and knowledge-based systems. These have been integrated into a single modelling system forming part of the KNPRRP ICIS. Difficulties have been encountered with the use of the large multi-component models. These difficulties may arise as a result of using large complex modelling systems as interdisciplinary tools, as well as when trying to obtain adequate data to implement and calibrate these systems.

It turned out that the Sabie River catchment may not have been the most suitable choice for the implementation of the ACRU-HSPF link. The project highlighted the typical problems and the solutions associated with linking models of different paradigms.

The successful resolution of scale issues in the development of an integrated modelling system, is highlighted in the report. Methods of resolving such scale issues are described in the report, and the use of hierarchies, together with consistent use of terminology, is recommended. Furthermore it is also recommended that future integrated catchment modelling exercises adopt the idea of a core catchment hydrology model with basic water quality functions, which may be coupled with a suite of pragmatic models, governed by some form of filter represented by management needs. "Traditional" modelling paradigms are not always appropriate to this approach. Consequently the use of qualitative rule-based models is recommended, where appropriate.

Cost: *R266 000*
Term: *1994-1997*

The Bowen ratio equipment and weather station used to monitor evaporation at the reed site in the Kruger National Park.

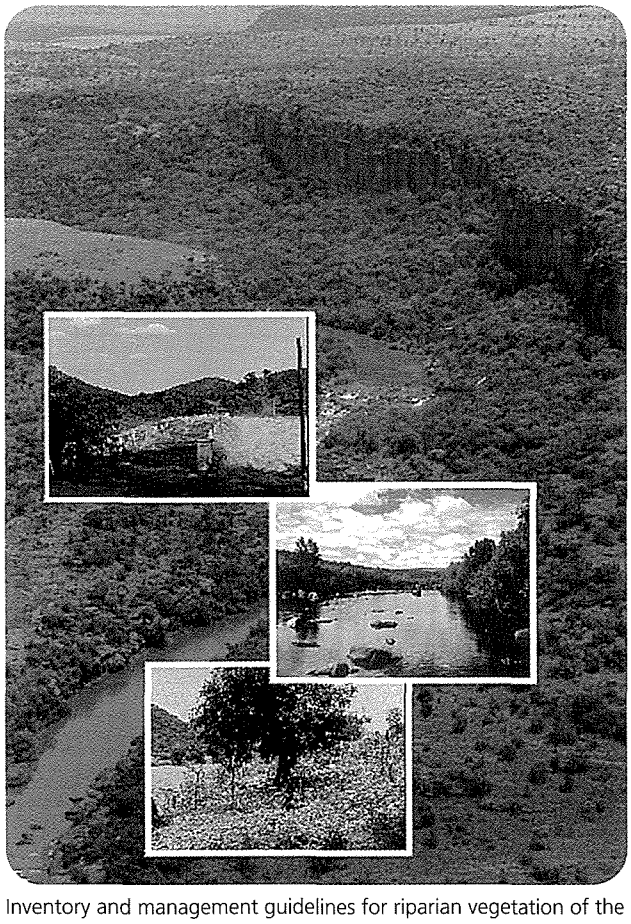
The eddy correlation data collection unit used for on-line data processing of the eddy fluxes of heat and vapour above the forest canopy.

System-related scale study to determine the functioning of the riparian vegetation of the Olifants River, Transvaal

(No 663) Range and Forage Institute, Agricultural Research Council

South Africa has only a few rivers which are currently not over-utilised, degraded or polluted. Many previously perennial rivers are utilised to such an extent that they only flow seasonally. The Olifants River is the second largest river in the former Transvaal (now the Northern Province and Mpumalanga) and drains 4.1% of the Republic. This formerly perennial river system is currently so heavily utilised that long stretches, especially downstream of the Mokgomo Matlala Dam (Arabie Dam), are characterised by pools linked by narrow streams at the end of the dry season. The mining-, industrial- and agricultural sectors are users whose activities directly impact on the Olifants River system. In the past, research done by agricultural organisations focused mainly on specific agricultural activities and related matters, normally within catchments, and river systems were generally only considered to be sources of freshwater. The initiation of this project was inter alia an attempt to obtain a holistic perspective of the current state of the riparian zone and to identify the impacts that could lead to the further degradation of the riparian zone and the river system itself.

The riparian zone of the Olifants River can broadly be divided into two types according to the structure of the vegetation associated with the river banks namely the banks, where woody cover is absent or restricted to a few dwarf shrubs (Grassland Biome) and the banks characterised by a dense woody component (Savanna Biome). In total eight plant communities were identified and 173 plant species were recorded (of which almost 15% are exotic) in the riparian zone of the Olifants River associated with the Grassland Biome. Nine plant communities were identified in the riparian zone of the Olifants River associated with the Savanna Biome and 450 plant species, which included 51 exotic species, were recorded. Four of these plant communities include variations which were not mappable at the scale at which the survey had been conducted. The negative impact of exotic plant species associated with the riparian zones poses a serious threat to the biodiversity of this area. The problems with regard to exotic vegetation and the control thereof can only be addressed if the various authorities and private riparian owners upstream become actively involved in eradication programs.



Inventory and management guidelines for riparian vegetation of the Olifants River.

During the survey the major impacts encountered, deemed responsible for the degradation of the riparian zone, were recorded. The most significant impacts recorded within the riparian zone and the adjacent land are due to activities of the mining-, industrial- and agricultural sectors. Other activities recorded which negatively impact on the Olifants River system are the development of holiday resorts and houses, farmsteads, the homes of workers and other activities of the local population such as collection of firewood, sand and stone for building purposes and the illegal netting of fish. These impacts were evaluated against current relevant environmental legislation to determine whether any of these activities transgressed the law. Management recommendations have been made with regard to the impacts caused by the agricultural sector and these findings and recommendations provide a sound scientific basis for the management of the riparian zone of the Olifants River system.

Cost: *R97 035*
Term: *1995-1998*

Survey for potential biological control agents for the troublesome alga *Cladophora glomerata*

(No 669) Plant Protection Research Institute, Agricultural Research Council

The filamentous alga *Cladophora glomerata* is a serious pest in canal systems, occurring in canals serving irrigation schemes as well as other industries such as water boards and power stations. This project investigated the possibility of using pathogens as a method of biological control against the alga, an option which has received little attention elsewhere against this pest.

In the field a wide variety of potentially pathogenic organisms was observed on the alga. However, the organisms of potential interest for biological control were all fungi. Fungi belonging to the groups Chytridiomycetes and Oomycetes were observed, but since these cannot be cultured on artificial media, they were not investigated further. They may, however, be important pathogens, and so a useful component of an integrated control programme. Hyphae of the fungal genus *Pythium* were the most frequently isolated, and were isolated from living, degenerating and dead cells. These were assumed to be pathogenic. Eleven groups of isolates were identified by the zoosporangia produced. These and other isolates were tested in initial pathogenicity tests, and were found able to

penetrate partly damaged cells within 24 h of exposure.

This research is being continued in a current project, entitled **An investigation into the use of pathogenic organisms for the biological control of the troublesome alga *Cladophora glomerata*** (Project No 918 under Agricultural Water Management).

Cost: *R149 500*
Term: *1995-1998*

Rule-based modelling for management of riparian systems

(No 813) Department of Botany, University of the Witwatersrand

The aim of this project was to evaluate the riparian vegetation abiotic/biotic links model of the Sabie River that was developed within the KNPRRP and improve/refine it as necessary. This model was found lacking and re-conceptualised using specific parts of the riparian systems as indicators of specific management problems. Management goals were developed, and the desired state and thresholds of probable concern (TPC) were defined for each of the following problems.

Management goals	TPC
Terrestrialisation of the riparian zone	Ratio of terrestrial to riparian species along the macro-channel floor
Loss of bedrock influence in the macro-channel	Negative J-curve of population structure of *Breonadia salicina* in pool/rapid channel type
Invasion by alien vegetation	Presence in riparian zone

Conceptual models were developed for the three management goals, and the goal "loss of bedrock influence in the macro channel" was then developed in detail to the point where it can be considered a river-section-scale tool which can be applied to catchment-scale decisions or actions. The model will be useful to researchers, managers and policy-makers. This is being further developed in a follow-up project entitled **Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park rivers** (No 1063).

Cost: *R470 000*
Term: *1997-1998*

Prediction of flow modification effects in the rivers of the Kruger National Park

(No 882) Centre for Water in the Environment, University of the Witwatersrand

Project No 777, entitled **Abiotic-biotic links in the Sabie River: The responses of riverine biota to changing hydrology and geomorphology** (the so-called BLINKS project), successfully developed largely prototype models of ecological response to changing catchment abiotic factors for the Sabie River. Further refinement and testing of these models were considered necessary in order that the model results may be able to be used with confidence in water resources and catchment exercises.

However, during the third phase of the KNPRRP, the emphasis of modelling efforts was shifted towards those that could serve management needs. These needs were expressed in terms of desired future states (DFS) and as thresholds of probable concern (TPC). It was, therefore, necessary to assess the current BLINKS model's ability to serve management needs. This was done by assessing the suitability of the existing models to serve the current TPCs prescribed for fish and geomorphology, and also by assessing the ability of additional TPCs to provide useful management thresholds.

The project concluded that, although the current BLINKS models are in many respects valuable contributions to the state of the art, there are a number of major shortcomings in these models – both in terms of the assumptions made in their development, and in providing decision support for management. It was recognised, however, that many of these assumptions were innovative and warrant further study, but could unfortunately not be attended to during the course of this project.

The stated aims of the original BLINKS project were to draw together the available abiotic and biotic information by means of qualitative rule-based models (QRBM). The great deal of innovation required by this development resulted in much less attention to the unstated (at the time) management requirements. In addition, the now accepted management approach (using an objective hierarchy and TPCs) was not in place during the development of the current BLINKS models. These models were, therefore, found to be not particularly management friendly.

These findings resulted in a new research project which plans more detailed analysis of those issues identified as needing further research whilst refining and refocusing the BLINKS models to produce outputs which are more appropriate to the now accepted management approach (Project No 1065).

Cost: *R50 000*
Term: *1997-1998*

Maintenance and updating of the KNPRRP meta-data catalogue

(No 883) Institute for Natural Resources, University of Natal

The Kruger National Park Rivers Research Programme (KNPRRP) is being executed by means of subprogrammes for each of the main thrusts of the Programme, one of these being the Information Management and Facilitation Subprogramme. The purpose of this subprogramme is to ensure that the information and understanding acquired and technology developed within the Programme is shared effectively, within the Programme and with resource managers, researchers and stakeholders in the catchments.

After the Programme had been running for several years, it became evident that researchers and managers were having difficulty in obtaining an overview of available data, particularly in relevant fields other than their own. To address this it was decided to set up meta-data files (data files describing data sets) for this purpose and properly catalogue and index these in as user-friendly but functional a way as possible. Since only one layout is available for any hardcopy catalogue, it was decided to adopt a project classification scheme for this purpose. Inside each category of this main classification, a standardised subclassification by media type (document, digital, GIS, models, collections, maps and videos) has been adopted. Finally inside these classifications, records are presented alphabetically by the surname of the custodian. Hopefully this classification scheme will meet most needs.

The digital version allows virtually unlimited sorts in the searching menus. A relational database version, with a versatile custom-built search engine, is also provided, and all products are also placed on a website (http://www.ccwr.ac.za/knprrp/index.html) via the Computing Centre for Water Research (CCWR).

Cost: *R31 000*
Term: *1997-1998*

New projects

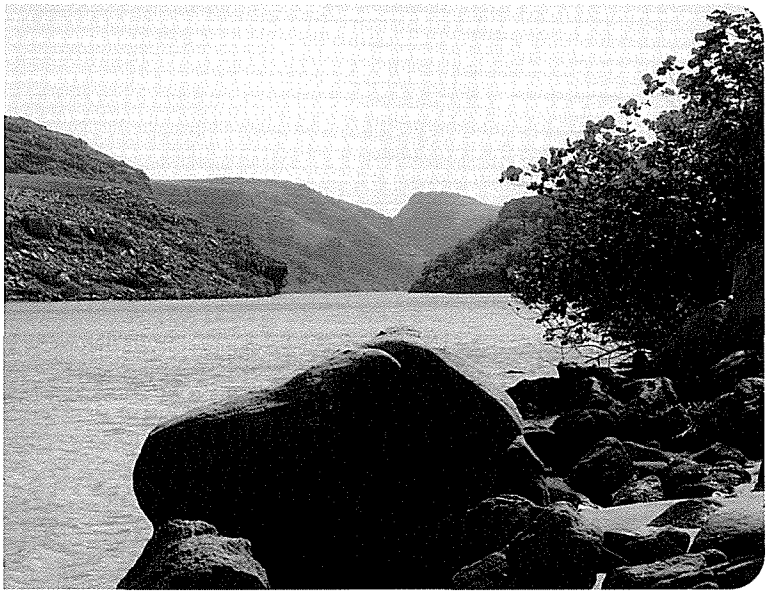
Development of a biomonitoring method, using protozoans, for assessment of water quality in seasonal/ephemeral rivers and groundwaters

(No 1017) Department of Zoology, University of Cape Town

Biomonitoring is widely accepted as a cost-effective tool for determining water quality. In well-watered countries the use of macroinvertebrates is sufficient. In more arid countries, however, other natural sources of water are used, and currently no biomonitoring method has been developed for resources such as ground- or ephemeral surface waters. The capacity of protozoans, specifically the ciliates, to fulfil this role is being researched in Europe where the group is proving useful as they are sensitive to water quality and respond to changes rapidly. Recent work examines the role of the ciliates found in groundwater as indicators of water quality. Their ability to colonise ephemeral waters from resistant stages as well as their occurrence in groundwater give us the potential opportunity to develop a broader-based biomonitoring tool than we have at the moment.

The project aims to identify indicator species, establish whether taxa used elsewhere can be used in South Africa as well, and to investigate the potential for monitoring groundwater.

Estimated cost: *R310 000*
Expected term: *1999-2000*



The Mtentu Estuary, on the Wild Coast, looking upstream from the mouth.

Development of management policies, procedures and structures for Eastern Cape estuaries

(No 1018) Institute for Natural Resources, University of Natal

Approximately 50% of the country's estuaries are in the Eastern Cape, but very little is known about these compared to those on other coastlines of South Africa. Estuaries form the focus of coastal development and ecotourism opportunities. They are also very sensitive to disturbance, and so can easily be degraded. If managed sustainably, however, they will remain productive and attractive.

This project will form the basis of a WRC research programme. The aim of the programme is to develop the capacity within the region to make informed decisions on the sustainable management of these estuaries. This will be done by raising the awareness of the importance of estuaries, by developing informed and organised stakeholder forums , providing these forums with relevant information and decision-support systems and empowering them to implement policy guidelines. Collaborative research to support this management will be structured and implemented.

