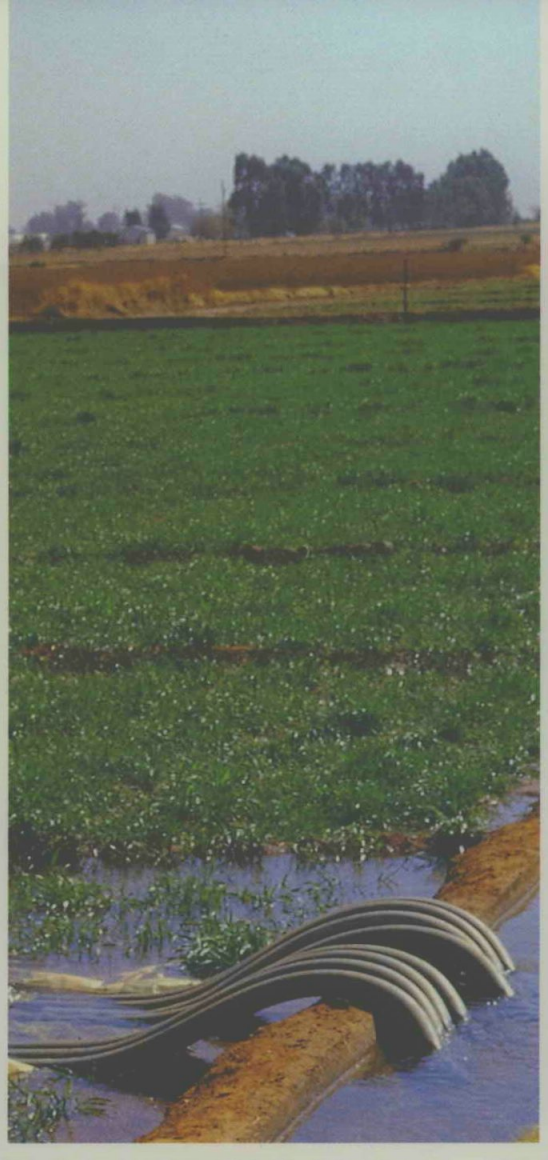

TECHNICAL REPORT

1998

WATER
RESEARCH
COMMISSION

Technical Report
1998

WATER RESEARCH COMMISSION

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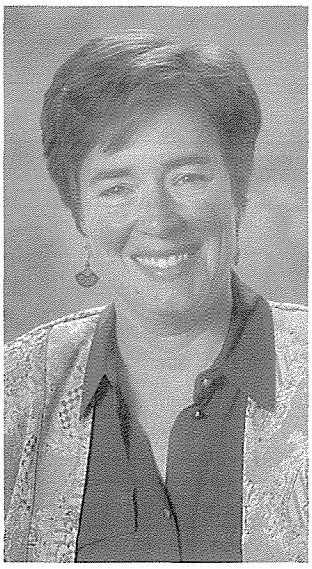

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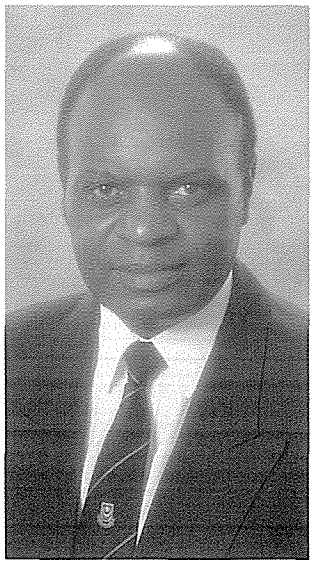

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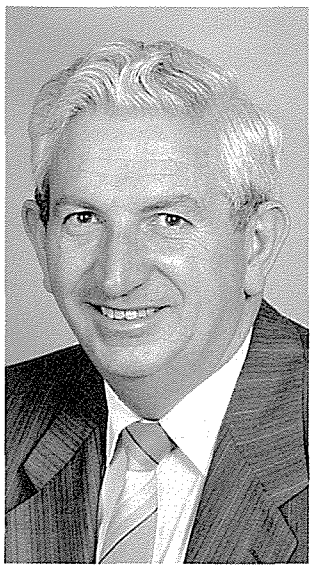

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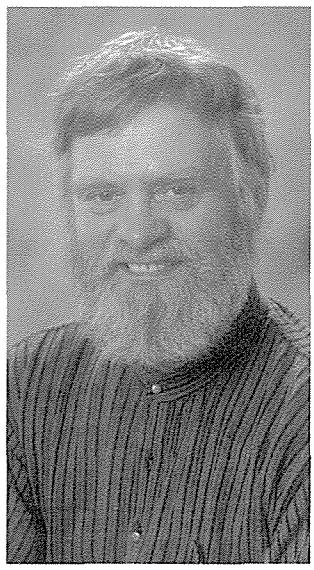

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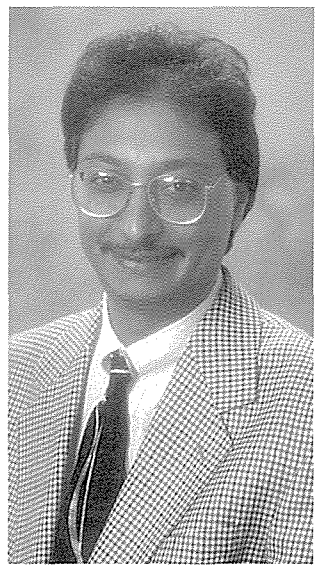

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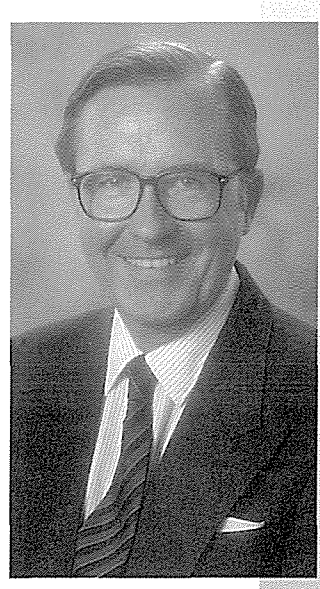

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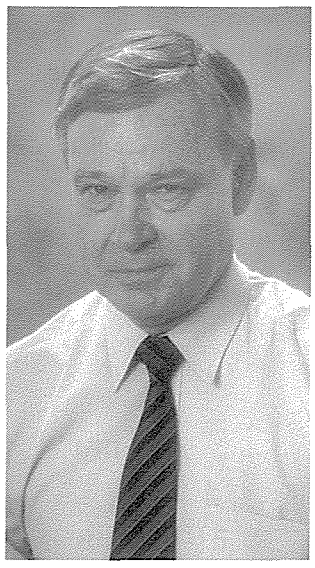

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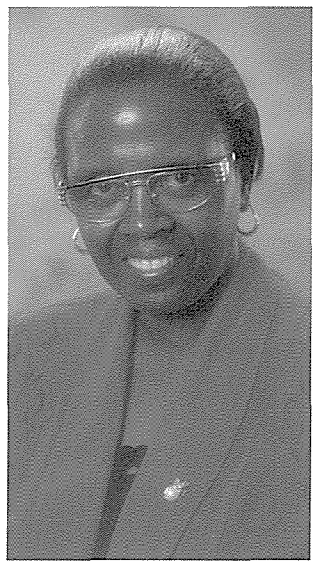

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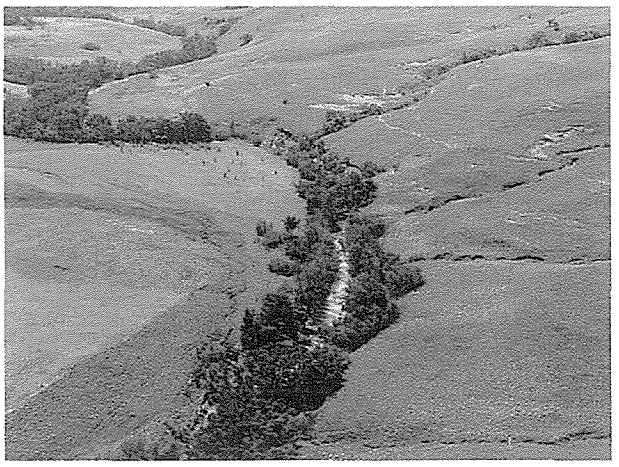


The diverse number of research fields supported by the Water Research Commission (WRC) bears testimony to its multidisciplinary approach to water research.

Table 1

Research sector	Number of times involved	%
Universities	145	52.2
Consultants	63	22.7
CSIR	35	12.6
Water boards	13	4.7
ARC	9	3.2
Government departments	4	1.4
Other	4	1.4
Technikons	3	1.1
Local authorities	2	0.7
TOTAL	**278**	**100**

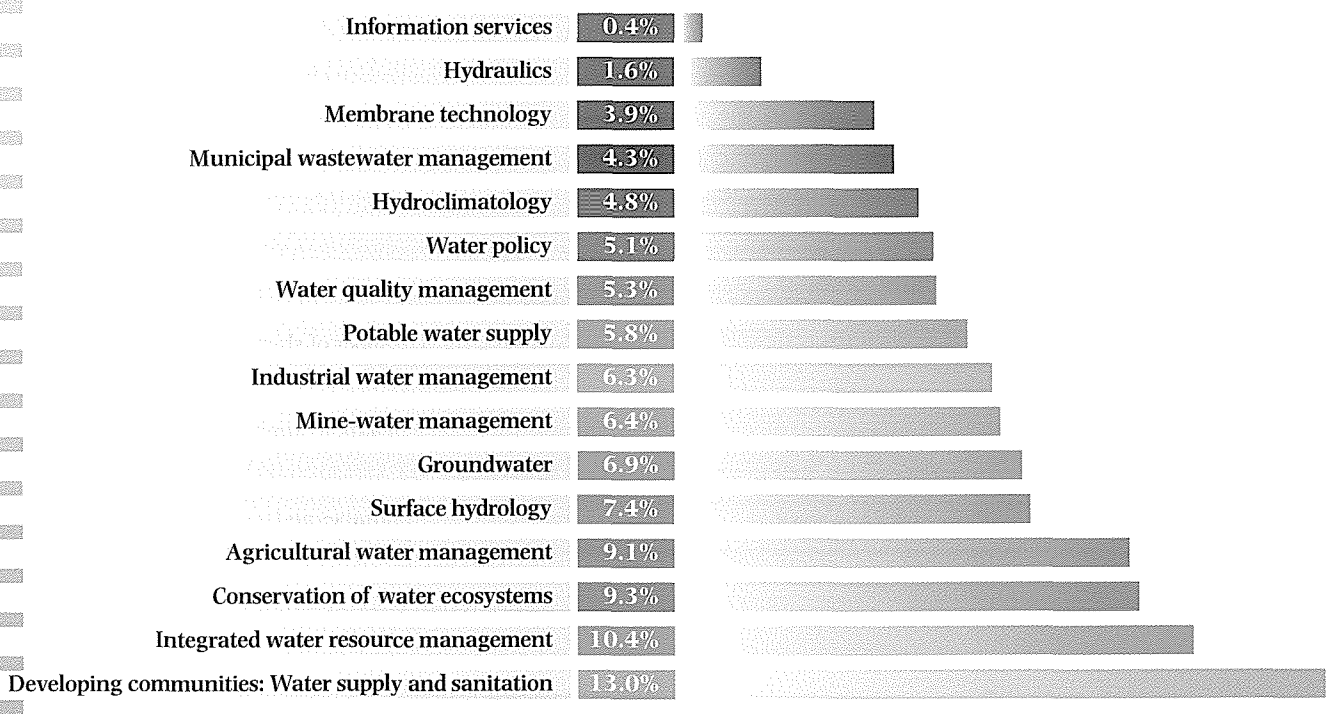
The research fields and allocation of funds to the various fields for 1998 are indicated in Figure 1.

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 52.2% of the total number of contracts. The number of times that organisations are involved, namely 278, exceeds the number of projects supported, for the reason that more than one organisation is, in certain cases, involved in the execution of a project. In 1998 the WRC financially supported 275 projects at a budgeted amount of R44 458 736.00.

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.

Figure 1: Allocation of funds (%) per research field during 1998



Institutional arrangements for water supply and sanitation services

During 1998, the WRC initiated several research projects that address the capacity-building needs of local authorities, rural councils and district councils. This research will produce guidelines for institutional arrangements and support facilities which are necessary to ensure sustainable rural water supply services.

The research output will materially contribute to the successful implementation of the Water Services Act.

Evaluation of on-site sanitation from a socio-economic perspective

The WRC contracted Bernhardt Dunstan and Associates to evaluate on-site sanitation systems from a socio-economic perspective. The study concluded that in all three case study areas, communities were dissatisfied with their on-site sanitation systems.

Women were particularly unhappy about being excluded from decision-making on the selection of sanitation technologies, because as managers of households, they are in a better position to select a sanitation system that is affordable, appropriate and socially acceptable.

The study recommended that local authorities should be assisted to utilise computer-based financial modelling programs so that they could calculate capital and operating costs and assess affordability of any sanitation system to both the end-user and local authorities.

Septic tank effluent drainage (STED) systems

The CSIR, through its Division of Building Technology, was contracted by the WRC to evaluate STED systems in South Africa, and to develop operation and maintenance guidelines. The results showed that with proper design, operation and maintenance, STED systems offer a cheaper alternative for meeting the sanitation needs of communities who want an intermediate level of service, but with the same convenience as a full water-borne system. Two guideline documents were published:

- *Operation and Maintenance of Solids-Free Sewer (SFS) Systems in South Africa: Guidelines for Engineers* (WRC Report TT 97/98)
- *Solids-Free Sewer (SFS) Systems in South Africa: A Community Leader's Guide* (WRC Report TT 96/98).

Courses on latest developments in leakage management

The WRC, in association with WRP (Pty) Ltd. and the SAICE, hosted four one-day courses on leakage management at different centres in South Africa. The objectives of the courses were to introduce the latest developments in the leakage management field. For this purpose, experts from Bristol Water, UK, were invited to make presentations together with local experts. A key and substantial element of the programme was the introduction of a number of research outputs emanating from WRC initiatives in the area of leakage management, these being:

- The Water Audit Reporting Process (which will become part of of the SABS *Code of Practice on Management of Distribution Systems*)
- Standard approach to evaluate burst and background losses in water distribution systems
- Economics of leakage management.

The courses also introduced a new approach to "pressure management" and its effect on leakage reduction. This topic, which is a current research initiative of the WRC, is drawing world-wide attention. The course was well attended and generated a great demand for the WRC research output.

Management guidelines for water service institutions

Management Guidelines for Water Services Institutions (Urban) (WRC Report TT 98/98), were published by the WRC during the year. The development of the Guidelines was very opportune, as it parallelled the drafting of the Water Services Act, Act 108 of 1997. It was, therefore, possible for the Guidelines to incorporate many of the principles of the Act.