Estimated cost: *R240 000*
Expected term: *1999-2000*

The Orange River blackfly, *Simulium chutteri*: Investigations into the physiology of the aquatic and non-aquatic stages so as to adjust the existing control programme to overcome summer outbreaks

(No 1019) Onderstepoort Veterinary Institute, Agricultural Research Council

This project, third in a series, aimed at developing cost-effective control of the blackfly. The problem is caused by the change in the ecological state of South African rivers induced by flow modification. The modified conditions favour the blackfly *Simulium chutteri* which has assumed pest status in the Orange-Vaal system, the Great Fish, Sundays, Gamtoos and Eerste Rivers where, depending on the wind, the problem can occur as far as 100 km from the river, in the middle and lower Orange River particularly. The bite of the female fly is painful which disrupts operations in the highly productive irrigated areas of the region, but the real loss is registered in the livestock industry, where the fly plagues cause the sheep to stop feeding and breeding, with a loss of condition and death.

This project aims to investigate the effect of temperature on the size and condition of the larvae, and link this to the physiological condition of newly emerged adults. The effect of key environmental variables on the adults will also be investigated and the blackfly control programme will be adjusted accordingly.

Estimated cost: *R512 000*
Expected term: *1999-2000*

Evaluating the environmental use of water-selected case studies in the Eastern and Southern Cape

(No 1045) Department of Economics, University of Port Elizabeth

The problems of natural resource and environmental degradation relate to a complex network of events such as over-

grazing, fuel-wood harvesting, land clearance, burning of crop residues, soil erosion, flooding and sedimentation. Pressure on natural resources increases because of low and skewed distribution of income levels, high time preference rates, short planning horizons and a lack of capital or finance. Attempts must be made to understand the relationships between biophysical events and economic consequences, to assess the impact of human activity and to express the benefits and costs in monetary terms where possible. In this regard one form of policy intervention is investment of public funds in projects to mitigate or reverse environmental degradation e.g. by means of reforestation, cleaning-up of pollution, removal of alien plants and construction of preventative soil erosion or ameliorative drainage works. All of these different projects must, strictly speaking, be preceded by benefit-cost analysis on a conceptual level and accompanied by regulation on a practical level.

In the *Working for Water Programme*, considerable capital and operating expenditure have already been incurred on the project to eradicate alien vegetation. The potential saving of water and appeal of reintroducing indigenous vegetation are generally accepted. However, a comprehensive identification, quantification and valuation of benefits and costs have so far not been undertaken. This information is essential to retrospectively justify expenditure of public funds and to ensure the economic and ecological sustainability of alien plant removal in different catchments. Selection of the Tsitsikamma region for this research has the added advantage of determining the net benefit of alien plant control and also evaluating a related concern regarding the environmental services of river estuaries. In part this project will therefore make a contribution to the Research Programme on the Management of Eastern Cape Estuaries. Research capacity in resource and environmental economics will also be enhanced by supporting co-operative research between the Departments of Biology and Economics at UPE.

The aims of the research are to:

- Determine the economic benefits and costs of alien plant control in selected catchments of the Eastern and Southern Cape
- Generate economic information on the cost of reduced freshwater supplies to an estuary.

Estimated cost: *R143 000*
Expected term: *1999-2001*

Cultivation of high-value aquatic plants in restored urban wetlands for income generation in local communities

(No 1054) Abbott Grobicki (Pty) Ltd.

The majority of rivers and stormwater canals in the Cape Metropolitan Area suffer from visible pollution, poor water quality and severe canalisation. This leads to a loss of recreational amenity value and a degraded urban environment in the vicinity of these streams. Furthermore, the natural drainage pattern over much of the Cape Flats prior to urbanisation was through seasonal wetlands, many of which have been in-filled. The ecological value of these wetlands has therefore been lost. Without wetlands, the value of the rivers as biological corridors has been compromised, even where concrete linings have not been introduced.

The objective of this pilot project is to establish an urban wetland which is planted solely with arum lilies and to assess the viability of cultivating and cutting the lilies as a sustainable income-generating project for the local community. Specifically, the aims are to:

- Investigate an innovative approach to the management of urban wetlands and urban drainage
- Optimise wetland design in order to meet the needs of urban horticultural/agricultural activities
- Evaluate the improvement in water quality, in terms of gross litter control, physico-chemical parameters and microbial content of the water, by restoring urban wetlands and using them for ornamental plant cultivation
- Assess the economic benefits of wetland horticulture schemes to local communities, and to evaluate the sustainability of such schemes
- Train local communities in the operation and maintenance of wetland horticulture schemes, and to assist in the establishment of sustainable non-profit organisations to support the income-generation capacity of these schemes.

It is envisaged that this project would have a number of beneficial outcomes for the local area in that:

- A degraded site would be turned into an economic asset, which will generate income for the local community
- A recreational amenity could be provided, with on-going maintenance by the community
- The water quality and the visual impact of the river corridor, in terms of reducing gross litter pollution and attenuating the nutrient loadings in the water could be improved.

Estimated costs: *R 550 000*
Expected term: *1999-2001*

Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park rivers

(No 1063) Department of Botany, University of the Witwatersrand

The widespread exploitation of South Africa's rivers has led to ecological degradation, causing considerable concern for the protection over the need to manage river flow to meet the needs of the natural biota. A constraint to effective management is, however, a lack of clarity on the specifics of management goals and an inability to predict the consequences of flow changes to riverine ecosystems, making it difficult to apply existing knowledge to ecosystem management. Strategic adaptive management (SAM) techniques are being developed to address this. The management goals of SAM are expressed as desired future state (DFS) and thresholds of probable concern (TPC), and when monitoring indicates that the state of a variable has reached the TPC as defined, management is then alerted to take action. In this way it is possible to pro-actively manage the problems rather than reacting to them, allowing measurable progress towards the DFS.

This follow-up project will finish the protocol for the development of the rule-based model for riparian vegetation developed to address the TPC for loss of bedrock influence on the Sabie River. During this project researchers will work closely with managers to ensure that the technology is sustainably transferred. They will also develop RBMs to address the TPCs of reed encroachment and terrestrialisation of the riparian zone, which were conceptualised during the previous

project. Finally, they will develop protocols for the transfer of RBM technology into the SAM process for use beyond the KNPRRP.

Estimated cost: *R710 500*
Expected term: *1999-2001*

Decision-support system for rehabilitation and management of riparian systems

(No 1064) Institute for Natural Resources, University of Natal

River systems and their estuaries reflect the state of their catchments, so effective linkages between catchment and river management need to be developed. The National Water Policy is firmly founded on the concept of integrated water resource management on a catchment scale. It foresees the formal and widespread establishment of statutorily directed catchment management processes. The National Department of Agriculture has launched a Land Care Programme which aims to rehabilitate degraded land and promote community-based care for the land and the resources it supports. It is important that the links between land use and river systems are firmly established so that 'land care' and 'water care' are seen to be inseparable parts of sustainable living.

This project aims to establish effective links between the land-care initiative of the National Department of Agriculture and the management of rivers, formulate a procedure to identify priority sites for intervention and integrate this into a rule-based model in such a way as to be widely applicable in South Africa.

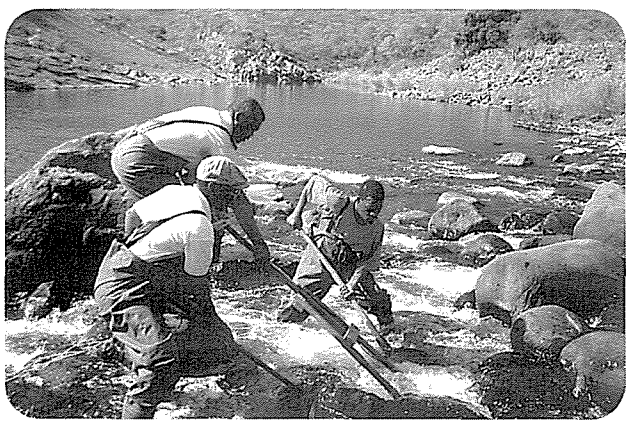
Estimated cost: *R600 000*
Expected term: *1999-2001*

Rule-based modelling of fish: Facilitating strategic adaptive management of the Kruger National Park rivers through model development and technology transfer

(No 1065) Institute for Water Research, Rhodes University

A management model for fish in the country's east-flowing rivers, based on the dynamics of the system, was developed following work done in the Sabie-Sand River system early in the decade. However, this did not fit the strategic adaptive management (SAM) model which is becoming widely adopted because it is so effective. In order to operationalise SAM it is necessary that the desired future state (DFS) and thresholds of probable concern (TPC) are formulated, and the model needs to be redefined to address the specific management needs. Within the above context, this project specifically aims to develop a conceptual framework for the problems surrounding fish biodiversity within the context of established "agents of change", and to refine the TPCs for both fish and geomorphology as defined in Rogers and Bestbier's DFS report (published in 1997 by the Department of Environmental Affairs and Tourism). The first edition of the RBM for fish will be converted to address management needs and the technology will be transferred to KNP management. This entails setting up a monitoring programme with KNP personnel.

Estimated cost: *R552 000*
Expected term: *1999-2001*



The River Health Programme: Electro-fishing in Mpumalanga.

Information management and facilitation in the Kruger National Park Rivers Research Programme (KNPRRP)

(No 1096) Computing Centre for Water Research, University of Natal

The establishment and structure of the meta-data catalogue of the KNPRRP's Information Management and Facilitation Subprogramme were reported on in the outcome of Project No 883. In order to continue maintenance and updating of the catalogue during the final year of Phase III of the KNPRRP, this project was launched and will be part of the operational aspects of handing over the KNPRRP software and data systems to SA National Parks by the end of Phase III in December 1999.

More specifically, the objectives of this project will be:

- Transfer of data from various sources into the KNPRRP preferred systems formats
- Effect increased exposure of the KNPRRP's Integrated Catchment System amongst SA National Parks researchers in the KNP and stakeholders in the Sabie catchment
- Identify and stimulate nodal points in a stakeholder communications network using the Internet
- Identify and collect meta-data on the rivers of the KNP to the west of the escarpment
- Transfer capability for operation, maintenance and updating of computer systems capabilities developed in the six years of the KNPRRP to the SA National Parks, Skukuza.

Estimated cost: *R75 000*
Expected term: *1999*

Multi-party strategic adaptive management (SAM) of the Sabie River

(No 1097) Centre for Water in the Environment, University of the Witwatersrand

Since its inception in 1988 the KNPRRP has developed a number of tools/protocols/procedures to facilitate decision-making and goal auditing in the management of the KNP rivers. However, availability alone of these tools will not ensure either their use or effective management, particularly where many divergent parties are involved in decision-making processes within catchment management agencies. A structured process of strategic adaptive management (SAM) must be in place to ensure that management goals are achieved and audited.

The overall objectives of this project are to:

- Establish and implement procedures for integrated modelling, monitoring and decision-making in multi-party management of the Sabie River.
- Ensure this implementation elicits appropriate responses and actions from the decision-makers, managers and researchers who should be involved in management of the Sabie River.

The intention is to put in place an operational SAM system for the Sabie River, and a protocol which can be used by catchment management agencies to ensure appropriate response to monitoring or modelling results which suggest that the desired state of a river will not be met. The result will set a precedent for environmental decision-making in catchment management.

Estimated cost: *R98 600*
Expected term: *1999-2000*

Development of monitoring methods for the ecological reserve (quantity) for rivers (also known as IFRs)

(No 1101) Institute for Water Research, Rhodes University

There is a requirement under the National Water Act to monitor the effects of water development schemes. In terms of the ecological effects of such schemes, pre-development data are necessary as a baseline against which to judge subsequent effects. At present there is no accepted methodology for assessing the effects of developments which cause flow modification on the aquatic ecology of the water body. This project aims to develop monitoring methods which will evaluate the efficacy of the flow modification aspect of the reserve in achieving the objectives set for a river. The work will be done on the Sabie and Luvuvhu Rivers, as both of these have impoundments planned for the near future.

The Act requires that the reserve be determined for all significant water resources in the country. The monitoring protocols developed in this project will form a template for monitoring programmes on other rivers.

Estimated cost: *R538 000*
Estimated time: *1999-2002*

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Research projects

Completed

- **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)
- **497** Geomorphological classification system for South African river systems (Rhodes University – Department of Geography)
- **627** Integrated modelling system for predicting the impacts of changes in water quantity and quality brought about by upstream development (Sigma Beta (CE))
- **663** System-related scale study to determine the function of the riparian vegetation of the Olifants River, Transvaal (Agricultural Research Council – Range and Forage Institute)
- **669** Survey for potential biological control agents for the troublesome alga *Cladophora glomerata* (Agricultural Research Council – Plant Protection Research Institute)
- **813** Rule-based modelling for management of riparian systems (University of the Witwatersrand – Department of Botany)
- **882** Prediction of flow modification effects in the rivers of the KNP (University of the Witwatersrand – Centre for Water in the Environment)
- **883** Maintenance and updating of the KNPRRP meta-data catalogue (University of Natal – Institute for Natural Resources)

Current

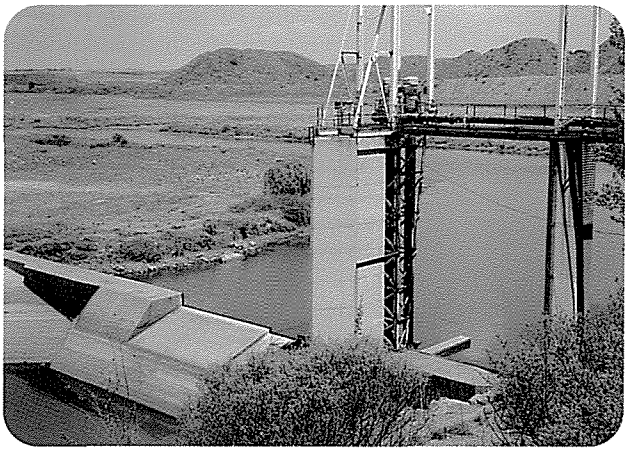
- **525** Natural and unnatural factors regulating the structure and functioning of estuarine systems (University of Natal – Institute for Natural Resources)
- **577** Decision-support system for the integrated management and conservation of estuaries (University of Natal – Institute for Natural Resources)
- **601** Freshwater requirements of plant communities in different types of estuaries (University of Port Elizabeth – Department of Botany)
- **665** Assessment of the ecological impacts of inter-basin transfer schemes in dryland environments (University of Cape Town – Department of Zoology)
- **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)
- **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)
- **754** Linking abiotic and biotic data on South African rivers (University of Cape Town – Department of Zoology)