The Guidelines are considered a first step towards providing support and capacity to the water services sector. They have been written so as to assist water service institutions in financial planning and management of their services in a systematic manner. An important output and component of the Guidelines is the section on Water Services Development Plans and the complementing software models (*WSSM – Water Supply Services Model* (WRC Report KV 109/98) and *SSM – Sanitation Services Model* (WRC Report KV 111/98)) which help generate these plans in a standard and simple report format. The models enable financial planning and determining of tariffs.

In recognition of the importance of the Guidelines, a series of five seminars (at different centres in the country) were arranged in association with the Department of Water Affairs and Forestry (DWAF), and with the Institutional and Management Affairs Technical Division of the Water Institute of Southern Africa (WISA). The inaugural seminar, held in Pretoria, was graced by an opening address by the Minister of Water Affairs and Forestry, Prof Kader Asmal, emphasising the importance of the Act.

The seminars introduced the Water Services Act, its requirements and implications. This was followed by an introduction to the Guidelines and how they can be used to meet some of the requirements of the Act.

The seminars were well attended and positive responses were received from participants. The seminars were followed by specialised training workshops. The success of the Guidelines and the seminars was a clear indication of the emerging partnerships in the sector.

Assessment of the quality of domestic water supplies

The WRC held a workshop in February 1998 to update the *Guide for the Assessment of the Quality of Domestic Water Supplies*, published in 1996. Presentations at the workshop centred on the implications of the new water legislation on potable water supplies.

The original Guide had been critically reviewed during a workshop in 1997, and a number of shortcomings were identified by users. The WRC then contracted two consultants to address these deficiencies, working with teams from DWAF, the Department of Health, a number of universities, and the SA Bureau of Standards (SABS). A series of three colour-coded user-friendly guides are envisaged, which will assist water suppliers, communities and individuals to assess the fitness for safe use of different water qualities, and to decide on treatment and management options.

The three volumes in the series are: *The Quality Assessment Guide* (WRC Report TT 101/98); the *Sampling Guide*; and the *Analytical Guide*. The first volume is complete, and the other two will be published during 1999.

Workshop on the microbial quality of potable water

The rapid and reliable monitoring of the microbial quality of drinking water is of fundamental importance for the management and control of water-borne diseases. It is, therefore, important that the water supply industry be progressively informed of new assaying techniques as well as the expanding spectrum of micro-organisms to be tested for.

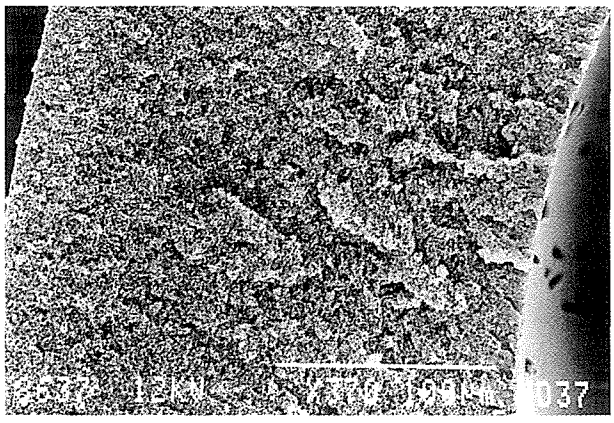
Against this background, the WRC sponsored a workshop on new developments in the microbial assessment of drinking-water quality using molecular techniques. The workshop was held in Pretoria during September 1998. Dr Colin Fricker from Thames Water in the United Kingdom was invited as guest speaker. He is an international leader in microbial water analysis, and shared his experience in water-borne disease outbreaks in the United Kingdom and Australia.

A new ultrafiltration (UF) membrane

An improved polysulphone UF membrane was developed by the Institute for Polymer Science, University of Stellenbosch. In earlier work an outer-skinless UF polysulphone membrane was produced for use in membrane bioreactor related research. With slight modifications, the membrane also served as a low-pressure filter for the treatment of non-saline surface and subsurface water for potable use. Typically, the membrane had instantaneous burst-pressures exceeding 1.5 MPa and flux rates of 2 Lmh/kPa.

In order to improve the tensile properties of the membrane, the number of load-bearing cells in the substructure had to be increased. This had to be done without increasing membrane resistance to product transport. A double-skinned membrane with a sponge-like substructure was designed, which satisfies both high bursting strength and high flux requirements.

The micrograph shows a cross-section of one of the membranes. The membrane has a very thin internal skin layer and the dimensions of the voids in the substructure are such that bacteria cannot penetrate, should the skin layer be punctured during filtration. The experimental ultrafilter has a molecular cut-off of 50 000 Dalton, with a pure-water flux exceeding 6 Lmh/kPa. The instantaneous burst-pressure exceeds 2.3 MPa. The membrane will be further investigated, *inter alia*, for the production of potable water for small communities.



Micrograph of the newly-developed, low-pressure ultrafiltration capillary membrane.

Control of balancing tanks

The inflow of wastewater into a treatment works is characterised by large variations in flow and pollutant load. Hence there is a need for a balancing tank in the circuit to dampen out the detrimental effects of such variations on the downstream bioreactors. Oversized balancing tanks should be avoided, as they could result in premature biological reactions and the settling of solids before reaching the bioreactors.

The WRC contracted Watson Edwards to develop a balancing tank controller which would ensure a fairly constant feed to the bioreactors. This was done successfully, and the controller developed was installed and commissioned at the following treatment plants operated by the Greater Johannesburg Metropolitan Council: Northern Works, Olifantsvlei and Goudkoppies.

The controllers at these plants were found to operate successfully, were easy to set up and configure, maintained a relatively constant outflow pattern, and prevented the tanks from either overflowing or running dry.

Workshop on biofiltration

The WRC sponsored a technology transfer workshop on the topics of biofiltration and secondary clarification in sewage treatment.

Dr Denny Parker from the USA, a recognised international expert in these fields, was invited to the workshop and shared his practical experience relating to the innovative use of biofilters.

Prof George Ekama from the University of Cape Town dealt with secondary clarification. He based his presentation on the recently released report of the International Association on Water Quality (IAWQ), *Secondary Settling Tanks: Theory, Modelling, Design and Operation.*

The workshop stimulated much interest and awareness regarding the potential for the innovative use of old biofilter installations in South Africa.

Southern African regional conference on cleaner production

Cleaner production is defined by the UNEP as "the continuous application of an integrated preventative environmental strategy to processes, products and services to increase eco-efficiency and to reduce risks to humans and the environment." Cleaner technology has been adopted as policy by DWAF, the Department of the Environment and Tourism, and the Department of Trade and Industry.

As an initiative to assist in the promotion of the concept, the WRC in May 1998, co-sponsored the Southern African Regional Conference on Cleaner Production in Midrand. The objectives of the conference were to promote a better understanding of cleaner production practices, examine ways of improving environmental performance while achieving cost savings, and encourage networking between practitioners who are engaged in cleaner production. The conference was well received, attracting representatives from a number of sub-Saharan countries as well as from overseas (18 different countries altogether).

First waste minimisation club launched in South Africa

During the year, the Pollution Research Group at the University of Natal commenced a project to establish waste minimisation clubs in South Africa on a pilot basis. The concept was developed in the United Kingdom in 1992, and aims at providing clusters of small- and medium-sized industries (by regions or sectors) with support to implement cleaner production practices.

The first club was launched for the metal finishing industry in Hammarsdale, involving some 30 members. Significant reductions in waste generation and substantial cost-savings have already been effected. The success of the project spawned interest by Umgeni Water to establish a similar club for metal finishers in the Pietermaritzburg area.

WRC project attracts European Union support

The project on waste minimisation clubs discussed above, has been directly instrumental in generating some R1 million support from the European Union by way of a collaborative project.

The next target sector for the WRC initiative on waste minimisation clubs, is the textile industry in Hammarsdale. Because of the relatively high energy demands in the textile industry, energy-use efficiency can be usefully addressed, alongside water conservation and waste minimisation. With this objective in mind, the Pollution Research Group, University of Natal, submitted a funding proposal for a collaborative project to the Thermie Programme of the European Union. The submission was successful and about R1 million is being made available for this purpose. Technical input will be made by consultants from the United Kingdom and Denmark (at no cost to South Africa).

These will be truly collaborative projects with substantial generation of synergy.

Solid-stabilisation of wastes containing heavy metals

The WRC is supporting innovative research at the University of Pretoria in collaboration with Mintek, for immobilising heavy metals present in wastes from the ferro-alloys industry. These heavy metals constitute a threat to groundwater supplies and community health. The metals are being solid-stabilised in bricks which are potentially suitable for selective use in building projects and/or recycling the metals back to the ferro-alloys industry.

Results to date are promising, in that a high degree of metal immobilisation can be achieved. Future work will be directed at determining the most beneficial route(s) in national terms for the reuse of the solid-stabilised materials produced.

Algal pond technology

The WRC has been supporting research into algal pond technology for almost a decade at the Rhodes University's Department of Biochemistry and Microbiology. In addition to demonstrating application of the technology for sewage treatment at Grahamstown, novel modifications have been made to operate algal pond systems in highly saline environments. This latter development has extended the application potential of the technology dramatically.

The modified technology has thus far found full-scale application in the treatment and odour reduction of tannery effluent in Wellington, and the cultivation of high-value *Spirulina* algae on industrial effluents. Currently the algal pond technology is being demonstrated on pilot scale for the treatment of acid mine drainage and the co-digestion of sewage sludge in large quantities. This is opening the way for the treatment of various other industrial effluents with high sulphate effluent streams. A range of patents have been registered.

Research Co-ordinating Committee for Industrial Water and Waste Management (CCIWWM)

In line with the WRC's mission of promoting research in its various fields of activity in a structured and transparent manner, a CCIWWM is being established to guide research in this area. Representation will be from industry, local authorities, government departments, academic institutions, treatment work operators, consulting engineers, trade unions, environmental groups and other interested and affected parties.

The CCIWWM will act in an advisory capacity to the WRC, assisting in identifying and prioritising research needs. Its first task will be to develop a strategic "master plan" for industrial water and waste research. This will be published in draft form on the WRC home page for comment and implementation.

Biotechnology in the pulp and paper industry

Research hy the Department of Biochemistry and Microbiology, University of the Orange Free State, in collaboration with SAPPI, is aimed at reducing the quantity of chlorine used in the pulp and paper industry. The focus is on a biotechnological approach as an environmentally friendly alternative to chlorine.

The work carried out to date has shown that bio-bleaching using enzymes from fungi can be used instead of chemical bleaching, producing much more benign effluents. Currently, attention is being given to the low-cost production of fungal enzymes, using effluents from the industry as growth media in order to make the process commercially more attractive.

New waste discharge standards

In terms of the new National Water Act, the Minister of Water Affairs and Forestry is to set new waste discharge standards. "Waste" in this context includes treated domestic sewage, industrial effluents including mine waters, and stormwater. The Department consulted with various parties, including the WRC, regarding technical and socio-economic issues.

It is encouraging that results generated by WRC research, carried out pro-actively over a number of years, sometimes over decades, are making useful inputs in this process. Some important examples are research on integrated catchment management, analytical methods for estimating the readily-biodegradable organic fraction in wastewaters, nutrient removal from wastewaters, and a wide range of water quality studies.

A water quality simulation model for open-cast coal mining

One of the problems facing regulating authorities and mines, is the lack of tools for predicting how mining operations affect water quality over time.

Wates, Meiring and Barnard (CE) Inc. developed a generic mine-water model which can be used to predict the water balance for an open-cast mining operation, including runoff, seepage, and groundwater recharge. The model simulates the water flow and associated water quality over the operational life of an open-cast pit. The simulation is done for a selected hydrological sequence and operates at a monthly time-step. The open-cast pit is divided into a number of individual mining blocks, to allow the mine scheduling to be incorporated into the model. Each mining block is further subdivided into up to 10 horizontal layers. This allows the simulation of the vertical spatial variation of oxygen and water migration.

The use of vegetation to reduce mine-water pollution

Reports dealing with two research projects on the use of plants to reduce mine-water pollution, were published during the year. The first deals with the feasibility of using trees with deep root systems and high transportation requirements, to reduce flow of water through mine material, thereby reducing the concomitant water quality degradation. Measurements at mine sites indicated that trees (mostly eucalypts) do grow well under the harsh environmental conditions associated with mines. They generally use considerably more water than grass covers.

The second project aimed to identify plant species which would be suitable for cultivation under irrigation with polluted mine waters, or as wetland species, in order to either improve the water quality, or put it to beneficial use. The research was done by the Department of Plant and Soil Science, University of Pretoria. Selected crops and pastures suitable for cultivation under prevailing climatic conditions and under irrigation were investigated under applicable glasshouse, growth chamber and field conditions, for their tolerance to lime-treated acid mine drainage (AMD). In addition, some wetland species were investigated, and some tentative studies conducted on possible soil physical and chemical changes caused by the application of AMD. It is now clear that neutralised AMD can be used for the irrigation of a large range of crops.

An information system for mine-water management

Millions of rands are annually spent in South Africa relating to mine-water management, and many times more are spent internationally. Despite this level of effort and funding, most local users remain unaware of the information which is available to assist them in managing mine-water systems. Furthermore, users such as mines, seldom have the capacity to keep up to date with all these developments.

The firm Pulles, Howard and De Lange Inc. developed a computerised *Information Transfer, Extraction and Management System* (ITEMS) (WRC Report TT 94/98) which enables users to gain access to local and international information on mine-water quality, management, treatment and research. Six modules are incorporated in ITEMS: literature; water quality guidelines; contaminant properties; research results; an impact assessment model; and a mine-water management manual. These modules, and the options available in each, render ITEMS an extremely versatile information tool. ITEMS is available on CD-ROM.

Workshop on research needs in hydraulics

It is a well-established procedure at the WRC to involve local expertise in the development of strategic research plans for specific research fields, by means of an intensive workshop on the research needs in the research field under consideration. This approach was also applied to hydraulics when a workshop in this regard was held in March 1998. Of the WRC's national water-related concerns, current hydraulics research projects are concentrating on water resource development, community water supply and protection of water ecosystems, whilst water conservation was attended to in recently completed projects.

In revising the current level of activity in hydraulics research nationwide, the workshop expressed its concern about the dearth of suitably qualified experienced hydraulics researchers, and advised on the establishment of multidisciplinary teams in this research field. The workshop commented favourably on the extent to which multidisciplinary approaches are already implemented regarding hydraulics research in the protection of water ecosystems.

In addition to the formulation of a proposed primary goal of hydraulics research in South Africa, the workshop also identified a number of secondary goals, the top three in order of priority being the following:

- Sediment properties, sediment transportation, sedimentation in reservoirs and dams, and desilting
- River hydraulics with special emphasis on river morphology and flood routing
- Eco-hydraulics, i.e. the requirements of the natural environment (e.g. rivers and estuaries) as far as hydraulics and associated issues are concerned.

The strategic research plan, consolidating the inputs of local experts in this field, should be a stimulus not only for increased research activity in hydraulics in South Africa, but also for increased interest in hydraulics as a career.

Artificial recharge of groundwater

The artificial recharge of groundwater constitutes a valuable tool for augmenting South Africa's rather limited natural recharge, while at the same time offering a strategy for limiting evaporation losses.

By far the majority of artificial recharge schemes in the world, including those in Southern Africa, are in primary aquifers. However, in Southern Africa over 90% of the groundwater resources are located in secondary fractured rock aquifers. The CSIR is currently implementing pilot artificial recharge schemes in these types of aquifers.

Four schemes are currently being tested. They range from a small rural water supply scheme in Namaqualand, to the large-scale injection of treated surface water into the Windhoek aquifer, in Namibia.

In Windhoek, the ultimate aim is to minimise evaporation losses by storing dam water underground. So far, 150 000 m^3 has been injected into a 200 m deep borehole, and this had the effect of "topping up" the aquifer in this region. The second scheme is in Calvinia in the Northern Cape. Here treated surface water will be injected into a brecciated pipe aquifer. The third scheme is a rural water supply scheme in Namaqualand. A non-perennial stream will be used to recharge the fractured granite aquifer. The fourth scheme looks at the effect that treated wastewater has on the Sand River and granite aquifers in Pietersburg.

Effect of aerosols on rainfall

Rainfall enhancement research previously supported by the WRC, clearly demonstrated that modifying the nature of the cloud condensation nuclei (CCN) ingested by continental convective storms can have a pronounced effect on precipitation formation processes. By seeding storms with correctly sized hygroscopic particles, rainfall per storm can in fact be enhanced by between 30% and 50% on average. Conversely, the prevalence of inappropriately sized CCN may cause precipitation processes to be less efficient and thereby reduce rainfall.

The Aerosols, Recirculation and Rainfall Experiment (ARREX), is a research project being conducted under the leadership of the University of the Witwatersrand's Climatology Research Group. It aims to investigate the physical properties and chemical composition of aerosol particles and CCN over the South African highveld and escarpment, their transport and recirculation over the eastern seaboard, and to draw inferences regarding their possible influence on precipitation development over the region. The research thus far involved extensive sampling, using aircraft, in collaboration with the Weather Bureau, the Schonland Centre for Nuclear Science, the Max Planck Institute in Germany and Eskom.

Initially ARREX was conceived as a one-year exploratory exercise. However, based on the successful acquisition of data, a two-year extension has been granted to achieve more representative coverage of atmospheric conditions, and to allow time for comprehensive analysis and microphysical modelling, in order to ensure greater confidence in conclusions which may be reached. An additional development is that ARREX will in all probability be linked to the NASA-sponsored SAFARI-2000 programme in 1999 and 2000, thereby giving ARREX access to a wealth of additional data and greatly enhancing its capacity to achieve its ultimate objectives.

Use of radar to monitor rainfall

The initial fruits of an ongoing WRC-Weather Bureau research partnership in connection with the use of radar to measure rainfall, are a series of rainfall maps available in real time, for an area which includes the Vaal Dam catchment. The maps which can be freely accessed on the Weather Bureau's home page on the Internet, are automatically constructed using data from the WRC's MRL5 S-band radar near Bethlehem, and from the Weather Bureau's C-band radar at Ermelo. They show instantaneous radar reflectivity as well as accumulated for the previous day, and for the current day from 08:00 and for the previous 60 min, updated every 5 min.

Ongoing research on radar-rainfall relationships, ensures that accuracy and reliability of the data used for these maps will improve continuously with time. The information will be of great value for flood mitigation purposes and for dam operation during periods of heavy rainfall. Moreover, the data – produced at a spatial resolution of 1 km x 1 km – will be archived and, for the first time, provide a sound basis for a short-term spatial rainfall climatology in South Africa.

Impact of alien invading plants on water resources in South Africa

This is a critically important issue, and the CSIR was contracted to produce a preliminary assessment of the extent to which South Africa has been invaded by alien plants.

The results present a bleak picture. It is estimated that approximately 10 million ha are infested by invading alien plants and that they are using in the order of 3.3 billion m^3 of water per year in excess of that used by indigenous plants. This is almost 7% of the country's streamflow. The report highlights various scenarios for the control of the problem. However, in all cases it is obvious that a continuous programme of clearing and controlling invading vegetation would be demanded at great cost. At the same time it is clear that the costs will escalate if action is not taken now. The *Working for Water Programme*, therefore, may have been initiated just in time.

Several recommendations for future research have been made. The use of appropriate information and the need for maintaining and updating a comprehensive and accessible database will play a key role in the scientific support for dealing with this challenge.

Many of our streams are choked by alien invading plants (left) and measures to solve this problem are in progress (*Working for Water Programme*) and are supported by the WRC (right).

Important baseline study in hydrology

In a time where the new Water Act demands that all water be considered to be part of the total water resource, it is extremely important that a good understanding – based on good data – be developed of what actually happens in South African catchments.

The collection of good data is no easy process, however. One study, completed during 1998, demonstrated that with dedication, good planning and technical know-how, this can be done. The study, undertaken by the CSIR, provided a comprehensive data set on the water balance of a grassland catchment, in one of the main water source areas in South Africa. The study also provided a role model for the intricate interaction between streamflow and groundwater, which occurs in some of the wetter parts of South Africa.

Reservoir sedimentation

Sedimentation generally limits the lifespan of reservoirs in South Africa. The replacement of lost storage capacity is a worldwide problem and the need therefore exists to limit reservoir sedimentation as much as possible. An obvious strategy is to limit erosion from land, but this has proven to be very difficult and not completely successful.

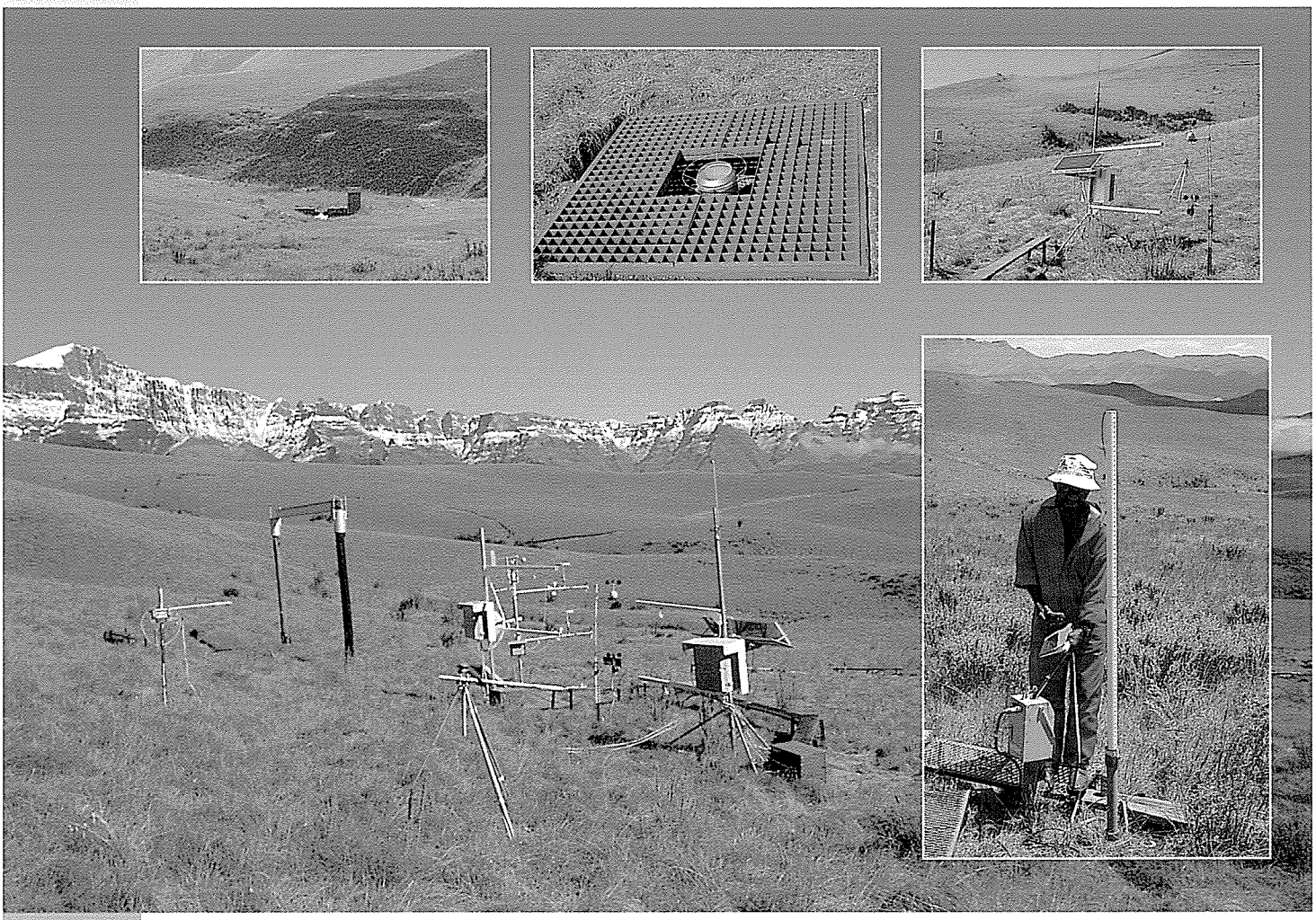
Another approach is to try and manage the accumulation of sediments in reservoirs by promoting the throughput of sediments. In this context, research by BKS (CE) Inc. focused on the hydraulics of sediment transport in reservoirs, on the basis of the stream power theory and a new transport equation was derived. Sediment transport by means of density currents was verified using Chinese and South African reservoir data. Calibration and verification of a modified hydraulic model for flood flushing at Welbedacht Reservoir were carried out successfully.

Guidelines for the design of sustainable reservoirs have been established. Aspects of reservoir dredging were also investigated.

The effect of changing land use on water quality and quantity

The Department of Agricultural Engineering, University of Natal, studied the relative soil loss and water use of timber, sugar-cane, and natural grassland on steep sloping land under various erosion control measures.

The project was beset by a series of catastrophic events: the longest and most severe drought in the area which occurred during the first years of the project, with the consequent die-back of trees; a fire which killed most of the trees; and chronic vandalism of equipment. Consequently data collection could not be conducted and concluded as envisaged. However, by making use of available data, and



Main photo: Monitoring and modelling components of the water balance in a grassland catchment in the summer rainfall area of South Africa.
Inset top left: Streamflow. Top centre: Rainfall. Top right: Evaporation. Bottom right: Soil water storage.

with the aid of the ACRU model for sugar-cane, realistic scenarios were simulated to supplement actual measurements. It was found, *inter alia*, that minimum tillage dramatically reduced soil loss whilst also reducing runoff, while afforestation had a greater impact on streamflow than sugar-cane. The impact of land use on runoff was found to be more pronounced on shallow than on deeper soils.

Sustainable water-based agriculture in rural communities

The members of rural communities in South Africa are generally considered to be disadvantaged or marginalised for various reasons. In this context, the efficient use of water resources through rain-fed or irrigated production of food crops, can contribute towards improved living standards. Accordingly, a research programme was initiated which aims at:

- Enhancing the management capacity of resource-poor farmers
- Increasing the understanding of the constraints experienced by subsistence, small-scale farmers
- Improving living conditions by moving out of a position of survival to achieving food security and eventually producing a surplus
- Promoting social change by empowerment of rural people through training and the gaining of access to water, land, finance and markets.

The programme requires involvement of stakeholders in the assessment of problems; analysing the causes of such problems; generating possible solutions by a multidisciplinary team of researchers together with the stakeholders; and practically implementing research findings.

Eight ongoing projects with a total funding level of R872 000 for 1998 can already be incorporated in the programme. With the selection of new research projects, the intention is to follow a pro-active approach, to create opportunities for capacity building, and to promote participation of stakeholders in order to facilitate the acceptance and application of research results.

Biological control of the red water fern *Azolla filiculoides*

The Plant Protection Research Institute of the Agricultural Research Council, recently completed the fist phase of an investigation into the biological control of the red water fern *Azolla filiculoides*. The frond feeding weevil, *Stenopelmus rufinasus* was held in quarantine, and the host specificity of the insect was tested against a range of plant species. Feeding, oviposition and larval development was only recorded on *Azolla* spp., with *A. filiculoides* being significantly the most suitable for the weevil.

Following approval from the authorities, the first release was made in the Austin Roberts Bird Sanctuary in Pretoria, where one of the water bodies was heavily infested. Within a relatively short period of time the numbers of the weevil had increased dramatically, and the water body was effectively cleared of *Azolla*. However, the water quality in this body is such that another small plant, *Wolfia*, was beginning to recolonise the open water. This underlines the necessity of having an integrated strategy for weed control.

Austin Roberts Bird Sanctuary pond on the day the biological control agent was released.

Two months post-release.

Courses on computerised flood irrigation design procedures

In **Chapter 7** completion of a research project on the computerisation of flood irrigation design procedures, is reported on. This project, entitled **Flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches**, was attended to by the University of Pretoria and Rehab Consultation.

The four volumes of the final report constitute the first in-depth investigation into flood irrigation in South Africa. It is complete; unique in the sense that it evaluated existing design techniques from the South African point of view; and acceptable as a foundation for courses aimed at improving the level of flood irrigation system design and management in South Africa – both for developed and developing irrigated agriculture.

Against this background the WRC contracted Rehab Consultation to present a series of courses on the results of this project, targeted at:

- Engineers and extension officers of Provincial Departments of Agriculture
- Consulting engineers
- Representatives of agricultural co-operatives and of dealers in irrigation equipment.

Over a period of four months six courses were held in Potchefstroom, Pretoria, Rietrivier, Vaalharts, Cradock and Pietermaritzburg.

These courses concentrated on the hydraulics theory forming the basis of the OPTIVLOED 2.2 design approach, optimisation of flood irrigation designs with specific reference to variation in infiltration rates, mechanisation and convenience of management; and construction of flood irrigation systems.

It is anticipated that the results of this project, and the transfer of the updated technology by means of the above-mentioned courses will contribute significantly to the upgrading of flood irrigation practices in South Africa.

Protection of the Eastern Cape estuaries

April 1998 saw the launch of the Eastern Cape Estuaries Research Programme at Port Alfred. The objective of the programme is the development of guidelines to protect and promote the sustainable use of these estuaries, particularly in the development of tourism.

The Eastern Cape is a province with relatively few resources, but tourism does offer the potential to stimulate economic development in the region. Most of the development potential is to be found along the province's coastal region which boasts almost 50% of all the estuaries in South Africa. However, there are indications that these unique assets are already under pressure as a result of changing patterns of land use in the catchments and poor management. It is, therefore, essential that guidelines for the scientific management of the Eastern Cape estuaries be developed and implemented as soon as possible, to avoid instances of irreversible degradation.