- **756** Decision support for the management and conservation of estuarine systems: Phase 2 (University of Natal – Institute for Natural Resources)
- **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)
- **812** Botanical importance rating of estuaries in the former Ciskei and Transkei (University of Port Elizabeth – Department of Botany)
- **849** Geomorphological research for the conservation and management of Southern African rivers (Rhodes University – Department of Geography)
- **850** Develop procedures for regional implementation and maintenance of DWAF's National Biomonitoring Programme (CSIR – Division of Water, Environment and Forestry Technology)
- **856** Interaction of reed distribution, hydraulics and geomorphology in semi-arid rivers (University of the Witwatersrand – Centre for Water in the Environment)
- **874** Instream flow assessments: Technology transfer of the building-block methodology (University of Cape Town – Department of Zoology)
- **877** *Verification of estimates of water use by riverine vegetation* on the Sabie River in the KNP (CSIR – Division of Water, Environment and Forestry Technology)
- **881** Development of a classification system for rivers of the KNP, and a model for analysing trends in the condition of these rivers (Rhodes University – Institute for Water Research)
- **884** Hydrological modelling to manage the environmental reserve within the KNP (University of Natal – Department of Agricultural Engineering)
- **915** Impact of herbicides used in water hyacinth control on natural enemies released against the weed for biological control (Agricultural Research Council – Plant Protection Research Institute)
- **916** Invertebrates of South Africa – Identification keys (Umgeni Water (for the South African Society of Aquatic Scientists))
- **917** Promotion of scientifically based estuaries management through the development of an estuaries management handbook (University of Natal – Institute for Natural Resources)
- **955** Use of indigenous riverine organisms in applied toxicology and water-resource quality management (Rhodes University – Institute for Water Research)
- **956** Development of numerical methods for assessing water quality in rivers, with particular reference to the "instream flow requirements" process (University of Cape Town – Department of Zoology)
- **957** *Ecological risk assessment in water resource management:* Research priorities, process development and implementation guidelines (CSIR – Division of Water, Environment and Forestry Technology)
- **975** Assessment of the implications of inter-basin water transfers for the genetic integrity of donor and recipient river basins using selected taxa (University of Cape Town – Department of Zoology)
- **986** Development of methodologies to promote interaction between the Kruger National Park Rivers Research Programme (KNPRRP) and catchment stakeholders (University of the Witwatersrand – Centre for Water in the Environment)
- **988** Development of a programme for water quality research and technology transfer on the rivers flowing through the Kruger National Park (KNP) (University of the Witwatersrand – Centre for Water in the Environment)

New

- **1017** Development of a biomonitoring method, using protozoans, for assessment of water quality in seasonal/ ephemeral rivers and groundwaters (University of Cape Town – Zoology Department)
- **1018** Development of management policies, procedures and structures for Eastern Cape estuaries (University of Natal – Institute for Natural Resources)
- **1019** The Orange River blackfly, *Simulium chutteri*: Investigations into the physiology of the aquatic and non-aquatic stages so as to adjust the existing control programme to overcome summer outbreaks (Agricultural Research Council – Onderstepoort Veterinary Institute)
- **1045** Evaluating the environmental use of water-selected case studies in the Eastern and Southern Cape (University of Port Elizabeth – Department of Economics)
- **1054** Cultivation of high-value aquatic plants in restored urban wetlands for income generation in local communities (Abbott Grobicki (Pty) Ltd.)
- **1063** Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park rivers (University of the Witwatersrand – Department of Botany)
- **1064** Decision-support system for rehabilitation and management of riparian systems (University of Natal – Institute for Natural Resources)
- **1065** Rule-based modelling of fish: Facilitating strategic adaptive management of the Kruger National Park rivers through model development and technology transfer (Rhodes University – Institute for Water Research)
- **1096** Information management and facilitation in the Kruger National Park Rivers Research Programme (KNPRRP) (University of Natal – Computing Centre for Water Research)
- **1097** Multi-party strategic adaptive management (SAM) of the Sabie River (University of the Witwatersrand – Centre for Water in the Environment)
- **1101** Development of monitoring methods for the ecological reserve (quantity) for rivers (Rhodes University – Institute for Water Research)

14 Mine-water management



World-wide, acid mine drainage (AMD) is the main water pollution problem associated with mining activities. AMD forms when the pyrite in ore and rock is exposed to air and water as a result of mining activities. Oxygen in the air, in the presence of water, reacts with pyrite to form dilute sulphuric acid – the main constituent of AMD. This oxidation reaction is greatly accelerated by sulphur-oxidising bacteria. Metals, such as iron, aluminium and manganese which dissolve under acid conditions mostly also form part of AMD. In water-rich countries with surplus capacity to dilute the accompanying salinity, the acidity and metal content of AMD are the main causes for concern. South Africa's limited dilution capacity ensures that the high salinity associated with AMD is a major source of concern. Another factor complicating mine-water pollution management, is the fact that it mainly originates from non-point sources which are difficult to manage and control.

The WRC is funding a fairly large portfolio of projects in the mine-water field. Excellent co-operation exists between the different Government departments, mining houses and the WRC concerning the identification of research needs and execution of projects. Several of the projects are being co-funded by more than one organisation. The Co-ordinating Committee for Mining-Related Water Research plays a major role in this regard.

The ideal mine-water management option is to prevent or minimise the formation of AMD in the first place. Past experience in this regard has not always been promising. Ongoing research dealing with the rehabilitation of mine waste materials by covering these with soil layers of various thickness, is yielding positive results. The formation of AMD is reduced to the degree that cover layers succeed in excluding oxygen from the pyrite-containing mine waste.

It has to be accepted that in spite of efforts to minimise its production, AMD will for the foreseeable future continue to be produced during and beyond, the operational life of mines. Much of the WRC's research effort is therefore aimed at the improved treatment and/or utilisation of AMD. Research is being conducted on:

- Passive (or more appropriately termed, low maintenance) systems which would be appropriate for the post-operational treatment of smaller AMD streams.
- Refining both theoretical and applied active biological sulphate removal systems. The emphasis in this research is to use waste products as energy sources.
- An active chemical neutralisation process aimed at increased efficiency and cost reduction. An economic and technical evaluation of treatment options indicated that by employing a number of innovative approaches which yield saleable products, it may be possible to desalinate AMD economically.

Another novel approach which holds much promise of alleviating the AMD problem, is to use neutralised AMD as a source of irrigation water. By employing this approach, salinity is removed from the water environment when gypsum is precipitated in the soil. In this way water which would otherwise be a liability is used beneficially, while at the same time reducing its impact on the water environment.

Other mine-water management aspects receiving attention, are:

- The water use of flotation plants, and of different slimes dam re-vegetation approaches
- Assessing the pollution of land underneath reclaimed mine dumps
- Compiling a generic water balance of coal mines
- The establishment of an Internet service centre on modelling systems for the mining industry
- The adsorption/desorption of radio-nuclides to sediments
- Acid-base accounting methods
- An investigation into the long-term impact of inter-mine flow in collieries.

Completed project

Calibration of models for the design of covers for open-cast mine and waste dump rehabilitation

(No 575) Wates, Meiring and Barnard (CE) Inc.

By covering mine waste materials with a layer of soil, the potential to generate acid mine leachate is reduced because the cover reduces both the ingress of oxygen (which is required to oxidise pyrite and produce sulphuric acid) and the throughflow of percolate. This project made use of an experimental facility of DWAF, where different soil materials (most of them vegetated) were used to cover coal discard, in order to evaluate the effectiveness of different soil cover designs and the predictive potential of mathematical models. Single-layered covers inhibited pyrite oxidation when compared to uncovered discard, while multi-layered soil covers largely prevented pyrite oxidation by creating permanent anaerobic conditions. Uncovered cells were least effective in reducing throughflow of water, while multi-layered covers were only slightly better than single-layer covers. Model calibration was unsuccessful in that higher than observed outflows were predicted. This aspect will be further investigated in a follow-on project (Project No 1002).

Cost: *R665 800*
Term: *1993-1998*

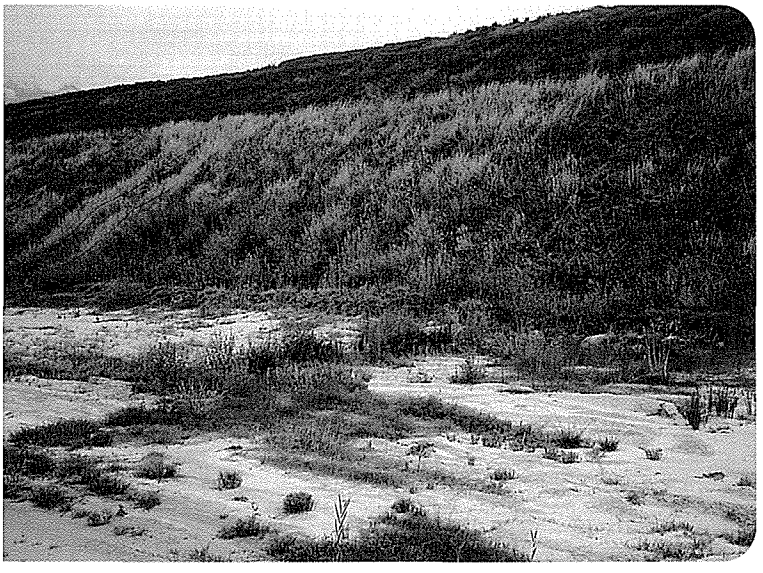
New projects

Guidelines for the development of rehabilitation management strategies for reclaimed gold-mine dump sites in South Africa

(No 1001) Pulles, Howard and De Lange Inc.

An earlier preliminary assessment of pollution contained in the unsaturated and saturated zones beneath reclaimed gold-mine dumps, indicated that there are currently more than 300 gold-mine dumps in South Africa, covering an area of approximately 180 km^2. They are mostly situated in close proximity to growing residential areas, sensitive agricultural areas and/or perennial streams. It was found that mine dumps can have a significant negative environmental impact on the underlying vadose zone and subsequently the groundwater system. This follow-on investigation will produce a comprehensive set of guidelines to assist the mining industry, government departments, consultants and research institutions in decision-making relating to the treatment, rehabilitation and optimal use of land which was once covered by mine discard material. Such guidelines should play a major role as a key tool for Government departments in decision-making processes such as the evaluation of proposed Environmental Management Programmes, as well as the development of rehabilitation strategies to satisfy mine closure requirements.

Estimated cost: *R595 000*
Expected term: *1999-2001*



Field plots for the evaluation of different approaches to slime dam rehabilitation.

Understanding and modelling of water flow through soil covers used for rehabilitating coal discard dumps and open-cast mines

(No 1002) Wates, Meiring and Barnard (CE) Inc.

Since 1993 the contractors have, with the collaboration of DWAF and with funding from the WRC, been running an experiment to determine the recharge through ten different natural soil covers. Part of this project was aimed at calibrating existing computer models for use as a tool to predict recharge through natural soil covers. The available models, however, did not adequately predict the relationship between rainfall events and recharge, especially for the typical short-duration thunderstorms of high intensity observed in South Africa. The predicted quantity available for recharge was found to be significantly lower than under low-intensity rainfall conditions. This follow-on project aims to develop a clear understanding of the flow mechanism in the top unsaturated soil layers of a natural soil cover on a microscale, in order to accurately model recharge. Existing mathematical models will be used as a basis for the study. Evapotranspiration will be derived with the help of a continuous logging weather station while the soil-water profile will also be monitored regularly.

Estimated cost: *R247 000*
Expected term: *1999-2000*

Investigation of water usage at gold- and platinum-mine flotation plants

(No 1003) Department of Environmental Engineering, Technikon Pretoria

The flotation process forms an integral part of the gold- and platinum-mining industry and is mainly used for the recovery of gold, platinum and pyrite. The density of the pulp is controlled by water addition to attain the necessary densities for optimum recoveries. In this process, control of water consumption is essential but the conservation of water is at this stage not the predominant feature in the control process. It is believed that flotation plants use large amounts of water, and that the effluent carries a high pollution load due to the chemicals used in the flotation process. This project will investigate these issues and identify the effects that the released

chemicals have on the water environment. Possible water wastage and means to address the pollution load of the effluent will also be identified as part of this investigation of several flotation plants.

Estimated cost: *R224 000*
Expected term: *1999-2000*

Field testing of real-time continuous flow and water quality monitoring instrumentation

(No 1004) Wates, Meiring and Barnard (CE) Inc.

The successful implementation of water quality management schemes such as the managed release of saline mine water during flood conditions, is increasingly dependent on a real-time on-line communication system linked to continuous water quality and flow monitoring equipment. There are a number of instrumentation manufacturers and suppliers as well as communication systems available. Although specifications and brochures are available, very little hard evidence exists regarding their performance in the field and the adequacy of service back-up. There is also a lack of general guidelines on the operational requirements and costs of continuous monitoring equipment. As part of this project, equipment manufacturers and suppliers will be identified both locally and internationally and a number of weirs selected for the installation of the equipment. A manual sampling programme will be implemented to provide base data against which to test the accuracy and the calibration requirements of the equipment. The performance of the equipment will be evaluated in terms of accuracy, reliability, calibration frequency, operating costs and maintenance requirements.

Estimated cost: *R300 000*
Expected term: *1999*

On-site and laboratory investigations of spoil in open-cast collieries and the development of acid-base accounting procedures

(No 1055) Institute for Groundwater Studies, University of the Orange Free State

The pyrite present in coal and other deposits oxidises when exposed to water and air to generate sulphuric acid. The base potential of the surrounding rock determines to what degree the acid is neutralised and whether mine drainage water will be acid or alkaline. Mines are required to carry out acid-base accounting (ABA) as part of their Environmental Management Programme reports. During the past 15 years, various methodologies have been developed for the determination of the acid-base characteristics of mine waste material at open-cast mines. The results from these methods do not agree and the regulating authorities, as well as the mining industry, have to standardise on ABA procedures as a matter of urgency. *In situ* testing of spoil at three collieries will be undertaken as part of this project. The near surface as well as flooded spoil will be investigated. This will be supplemented by extensive laboratory investigations using static and kinetic

Field testing of real-time continuous flow and water quality monitoring instrumentation.

tests. These results will be compared to historic ABA results and recommendations for standardised test procedures will be put forward. The three case histories will be documented fully for use as a reference during future ABA tests.