Over the years the WRC has developed models which facilitate the management of estuaries, but these rely on the input of accurate and extensive data – data which mainly do not exist in the Eastern Cape.

The WRC contracted the Institute for Natural Resources, University of Natal, to plan and co-ordinate the research programme. The intention is that the research will be undertaken by organisations in the region, including Rhodes University, the University of Fort Hare, the University of Transkei and the University of Port Elizabeth. The programme will enhance capacity at these institutions, so that they can better serve the needs of those who have the responsibility of managing estuaries.

Commercialisation of intellectual property at academic institutions

With declining government support of academic institutions, a significant source of supplementary income could potentially be derived from the commercialisation of intellectual property. A significant portion of such intellectual property, distributed over many of the institutions, is derived from WRC-funded research.

The practical commercialisation of intellectual property – in the form of patents, software, know-how and expertise – is no simple matter, however. Hence there is great divergence in the strategies developed by those academic institutions in South Africa that have taken initiatives in this regard. For this reason the WRC arranged a national workshop on this topic, held in Midrand on 16 November 1998. Representatives from academic institutions reported on their strategies and experiences, and exchanged ideas relating to the issue. All South African universities and technikons were invited to participate.

The delegates enthusiastically supported the concept of synergy creation through continued exchange of information and collaborative initiatives. They decided to establish a network for this purpose, making use of the Internet. It was also decided to have similar meetings in the future to maintain momentum.

An improvement in the commercialisation of intellectual property at academic institutions generally, will also impact positively on the implementation of WRC research output specifically.

Launching a company to promote the sale of South African water expertise and technology abroad

South Africa enjoys widespread international recognition for its technological achievements and managerial abilities in the field of water. However, very little has been done to capitalise on this situation by way of export promotion. Some individual companies have indeed made significant inroads in this respect. Generally, however, efforts thus far have been isolated and fragmented, and the time has come that marketing should be done professionally and collectively.

Against this background, the WRC took steps to facilitate the establishment of a company to promote the sale of South African water expertise abroad. The concept was launched in Johannesburg on 12 October 1998, at a press conference led by Prof Kader Asmal, the Minister of Water Affairs and Forestry. This was followed by a meeting of some 100 representatives from interested companies. The concept was unanimously supported by the meeting and a steering committee elected to develop a business plan and to finalise the memorandum and articles of association for registering the company. These will be subject to final approval by a second meeting of interested parties. The intention is to register the company early in 1999.

News concerning senior staff and board members

Mr AG Reynders, the WRC's Research Manager responsible for groundwater projects, passed away on 5 July 1998, after a year-long struggle with leukemia. He was 39 years old.

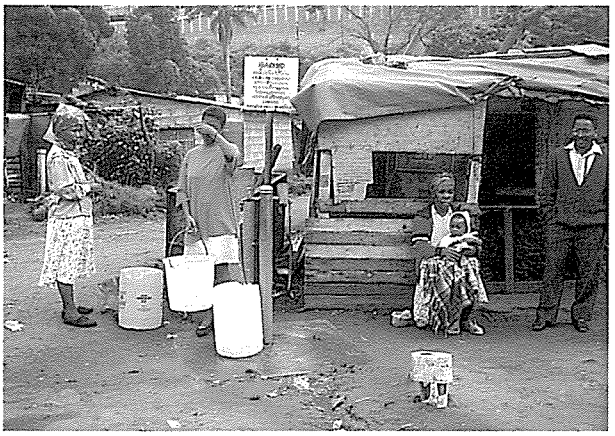
Prof CT Johnson, Chairman of the WRC Board, was appointed President of the Agricultural Research Council, as from 1 January 1999. At the time of his appointment, Prof Johnson was Acting Vice-Rector (Academic), University of the Western Cape.

Mr PE Odendaal, Executive Director of the WRC, was elected President of the International Association on Water Quality (IAWQ) at the Association's biennial conference in Vancouver, Canada, June 1998.

Mr KC Pietersen was appointed Deputy Research Manager responsible for groundwater projects, in November 1998.

Mr JA Venter was promoted to the position of Director: Administration.

Developing communities: Water supply and sanitation



According to the Water Services Act of 1997, local authorities and district councils are responsible for providing water and sanitation services to communities in their areas of jurisdiction.

However, in many parts of South Africa, these institutions currently lack technical, management and financial capacity to exercise their function. There is therefore an urgent need to build the capacity of these institutions so that they can fulfil their obligations.

During the year under review, the WRC initiated several research projects that address the capacity-building needs of local government structures. The research will produce guidelines for institutional arrangements and support facilities necessary for sustainable rural water supply schemes. The research output will contribute towards the strengthening of local authorities and district councils so that they can perform their functions more efficiently.

The water supply and sanitation (WSS) sector in South Africa is currently faced with a serious shortage of financial resources to implement new water-supply projects. Research can play an important role in developing innovative approaches for financing infrastructure projects without relying entirely on government grants.

Another challenge that is facing the WSS sector is poor cost recovery from the existing water-supply schemes. There is a need to develop cost-recovery options which would be acceptable to all stakeholders. There is also a need to develop appropriate incentives to encourage communities to pay for the services that they receive.

Completed projects

Evaluation of on-site sanitation from a socio-economic perspective

(K8/279) Bernhardt Dunstan & Associates

It is estimated that South Africa currently has 18 million people who lack access to adequate sanitation. In order to ensure that the sanitation improvement programme is a success, it is essential to provide sanitation systems that are affordable, appropriate and acceptable to the user communities. The main aim of this study was to evaluate on-site sanitation systems from a socio-economic perspective with special reference to affordability, appropriateness and social acceptability. The study was undertaken in three case study areas, namely, Soshanguve TT, Ivory Park and Ga-Mmotla.

The research findings for the three areas were:

- In Soshanguve TT, most members of the community were dissatisfied with the low-flush volume on-site sanitation systems because of high operating costs and inconvenience associated with the use of these systems.
- In Ivory Park, most of the on-site sanitation systems were malfunctioning due to poor operation and maintenance. The end-users were not paying for these sanitation systems because they considered them to be inferior and unacceptable.
- In Ga-Mmotla, most households were using unimproved pit latrines. The community was keen to get ventilated improved pit (VIP) toilets which would help eliminate flies and bad smells which are normally associated with the use of unimproved pit latrines.

The study concluded that in all three case study areas, communities were dissatisfied with their on-site sanitation systems. Women were unhappy about being excluded from decision-making on the selection of sanitation technologies, because as the main users, they are better qualified to select a sanitation system that could be operated and maintained by the users. The study has recommended that both men and women must be empowered so that they can make informed choices and be able to base the selection on affordability and ability to operate and maintain.

Local authorities should be assisted to utilise computer-based financial modelling programs so that they can calculate capital and operating costs and assess the affordability of any sanitation systems to both the end-users and local authorities.

Cost: *R54 200*
Term: *1997-1998*

Dynamics of community non-compliance with basic water supply projects

(No TT 93/98) Lynette Dreyer and Associates

The water supply programme drive is intended to meet the basic water needs of the villagers, for which they are to pay operations and maintenance costs. In the projects studied here, agreements were negotiated with elected community representatives who comprise a water committee, while community members were trained to manage the project as well as the ultimate water scheme. The research found that many communities already had their basic needs for water met, and wanted a higher level of service than the national water supply programme envisaged. The projects that were successful were situated in villages with a dire need for water and who benefited appreciably from the project. When the communities that felt that their basic need for water had already been satisfied, found that their expectations for a higher level of service would not be met, they withdrew their payments. The collapse of water projects did not happen simply and directly. There were usually other problems during implementation which were the manifest reason for project failure, but for which the water committee or community in general could not find enough enthusiasm to resolve, probably because they did not really need the water.

For the implementation of the water delivery programme, the assumption is usually that community cohesiveness is a valid basis for the election of a water committee with whom outsiders can negotiate and conclude agreements. The research cast doubts on this assumption. In the cases where there did appear to be significant community cohesion, the cohesion itself was sometimes the last straw in the collapse of the project. In these cases, the community preferred to abandon the project rather than risk community conflict over water problems.

Cost: *R99 600*
Term: *1997*

Development of cross-flow microfiltration for rural water supply

(No 386) Pollution Research Group, University of Natal and Scientific Services, Umgeni Water

The main aim of the project was to evaluate the applicability of a cross-flow microfilter for the supply of potable water to rural and peri-urban areas. Aspects such as manpower requirement of operation, water quality and costs were assessed.

Overall, the unit showed an excellent turbidity rejection. When used with a precoat, the permeate turbidity was usually around 0.1 NTU for feed turbidities ranging from 5 NTU to larger than 800 NTU. The unit consistently produced this high turbidity removal over the project period. The bacteriological rejection capabilities were also very good. In tests conducted by Umgeni Water's laboratories, a higher than 99.9% removal of coliforms, *E. coli* and faecal streptococci was reported. The ability of the unit to remove viruses was not tested during the project. However, further improvements to the mechanical reliability are necessary before the unit may be regarded as a reliable one for potable water in rural and peri-urban areas.

Cost: *R912 000*
Term: *1991-1995*

Cost recovery for water schemes to developing urban communities: A comparison of different approaches in the Umgeni Water planning area

(No 521) Division of Water, Environment and Forestry Technology, CSIR and Corporate Services, Umgeni Water

About 10 million South Africans live in developing urban communities. Approximately half live below the poverty datum level (PDL) whilst a small minority have quite a high standard of living. In the Umgeni Water supply area only about 10% of households have house connections and even those with house connections only use on average about one third of the water used by households living in established urban communities. The large number of people falling into this category, their economic standing and low water usage all suggest that planners should facilitate the implementation of multi-level service schemes for these communities. Water charges should be based on the total actual cost of delivery, the only exception being the non-repayment of capital where grant finance has been obtained for the construction of basic minimum levels of service. Thereafter individual households should be allowed to choose the level of service they want.

Umgeni Water recovers about 90% of all invoiced amounts from customers with house connections, including those households owning metered shared standpipes. This recovery is only achieved against a background of a high quality of service, the existence of active water committees in all the communities and Umgeni Water branch offices in many of them.

Along with the current investment programme to expand coverage there is an urgent need to start an equally well-resourced strategy to enhance the capacity of communities and other local structures to manage small water schemes and to introduce meaningful cost recovery. For this purpose it will be necessary to draw up a budget of which costs are to be recovered and from whom costs are to be recovered. This planning must be done within a framework of consultation and negotiation between the prospective customers and the fledging water service provider because households will only pay for water when they accept:

- The level of service as being adequate and reliable
- The charges for water delivered as being equitable
- The authority of the water service provider as being sound.

Cost: *R234 500*
Term: *1993-1994*

Assessment of common problems associated with drinking-water disinfection in the developing areas

(No 649) Division of Water, Environment and Forestry Technology, CSIR

The aims of the project were to assess the problems with present disinfection systems in the developing areas, most of which are chlorine-based systems. The resulting health implications with respect to intermittent disinfection could be serious, and give rise to severe criticism of local authorities.

The results showed that, in many of the water treatment plants and small water supply schemes, existing disinfection practices are unreliable and often not monitored. In a number of systems no chlorination is practised at all. Failure of disinfection is essentially not due to technology problems with equipment (although equipment did fail – after which

the alternative of hand addition of chlorine was mostly practised). The reasons for failure and unreliability of disinfection include:

- Lack of chlorine chemicals
- Lack of operator attention
- No provision made for chlorine addition
- Lack of funds for purchasing chlorine
- No monitoring of chlorine residuals to detect chlorine levels.

Probably the most important aspect derived from this study is that the operators controlling the plant do not have the knowledge and understanding of the background of water disinfection, the importance thereof and the possible consequences to the community they are serving. Proper training was, therefore, deemed as being absolutely essential.

Cost: *R40 000*
Term: *1994-1995*

Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater

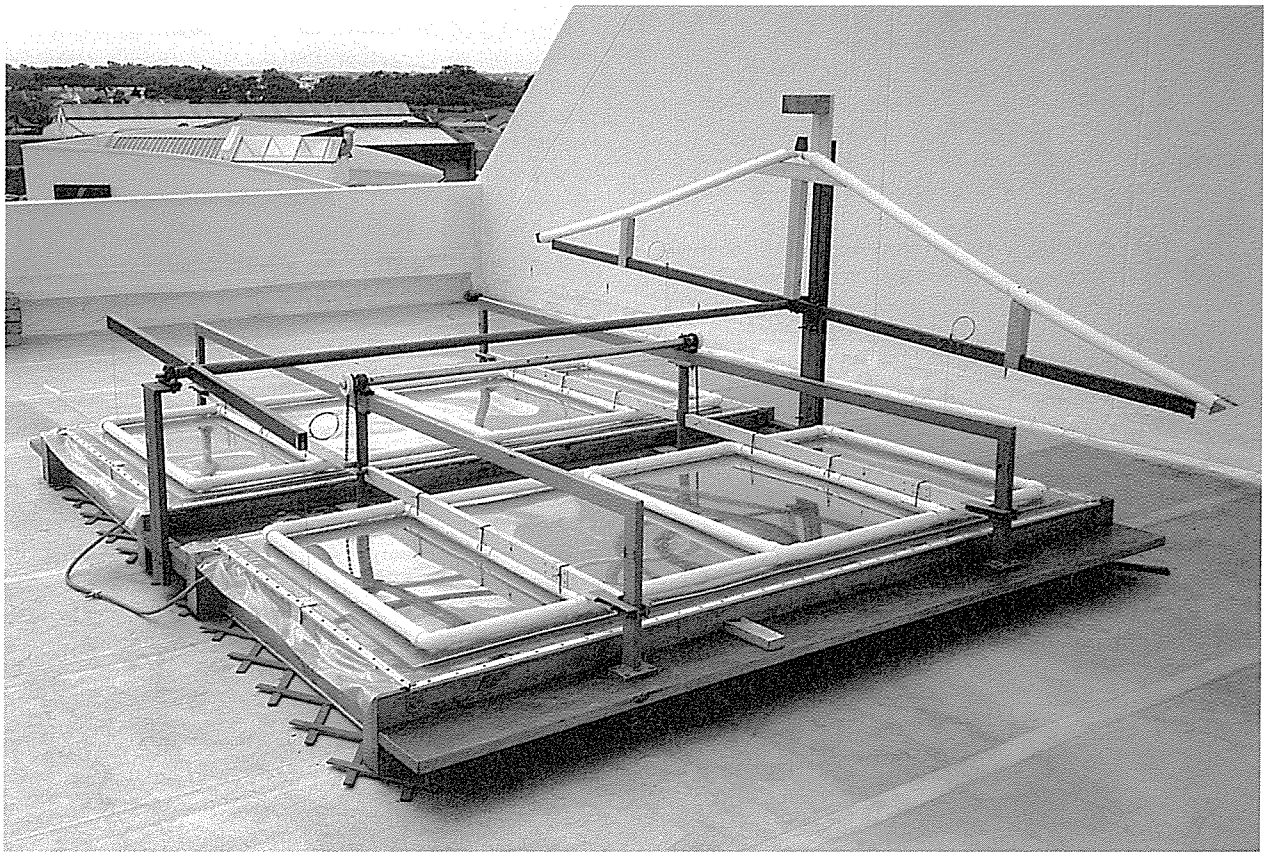
(No 677) Institute for Water Research, Rhodes University

Many examples of failed or inappropriate rural water supply schemes, resulting from, *inter alia*, the lack of a systematic, integrated approach to evaluating different community water-supply options and inadequate quantification of small-scale water resources, provided the stimulus for this project. The aims, therefore, were to develop guidelines for assessing the water supply alternatives for relatively small-scale development projects and identifying and evaluating the factors (physical, social and economic) affecting the type of water source and infrastructural system to be developed. Because of the increasing pressure on groundwater development as a means of solving rural water supply problems, the research focused strongly on the assessment of groundwater resources and related issues. These related issues were identified using both international literature and the outcome of an intensive multidisciplinary workshop held at the commencement of the project. They include:

- The effective involvement of the community in the selection, design, implementation, operation, maintenance and financing of the system
- The selection and development of a water source which can meet community requirements in terms of quantity, quality, accessibility and reliability
- The selection of technology to match the environment and the human, economic and logistical resources to sustain it
- The initiation of institutional and human resource development programmes which match the operational requirements of the system.

The resulting guidelines are presented in a structured and systematic manner and lend themselves to incorporation into a computer-based decision support system (DSS). The development of such a DSS is the topic of a follow-up project.

Cost: *R205 000*
Term: *1995-1997*



A prototype solar powered Stirling motor for water pumping, suitable for use in remote sites and in developing economies. Although a low-tech product, it is the result of recent developments in a new technology. A Stirling motor is a form of heat engine that operates by compression and expansion of the working fluid (in this case air at ambient temperature) to convert a fraction of the incident solar radiation to useful work used to drive a low-pressure water pump.

Development of a community-based integrated catchment management programme with special reference to water supply and sanitation in the Ntshongweni catchment

(No 684) Farmer Support Group, University of Natal

The Ntshongweni catchment is a microcosm of South Africa. Virtually all of the problems encountered in the various communities and activities around the country are found in this catchment. The primary goal of the project was to develop a framework for community participation in catchment management in South Africa.

The following is a brief summary of achievements in the first two years:

- The Ntshongweni Catchment Management Programme (NCMP) has been started with the active co-operation of a host of local groups and organisations. Part of the reasons for the success is the fact that the project staff is of local origin.
- Three community gardens have been started in the Ntshongweni area, another three in the nearby Mpumalanga Township. This includes the formulation of constitutions, training of committee members and building of networks with local authorities.
- Ecological aspects of riverine rehabilitation were integrated with the Shongweni Resources Reserve, which in turn was integrated with the Durban Metropolitan open space system.
- The NCMP has engaged with well over a hundred organisations in the process of supporting community participation in catchment management and has helped several community groups to form themselves into organisations, action groups or projects.
- A number of local companies have made contributions of finance, expertise and equipment. Umgeni Water and Mondi Forests have contributed financially.
- The Umlaas Irrigation Board has appointed a full-time conservation officer to assist with catchment management. An action plan for riverine conservation has been compiled and the Tala Valley has been demarcated as the first subcatchment.
- The Outer East Substructure of the Durban Metropolitan Authority has agreed to support the development of an Environmental Education Resource Centre in Mpumalanga township and has asked NCMP to administer funds.

The results of this project have laid the foundation for community involvement in integrated catchment management and a follow-up project has been approved.

Cost: *R542 100*
Term: *1995-1996*

Guidelines for the operation and maintenance of septic tank effluent drainage (STED) systems by communities in South Africa

(No 708) Division of Building Technology, CSIR

Research undertaken in South Africa has shown that communities lacking adequate sanitation services believe that full water-borne sanitation is the only system that will satisfy their needs. However, the high cost of full water-borne sanitation prohibits the use of these systems country-wide. STED systems can provide an alternative sanitation option which offers a level of service that is similar to that of a full water-borne sanitation system but at a reduced cost. Briefly, the STED system comprises a septic tank installed on the property which retains the solids fraction on-site, while the liquid fraction is transported off-site via a small-bore pipe, for treatment, usually in a pond.

This study evaluated the STED systems in South Africa. It showed that STED systems were used on over 16 000 erven in South Africa. The study showed that problems experienced with these systems were mainly due to poor operation and maintenance. The study also showed that some incidents of blockages were due to incorrect design and construction of the STED systems. The study concludes that with proper design, operation and maintenance, STED systems offer a cheaper alternative of meeting the sanitation needs of communities who want an intermediate level of service with the same convenience as a full water-borne system. The output of this research includes two guidelines, namely *Operation and Maintenance of Solids-Free Sewer Systems in South Africa: Guidelines for Engineers;* and *Solids-Free Sewer Systems in South Africa: A Community Leader's Guide.*

Cost: *R145 000*
Term: *1995-1997*

Groundwater pump for use in informal settlements

(No 876) Stass Environmental

This project had as its objective the design of an inexpensive groundwater abstraction system for use in informal settlements, utilising wind energy to provide compressed air to drive the pump. It succeeded in developing a practical, novel and cost-effective system and demonstrated that it functions satisfactorily. Through a wind-driven compressor, air pressure is generated and stored in a receiver tank, as opposed to storage of the pumped water in a water tank.

Storing the energy rather than the water has the major advantage that the quality of the water eventually obtained by the community will not be affected by insects, vandalism or vermin, and also making the water less susceptible to pollution due to poor sanitation practices.

Since no water is lost by evaporation and water is being pumped only as required, water conservation is promoted by the system. Furthermore it has the advantage that the windwheel can be positioned in a location optimal for the capture of wind (e.g. top of a hill), whereas the borehole can be installed at a point most advantageous from the point of view of groundwater availability.

Whereas wind energy is generally not considered to be a very reliable energy source due to the variable nature of wind occurrence, storing wind energy presents a technical challenge requiring innovative thinking. Compressed air, although an environmentally friendly "fuel", is also one of the few renewable energy sources. Although compressed air has a number of disadvantages and if generated by any other means is not economical, utilising wind energy under the circumstances for which this research was intended, opens a door which justifies further investigation as is intended in Project No 976, more information on which is provided later on in this chapter.

Cost: *R140 200*
Term: *1997*

New projects

Development of a framework for the calculation of a monthly tariff payable in stand-alone community water supply schemes

(No 886) Mvula Trust

The beginning of the new political dispensation has seen a sense of urgency to provide water supply and other infrastructure to previously marginalised communities. A large number of these schemes are now installed and operating. Recently there has been a marked change in emphasis from rapid delivery towards a need to ensure sustainability in delivery.

The operation and maintenance requirements for rural community water supply schemes, which have typically been built during the reconstruction and development programme, differ considerably from schemes in urban areas which are operated by large water utilities. Further, it is important for planners to take into account the rural environments with limited employment opportunities, with many local residents depending for their livelihood on money which comes from migrant relatives in cities.

The sustainability objective will be considerably promoted through efforts to understand the basic financial requirements necessary to operate and maintain schemes. It is even more important to endeavour to understand the rural economic fabric so that the financial models which are proposed, demonstrate a practical and pragmatic approach to the realities of rural communities. There is also a real possibility that the actual costs of running these schemes are beyond the means of the rural poor, and thus will be dependent on external subsidies.

The aims of the research programme are as follows:

- To determine the minimum factors which constitute the monthly running costs for community supply schemes to ensure that the scheme is operated and maintained in a sustainable manner utilising local resources
- To obtain empirical data of the monthly running costs from existing water supply schemes
- To develop a financial framework which provides guidelines to consultants, planners and local authorities on the basic monthly running costs of such schemes.

Estimated cost: *R378 000*
Expected term: *1998-1999*

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

(No 895) Mattcomm

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 (O&M). 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 and input from community level in order to ensure that emerging policy for rural water supply management is effective, appropriate and applicable on the ground.

Hence, the study aims to:

- Improve the understanding of the on-the-ground issues affecting the management of water supply to rural settlements.

Domestic water supply for a rural community in the far Northern Province (Venda). A senior citizen guards the line of some 200 household containers awaiting the tanker truck to deliver water. This enables the owners to carry on with other duties during the long wait. The role of this water supply system in the spread of water-borne viral diseases is being investigated.

- Use a detailed case study as a basis for assessing local management arrangements and to then draw lessons and make recommendations regarding good practice for O&M management arrangements generally.
- Draw particular attention to arrangements for financial management which allow local systems to be sustainable.
- Use a process of participatory workshops to develop specific options for appropriate management arrangements that would then be ready to be applied in a pilot-project area. This process is to build on the general DWAF guidelines.

Estimated cost: *R184 000*
Expected term: *1998*

Fog-water collection: Implementation of an operational prototype system

(No 902) Department of Geography, University of the North

There are numerous villages in rural South Africa where shortages of water are exacerbated by poor accessibility and bacterial contamination of available supplies. This is the case even in relatively higher rainfall areas adjacent to the mountains of the eastern escarpment. A study recently completed in the Northern Province has established the potential of high-elevation fog as a source of water which is suitable for human consumption. In fact, yields obtained are 3 to 4 times higher than in a Chilean fog-water supply sys-

tem which has been fully functional since 1987. Systems designed to deliver more than 250 kl/d ought to be possible at some sites. However, the greater requirement would probably be for smaller fog-water harvesting systems to supply potable water to small village communities.

The aims of this project are to:

- Design, install and operate a pilot fog-water collection system to provide potable water to a small rural community
- Continue researching meteorological, geographical and water yield and quality factors at the site with a view to refining design and operational procedures
- Train local community members and staff in the operation and maintenance of the system.

Estimated cost: *R500 000*
Expected term: *1998-2000*

Assessing the causes and pathways of water-borne disease in rural settlements with limited formal water supply and sanitation

(No 925) Umgeni Water

As rural people are not usually able to compete on the open market for financial resources, they are particularly dependent upon RDP and rural development programme funding to meet the capital costs of infrastructure provision. Evaluation of the effect of these projects on the health of the inhabitants has become a critical management information need for water infrastructure providers. To fulfil this need, research aimed at understanding and describing the health benefits associated with water supply and sanitation must be undertaken. Results will assist in motivating the upgrading of settlements and identifying the most important factors to be addressed in the design and education surrounding infrastructure development and use.

The intention of this research is to identify the most appropriate health indicators and to establish the critical factors relating environmental- and drinking-water quality and personal hygiene to the health of consumers. Although the case study will be located in southern Natal, the results will be applicable to many other rural areas in Southern Africa.

The importance of this proposal, particularly in the developing world, is that it will provide information about the actual relationships between water quality at different stages in the water supply process and the potential for disease.

Estimated cost: *R175 000*
Expected term: *1998-1999*

Institutional structure for the management of a rural water and sanitation supply scheme involving five local authorities

(No 958) Association for Water and Rural Development (AWARD)

The Association for Water and Rural Development (AWARD) is a participant in an RDP project aimed at establishing a functional water and sanitation management capacity. As a national pilot scheme, this project offers lessons and guidance for other potential new schemes. As part of this project, a bulk supply authority, the Bushbuckridge Water Board is being established. This project has national implications, as the models established here can be applied in other areas and the lessons learned will impact on government policy formulation.

The main objectives of the research are to:

- Develop models of appropriate management structures that will ensure co-operation between local government structures, water committees and NGOs
- Disseminate lessons learned from the implementation of this Presidential Lead Project to all stakeholders.

The results of the study will impact upon the regulating framework including tariff-setting mechanisms, water allocation mechanisms and relationships between bulk supply authorities and local authorities.

Estimated cost: *R120 000*
Expected term: *1998*

Institutional arrangements and support facilities required for sustainable community water supply

(No 959) Water Systems Management

Poor operation and maintenance of water supply infrastructure has been identified as one of the main reasons why most water supply schemes fail in developing countries. In order to ensure that large investments that are presently being made by the national government are not wasted, it is important to build the capacity of district councils and rural councils to enable them to deliver services to target groups in a sustainable manner. According to the Constitution, the local government structures are responsible for the provision of basic services. These structures suffer from lack of capacity and have limited support infrastructure. There is therefore an urgent need to build their capacity through developing appropriate training programmes.

This project will identify the strengths of existing institutional structures so that these may be duplicated in the proposed new institutional structures.

The main objective of the project is to initiate the establishment of effective and efficient institutional structures for the operation, maintenance and management of rural water supply schemes. The specific aims of the project are to:

- Assess the current institutional arrangements in rural water supply schemes
- Recommend ways of improving institutional arrangements for supporting the delivery of services to rural communities
- Initiate the process of transition in a selected transitional local council.

The study will also develop guidelines for refining the training offered in collaboration with the National Community Water Supply and Sanitation Training Institute, Mvula Trust and other RDP initiatives.

Estimated cost: *R500 000*
Expected term: *1998-1999*

Improving water use, sanitation practices and hygiene education for primary-school children in South Africa – Phase II

(No 960) Public Health Programme, University of the Western Cape

Without an understanding of children's perception of water and sanitation and how it is related to health, it is difficult to develop appropriate hygiene education programmes. Appropriate scho' ' hygiene education curricula can play a major role in the ,eduction of water-borne diseases.

There is a need for a long-term programme of action to ensure that sound health education around water and sani-

tation issues is institutionalised through the curriculum and teacher-training programmes within the National Department of Education. Schools should be the major focus for the promotion of positive hygiene practices because children can act as informal educators in their communities.

This research project will use the imagination and creativity of the children to develop culturally sensitive multimedia learning strategies.

The main objectives of the research project are to:

- Gather data from schoolchildren on their perceptions of water use, sanitation and hygiene practices in order to understand their knowledge, attitudes, practices and behaviours
- Develop an improved hygiene education curriculum for different categories of primary schools based on socio-economic and cultural parameters
- Develop techniques, methodologies and materials for teachers on improved hygiene education which will be appropriate in a social and cultural context.

The research output will contribute towards the development of a national hygiene education curriculum for primary schools.

Estimated cost: *R344 000*
Expected term: *1998*

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 water quality. The preferred methods should be simple so that they can be performed by local communities without any special technical skills. The H_2S strip test has been successfully used in small communities in South America for assessing the water quality. 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 H_2S strip test provides a potentially effective method for use in South Africa for increasing the awareness of Environmental Health Officers (EHOs) and communities about potential health risks associated with the use of contaminated water.