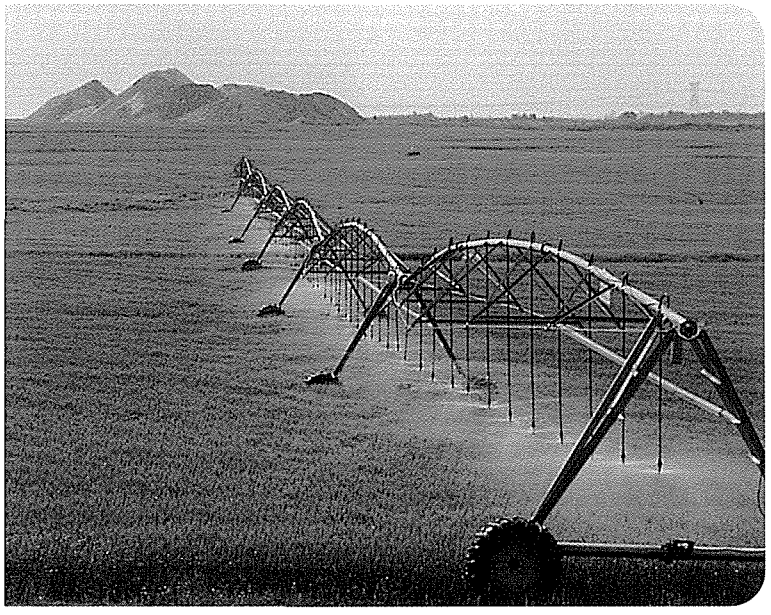
Estimated cost: *R866 000*
Expected term: *1999-2000*

Investigation into the long-term impact of inter-mine flow in the Mpumalanga collieries

(No 1056) Institute for Groundwater Studies, University of the Orange Free State

The mining industry in 1996 conducted an investigation into inter-mine flow. This investigation dealt with a trial area of 30 x 30 km, south of Witbank, which constitutes about 30% of the Mpumalanga coalfield. From this investigation it was concluded that mining activities have extensively disrupted natural groundwater flow paths and that it is the pathways within mines which will in future dictate flow of underground water and where water will decant onto the surface. The combined potential impact of inter-mine flow and water to be decanted onto the surface is of a magnitude not previously anticipated in modelling exercises. The flow of polluted mine water between collieries in Mpumalanga is an issue that needs to be resolved before a holistic mine-water management scheme can be implemented. This investigation will, *inter alia*, establish a geographic information system for all the collieries in the Mpumalanga coalfield, showing mined out areas, future areas to be mined and mining methods, identify seepage and decant positions where water from mines will impact on groundwater and surface water, and quantify contributions through field investigation and modelling.

Estimated cost: *R897 000*
Expected term: *1999-2000*



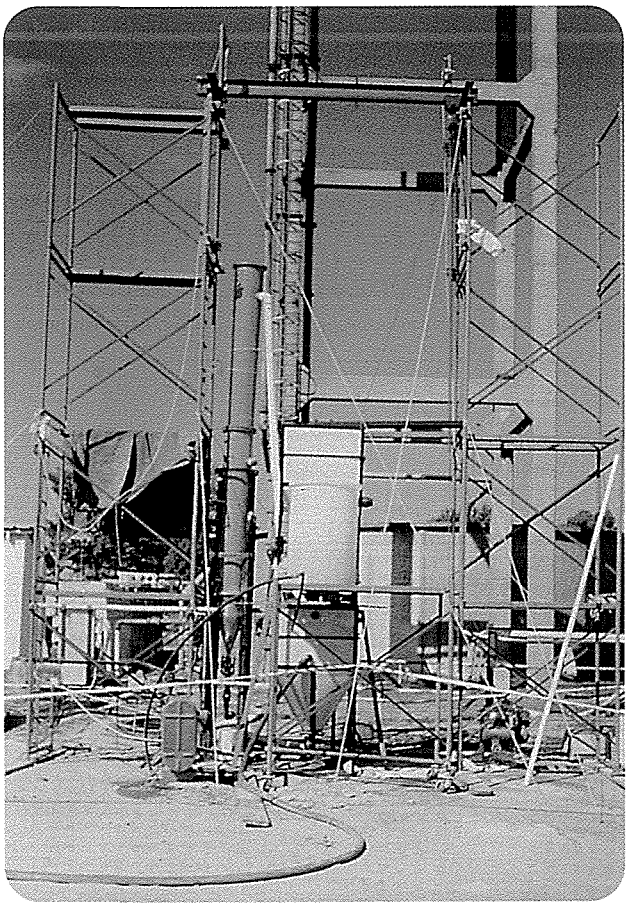
Large-scale assessment of the feasibility of irrigating with gypsiferous mine water and its effect on soil properties and drainage water (mine dumps are shown in the background).

Neutralisation of acid mine water and sludge disposal

(No 1057) Division of Water, Environment and Forestry Technology, CSIR

Since their low pH and high metal content make acid mine drainage waters unacceptable to the aquatic environment, they have (as a minimum requirement) to be neutralised and steps taken to ensure the safe disposal of the metal-rich sludge which is formed during neutralisation. In Gauteng alone, 240 Ml/d of acid water from gold mines is being produced. The calculated cost of the lime required as neutralising agent amounts to about R57 m./a. Several alternative and supplementary processes to increase the efficiency and/or reduce the cost associated with the active treatment of acid mine water, have been identified and tested over the years. In an earlier investigation, researchers on this project were able to reduce the cost of chemicals by a factor of three through substituting lime with limestone in the neutralisation process. This project aims to take this process further by conducting laboratory- and full-scale pilot studies, supplemented with further laboratory studies, which will address several of the urgent needs associated with active neutralisation of acid mine water.

Estimated cost: *R700 000*
Expected term: *1999-2000*



Pilot-scale investigations on the neutralisation of acid mine water.

Development and piloting of the integrated biodesalination process for sulphate and heavy metal removal from mine drainage water incorporating co-disposal of industrial and domestic effluents

(No 1078) Department of Biochemistry and Microbiology, Rhodes University

The development of active biological processes for the treatment of high-volume AMD flows is constrained by cost-effective reactor design and the availability of carbon sources. Recent WRC projects have researched algal ponding technologies and applied these low-cost processes to the treatment of mining and tannery wastewaters. This has led to the development of a sulphate-reducing bacterial biodesalination process using sewage solids as the carbon source for the removal of sulphates and the neutralising of acidic drainage streams for removal of heavy metals. In this project the completely integrated process is being tested on pilot-plant scale, to allow evaluation over an appropriate time period and to support current research partners with full-scale process scale-up and technology transfer functions. The aims of the project therefore include the complete pilot-scale evaluation of sewage solids as an example of a complex carbon source used as an electron donor in the integrated biodesalination process, development and optimisation of the process, operation of the final configuration as a demonstration plant for an appropriate period for technology transfer and generation of the appropriate input data required for modelling and process decision-making relating to the full-scale engineering of the process.

Estimated cost: *R1 700 000*
Expected term: *1999-2002*

Investigation into sulphur chemistry with specific application to biological sulphate removal processes

(No 1079) Department of Civil Engineering, University of Cape Town

This project complements other current research into active biological processes for sulphate removal. Firstly, differential precipitation and separation of the dissolved metals has the potential to close the materials cycle for those metals. The recovered metals could be returned to appropriate processes, or, at worst, a multi-component metal sulphide precipitate is more stable, more compact and easier to de-water than the equivalent hydroxide precipitate. Secondly, the interactions of aqueous and gaseous sulphide species, and their responses to changes in process variables such as temperature and pH, have not been well explored in the context of optimising the biological sulphate-reducing processes. Thirdly, the potential for recovery of elemental sulphur from this process is one of the key factors favouring this process approach.

The aims of the project with specific application to biological sulphate removal processes are therefore to develop simulation models for:

- The precipitation and selective recovery of metals in various process configurations for optimum metal recovery
- Sulphide chemistry (aqueous and gaseous phases) including the effects of pH and temperature on speciation and solubility with active stripping of H_2S
- The recovery of elemental sulphur through oxidation of soluble sulphides, including theoretical considerations to explore the extent of conversion, reaction kinetics and control of the process.

Estimated cost: *R280 000*
Expected term *1999-2000*

Mechanism and kinetics of biological treatment of metal-sulphate-containing effluent

(No 1080) Department of Chemical Engineering, University of Cape Town

Bioprocessing of AMD using relatively expensive electron donors for bacterial sulphate reduction, as practised in Europe and the USA, is generally not economically viable in South Africa. The use of other cheap but more complex organic sources as electron donors shows promise. One of these is the use of sewage sludge as in WRC Projects No 869 and 972 being carried out by Rhodes University. This project aims to provide appropriate engineering input to those projects and to develop simulation models to allow process optimisation. The specific aims of the project include the following:

- To develop a simulation of the WRC/Rhodes University process (and other similar processes) for treatment of AMD streams to effect process optimisation
- To establish the kinetics of the critical subprocesses in order to inform and refine the predictive models discussed above
- To optimise the recovery of elemental sulphur as an end-product.

Estimated cost: *R574 000*
Expected term: *1999-2000*

Tier 1 risk assessment of radionuclides in selected sediments of the Mooi River

(No 1095) Division of Water, Environment and Forestry Technology, CSIR

An investigation into the fate of radioactive metal releases into the Mooi River conducted by DWAF, indicated that the radionuclides in the water column dissipate with distance from the source – presumably because the radionuclides bind to sediments. The implication is that large quantities of radionuclides which have been removed from the water phase in this way, may be remobilised under a different set of conditions. It is important to know under which conditions these radionuclides may be remobilised, and if this occurs, how much of a risk to human health they may pose. A large database of water-column radiological data has been collected by the earlier DWAF investigation. It is envisaged that this cursory investigation of the radioactivity of the sediments will complete the data required to understand the fate of radionuclides in the Mooi River and the risk they pose.

Estimated cost: *R96 000*
Expected term: *1999*

Research projects

Completed

- **575** Calibration of models for the design of covers for open-cast mine and waste dump rehabilitation (Wates, Meiring and Barnard (CE) Inc.)

Current

- **454** Occurrence of bacteria causing acid drainage in the outer layers of coal waste dumps (University of Stellenbosch – Department of Microbiology)
- **647** Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers (CSIR – Division of Water, Environment and Forestry Technology)
- **699** Prediction techniques and preventative measures relating to the post-operational impact of underground mines on the quality and quantity of groundwater resources (University of the Orange Free State – Institute for Groundwater Studies, Chamber of Mines of South Africa, and DWAF)
- **700** Pilot-scale development of integrated passive water treatment systems for mine effluent streams (Pulles, Howard and De Lange Inc., Chamber of Mines of South Africa, Eskom, and Sasol Coal)
- **745** Suitability and impact of power station fly ash in mining rehabilitation (University of the Orange Free State – Institute for Groundwater Studies)
- **797** Preliminary assessment of pollution contained in the unsaturated and saturated zones beneath reclaimed mine dumps (Geo-Hydro Technologies)
- **800** Economic and technical evaluation of regional treatment options for point source gold-mine effluents entering the Vaal Barrage catchment (Stewart Scott (CE) Inc.)
- **801** Generic water balance for the South African coal-mining industry (Pulles, Howard and De Lange Inc.)
- **802** Determination of the suitability of alternative carbon sources for sulphate reduction in the passive treatment of mine waters (CSIR – Division of Water, Environment and Forestry Technology)
- **899** Quantitative evaluation of water utilisation in different rehabilitation methods on gold slimes dams (Envirogreen and Freegold)
- **900** Development of a management strategy for the controlled release of saline mine water during flood conditions in the Witbank Dam catchment (Wates, Meiring and Barnard (CE) Inc. and Ninham Shand (South) Inc.)
- **901** Development of an Internet service centre on water-modelling systems for the mining industry (Pulles Howard and De Lange Inc.)

New

- **1001** Guidelines for the development of rehabilitation management strategies for reclaimed gold-mine dump sites in South Africa (Pulles, Howard and De Lange Inc.)
- **1002** Understanding and modelling of water flow through soil covers used for rehabilitating coal discard dumps and open-cast mines (Wates, Meiring and Barnard (CE) Inc.)
- **1003** Investigation of water usage at gold- and platinum-mine flotation plants (Technikon Pretoria – Department of Environmental Engineering)
- **1004** Field testing of real-time continuous flow and water quality monitoring instrumentation (Wates, Meiring and Barnard (CE) Inc.)
- **1055** On-site and laboratory investigations of spoil in open-cast collieries and the development of acid-base accounting procedures (University of the Orange Free State – Institute for Groundwater Studies)
- **1056** Investigation into the long-term impact of inter-mine flow in the Mpumalanga collieries (University of the Orange Free State – Institute for Groundwater Studies)
- **1057** Neutralisation of acid mine water and sludge disposal (CSIR – Division of Water, Environment and Forestry Technology)
- **1078** Development and piloting of the integrated biodesalination process for sulphate and heavy metal removal from mine drainage water incorporating co-disposal of industrial and domestic effluents (Rhodes University – *Department of Biochemistry and Microbiology*)
- **1079** Investigation into sulphur chemistry with specific application to biological sulphate removal processes (University of Cape Town – Department of Civil Engineering)
- **1080** Mechanism and kinetics of biological treatment of metal-sulphate-containing effluent (University of Cape Town – Department of Chemical Engineering)
- **1095** Tier 1 risk assessment of radionuclides in selected sediments of the Mooi River (CSIR – Division of Water, Environment and Forestry Technology)

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15 Water policy

In a situation of water scarcity, the central challenge is to reduce the quantity of water consumed or decrease the demand for water while also simultaneously improving the opportunities for economic growth. For this purpose a water conservation and demand management strategy framework is being drawn up by DWAF, as part of the implementation of the National Water Policy. The objectives are the efficient, equitable and sustainable use and allocation of water, and cornerstone principles of the strategy framework are the responsibility and accountability of water users.

The success of any type of policy intervention depends on determining the incentives for the behaviour of water users and assessing the prospects for changing that behaviour. Water users will respond to policy measures if their own interests can be improved. These interests include those of households reducing the expenditure on water within the constraints of the budget or those of firms producing more and earning higher income with the same or lower expenditure on water. The requirement is obviously to promote own interests without harming the interests of others. The precautions which must be taken involve mainly preventing deterioration of water quality, decreasing the threat of water-borne diseases, protecting biodiversity and maintaining the ecological balances of river systems.

Policy measures must therefore be taken which enable water users to relate water use to cost and to compare water values with cost. The pre-conditions which must be satisfied are secure water entitlements, measurement of water use and some form of volumetric charging. Essentially this means that water users must receive the message that there are costs attached to supplying water, that there are alternative uses for water and that water is a valuable resource. The effective policy options to achieve this are applying a combination of economic and regulatory instruments to influence water use as well as combining market and administrative processes to influence water allocation.

The quantity and quality of water demand can in particular be influenced by means of economic policy instruments such as **water tariffs** and **pollution charges**. Tariffs and charges always have a double effect since they act as an incentive to change behaviour and they raise funds. The response of reasonable water users will be to:

- Obtain more information on e.g. consumption patterns in the house and garden or water requirements of different production processes
- Apply appropriate technology in the home, farm or factory to prevent waste and reduce use of water.

While it is the responsibility of water users to make the best use of existing, available water resources, representative agencies and authorities must be accountable regarding the use of funds collected through tariffs and charges on water. The research projects which are reported all aim to assist water users, service providers and policy advisors in performing their functions.

Completed projects

Pricing water as an economic resource

(No 678) Palmer Development Group

This project was undertaken during a particularly fluid research and policy environment within South Africa. Since the original conception of the project in 1993 many changes have taken place within the water sector. At that point, this project was one of a few initiatives undertaken specifically on water pricing. Subsequently many more research, policy and legislative initiatives have been launched. Hence this project has been adapted along the way so as best to meet the changing water sector needs. The scope and focus of the project was narrowed to examine water supply pricing or tariffing issues related primarily to urban water use, including the wholesale provision of water to (or by) local government. During this process, the researcher was actively involved in and/or contributed to a number of important policy initiatives in the sector, in particular, the development of the first-tier water tariff strategy, the Water Services Act and the regulations related to third-tier water tariffing. Thus it is fair to say that the research outcomes which are reported have already helped to shape the current water policy environment. However, in many instances, the research presented has gone beyond existing policies and current practice. Hence a number of recommendations for further changes to principles to promote equity, efficiency, financial and ecological sustainability are made. Similarly, policy recommendations pertain-

ing to retail (third-tier) water tariffs are formulated.