The main objectives of the research project are to test:

- A novel H_2S strip method for its suitability as a water quality indicator
- The method for its suitability for detecting contamination of water supplies without the need to incubate samples at 37°C
- The H_2S strip method as a field test kit for assessing the water quality of small community water supplies.

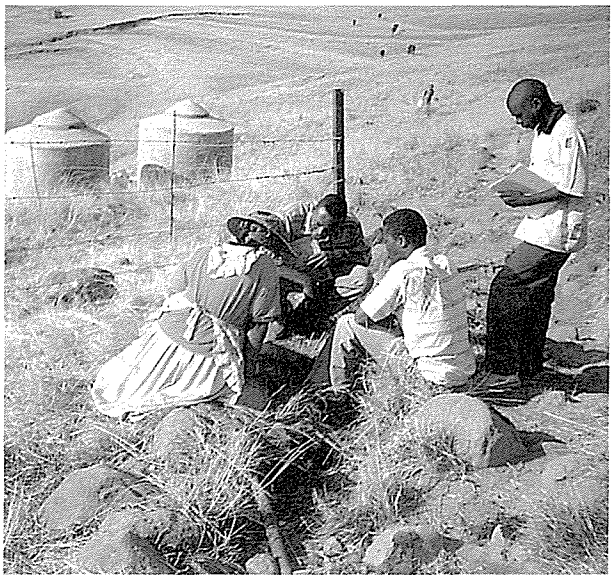
Estimated cost: *R100 000*
Expected term: *1998*

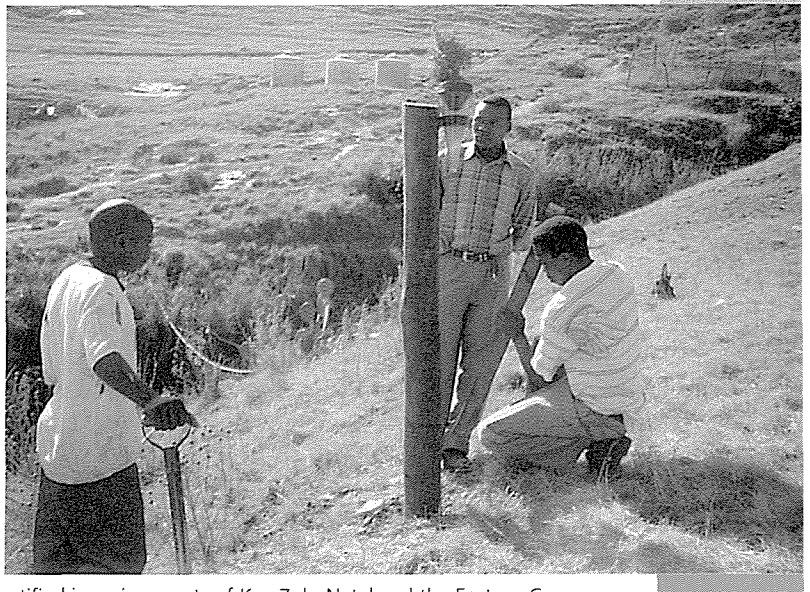
Water-supply management for small communities: Development of expert-systems-based decision-support software and a guidelines manual

(No 962) Division of Water, Environment and Forestry Technology, CSIR

World-wide, authorities involved in waste and water-resource management are under pressure to provide more cost-effective services, involving more complex planning and operational activities. In South Africa, the problem of limited expertise in disciplines related to waste, water and the environment, makes it necessary to find ways and means of making information accessible to those who lack specialised training in waste and water-resource management. There is therefore a need to convert the relevant expertise into computer-based management planning aids and educational tools. The proposed expert-systems-based decision-support software and a guidelines manual will provide information on the following:

- Cost-effective water treatment options for small communities
- Planning and design guidelines for cost-effective water supply systems.





A number of small springs which serve rural communities have been identified in various parts of KwaZulu-Natal and the Eastern Cape. The springs have been sampled to assess the quality of the water obtained from these spring systems, and flow-monitoring equipment has been installed. Local residents have joined the research team and are responsible for reading the flow gauges and rainfall in the catchment, as well as keeping a record of all activities which take place in the catchments.

The main objectives of the research are to:
- Collate existing expertise and information on cost-effective water treatment and supply for small communities
- Collate existing expertise and information on practical measures to protect local water supplies from pollution, applicable to small communities
- Establish decision-support guidelines and methodologies in the form of PC-based expert-systems applications as well as a guidelines handbook.

The research output will include expert-systems-based software and guidelines for decision-makers regarding cost-effective treatment and management of local water supplies.

Estimated cost: *R500 000*
Expected term: *1998-1999*

Continuous-flow airlift groundwater pump for rural applications

(No 976) Stass Environmental

In a preceding research project, the aims were to further develop and test a new pumping mechanism, utilising compressed air as energy source; and to develop technology to utilise wind to drive a unit to provide the compressed air required to drive the pumping mechanism. An important condition was that the pumping mechanism and the energy storage technology should be such that it would provide an inexpensive groundwater abstraction system for use by informal settlements with an acceptable degree of reliability, capacity and efficiency.

The prototype (pump and compressed-air unit) has been constructed and surface and initial subterranean tests have been completed. Although some modifications had to be made to enhance the robustness of the pump, and certain constructional improvements were necessary, the prototype performed with good results.

The next phase is to prove the functionality of the pumping mechanism and compressed-air energy source under a number of actual field conditions. These tests are to be preceded by the development of a design modification to provide for the possibility of the water source running dry. Six experimental installations serving actual informal settlements are then to be commissioned to allow monitoring of its performance under these conditions.

Estimated cost: *R262 000*
Expected term: *1998-1999*

Incorporation of water, sanitation, health and hygiene issues into Soul City, a multimedia edutainment vehicle

(No 981) Soul City

"Soul City" is a multimedia health care campaign which was initiated in 1992 with the aim of raising people's awareness of health-related issues. It utilises the concept of "edutainment" which combines learning with entertainment. The multimedia edutainment vehicle consists of multilingual TV drama series, radio drama series, booklets with easy-to-read health information and education packages for adult basic education.

Most development initiatives attempt to empower people through knowledge in order to enable them to make positive, informed decisions concerning their lives. Mass media are powerful communication tools that can be used to reach more people. "Soul City" is planning a campaign that will educate people about water, sanitation and hygiene issues. This campaign will be launched in 1999.

The main aims of this project are:
- To develop education material for water and sanitation through:
  - a literature review
  - focus groups with the target audience
- To pre-test all materials developed to assess the appropriateness, clarity of messages, cultural acceptability and entertainment value.

The results of this study will contribute towards the promotion of health and hygiene awareness in South Africa.

Estimated cost: *R100 000*
Expected term: *1998*

Development of a rapid capacity-building programme for management of water and waste services at district council and local authority levels

(No 982) Institute for Development Planning and Research, University of Port Elizabeth

One of the biggest threats to the sustainability of new community water supply schemes is the lack of capacity at both district council (DC) and local authority (LA) level especially in the Eastern Cape. Although the Water Services Act of 1997 states that the DCs and LAs should be responsible for the delivery of services to their communities, presently most of these institutions do not have the necessary capacity to meet their obligations. It is therefore necessary to develop innovative ways of building the capacity of these institutions so that they can deal with problems of water and waste in their areas of responsibility. The proposed rapid capacity-building programme is conceptualised as a process where specific needs regarding training in service delivery and management are identified and addressed. This approach focuses on specific needs and problem areas and these are addressed immediately instead of using standardised training which may not be relevant to specific local needs. The main aims of the study are to:
- Advise on the staffing levels and competencies required to perform the task efficiently
- Determine the skills gap between the present skill level and competencies needed to fulfil the task effectively
- Develop a rapid capacity-building programme and test its appropriateness for training service providers at DC and LA levels.

Estimated cost: *R100 000*
Expected 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 level at which 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. On the one hand politicians and civic groupings are pushing for full water-borne sanitation. On the other there are economists and local government treasurers who see the high costs of such systems and the associated inability of many households and local authori-

ties to afford them. Yet there are options "in the middle" where flush systems can be used but at reasonable cost. These options need to be explored in order to make information available on a full spectrum of sanitation options.

One of these options, which is well referenced in the literature, is shallow sewerage and associated simplified sewerage systems. While this option appears to have merit, it has not been applied in South Africa and there remains insufficient understanding of how such a sanitation option could be applied in a typical project situation, whether for a new housing development or an *in situ* upgrade situation.

Hence, this study aims to:

- Review international literature on shallow sewerage systems, their international application and development
- Evaluate case studies on implementation of this technology and create links with institutes successfully implementing this technology
- Based on the above, determine its appropriateness for use in South African conditions, technical and social
- Put a cost to the system if applied in South Africa, and compare this with other forms of sanitation and sewerage systems.

Estimated cost: *R111 500*
Expected term: *1998*

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

(No 991) Department of Development Studies, University of Fort Hare

The newly established district councils (DCs) and transitional rural councils (TRCs) have a very important role to play in ensuring that rural water supply and sanitation schemes are sustainable. In the Eastern Cape and other rural areas, the DCs and TRCs are unable to meet their obligation of providing basic services to communities because they lack capacity to perform their tasks.

A research project undertaken by the University of Fort Hare, has shown that almost 60% of non-functional boreholes in the Eastern Cape were due to broken infrastructure. This emphasises the importance of training rural communities to operate and maintain their water supply and sanitation schemes. If this training component is neglected, the millions of rands invested by government in infrastructure projects would fail to achieve the objective of improving the quality of life for all South Africans.

The specific objectives of this research project are:

- To investigate the capacity-building needs of DCs and TRCs in order to empower them to play a meaningful role in the management of community water supply and sanitation schemes
- To develop and promote appropriate training and capacity-building programmes for community-based development in water supply and sanitation in the target areas
- To develop a model for management of water supply and sanitation services at local level in rural communities with special reference to the Eastern Cape.

Estimated cost: *R209 000*
Expected term: *1998-2000*

Research projects

Completed

- **K8/279** Evaluation of on-site sanitation from a socio-economic perspective (Bernhardt Dunstan and Associates)
- **TT93/98** Dynamics of community non-compliance with basic water supply projects (Lynette Dreyer and Associates)
- **386** Development of a cross-flow microfilter for rural water supply (University of Natal – Department of Chemical Engineering, and Umgeni Water)
- **521** Cost recovery for water schemes to developing urban communities: A comparison of different approaches in the Umgeni Water planning area (CSIR – Division of Water, Environment and Forestry Technology, and Umgeni Water – Corporate Services)
- **649** Assessment of common problems associated with drinking-water disinfection in the developing areas (CSIR – Division of Water, Environment and Forestry Technology)
- **677** Guidelines for the evaluation of water resources for rural development with an emphasis on groundwater (Rhodes University – Institute for Water Resources)
- **684** Development of a community-based integrated catchment management programme with special reference to water supply and sanitation in the Ntshongweni catchment (University of Natal – Farmer Support Group)
- **708** Guidelines for the operation and maintenance of septic tank effluent drainage (STED) systems by communities in South Africa (CSIR – Division of Building Technology)
- **765** Evaluation of on-site sanitation systems for applicability in low-cost housing from a socio-economic perspective (Bernhardt Dunstan and Associates) (Confidential – no report)
- **876** A groundwater pump for use in informal settlements (Stass Environmental)

Current

- **346** Study of the relationship between hydrological processes and water quality characteristics in the developing Zululand coastal region (University of Zululand – Department of Hydrology)
- **384** Water resources and sanitation systems sourcebook with special reference to KwaZulu-Natal (University of Natal – Department of Economics)
- **435** Development of a training programme on community water supply management for village water committees (CSIR – Division of Water, Environment and Forestry Technology, and Appropriate Technology Information)
- **514** Groundwater contamination as a result of Third-World type urbanisation (CSIR – Division of Water, Environment and Forestry Technology)
- **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)
- **599** Co-disposal and composting of septic tank and pit latrine sludges with municipal refuse (CSIR – Division of Water, Environment and Forestry Technology, and La Trobe Associates)
- **603** Development of effective community water supply systems using deep and shallow-well handpumps (CSIR – Division of Water, Environment and Forestry Technology)
- **622** Rapid quantitative evaluation of water quality using a modified biological test – Phase 1 (University of the Witwatersrand – Department of Microbiology)
- **631** Assignment of a financial cost to pollution from on-site sanitation, with particular reference to Gauteng (University of the Witwatersrand – Department of Civil Engineering)
- **651** Appropriate low-cost sewage treatment using the advanced algal high-rate oxidation pond (Rhodes University – Department of Biochemistry and Microbiology)
- **656** Appropriate low-cost treatment of sewage reticulated in saline water, using the algal high-rate oxidation ponding (AHROP) system (Rhodes University – Department of Biochemistry and Microbiology)
- **670** Graded standards for landfilling in South Africa: Establishing appropriate affordable standards for disadvantaged communities (University of the Witwatersrand – Department of Civil Engineering)
- **671** Fog collection as a supplementary water source for small rural communities (University of the North – Department of Geography)
- **685** Occurrence and survival of protozoan parasites in source water and drinking water used by unserved rural communities (CSIR – Division of Water, Environment and Forestry Technology)
- **698** Land-based effluent disposal and use: Development of guidelines and expert-systems-based decision support (CSIR – Division of Water, Environment and Forestry Technology)
- **709** Preparation of standard engineering drawings, specifications and guidelines for ventilated improved pit latrines in South Africa (CSIR – Division of Building Technology)
- **710** Pilot study for the development of a GIS database on water and sanitation in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **712** Biological processes in on-site low-flush volume sanitation systems (CSIR – Division of Water, Environment and Forestry Technology)
- **714** Socio-biological study of the aquatic resources and their utilisation in an underdeveloped rural region, the Mutshindudi River catchment (University of Venda – Department of Zoology)
- **715** Quantitative determination and removal of nitrogenous pollutants from natural waters (University of the Northwest – Department of Chemistry)
- **724** Pollution of domestic water supply and health-related problems in the rural areas of the Molopo region of the Northwest Province (University of the Northwest – Departments of Nursing Science, Chemistry and Agriculture)
- **727** Effect of water supplies, handling and usage on water quality and quantity in relation to health indices in the Eastern Cape Province (Prowater Health) (University of Fort Hare – Department of Development Studies)
- **734** Development of a strategy for disseminating information from the hydrogeological mapping programme to village water committees (Water Systems Management)
- **738** Guidelines for the upgrading of existing rural water treatment plants (CSIR – Division of Water, Environment and Forestry Technology)
- **743** Health impact of water-borne viruses and methods of control in high-risk communities (University of Pretoria – Department of Medical Virology)
- **764** Water supply to rural and peri-urban communities using membrane technology (University of Stellenbosch – Institute for Polymer Science)
- **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** Information booklet on drinking water for creating a greater awareness among the general public (CSIR – Division of Water, Environment and Forestry Technology)
- **786** Application of visual settlement planning (ViSP) computer software in South Africa: Building the capacity of local communities in urban development (University of Cape Town – Department of Civil Engineering)
- **792** Sustainability and affordability of community-based integrated waste and wastewater management for dense, informal urban settlements (McCracken Solar Stills Company (Pty) Ltd.)
- **817** Development of strategies for empowerment of women in water supply and sanitation (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 (University of the North – 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 FRD)