In this regard a methodology for the implementation of the retail (third-tier) water tariff policy is proposed. The methodology builds on the existing set of management guidelines for setting urban water tariffs in South Africa and the Water Supply Services Model (WSSM). A set of practical guidelines for tariff design is provided. These guidelines provide an approach that is helpful to assess the broad feasibility of different subsidy and tariff structure options. Once a broad outline has been worked out following this approach, the estimates can be tested and refined using available or custom-developed financial and tariff models.

Cost: *R564 952*
Term: *1995-1998*

Development of a philosophy and methodology for the implementation of "the polluter pays" principle in the context of receiving water quality objectives

(No 793) Stewart Scott (CE) Inc.

Experience in many countries and earlier research by the WRC indicated that the traditional command-and-control (CAC) approach to regulate water pollution often fails to provide cost-effective solutions for water quality management. Economics-based measures were proposed to achieve the same environmental benefits with simpler administration and at lower cost. This project investigated the philosophy behind, and the implementation of "the polluter pays" principle (PPP) for pollution control under South African conditions. The philosophy underlying the PPP was found to be both ethical and economically sound. Internationally the trend was found to combine CAC-based systems with PPP-based pollution charge systems. The Witbank Dam catchment and the pollutant sulphate were selected for a theoretical case study of pollution charges. A change system with cost covering and incentive components (consisting of an administrative charge, a waste load charge and a non-compliance charge) was designed and tested on data from the Witbank Dam catchment. It was concluded that pollution charges are a viable water quality management tool for implementation in South Africa and that it should be implemented in a phased approach.

Cost: *R355 000*
Term: *1997-1998*

Pricing of water resources in South Africa with specific reference to riparian surface water

(No 870) Department of Agricultural Economics, University of Natal

The agricultural sector, which consumes the most water in South Africa, is regarded as the primary source to meet demand through water savings. Despite this rationalisation of water use in agriculture, irrigated agriculture will have to maintain and improve productivity to meet growing food demand in future. This will require an enabling environment that allocates irrigation water optimally. Water marketing is one such mechanism that can allocate water to its highest valued use in an efficient and flexible manner.

This research entails a detailed evaluation of the policy scenario of water market allocation and identifies the general criteria for a well-functioning market, efficiency advantages of market allocation, and potential constraints to market establishment and operation. A literature review of water markets in a number of countries identifies the procedural requirements for water markets in each situation. The research also highlights the facilitating institutional arrangements and benefits from market trades of "outer land" water rights along the Lower Orange River, as well as the potential for and necessary institutional changes to facilitate tradable water rights along the Mhlatuze River. The new Water Law principles are briefly evaluated and their possible effect on irrigation farmers are assessed. Finally, the study attempts to deal with the issue of how water-use licenses will be quantified. However, further hydrological research into this topic in each river catchment is necessary to identify the method in which the water allocation to irrigated agriculture and individual irrigators will be determined.

Cost: *R50 000*
Term: *1997-1998*

New projects

Preparation of guidelines and a model for the financing of district councils' water supply functions

(No 994) Palmer Development Group

By far the greatest deficits with regard to service provision exist in rural areas. Yet it is here that the organisational capacity to deal with the problem is the weakest. Although there have been great advances in the establishment of local government structures in rural areas, these new organisations are organisationally weak. There is a two-sphere system of local government established at present, with primary local government in the form of transitional rural councils or representative councils, and with district councils operating at a larger geographic scale. At present it is district councils who have been given the executive authority for providing services in most provinces. However, those with primarily rural areas have up to one million largely poor people to serve, and yet have very small management and administrative units.

Looking at the financial situation there is currently a serious lack of understanding regarding the sources of finance available to district councils and the way these are best used to finance particular activities. On the current account side, where the problems are greatest, these sources include district council levies, inter-governmental grants (IGGs) and income raised from tariffs for services provided. Presently there is little income from rural areas and the district councils have received a relatively small share of IGGs. However, this latter situation is changing, with new policy now approved regarding the allocation of the "equitable share" of transfers from the fiscus.

On the expenditure side the district councils are also being faced with new difficulties as they are being required to take over responsibility for operating water supply schemes presently being run by DWAF. This creates a draw on their resources and highlights the need for financial planning to be carried out carefully to accommodate this. Secondly, district councils have new obligations under the Water Services Act.

They will generally be identified as water service authorities and this places specific obligations upon them to perform certain high-level activities such as water service development planning and contracting service providers. This will generate further new costs they have to face. A third new obligation, with associated costs, relates to the need for district councils to take on a greater role with regard to the management of capital investment programmes in their areas.

It is clear from the above that district councils are faced with a relatively complex set of financial challenges and particularly those responsible for former homeland areas, have serious capacity constraints. The intention of this project is to provide information which can be used to build their capacity to manage water supply services in their areas, through the provision of models to assist with financial analysis and guidelines to assist with decision-making.

Estimated cost: *R97 000*
Expected term: *1999-2000*

Gender dimension of water policy and its impact on water and sanitation provision and management in the Eastern Cape: The case of Peddie district

(No 1021) Department of Development Studies, University of Fort Hare

Although the Government policy on water supply and sanitation recognises the important role that women have to play in the provision of basic services, currently there are no enabling policies for implementing gender-balanced approaches in the provision of water and sanitation services. There is growing evidence that a gender-balanced approach is critical to the achievement of sustainable water and sanitation services in developing countries.

Women as primary beneficiaries of improved water supply services are more committed to ensuring that the water supply schemes are properly operated and maintained. It is, therefore, important to involve them at all levels of planning and implementation of water and sanitation projects.

The main objectives of this research are to:

- Undertake a critical analysis of the gender dimension in the development of the water policy for South Africa
- Investigate the strategies and institutional arrangements for water supply in terms of decisions concerning the location of the water supply scheme, the choice of technology, operation and maintenance, community participation and how these affect women as managers of households.

Estimated cost: *R303 000*
Expected term: *1999-2000*

Development of guidelines for the financing of catchment management in South Africa

(No 1044) Palmer Development Group

According to the National Water Policy, a major thrust will be to involve water users in water management on a local level. Provisions have therefore been made in the National Water Act for the creation of organisations such as catchment management agencies (CMAs) and water user associations. In terms of the said Act, a strategy for setting water-use charges may be formulated amongst others for funding water resource management. Expenditure on resource management relates to functions performed by DWAF or agencies exercising delegated or assigned powers. These functions include the following:

- Monitoring and assessment of water resource availability, quality and use
- Water quantity management, including flood and drought management, water allocation and control over water abstraction, storage and other water uses
- Water resource protection, water quality management and water pollution control.

Budgetary implications of catchment management are specified in the discussion document on *A Strategic Plan for DWAF to Facilitate the Implementation of Catchment Management in South Africa* (WRC Report No KV107/98). Broad guidelines on financing of catchment management are given in WRC Report No KV108/98. However, no detail is provided on methods to calculate costs of the different components of catchment management and what mechanisms should be followed to collect catchment management charges from beneficiaries. After consultation with DWAF it was confirmed that operational manuals are required on costing and financing of catchment management.

The study is intended to develop a framework for catchment management financing. Therefore, the project has the following aims:

- To review the current policy with regard to the charges which may be levied by CMAs
- To establish cost centres associated with catchment management functions and typical costs which may be incurred in the management of catchments
- To identify the financial flows associated with CMAs, to and from either Government or external stakeholders
- To evaluate appropriate mechanisms to ensure the sustainable financing of catchment management functions
- To combine this financial information into a model which can be used to assess the viability of a CMA in any catchment area
- To test the model on two catchments in South Africa.

Estimated cost: *R235 000*
Expected term: *1999*

Rural service delivery: A study of current water policies in relation to rural people's experience of its implementation – Case studies from the Eastern Cape

(No 1066) Rural Support Services

Since 1994, the Government has had a commitment to provide basic services to the millions of South Africans who currently lack access to these services. Large investments in infrastructure have been made, especially in rural areas where the needs are most severe.

In 1997 DWAF commissioned the evaluation of water projects that had been implemented during the preceding three years. The focus of this evaluation was on technical and institutional aspects of the projects. So far no evaluation of the impact of the water policies on recipient communities has been done. The proposed study will provide information on people's experience and the impact of Government policies on their lives. This information will help the Government in assessing the success of the infrastructural projects in

improving the quality of life for rural people. Where problems are identified, this information will help the Government to make the necessary adjustment in the water policies and their implementation. The study will investigate the practical implementation of policies and their impact on rural people with special reference to issues such as choice, affordability, willingness to pay and levels of service. The main output of this research will be recommendations for future changes in Government policies for the delivery of basic services to rural communities.

Estimated cost: *R113 000*
Expected term: *1999*

Research projects

Completed

- **678** Pricing water as an economic resource (Palmer Development Group)
- **793** Development of a philosophy and methodology for the implementation of "the polluter pays" principle in the context of receiving water quality objectives (Stewart Scott (CE) Inc.)
- **870** Pricing of water resources in South Africa with specific reference to riparian surface water (University of Natal – Department of Agricultural Economics)

Current

- **512** Development of procedures for decision support in water resources management (University of Cape Town – Department of Statistical Sciences)
- **790** Estimation of the residential price elasticities of demand for water by means of a contingent valuation approach (Economic Project Evaluation (Pty) Ltd.)
- **854** Review of industrial effluent tariff structures in South Africa and guidelines on the formulation of an equitable effluent tariff structure (DA Kerdachi, Private Consultant)
- **887** Development of a tool for evaluating the effect of alternative funding options (with different risk profiles on water tariffs) (PAA Ramsden, Private Consultant)
- **896** Financial planning and modelling for regional water supply service providers (Palmer Development Group)
- **897** Improved management of assets in the water supply industry with regard to possible privatisation (University of the Witwatersrand – Water Systems Research Group)
- **943** Development of a methodology to determine the true value of water in the Berg River basin (University of the Orange Free State – Department of Agricultural Economics)
- **949** Development of a framework for the introduction of waste discharge charge systems in South African catchments (Stewart Scott (CE) Inc. and Development Planning and Research)
- **977** Human resources needs assessment – tertiary level: South African water sector up to 2015 (University of the Witwatersrand – Department of Civil Engineering)
- **978** Incorporation of economic considerations into quantification, allocation and management of the environmental water reserve (University of Natal – Institute for Natural Resources)
- **987** Modelling the value of water as an economic resource in selected catchment areas of South Africa: **Great Fish and Sundays Rivers** (University of Natal – Department of Agricultural Economics)
- **989** Modelling the value of water as an economic resource in selected catchment areas of South Africa: **Great Letaba River** (Economic Project Evaluation (Pty) Ltd.)
- **990** Modelling the value of water as an economic resource in selected catchment areas of South Africa: **Vaal River** (Greengrowth Strategies cc)

New

- **994** Preparation of guidelines and a model for the financing of district councils' water supply functions (Palmer Development Group)
- **1021** Gender dimension of the water policy and its impact on water and sanitation provision and management in the Eastern Cape: The case of Peddie district (University of Fort Hare – Department of Development Studies)
- **1044** Development of guidelines for the financing of catchment management in South Africa (Palmer Development Group)
- **1066** Rural service delivery: A study of current policies in relation to rural people's experience of its implementation – Case studies from the Eastern Cape (Rural Support Services)

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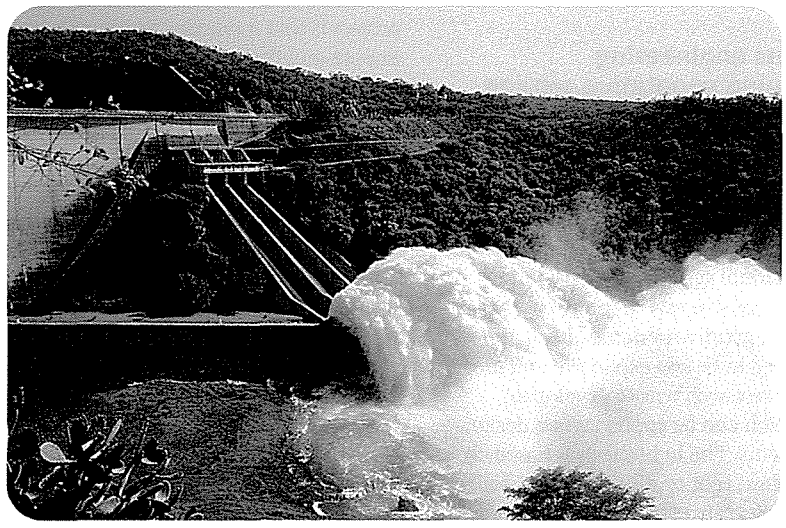
16 Hydraulics



Artificial flood release of 800 m^3/s from Pongolapoort Dam during October 1999. A total volume of about 200 million m^3 has been released for mainly environmental and agricultural purposes, and field monitoring of the flood routing and sediment transport through the 120 km river system has been carried out.

For a hydraulic system to be to the benefit of the community at large, a number of conditions have to be met. It has to be in harmony with the natural environment, it must be accepted by the community and it must be economically viable. Meeting these conditions implies design, construction, operation and maintenance of these systems on a level commensurate with its potential value to the community, and with the impacts its failure may have. All of these, at one stage or the other, require purposeful hydraulics research aimed at the development of theories and methods, and/or the generation of results which would enable engineers to attend to these tasks effectively and responsibly.

The International Association for Hydraulic Research (IAHR) defines hydraulics research as "the development of basic knowledge and its transferring to engineering methods, for the purposes of designing socially acceptable solutions to water related problems. It includes both the human environment and the protection of the natural environment".

Researchers in this field are confronted with the situation where their research is dealing with a substance that could either be a hazard, or needs to be protected. This situation, together with other variables such as ill-defined or complex boundary conditions in which local geology and human interventions play a part, creates a research field with peculiar demands in terms of manpower capabilities and funding requirements.

Against the above background the hydraulics research community in South Africa, as in all the other parts of the world, is faced with challenges to contribute, through their research, to promoting sustainable development and to avoiding non-sustainable development. In the case of the former, both the design of new developments and optimisation of existing systems are included. A holistic view of the environment is required in order to reach acceptable trade-offs. Any system of water supply and use, including water-related risk management, will fail if either technical or non-technical demands are not fully met.

In order to avoid non-sustainable development, every threat by or to water needs to be assessed by an analysis of possible scenarios. In this regard the environment is one of the major concerns which requires extensive research in order to improve knowledge and understanding of the phenomena, thus enabling prediction of the effects of human interventions on natural ecosystems. The complexity of nature, being a multidisciplinary domain, requires the co-operation and exchange between various branches of engineering and science which, at this stage, are not always or altogether the case.

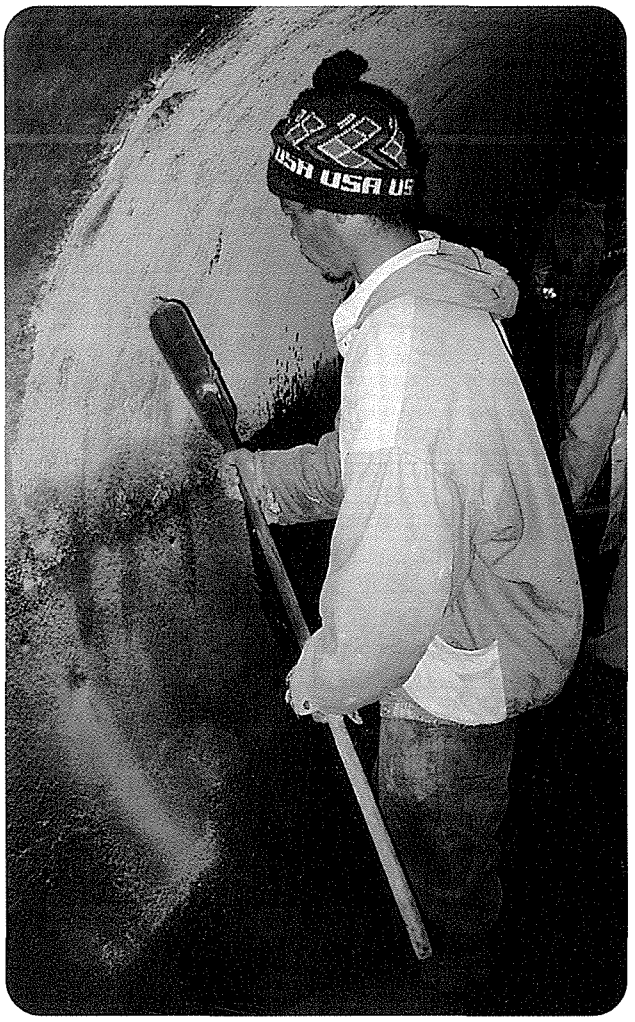
The step by the IAHR to establish "eco-hydraulics" as a subsection of hydraulics research, is a significant development which needs to be formalised in South Africa as well. Although hydraulic modelling of aquatic ecosystems has to a certain extent been addressed in local research, recognising eco-hydraulics as a research field in its own right, will elevate it to a more prominent level of priority, thus stimulating more research in this field. It is expected that these developments will have an impact on the WRC's involvement – both in a facilitating and funding capacity. Obviously this will require careful co-ordination with the activities in the research field **Water Ecosystems** (Chapter 13).

Completed projects

Development of rigorous engineering methodology for designing vegetative erosion protection systems: Phases 1 and 2

(Nos 444 and 643) SRK (CE) Inc.

The massive problem of soil erosion and the associated soil and water losses caused by excessive rainfall runoff has still a long way to go before being solved. Experience in recent years has shown that conventional systems of earth bunds or terraces on farmland are expensive and in many cases ineffective. Currently applied vegetative systems of soil and water conservation have proved to be less expensive and more effective. The objective of this research was to develop an engineering methodology which can be applied when designing vegetative protection systems. The hypothesis is based on the rigorous formulation of plant root reinforcement of soils using the strength properties of grass roots. Six grass species were studied under a variety of conditions and management practices in a laboratory set-up.



Cleaning of a 150 m section of the RoodeElsberg Tunnel as part of the hydraulic ageing investigation of soft water corrosion of concrete.

The central contribution to the state-of-the-art by the project is that it enables the demands that flowing water may impose and the resistance to erosion that the land surface, in natural or engineered form, may offer thereto, to be quantitatively determined in virtually all situations. Incorporation of the concept into standard rainfall-erosion models is being investigated.

Cost: *R849 000*
Term: *1992-1998*

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

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

Pumping costs represent a significant component of running expenses (16 to 20%) of many large water service institutions, and most of it is used for electricity or other energy. In the case of Rand Water this is estimated to be 16% of running expenses. A reduction in this operating cost will result in large savings. The savings can contribute to a general decrease in the tariffs for all customers and in making services more affordable. Optimisation of operating rules for pumping and reservoir storage can provide these savings.

Hence, the objective of the study was to reconcile water supply optimisation techniques by means of computerisation to enable water supply authorities to keep up with new research developments and demands amongst their customers.

The result of the study was the development of two separate but related optimisation models that can be used to enhance operating functions. These are:

Pumping rules phase report and software program

A dynamic computer simulation model was investigated which was then used to optimise operating rules for pumping used by the operators of reservoir storage systems with respect to demand patterns, pumping costs and storage volumes. The research in this phase culminated in the computer program Reservoir System Pumping Optimisation (RSPO), allows historical demand data to be imported and analysed, a stochastic model of those data to be fitted, and optimum operation policies to be calculated.

The policies calculated by these methods have been shown to be both very close to optimum, and useful for the continued operation of the reservoir system. The effect of local optimum points in the cost space was also investigated. It was found that, although there are local optimum points that do tend to prevent the system from finding the global optimum solution, these tend to be small and do not reduce the accuracy of the solution by more than 1%. It was also found that the accuracy of the optimum solution thus obtained is not very sensitive to the length of the data set used in the optimisation process.

A comparison with historical operating data reveals that the reservoir systems can be operated as well in terms of the optimum policy as by an experienced human operator, and even achieve a small saving on the amount of power consumed.

Design parameters phase report and software program

This phase of the project investigated and evaluated existing design parameters relating to storage capacity for balancing draw-off and pumping and emergency storage in the light of the costing model and the design parameters calculated from it. The model determined and proposed in this report is able to assess rapidly various options for a water supply system with regard to service or distribution water storage and conveyance. The research culminated in the computer program Reservoir System Design Optimisation (RSDO).

The optimal design problem was to find the component characteristics (e.g. pipe diameter, pump heads and reservoir volumes) that minimise the total system cost. The capital cost optimisation program – RSDO Version 1.01 – compiled by the Water Systems Research Group is a useful tool now available to the water supply industry in South Africa. By means of this computer tool a rapid assessment of various cost optimisation scenarios involving the optimal sizing of the pumps, pipe diameter and balancing storage can be performed on a standard computer facility.

The capital cost optimisation program provides the individual designer with the costing model and the design parameters calculated from it, thus allowing him to improve the current design methods and also to scrutinise the current design standards.

Cost: *R364 000*
Term: *1996-1998*

Development of a standardised approach to evaluate burst and background losses in water distribution systems in South Africa

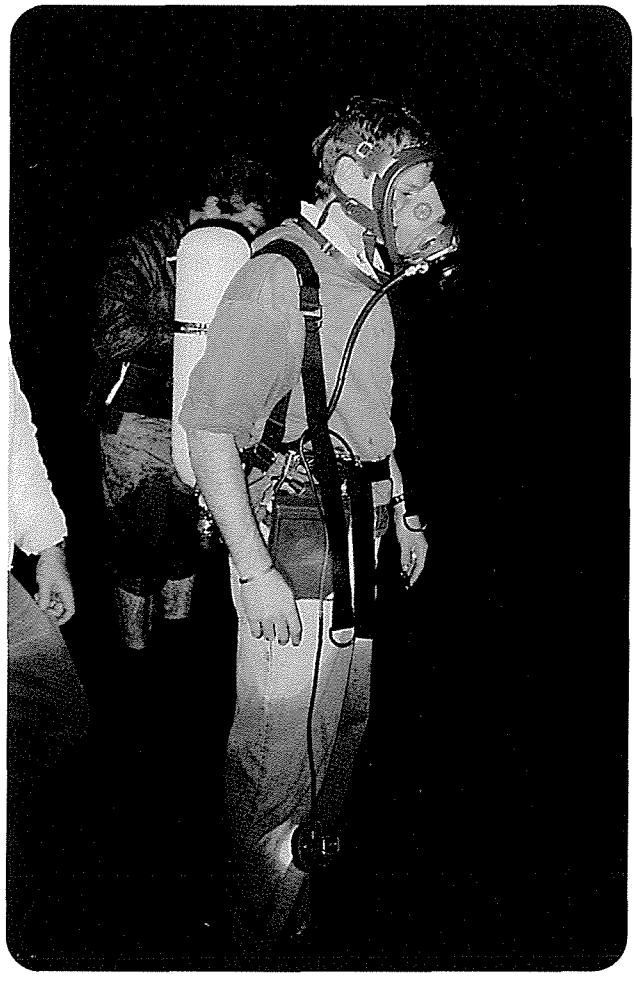
(No 803) BKS (CE) Inc.

The Water Services Act, Act 107 of 1998, requires that water service institutions account for all their water use, and demonstrate that they are taking measures to minimise wastage. The most practical and methodical way of reducing leakage is to implement a proper leakage management programme and the first step to such a programme is the control of bursts.

As early as 1996, the WRC had identified the need to address various issues associated with leakage from water distribution systems, and pro-actively supported this sector by funding research projects on these issues, and the impending draft legislation. This project aimed to develop a new model to assist with the interpretation of nightflow data, based on the United Kingdom's BABE techniques. The result of the study is a user-friendly program called SANFLOW (South African Night Flow Analysis Model), which is an improvement over the other models for this purpose. The availability of SANFLOW and the accompanying guide came at a very opportune time, as it will also be complementing the recently launched SABS 0306 – Code of Practice for the management of potable water distribution systems. SANFLOW is referred to in the Code and will be one of the tools, together with the Water Audit Reporting (WAR) software developed through WRC support and available with the Code, to assist water service institutions in managing unaccounted-for water.

The methodology used in the development of SANFLOW is a systematic diagnostic method, mainly based on test results from the UK and elsewhere in the world. The approach utilised is to determine where losses are located by analysing night flows throughout the systems. This method avoids the time-consuming and expensive task of checking each pipe for leakages, by narrowing the possibilities to leak occurrence to zones. These zones are then subjected to field measurement and testing to locate the leakages, saving time and costs. The program compares calculated nightflow readings with measured nightflow readings over a period of time. The difference is an indication of the level of leakage in the zone. The software is supported by a detailed and comprehensive user guide called *Development of a Standardised Approach to Evaluate Burst and Background Losses in Water Distribution Systems in South Africa* (Report No TT 109/99). Both the guide and software are also available for download from the WRC website http://www.wrc.org.za/software/sanflow.

Cost: *R121 000*
Term: *1997*



Inspection of the nearly 30-year-old RoodeElsberg Tunnel at De Doorns, by members of DWAF, Hex River Irrigation Board and the project team. Christiaan Olivier of the Hex River Irrigation Board is shown in the tunnel with the safety equipment.

New projects

Reduction of urban litter in drainage systems through integrated catchment management

(No 1051) Department of Civil Engineering, University of Cape Town

In **Volume 1** of the final report (Report No 691/1/98) on the project entitled **The removal of urban litter from stormwater conduits and streams**, reference is made to the dearth of information on litter wash-off rates in urban areas, and the need to reduce the quantity of litter that finds its way into stormwater drainage systems. In addition to amounts, more detailed information is required, not only on the source and types of litter encountered in urban catchments, but also on the efficiency of various catchment management techniques to ensure a reduction in urban litter reaching drainage systems.

Further research in the above regard was strongly supported at a workshop in March 1998. In 1991 it was estimated that 780 000 t of litter annually enter drainage systems in South Africa, and at a current removal cost of approximately R1 000/m^3, it amounts to a total annual cost of R780 m. Ways to reduce litter loadings through better management are, therefore, urgently required – not only from a cost point of view, but also as far as its negative impact on the environment is concerned.

This project will be focusing on the above-mentioned needs, and has the potential to drastically reduce urban litter pollution in streams, resulting in considerable cost savings to local authorities. Against this background the project addresses the following aims:

(i) To improve the knowledge of the source type and amount of urban litter coming from different types of urban catchments

(ii) To provide scientific data on the efficacy of various management techniques in reducing the amount of urban litter reaching drainage systems. This information, together with that of aim (i), would enable the development of Litter Management Plans (LMPs) resulting in reduced litter loadings and realising considerable cost savings.

The project will be executed in partnership with the Cape Metropolitan Council which will be contributing to installation costs of the various litter removal structures.

Estimated cost: *R690 000*
Expected term: *1999-2002*

Hydraulic analysis of tunnel ageing and possible remedial measures

(No 1088) Ninham Shand (CE) Inc.

During 1997 the WRC accepted the final report on Project No 579, entitled **Hydraulic roughness of tunnels bored by machine through various rock-types**, a project which contributed significantly to the technology available for friction factor determination in machine-bored tunnels. In March 1998, during a workshop on the Research Needs in the Field of Hydraulics, *inter alia* the effects of tunnel ageing on friction factors and the delivery capacity of tunnels under conditions of ageing, were identified as issues requiring further research attention.

Concrete-lined tunnels could lose as much as 20% of their hydraulic capacity over a period of 30 years due to ageing. Recent commissioning tests of the LHWP transfer and delivery tunnels confirmed the adequacy of the currently available knowledge of the hydraulic roughness of new tunnels. There is, however, a need for a better understanding of the tunnel ageing process in order to plan for future tunnelling requirements as water demands increase.

This project addresses the above issues, and should provide more accurate information in this regard, thereby allowing more acceptable provision for these effects during the design of these tunnels, thus ensuring acceptable performance for longer periods of time. In addition to the above, the project also aims to establish whether remedial measures, e.g. flushing and mechanical cleaning, could be implemented to reverse the tunnel ageing process.

It needs to be mentioned that DWAF (for maintenance purposes) worked on the Orange-Fish Tunnel during 1999, thereby providing an ideal opportunity for facets of this project. In addition the Department is also making a contribution to cover part of the expenses of the project.

Estimated cost: *R280 000*
Expected term: *1999-2000*

Sediment transport through hydraulic structures in rapidly varied channel flow

(No 1098) Department of Civil Engineering, University of Cape Town

In almost all water-source developments, the impact of human intervention is unavoidable. These structures may give rise to additional sediment in the water through induced scouring, or may require prevention of sedimentation by keeping the sediment in suspension, or may result in deposition of sediment, thereby causing new or additional problems in e.g. reservoirs and estuaries. These problems, together with others related to sediment properties and sediment transportation, have been identified as high research priorities at a workshop on Research Needs in the Field of Hydraulics.

This project aims to address the prediction of sediment movement in and around man-made structures, particularly where the flow has significant components in all three dimensions. For various reasons most theoretical analyses of sediment transport approach the problem from a one-dimensional point of view. In those cases requiring analyses from two- or three-dimensional perspectives, semi-empirical or probabilistic equations are being used, often for situations where the conditions of these equations are not altogether being met. Furthermore, those numerical models available for three-dimensional flow patterns are very data-intensive and require substantial expertise and funds to run.

Against this background the project will be addressing the following objectives:

- Investigate the use of the stream-power approach as a method to conceptualise, and subsequently model, the movement of sediment through abrupt changes in channel sections
- Develop a simplified design methodology for use by practitioners concerned with the movement of sediment through hydraulic structures located on open channels.