New

- **886** Development of a framework for the calculation of a monthly tariff payable in stand-alone community water supply schemes (Mvula Trust)
- **895** Case study of a management system for rural water supply: Matatiele district (Mattcomm)
- **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)
- **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)
- **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 (Stass Environmental)
- **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)
- **983** Applicability of shallow sewer systems/simplified sewerage systems for dense urban communities in South Africa – An economic and technical study (Palmer Development Group)
- **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)

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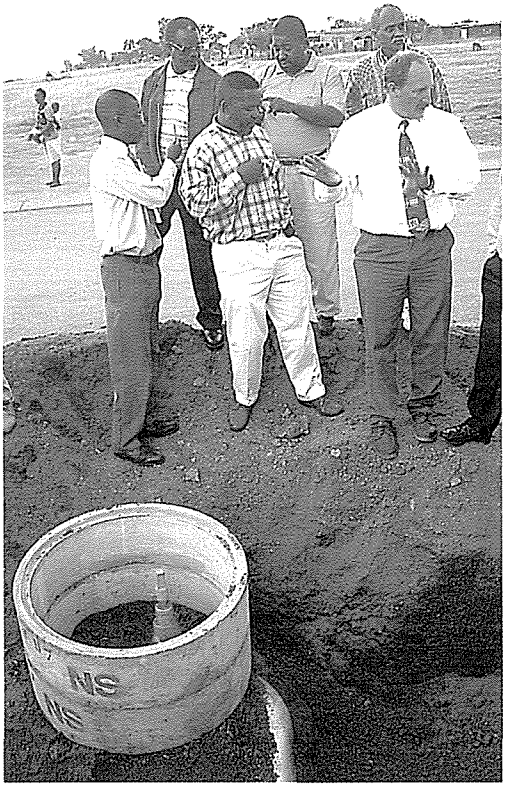
3 Potable water supply



The development, selection and optimisation of processes for the production of high-quality drinking water demands a sound balance between fundamental research on water treatment technologies and processes and the need for practically implementable solutions.

The need for an improved phase-removal process for particles such as protozoan oocysts, which may not be inactivated by chemical disinfection, has become more urgent. On the other hand there is the need to strengthen research into water treatment and supply for rural and peri-urban communities. One of the major challenges associated with small systems is sustainability. Problems such as lack of well-trained operators, maintenance and cost recovery have been experienced, with a number of installed small water treatment plants also not producing enough 'safe' drinking water. The following major research areas highlight the WRC's approach to acquiring the necessary knowledge and technologies.

Water treatment and reclamation: This area of research deals with the development, improvement and selection of cost-effective plants and processes for the supply of drinking water which complies fully with the Department of Health's water quality guidelines. The research is guided by the Strategic Plan for Research on Potable Water Treatment in South Africa, which is currently under review. Evaluation of phase removal using particle size analysis is being recognised as an important tool for analytical and process monitoring. Research in this area will lead to a more fundamental understanding of flocculation, settling and filtration processes. Investigations into the application of activated carbon and its regeneration in treatment plants, as well as other methods of removal of organics in water, are some of the research areas currently supported by the WRC.

Drinking-water quality and health aspects: Water quality and safety are issues that increasingly attract the attention of public health authorities. Fresh challenges, such as the recent outbreak of cryptosporidiosis abroad, have highlighted that dependence on indicator organisms, namely coliforms, does not necessarily ensure water free from pathogens. The occurrence of *Giardia* and *Cryptosporidium* raises similar concerns to those which troubled water supply authorities 150 years ago – when filtration and chlorination were first introduced. The need for a better capability to identify and characterise different pathogens that occur in South African waters has been identified.

Rural and urban water supply: The supply of safe water, especially to small communities which are currently unserved, and problems associated with distribution of water to currently-served communities will continue to receive attention. Current studies on the management of potable water distribution systems have great potential to improve cost-effectiveness in providing water supply services. Of importance is the deterioration of water quality in reservoirs and during storage. Since changes affecting the microbiological quality of water are of great concern, the WRC is funding certain projects in this area. The development of chemical and biological test kits for rural communities is also receiving attention.

Completed projects

Development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss

(No 489) De Leuw Cather Inc.

Unaccounted-for water (UAW) in South Africa is estimated to amount to about 20% of the urban and industrial demand. As 60% of UAW is believed to constitute actual water loss, the amount of water lost in water distribution systems throughout the country is possibly greater than the total demand of the largest cities, Johannesburg, Cape Town and Durban. If a practical limit of reduction of 50% over UAW is set and achieved, the annual saving of top class purified water would be more than 200 x 10^6 m^3. At only 50c per k*l* this amounts to some R100 m./yr. The project set out to create a set of procedures, with appropriate methodologies, to equip managers of water distribution systems to exercise proper control of UAW and thus reduce water losses. The end-product of the research was a manual for use by local authorities. This manual deals with all aspects of UAW, giving guidance and recommendations on the formulation and implementation of systems for the effective control of UAW.

Cost: *R1 600 000*
Term: *1992-1996*

Guidelines for the treatment of Eastern and Southern Cape coloured water

(No 534) Division of Water, Environment and Forestry Technology, CSIR

A practical South African guideline for the treatment of highly coloured water has been produced for use by decision-makers, designers and plant personnel. In the southern coastal areas of South Africa, organically coloured surface waters are used as a main source for potable water supply. At the commencement of the research, the treatment of these coloured waters was to a great extent still empirical and little documented knowledge existed on the chemistry of the treatment process.

During the study, a survey of existing plants treating coloured water was made. Based on problems experienced, opinions of various experts and bench-studies were required, and practical guidelines for the efficient treatment of these coloured waters were compiled.

The guidelines address the following issues:

- The selection of most suitable treatment configurations and unit treatment processes.
- Chemical precipitation and phase separation processes for treatment of coloured water.
- Design and operation of processes used in coloured-water treatment plants.
- Problems with the treatment of coloured water and specific approaches for solving or remedying the problems.

Cost: *R382 000*
Term: *1994-1996*

Development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges

(No 568) Scientific Services, Umgeni Water

The tubular filter press unit (TFP) at HD Hill Waterworks has been in operation since 1987. During an evaluation of the unit for the application of dewatering waterworks sludges, it was found that there were significant weaknesses in the design, which caused tube blockages and other operating problems. These needed to be rectified in order to produce a marketable product. It was concluded that an important factor in the successful operation of the tubular filter press, would be the availability of a full-scale or pilot plant for experimental and developmental purposes.

In meeting the objectives of the project, a vertical tubular filter press was designed and developed for the dewatering of waterworks sludges. The limitations of the previous design, especially those responsible for the tube blockages, were totally eliminated. Provided the process can operate without the use of rollers for sludge removal and tube cleaning, a reliable and inexpensive process has been developed.

Cost: *R545 000*
Term: *1993-1996*

Stabilisation of aggressive and corrosive waters

(No 613) Division of Water, Environment and Forestry Technology, CSIR

Approximately 40% of the surface waters in South Africa, and all the surface waters of Lesotho, characteristically have low calcium, alkalinity and carbonate species concentration. These characteristics render the water aggressive to asbestos-cement piping and corrosive to metal piping. The project was aimed at evaluating of the use of solid calcium carbonate (limestone) for water stabilisation, using both in-line, smaller units (approximately 50 m^3/d) and a fluidised bed, larger unit (for users >500 m^3/d).

Results obtained from the two small systems, i.e. one for groundwater stabilisation ("Spraystab") and the other for surface waters ("Presstab") show significant promise. These systems are cost-effective and can be used by all small water users. No other (practical) stabilisation systems currently exist for these users. A few such systems are already in use for borehole water, membrane permeate and soft surface water stabilisation and have drawn favourable comments. The larger system is not as cost-effective because of the expensive fluidised bed reactor involved and because this type of contactor dissolution system can never saturate the water stream completely with lime (which would require infinite contact time). However, although not mentioned in the report, the CSIR has patented a new side-stream system which is able to saturate and stabilise the water completely with limestone. Further development work on the side-stream system is continuing with partial WRC funding.

Cost: *R129 900*
Term: *1993-1994*

Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment

(No 615) Scientific Services, Umgeni Water

In this project, user-friendly models were developed relating algal abundance to important water quality variables, and further to the associated actual daily costs of water treatment. In most cases, the models developed were related to algae that were known to adversely affect water treatment. The factors which most impacted on water treatment, and hence treatment costs, were determined at selected waterworks. Models were developed relating raw water quality entering respective waterworks to costs incurred in treating that water. It was found that lake water quality had a significant impact on the treatment cost of water in each of the major waterworks examined. Within the range of the data

analysed, abiotic water quality factors generally affected water treatment more significantly than algae, except where potentially powerful taste- and odour-forming algae (principally *Anabaena*) were present. The model predicts actual costs quite well and can be easily applied in simulation exercises. Although the study was done in the Umgeni catchment, the methodology used may now be employed fairly easily by other water authorities in other catchments.

Cost: *R293 000*
Term: *1994-1996*

Enhanced coagulation for the removal of disinfection by-product precursors

(No 773) Scientific Services, Umgeni Water

The project was aimed at investigating, and providing some guidelines, on the use of enhanced coagulation in potable water treatment. In general, conventional coagulation is defined by the conditions that lead to optimal turbidity removal using coagulant alone, while enhanced coagulation is defined by the conditions that lead to optimal natural organic matter or disinfection by-products removal using a coagulant (usually inorganic, metal coagulants) with or without acid addition.

The results obtained from this project are extremely encouraging. This is because they show that, when used correctly, generally-available and affordable metal coagulants come fairly close to achieving the same treatment efficiencies in terms of organics removal (except for taste, odour and pesticides) than much more expensive processes such as activated carbon treatment and ozonation of the water. Since taste, odour and pesticide problems are not widespread and are only infrequently encountered, the findings and guidelines presented in this report can be very useful for water suppliers who might have neither the technical personnel and know-how, nor the money, to implement activated carbon or ozone treatment in their waterworks.

Cost: *R60 000*
Term: *1996-1998*

In situ calibration of large water meters

(No 871) Stewart Scott (CE) Inc.

The Water Services Act, Act 108 of 1997, makes it a requirement that all water service providers conduct annual water audits and determine the need for water conservation measures and active leakage management. A vital factor in carrying out these measures, is the accuracy of the water meters. The accuracy of water meters deteriorates with age and leads to errors in the measurement of water use. Meters may also behave accurately under ideal conditions but have reduced accuracy when installed on-site. Resulting errors contribute towards unaccounted-for water (UAW) and give a very distorted picture of a water service provider's consumption figures. Inaccuracy also greatly impacts on the revenue of the water services provider.

The aim of this study was to establish a flow reference standard, acceptable to the Director of Trade and Metrology, for the cost-effective *in situ* calibration of large water meters. This would enable the accuracy of permanently installed water meters to be compared periodically against the standard to ensure that meters remain within the prescribed limits of accuracy.

Results of this research indicated that the method established for *in situ* calibration of large water meters can achieve accuracies that comply with required standards. However, practical limitations of the meters' performance and the limitations of the hydraulic system in which they are installed could restrict the flow range over which meters can be tested or calibrated. It was recommended that the flow reference standard, consisting of insertion flow meter measurements, a velocity-area method and a velocity-profile function as detailed in the report, be adopted as an accepted test method for the *in situ* calibration of large water meters.

Estimated cost: *R100 000*
Estimated term: *1997*

New projects

Economic model for leakage management

(No 898) BKS (Pty) Ltd.

A difficulty with active leakage control is that it is often not clear how often the water services provider should scan an area for unreported leaks. In some cases once every two years is sufficient and in other cases once every six months is desirable. This frequency has serious financial implications for water service providers.

The aim of the project is to develop a user-friendly computer-based program to enable water suppliers and municipalities to evaluate the need for, and value of, active leakage control. It is envisaged that the the proposed software will set out the various costs associated with active leakage control. Using the software, the water supplier will be able to derive various economic indicators from which the optimum cycle for active leakage control for a specific area could be determined. The program will, furthermore, enable various possible scenarios to be tested to determine the financial implications of the different leakage detection and control options.

The proposed program will combine with the background night flows program, already under development for the WRC, to provide a set of tools to assist water suppliers to address difficult questions relating to leakage and leakage management.

Estimated cost: *R197 000*
Estimated term: *1998-1999*

Optimisation of an automatic backwashing filter for the cost-effective production of potable water for rural areas

(No 919) Scientific Services, Umgeni Water

The choice and complexity of a water treatment process for potable water production is influenced by the water quality, water quantity, physical location and the availability of resources for operation and maintenance, and not necessarily by the capacity of the plant. The smaller plants generally used in smaller isolated communities, remain under pressure to reduce both capital and operating cost. The challenge to designers is therefore the provision of low-cost, low-maintenance plants without compromising performance. Processes must be simple so as not to require highly skilled operators.

It is against this background that the automatic backwashing gravity filter will be evaluated as it has no internal moving parts, requires no operator intervention, no electricity, can accommodate a wide choice of filtration media and is suitable for gravity-powered chemical dosing systems. The objectives of this project are to:

- Assess the suitability of a proprietary automatic back-

washing filter for inclusion in low-maintenance treatment processes for potable water production from surface waters and the removal of iron and manganese from groundwater supplies
- Propose, where necessary, design modifications aimed at improving the reliability and reducing the capital costs of such an automatic backwashing filter
- Propose specific operating rules by which the unit should be operated and maintained and to prescribe minimum levels of operator supervision.

Estimated cost: *R138 000*
Expected term: *1998-1999*

Evaluation of a filter wash-water recovery plant to establish guidelines for design and future operation

(No 920) Scientific Services, Rand Water

Filter wash-water contains high concentrations of impurities which originate from raw water sources. In most water purification plants this water is returned to the beginning of the process for re-treatment. The impurities are mainly suspended matter but can also include micro-organisms, algae and taste- and odour-causing substances. Pathogenic micro-organisms such as *Giardia* and *Cryptosporidium* are known to pass through conventional treatment processes under certain conditions and to resist disinfection by conventional means. The disadvantage of recycling filter wash-water back to the head of the process is that the above micro-organisms can be concentrated in the system.

The aims of the project are to establish guidelines for the design and future operation of filter wash-water recovery plants with emphasis on the following:
- Removal of suspended matter
- Removal of pathogenic bacteria
- Removal of taste- and odour-causing compounds and algae
- Establishment of design and treatment requirements and operational procedures to produce water of potable quality.