Estimated cost: *R440 000*
Expected term: *1999-2002*

Hydraulics of the impacts of dam development on the river morphology

(No 1102) Department of Civil Engineering, University of Pretoria

Utilisation of a man-made structure, such as a dam, is very often unavoidable in water-source developments. The impact of the dam is that it alters the river flow regime and with it the sediment transport characteristics, thereby resulting in changes in the river morphology and the river's conveyance capacity.

Both of these factors affect the aquatic habitat of the river. Under regulated flow conditions as a result of a dam, removal of fine sediment through flushing flows does not occur – flows that are very important for the maintenance of several characteristics of the river channel. Flushing flows, one of the facets of in-stream flow requirements (IFRs), has up to now not received adequate attention from a fundamental hydraulics point of view.

Flushing flows are important for a number of reasons. In addition to maintaining a suitable fishery habitat, maintenance of channel geometry and riparian vegetation, formation of pool areas and retention of adequate habitat heterogeneity, are all dependent on the occurrence of flushing flows of the required intensity and frequency. Current methodologies for the determination of the IFR of a river do not fully utilise acceptable hydrodynamic approaches based on sound theory of sediment transport.

The main objective of this project is thus to obtain a better understanding of the river sediment transport processes and the impacts of dam construction thereon. From this will emanate a methodology for determining flushing flow magnitudes, duration and frequency, thus ensuring maintenance or restoration of river morphology as close as possible to natural or desired conditions. In this regard fundamental hydraulic principles of sediment transport will play a very important role.

This project also emanates from the Workshop on Research Needs in the Field of Hydraulics which took place in March 1998. This workshop identified, *inter alia*, flushing flow IFR, river morphology, river restoration, sediment "management" and computational hydraulics as high priorities in hydraulics research.

Estimated cost: *R660 000*
Expected term: *1999-2002*

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Research projects

Completed

- **643** Development of rigorous engineering methodology for designing vegetative erosion protection systems: Phase 2 (SRK (CE) Inc.)
- **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)
- **803** Development of a standardised approach to evaluate burst and background losses in water distribution systems in South Africa (BKS (CE) Inc.)

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)
- **910** Monitoring reservoir-induced crustal deformation using satellite-borne interferometric imaging radar (University of Cape Town - Department of Electrical Engineering)
- **911** Sediment-induced density current formation in reservoirs (University of Pretoria – Department of Civil Engineering)
- **979** Hydraulic characteristics of ecological flow requirement components in winter rainfall rivers (University of Stellenbosch – Department of Civil Engineering)
- **980** Measurement of high flows in rivers (Sigma Beta (CE))
- **985** Development of a stochastic technique for the optimisation of pipe and reservoir systems (Rand Afrikaans University – Department of Civil and Urban Engineering)

New

- **1051** Reduction of urban litter in drainage systems through integrated catchment management (University of Cape Town – Department of Civil Engineering)
- **1088** Hydraulic analysis of tunnel ageing and possible remedial measures (Ninham Shand (CE) Inc.)
- **1098** Sediment transport through hydraulic structures in rapidly varied channel flow (University of Cape Town – Department of Civil Engineering)
- **1102** Hydraulics of the impacts of dam development on the river morphology (University of Pretoria – Department of Civil Engineering)

17 Research support services

WATERLIT

The year 1999 was one of the most important years in the 24-year-long history of the WATERLIT bibliographic database. Not only did the number of references in the database exceed the 300 000 total, but a whole new system for database building and management was implemented.

During the past 24 years the CSIR was contracted by the WRC to build, maintain and store this unique South African database. Since 1 July 1999, that responsibility has now moved to the WRC. A network of indexers, working in different parts of the country, is used to access and process information available at co-operating libraries. By implementing this system, access to a wider range of publications has became possible, while the savings in database building cost will also be considerable.

Since Internet access to the database was implemented during April 1998, the number of subscribers to the service has been growing at a steady pace, and currently the number of subscribers is fast approaching the 1 000 mark. New subscribers are invited to consult the experts at the WRC if they experience problems in retrieving the desired information from WATERLIT, especially for more complex literature searches.

Internationally, the database is still published by NISC on CD-ROM and copies have been sold to a wide range of local and international academic and government institutions. A subset of WATERLIT covering references to Africa health-related publications, has been packaged as part of a new CD-ROM published as the African Health Anthology by NISC.

Computing Centre for Water Research (CCWR)

The Computing Centre for Water Research (CCWR) was established jointly by the WRC, IBM South Africa and the University of Natal in 1986 and has been supported by the WRC since that time. The WRC views the CCWR as a strategic initiative to support four key elements of the WRC's overall strategy which is to:

- 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 technological knowledge.

These strategic actions provide considerable support for the basic thrust of the New Water Act namely efficient, equitable and ecologically sound management of SA's water resources. Integrated water resource management is one of the key principles of the new Water Act. The WRC's continued support for the CCWR is testimony to its commitment to promote integrated water science as an essential foundation for integrated water resource management.

South Africa has a number of world-class water scientists and their supporting groups. However, they are separated geographically, organisationally and in terms of their disciplines. This separation has both advantages and disadvantages because these experts need to specialise but at the same time they also need to integrate their highly complex, multi-faceted and interdependent fields of water science. The CCWR's activities are one of the many actions which the WRC supports in order to creatively and cost-effectively minimise the disadvantages and maximise the advantages of the geographic separation of our limited scientific intellect. The incredible growth in wide area computer networking technology has enabled the WRC to create a virtual centre, in the CCWR, where intellect from throughout Southern Africa and indeed the world can interact to co-create new perspectives which in turn lead to more effective actions in the equitable and sustainable use of our water resources.

Effective actions are certainly required in the management of water issues in Southern Africa. Fully 70% of the land area in the Southern African Development Community (SADC) is comprised of shared river basins. There is thus a need to broaden participation and thereby democratise the process of integrated water resource management for sustainable water resource development. This need is fundamental to peaceful, holistic and equitable progress in Southern Africa, a region so racked with conflict and riven with inequalities which exacerbate the already complex situation surrounding the sustainable development of scarce water resources.

The region has come through the era's of "getting more water" and "using water more efficiently" and these issues are still important. However, we have now entered the "era of allocation" and allocation is a social process. The WRC's foresight in developing the CCWR is now really beginning to pay off as communication, transparency, trust and relationships begin to be vital in underpinning the drive for equity and the smooth implementation of the New Water Act, particularly insofar as processes which will lead to the upliftment

of previously disadvantaged communities is concerned.

The social process of democratising the wise and equitable allocation of water resources requires, *inter alia*, a knowledge of water resource systems by participants. In a rights-based bargaining paradigm which characterised the Old Water Act this gave an unfair advantage to those with the intellectual resources. Under the New Water Act and given the uncertainty which dominates water resource issues an interest-based bargaining paradigm is emerging. Under such a paradigm the State plays the role of coach and facilitator and also referee to ensure equity within the framework of bargaining. What is particularly helpful to the disadvantaged under this paradigm is the behaviour of the stronger parties towards the weaker parties. World-wide evidence in many industries has shown that the stronger parties spend some of their resources uplifting the weaker into a more informed bargaining position. Through this and also the self-policing mechanism of interest-based bargaining the State is freed up to put more resources into upliftment and the monitoring of equity and delivery.

The WRC's initiative to develop integrated scientific endeavours through the improved communication and simulation modelling which the CCWR supports, has meant that the cause of interest-based bargaining and hence delivery to previously disadvantaged communities has been considerably enhanced.

The CCWR's small staff of 6 professionals serves the on-line, medium- and long-term needs of more than 300 registered users who are based at no fewer than 103 departments within 68 institutions. In addition to the service role implied above, the CCWR is partnering several innovative and highly relevant endeavours to serve future catchment management agencies and stakeholder groupings with systems software.

Research support services

Current

- **K 6/1** Ongoing development and maintenance of the WATERLIT bibliographic database (CSIR – Division of Information and Communications Technology) (until 30 June 1999); now WRC Internal Project No W1)
- **K 6/3** Computing Centre for Water Research (University of Natal – CCWR)
- **912** An archiving system for research projects on crop water-use systems (NB Systems)

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18 Information services (IS) and 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, to which has now been added the Information Services (IS) group, located at the WRC. 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.

Information services (IS)

The WRC on the Internet

Keeping up with international trends, the WRC is using its website more and more as an effective way to make information available to users in all parts of the world. During 1999, the WRC's website was regularly enriched and updated while outdated information was removed to maintain the website's relevancy. Not only are details of the organisation provided, but titles of all new WRC research reports are announced regularly. A special feature of the current website is that several computer programs and models (resulting from WRC research projects) may now be downloaded from the website. As was mentioned under the previous section of this report, the offer of free access to the WATERLIT bibliographic database via the WRC's website has attracted a considerable number of database users.

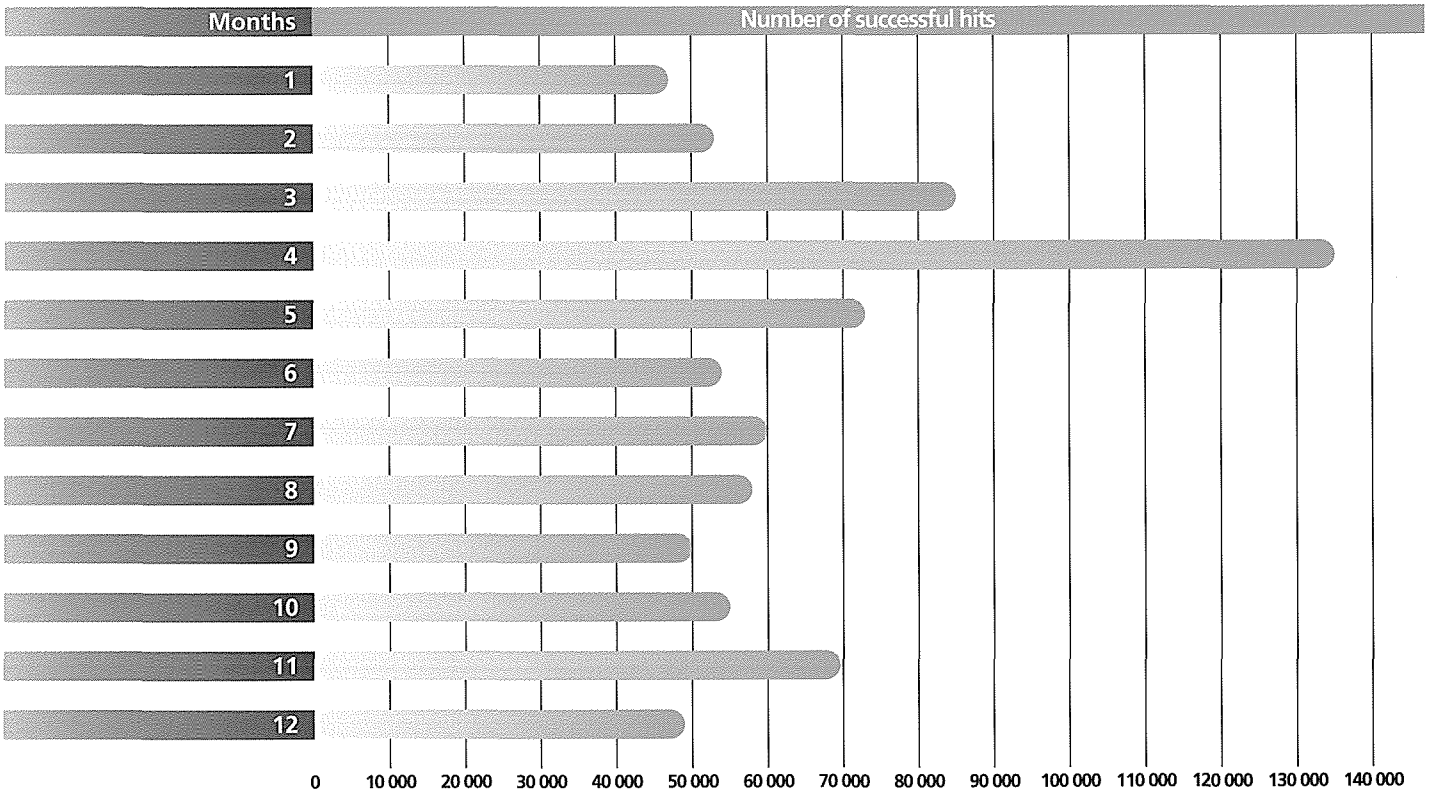
Also published on the website, are the full text versions of the two regular WRC publications, *Water SA* and the *SA Waterbulletin*, as well as the *WRC Annual Technical and Parliamentary Reports*. The proceedings of two international conferences organised by the WRC were also published on the web.

The research proposal submission previously installed on the organisation's website was completely revised and improved for the submission of proposals during April 1999, resulting in a peak in visitor numbers experienced during that period!

The number of visitors to any organisation's website serves as a good measure of the interest generated internationally by such a website. During the past year, the number of visitors has grown at a healthy rate as is indicated below. Of special interest is the fact that more and more visitors from other countries are visiting the website.

Web address: http://www.wrc.org.za

Visits to WRC website during 1999



Computer network management

During the past year, computer hardware and software at the WRC were constantly upgraded, resulting in a hugely improved and functional network system. The appointment of a new service provider reduced downtime in the Internet connection considerably.

During 1999, a considerable amount of time and effort were spent to ensure that all the computer equipment and programs used by the WRC are Y2K compliant. Where needed, non-compliant equipment was replaced.

Since the WRC produces and receives an exceptionally high number of documents annually (letters, faxes, minutes of committee meetings, draft and final reports, etc.), the network manager is currently evaluating several electronic document management software programs for implementation at the WRC. Such a system will obviously occupy less space and will provide the WRC with a system for easy management and retrieval of documentation at the WRC.

Intranet

The WRC Intranet was launched in early October 1999, offering WRC staff the facility to consult internal policy documents and other official documentation from their desk tops. Links to a wide range of interesting and useful local and international websites have also been installed.

Brochures

Marketing research results and products resulting from WRC-funded research, has become an important task, and much has been achieved in this regard during 1999. Two sets of colourful brochures, providing information about the WRC's functions and activities, as well as on the WATERLIT bibliographic database, were published. These brochures are distributed to conference delegates, visitors and are also used on overseas visits.

Exchange agreement with the FWR

During 1999 the WRC entered into an agreement with the Foundation for Water Research (FWR) in the United Kingdom, providing for an exchange of research reports published individually by the two organisations. The FWR has set aside part of their website to list new research reports issued by the WRC, and has also added an electronic order form to forward orders for WRC reports directly to the responsible person at the WRC.

The 3rd Ministerial Conference on Health and Environment

To draw attention to their co-operation with international research organisations, the FWR in the United Kingdom invited the WRC to share an exhibition space during the 3rd Ministerial Conference on Environment and Health which was held during June 1999 in London. The theme of the conference was "Action in Partnership" and the event was attended by some 70 ministers and over1 000 participants from 51 countries of the World Health Organisation European region. A set of posters, illustrating the functions and activities of the WRC were developed locally and couriered to the UK, together with WRC brochures and copies of selected WRC research reports.

IWEX

The International Water and Effluent Treatment Exhibition (IWEX) was held from 19 to 21 October 1999 in Birmingham, England. The FWR also exhibited at this event, again using the same set of posters and other promotional material provided by the WRC.

The Delft Water Week

The cities of Delft, the Netherlands, and Pretoria have formally been declared as "sister cities". In this respect, the city of Delft invited Pretoria to participate in their annual Water Week from 4 to 9 October 1999. A representative of the City Council of Pretoria contacted the WRC and subsequently attended this happy event, armed with copies of the WRC brochures.

Water projects database

In an attempt to keep track of research undertaken in South Africa on all water-related subjects, a database providing information on such projects has been developed and made available for free access on the Internet. Annually, details of all new WRC projects are added to the database, and other research and funding organisations are invited to provide details of their own research projects for inclusion into the database. At this stage, projects are listed on the Internet according to specific subject fields, but it is planned to install a database search facility to allow for easy retrieval of information.

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. In 1999 64 articles were published in *Water SA* by a total of 159 authors.

Water SA has an extensive local as well as overseas readership. Currently there are 3 418 subscribers to *Water SA* of whom 895 are abroad. It also enjoys world-wide coverage by all the major international abstracting services who publish and distribute summaries of articles which appear in *Water SA*.

Since 1997 the full text version of the journal is also available on the Internet via the WRC website (http://www.wrc.org.za).

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 WRC publications

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1999 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.

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Annexure

Publications emanating from research financed wholly or partially by the WRC

This Annexure contains a list of publications released in 1999, as well as a complementary list of 1998.

Requests for articles and papers should be directed to the authors.

Developing communities

Articles and papers (1999)

- Blight GE and Fourie AB (1999) Leachate generation in landfills in semi-arid climates. *Proc. of the Inst. of Civil Eng., Geotechn. Eng.*
- Blight GE, Fourie AB, Shamrock J, Mbande C and Morris JWF (1999) The effect of waste composition on leachate and gas quality: A study in South Africa. *Waste Manage. and Res.* **17** (2) 124-140.
- Blight GE, Fourie AB, Shamrock J, Mbande C and Morris JWF (1999) The effect of waste composition on leachate and gas quality: A study in South Africa. *Waste Manage. and Res.* **17** 124-140.
- Botha ME, Vivier JC, Webber LM, Grabow WOK and Clay CG (1999) Enteroviral infections: How many cases are we missing? Poster presentation at Lesedi Africa '99 Congr. 21-24 November.
- Cain J (1999) Case study of a management system for rural water supply: Matatiele case study. Paper presented at Feedback Workshop to Communities and Local Roleplayers. September.
- Cain J (1999) Case study – Institutional arrangements in the Eastern Cape. Paper presented at Appropriate Practice Conf., East London. March.
- Cain J (1999) Partnerships: Community management and local government. Paper presented at Water Eng. and Development Conf., Addis Ababa. September.
- Cain J (1999) Presentation of findings to Wild Coast District Council and Matatiele TRC. September.
- Coetzee MAA (1999) The removal of nitrogen from ventilated improved pit latrine systems. Paper presented at the Afr. Int. Environ. Protection Symp., Pietermaritzburg. 4-8 July.
- Dreyer L (1999) The dynamics of community non-compliance with basic water supply projects. Workshop on the Develop. of a Natl. Strategy on Water Conservation and Water Demand Manage., Namibia. 8-9 September.
- Dreyer L (1999) Willingness to pay: Community non-compliance with basic water supply projects. Appropriate Practice Conf., East London. 14-17 March.
- Duncker LC (1999) Hygiene awareness in rural communities in South Africa. Paper presented at Water Eng. for Developing Countries Conf., Ethiopia. September.
- Duncker LC (1999) Hygiene in rural areas in the poor provinces of South Africa. Paper presented at Appropriate Practices Conf., East London. March.
- Erasmus B, Botma K, De Villiers JC, Vrey A, Vivier C, Uys M, Van der Watt E, Cox N, Clay CG and Grabow WOK (1999) Detection of enteric viruses in recreational waters by the polymerase chain reaction. Paper presented at Faculty Day, Fac. of Med., Univ. of Pretoria. 25 August.
- Fourie AB, Blight GE and Pinheiro J (1999) Subsurface contamination by leachate at six unlined landfill sites in South Africa. Paper presented at 7th Int. Waste and Landfill Symp., Sardinia, Italy. 4-8 October.
- Fourie AB, Röhrs LH and Blight GE (1999) Evaluating the increased risk of leachate generation resulting from co-disposal of sewage sludge in a municipal solid waste landfill in a semi-arid climate. *Waste Manage. and Res.* **17** 27-36.
- Grabow WOK, Taylor MB, Clay CG and De Villiers JC (1999) Molecular detection of viruses in drinking water: Implications for safety and disinfection. Poster presentation at the 2nd Conf. of the Int. Life Sci. Inst.: The Safety of Water Disinfection: Balancing Chemical and Microbial Risks. Radisson Deauville Resort, Miami Beach, Florida, USA. 15-17 November.
- Grabow WOK, Uys M (1999) Phages gain ground as water quality indicators. *Water 21* (Magazine of the International Water Association) November-December. 36-37.
- Grobicki A (1999) Urban catchment management: Case study on the Great and Little Lotus Rivers, Cape Town. Paper presented at Swedish Int. Programme on Manage. of Groundwater for Urban Areas, CSIR, Stellenbosch. 25-26 March. Also at Seminar at the Dept. of Chem. Eng., Univ. of Cape Town, 7 May; and at Seminar at the Dept. of Environ. and Geograph. Sci., Univ. of Cape Town, 1 June.
- Jagals P, Bokako TC and Grabow WOK (1999) Changing consumer water-use patterns and their effect on microbiological water quality as a result of an engineering intervention. *Water SA* **25** (3) 297-300.
- Matika S and Grobicki A (1999) Participatory urban catchment management and its role in urban development. Paper presented at the Inst. of Commonwealth Studies Conf. South to South: Urban-Environmental Policy and Politics in Brazil and South Africa, London. March.
- Morris JWF (1999) Validation of a system for measurement of landfill gas emissions by means of a test bed. *Proc. 3rd Conf. on Environ. Eng.*, Kwa-Maritane. May. 13 pp.
- Morris JWF, Fourie AB, Blight GE and Mistry P (1999) Greenhouse gas emissions from landfills in semi-arid climates: A field study in South Africa. Paper presented at 7th Int. Waste Manage. and Landfill Symp., Sardinia, Italy. 4-8 October.

- Müller EE, Clay CG and Grabow WOK (1999) Detection and isolation of *Escherichia coli* O157:H7 from sewage and environmental waters using immunomagnetic separation. Paper presented at Faculty Day, Fac. of Med., Univ. of Pretoria. 25 August.
- Murphy KO'H (1999) A comprehensive regulatory process for land-application on effluents: Does South Africa need one? Paper presented at the Afr. Int. Environ. Protection Symp. (AIEPS'99), Pietermaritzburg. 4-8 July.
- Murphy KO'H (1999) Effluent treatment using soils and vegetation: A potentially cost-effective approach to mitigating impact on water resources. Paper presented at the Industrial Water Manage. Conf., Sandton Crowne Plaza Hotel, Johannesburg. 26 May. Hosted by the Institute of International Research.
- Olivier J (1999) Fog water harvesting. National Community Water and Sanitation Training Institute Workshop, Sovenga. 20 July.
- Vivier JC, Clay CG, Botha ME and Grabow WOK (1999) Molecular typing of enteroviruses. Poster presentation at Lesedi Africa '99 Congr. 21-24 November.

Articles and papers (1998)

- Dreyer L (1998) The dynamics of community non-compliance with basic water supply projects. DWAF Information Session for Social Consultants, King William's Town, 22 July; also to District Councils, Implementing Agents, Social and Civil Consultants, King William's Town, 5 November.
- Duncker LC (1998) Gender in water supply. Paper presented at the S. Afr. Soc. for Cultural Anthropol. Conf., Pretoria. September.
- Louw C, Van Heerden J and Olivier J (1998) Prediction of orographic clouds (high elevation fog) along the eastern escarpment of South Africa through discriminant analysis. Paper presented at Conf. on Fog and Fog Collection, Vancouver. July.
- Louw C, Van Heerden J and Olivier J (1998) The South African fog-water collection experiment: Meteorological features associated with water collection along the eastern escarpment of South Africa. *Water SA* **24** (4) 269-280.
- Olivier J (1998) A high elevation fog water collection experiment in South Africa. Paper presented at Conf. on Fog and Fog Collection, Vancouver. July.
- Olivier J (1998) Fog water harvesting in South Africa. *Strategic Insights, Environmental Issues* **3** (2). Inst. for Future Res., Univ. of Stellenbosch, Bellville.

Reports (1999)

- Cain J, Ravenscroft P and Palmer I (1999) Case Study of Management System for Rural Water Supply: Matatiele District, February 1998. WRC Report No 895/1/99.
- Du Preez M and Gericke M (1999) Occurrence and Survival of Protozoan Parasites in Source Water Used by Unserved Rural Communities. WRC Report No 685/1/99.
- Genthe B and Franck M (1999) A Tool for Assessing Microbial Water Quality in Small Community Water Supplies: An H_2S Strip Test. WRC Report No 961/1/99.
- Hazelton DG and Harris J (1999) Pilot Study for Collection and Use of Data on Rural Village Water and Sanitation in SA. WRC Report No 710/1/99.
- Kelbe B and Germishuyse T (1999) A Study of the Relationship Between Hydrological Processes and Water Quality Characteristics in the Zululand Coastal Region. WRC Report No 346/1/99.
- Pearson I and La Trobe B (1999) Co-disposal and Composting of Septic Tank and Pit Latrine Sludges With Municipal Refuse. WRC Report No 599/1/99.
- Wright A (1999) Guidelines for the Use of Septic Tank Systems in the South African Coastal Zone. WRC Report No TT 114/99.

Report (1998)

- Westaway MS (1998) Determining Personal and Domestic Health and Hygiene Knowledge, Attitudes and Behaviour: A Pilot Study. WRC Report No KV 106/98.

Theses

- Botma KL (1999) Studies on Methods for Increasing the Susceptibility of Cell Cultures to Enteric Viruses. M.Sc. (Med. Virol.) Thesis, Dept. of Med. Virol., Univ. of Pretoria.
- Uys M (1999) Molecular Characterisation of F-Specific RNA Phages in South Africa. M.Sc. (Med. Virol.) Thesis, Dept. of Med. Virol., Univ. of Pretoria.

Potable water supply

Articles and papers (1999)

- Breet E, Janse van Rensburg S, Steenkamp C, Van Wyk F and Van Wyk M (1999) Novel supercritical fluid based processes for industry and environment. Poster presentation at Inorganic '99, Stellenbosch. 17-20 January.
- Breet E, Steenkamp C, Van Wyk M, Van Zyl P, Viertel J and Zölfl C (1999) Novel supercritical carbon dioxide based processes for industry and environment. Paper presented at 5th Int. Conf. on Carbon Dioxide Utilisation, Karlsruhe. 5-10 September.
- Cloete V, De Villiers D, Engelbrecht WJ and Wessels GFS (1999) Photocatalytic treatment of humic substances in raw natural water destined for drinking purposes. Paper presented at 4th Int. Conf. on TiO_2 Photocatalytic Purification and Treatment of Water and Air, Albuquerque, New Mexico, USA. May.

- Coetzee PP (1999) The effect of electromagnetic fields on interfacial interactions in physical water treatment. Paper presented at Seminar, Dept. of Phys., Rand Afrikaans Univ. August.
- Coetzee PP (1999) The role of zinc in physical water conditioning. Paper presented at 3rd Int. Meeting on Antiscale Treatment and Physical Conditioning, Cranfield Univ., UK. April.
- De Villiers D, Engelbrecht WJ, Shephard GS, Stockenström S and Wessels GFS (1999) TiO_2S immobilization on fibrous activated carbon sheet modules in a falling film photocatalytic reactor. Paper presented at 4th Int. Conf. on TiO_2 Photocatalytic Purification and Treatment of Air, Albuquerque, New Mexico, USA. May.
- Engelbrecht WJ, Cloete V, De Villiers D, Niewoudt TW and Wessels GFS (1999) Novel photocatalytic reactors for water treatment. Paper presented at CNRS/CSIR/WRC Workshop on Water Issues, Pretoria. July.
- Mackintosh G and Toerien D (1999) Limestone mediated stabilisation of soft, acidic waters. *Water21* (July/August).
- Mackintosh GS, De Villiers HA, De Souza P and Callaghan BC (1999) Small systems water supply: Corrosion mitigation considerations. Paper presented at 14th Int. Corrosion Congr., Cape Town. 30 September.
- Momba M, Venter F, Kfir R and Cloete TE (1999) Examination of the behaviour of *E. coli* in biofilms established in laboratory-scale units receiving chlorinated water. *Water Res.* **33** (13) 2937-2940.
- Ringas C, Ramotlhola JS and Cromarty R (1999) Exposure of generic coating systems in South African dam waters. Paper presented at 14th Int. Corrosion Congr., Cape Town. 26 September – 1 October.
- Shephard GS, Stockenström S, De Villiers D, Engelbrecht WJ, Sydenham EW, Thiel PG and Wessels GFS (1999) Photocatalytic degradation of cyanobacterial microcystin toxins in water. Paper presented at 4th Int. Conf. on TiO_2 Photocatalytic Purification and Treatment of Water and Air, Albuquerque, New Mexico, USA. May.
- Slabbert JL and Venter EA (1999) Biological assays for aquatic toxicity testing. *Water Sci. Technol.* **39** (10-11) 367-373.

Articles and papers (1998)

- Mackintosh GS, De Villiers HA and Loewenthal RE (1998) The development of a novel process for the stabilisation of aggressive, corrosive waters using limestone in a sidestream process. Poster presentation at IAWQ Bi-annu. Conf., Vancouver, Canada.

Reports (1999)

- Bondonno A, Ringas C, Ramotlhola J and Prinsloo C (1999) Microbial Corrosion of Common Piping Materials in the PWV Area. WRC Report No 432/1/99.
- Genthe B and Rodda N (1999) Application of Health Risk Assessment Techniques to Microbial Monitoring Data. WRC Report No 470/1/99.
- Grobicki A and Cohen B (1999) Water Reclamation for Direct Reuse in Urban and Industrial Application in SA and its Projected Impact Upon Water Demand. WRC Report No KV 118/99.
- Grundlingh JA, Nel C, Kotze E and De Wet CME (1999) Biodegradable Compounds and Microbial Regrowth in Water. WRC Report No 541/1/99.
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Mission statement

To contribute effectively to the best possible quality of life for the people of South Africa, and to the protection of the water environment, by promoting water research and the application of research findings.

Therefore, the WRC endeavours dynamically and purposefully to:

- *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.*