Estimated cost: *R214 000*
Expected term: *1998-1999*

Water quality deterioration in potable water reservoirs relative to chlorine decay

(No 921) Scientific Services, Rand Water

A recent study, **The prediction of chlorine decay from potable water in pipeline systems** (WRC project No 704), showed that once the nth-order kinetic constants for a particular water sample have been determined, the rate of chlorine decay in a pipeline can be determined accurately. It is often found that bacteriological quality of the water deteriorates significantly after the water has passed through a reservoir. In reservoirs, this may be caused by stagnant water pockets, stratification, long residence time and sedimentation, whilst in pipelines, the situation is different. Therefore a knowledge of the residence time distribution (RTD), the kinetics of bulk chlorine losses, chlorine demand of the water as well as chlorine losses to the atmosphere will allow one to calculate the amount of chlorine which should be dosed. It will also provide information on the requirements for additional dosing at the exit of the reservoir.

The aims of the project are to:
- Characterise the flow patterns in a reservoir in terms of residence time distribution
- Relate chlorine losses in terms of the water age (based on RTD-values and kinetic models)
- Account for chlorine losses to the wall (including bottom) effects
- Account for atmospheric losses
- Relate the bacteriological quality of the water to the levels of chlorine in the reservoirs
- Compare the bacteriostatic effect of monochloramine and free residual chlorine in reservoirs.

Estimated cost: *R168 000*
Expected term: *1998-1999*

STASOFT IV – A user-friendly computer program for use in the treatment of municipal water supplies

(No 922) Department of Civil Engineering, University of Cape Town

The original STASOFT (III) was developed for the WRC in 1989, and is used in South Africa for calculations involving pH control and mineral ($CaCO_3$ and $Mg(OH_2)$) precipitation and dissolution and gas (CO_2) interaction between water bodies and the air. The demand and expectation for much higher standards of user-friendliness, ease of learning and consistency of action among users of computer software has increased. For example, facilities offered by the Windows operating system were not available at the time the current STASOFT program was developed.

It is therefore proposed to bring STASOFT up to modern standards, whilst incorporating the following improvements:
- Consolidation on one display screen of the original, treated and equilibrated water compositions – immediate recomputation and redisplay
- Increased number of treatment options to address pH control in such processes as coagulation/flocculation/disinfection
- Elimination of 'bugs' and other shortcomings.

The aims of this project are to produce an upgrade of the existing computer program STASOFT (III) to be called STASOFT (IV) so that:
- The program can be more easily used by design engineers and chemists working in the water field
- The capabilities of the existing program are extended to more facets of water treatment unit processes – in particular to the coagulation/flocculation/disinfection processes.

Estimated cost: *R156 000*
Expected term: *1998-1999*

Supercritical fluid regeneration of activated carbon applicable to water fraternity

(No 923) Centre for Separation Technology, Potchefstroom University

Activated carbon is very efficient and relatively cost-effective in the removal of toxic substances at very low concentrations in drinking water. For economic reasons, the use of activated carbon is limited. Regenerating activated carbon by desorption of adsorbed substances can effectively lower the costs through reuse. Existing methods of regeneration have inherent drawbacks such as loss of efficiency, deterioration of carbon in successive thermal regenerations, high cost of reagents and environmental pollution. It is therefore necessary to develop new methods for regeneration. Supercritical carbon dioxide (sc-CO_2) is capable of extracting a broad spectrum of substances from carbon surfaces, trapping the substances with ease on depressurising the fluid and possibly having several cycles of successive regeneration

Research into systems for the abstraction of surface water through river sand-beds. Side view of the model unit (Project No 829).

without ill-effect on the activated carbon and the environment. A feasibility study on the sc-CO_2 regeneration of granular activated carbon (GAC) supplied by Eskom on the basis of a few similar studies is underway. Already there are indications of recoveries up to 75% of the adsorbing capacity of the unused activated carbon.

The aims of the project include the following:

- To exploit, optimise and upscale promising first results obtained for the sc-CO_2 regeneration of spent activated carbon
- To assist industries having specific water quality requirements, such as Eskom, to effect faster, more efficient and more cost-effective regeneration of activated carbon used in filters
- To attempt a unique application of supercritical fluid technology.

Estimated cost: *R125 000*
Expected term: *1998-1999*

Characterisation and chemical removal of organic matter in South African coloured surface waters

(No 924) Chris Swartz Engineering

Considerable work on the characterisation of organic matter in coloured waters has been done overseas. However, a study carried out at the University of Cape Town showed that South African coloured waters have considerably higher colour levels than those studied overseas. The results of natural organic matter characterisation performed overseas cannot therefore be applied directly.

The objective of the project is to characterise the natural organic matter in South African coloured surface waters and to develop operational coagulation diagrams for the removal of the organic matter. This will improve the effectiveness and cost-efficiency of treatment of these coloured waters. The aims are as follows:

- Establishment of a coloured water characterisation and classification approach
- Characterisation of the natural organic matter
- Classification of coloured waters
- Tests on performance of bench-scale coagulation
- Application of characterisation data and coagulation diagrams
- Drafting of a manual on the treatment of South African coloured surface waters.

Estimated cost: *R317 000*
Expected term: *1998-2000*

Water meters: Influence of various fittings and installation configurations on accuracy

(No 948) SABS

In the past much work has been done with regard to meter specifications and the correct test procedures. At present it is well known how water meters perform on the test bench but little is known about how installation practice and the use of various fittings affect the accuracy of the meters in the field. Local small contractors are often employed on government-sponsored community water-supply schemes. In many cases these contractors pre-assemble and install water meters, but have insufficient knowledge of the selection of the correct fittings and installation procedures.

With the new National Water Supply Regulations requiring proper water audits and the pending *Code of Practice for Unaccounted-for Water within Distribution Systems*, it is absolutely essential to know the effect on accuracy of fittings used for the installation of water meters. This will enable municipalities and contractors to be advised on the correct procedures, and at a later stage, the *Code of Practice* to be updated accordingly.

The project aims to:

- Establish proper reference values for various fittings currently used by meter manufactures in order to establish pressure drop across a meter installation
- Determine the influences of these fittings on the accuracy of the water meter
- Determine the effect of the use of non-standard fittings and various installation configurations on the accuracy of the meter
- Develop guidelines for correct installation.

Estimated cost: *R250 000*
Expected term: *1998*

Trouble-shooting guide for the domestic consumer

(No 963) Scientific Services, Rand Water

Water suppliers commonly receive an assortment of queries and complaints from consumers concerned about the safety of water. Many of these arise from unsubstantiated rumours or even misinformation spread by parties with various vested interests. Having secure and reliable information readily at hand in pre-packaged form could assist in dissipating damaging effects of the popular speculation that every so often seeps through the community. It would be possible to compile information by analysing a database of typical queries and appropriate answers developed by a multi-disciplinary team of scientists and sociologists. Furthermore, the effective dissemination of information pertaining to frequently asked questions (FAQs) through, for example, a workbook in calendar format appropriate to a kitchen wall, a simple pamphlet, a website, a CD-ROM, etc., could be investigated.

This project aims to:

- Collect and collate questions about perceived problems that they may encounter with drinking water in South Africa
- Present these FAQs and the answers in an easily comprehensible form
- Propose different ways of disseminating this information to the public.

Estimated cost: *R 110 000*
Expected term: *1998*

Benchmarks and cost parameters in water and wastewater treatment

(No 984) Philip Pybus (CE)

South Africa is entering a phase of massive infrastructure expansion, particularly in the provision of water supply and sanitation services. This will entail the design, construction and operation of a very great number of works, large and small, and for both potable supplies as well as for wastewater treatment. It is important that the questions of cost and effectiveness of performance are approached conscientiously and consistently so that the parties involved can benchmark what they are doing and so make their designs and operations fully competitive and operationally cost-effective. An additional feature of this expansion is the establishment of new local authorities and water boards.

The aim of the research will be to ascertain from the local authorities, designers and water boards the nature and extent to which they benchmark their activities. In the event that they are already doing so, it should be established which activities and parameters they benchmark, with whom and how frequently. Finally it would have to be established to what extent they would benchmark in the future, given a suitable methodology to follow and what benefits they would expect to gain.

The findings of this study will prove valuable for the motivation and extent of future research on this subject. It will also identify the specific needs of the sector in moving towards a national benchmarking strategy.

Estimated cost: *R 40 000*
Expected term: *1998*

Research projects

Completed

- **489** Development of procedures for the control of unaccounted-for water in water distribution systems and for the reduction of water loss (De Leuw Cather Inc.)
- **534** Guidelines for the treatment of Eastern and Southern Cape coloured water (CSIR – Division of Water, Environment and Forestry Technology)
- **568** Development of an Exxpress unit for the production of potable water and the dewatering of waterworks sludges (Umgeni Water – Scientific Services)
- **613** Stabilisation of aggressive and corrosive waters (CSIR – Division of Water, Environment and Forestry Technology)
- **615** Modelling the causes of algal blooms in impoundments of the Umgeni catchment and the consequences for potable water treatment (Umgeni Water – Scientific Services)
- **773** Enhanced coagulation for the removal of disinfection by-product precursors (Umgeni Water – Scientific Services)
- **871** *In situ* calibration of large water meters (Stewart Scott (CE) Inc.)

Current

- **280** Evaluation of full-scale flotation-filtration and chlorine dioxide plants (Orange Free State Gold Fields Water Board)
- **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)
- **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)
- **470** Application of health risk assessment techniques to microbial monitoring data (CSIR – Division of Water, Environment and Forestry Technology)
- **541** Bio-degradable organic compounds and microbial regrowth in drinking water (Rand Water)
- **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)
- **587** Evaluation of water pipe leaks in the Johannesburg municipal area (CSIR – Division of Materials, Sciences and Technology)

- **611** Development of procedures for bio-degradability 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 waste-water treatment plants (University of Natal – Department of Chemical Engineering)
- **679** Compilation of a computerised, diagnostic system for algal-related water purification problems (Rand Water – Scientific Services)
- **662** Evaluation and optimisation of a cross-flow microfilter for the production of potable water (University of Natal – Pollution Research Group)
- **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)
- **803** Development of a standardised approach to evaluate burst and background losses in water distribution systems in South Africa (BKS Inc. – Water Resources Department)
- **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)
- **872** Design and analysis package for air saturation systems used in dissolved air flotation (Rand Afrikaans University – Department of Civil Engineering)
- **873** Chemical and microbiological evaluation of the performance of commercially available home treatment devices (Rand Water – Scientific Services)

New

- **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 (University of Natal – Dept of Civil Engineering and 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))

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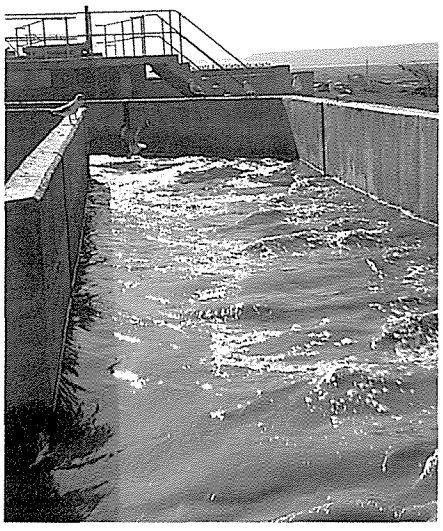
Municipal wastewater management



In response to changing social needs, research sponsored by the WRC into the collection, treatment and disposal of domestic sewage has in recent years been divided between the research needs for centralised service agencies such as municipalities (managing wastewater from established urban areas) and the research needs for developing peri-urban communities.

The research priorities in these two (sometimes overlapping) broad fields are summarised in their respective "master plans for future research". Current concerns regarding sanitation research for developing communities are dealt with in **Developing Communities: Water Supply and Sanitation**, and are not considered further here. Research priorities for municipal wastewater management in this section were identified in consultation with the Co-ordinating Committee for Municipal Wastewater Management (CCMWM) and are described briefly in the following subsections dealing respectively with municipal wastewaters and sludges.

Sewage purification

In reviewing the primary goals identified in the research plan for municipal wastewater management in the context of current needs and activities in the RSA in this field, it is important to note that, firstly, municipal sewage works receive significant quantities of industrial discharges as well as domestic sewage, and that, secondly, the treated wastewater discharged (generally to rivers, except in some coastal areas) constitutes a significant proportion of the dry weather flow in some rivers. In the water-scarce RSA situation, these flows are subsequently often abstracted, stored (short-term) or impounded (longer-term) for further treatment and reuse. The discharge quality of the treated municipal wastewater is thus strategically significant, and this dictates the technological and management (including human resource) research needs.

The discharge of industrial effluents to municipal works for biological co-treatment with sewage adds various challenges to meeting the requisite treatment standards, including potential inhibition or toxicity of some components, slower or lesser biodegradability of some organic fractions (all COD is not equal), imbalances between available carbon and nutrient loads (leading in some cases to nutrient deficiency and in others to a high demand for nutrient removal), the accumulation of metals in biological sludges, and various other operating factors. Generally, research carried out to date has provided at least partial solutions to many of these problem areas.

Sewage sludge treatment and disposal

Improved sludge handling and utilisation is Primary Goal 2 in the strategic research plan in this field. Several of the "problem areas" identified stem from the presence of constituents of industrial origin, as indicated above for sewage purification. In this respect, the source reduction initiatives in the **Industrial Water Management** portfolio will, when implemented, assist in reducing pollutant loads such as high metal concentrations which currently accumulate in wastewater sludges. In 1997, the WRC published a collaborative guide for *Permissible Utilisation and Disposal of Sewage Sludge* (edn. 1) (WRC Report No TT 85/97). Feedback from sewage treatment plant operators indicates that in practice there are difficulties in meeting the proposed requirements, indicating that there is a need for on-going consultation and review of the application of the guidelines.

Completed, current and new projects in sewage sludge treatment and disposal as listed indicate the active research areas, which include the use of municipal wastewater sludges as a resource. Examples are accelerated bio-hydrolysis of sewage sludges to provide a sustainable carbon source for biological sulphate reduction processes applied to the treatment of acid mine drainage waters and other industrial effluents, the use of waste activated sludge as a bio-sorbent for metal removal from wastewaters, and the use of wastewater bio-mass to increase the rate of phosphate removal

from wastewaters. As can be seen from this brief outline, ongoing research is directed not only at the destructive disposal of wastewater sludges, but also at their beneficial use in various innovative applications.

Completed projects

Aspects of sewage sludge treatment and disposal

(No 316) Greater Johannesburg Metropolitan Council (GJMC)

Sludge disposal is a world-wide problem and is rapidly assuming major proportions in the larger cities of South Africa. It is estimated that the daily sludge production from Johannesburg plants is expected to reach 500 dry t/d by 2015. A number of options for the safe disposal of sludge are available, such as composting, co-disposal of sludge with household refuse in landfills, disposal on sacrificial land and lawn sod farming. Optimisation of the available processes and evaluation of the cost benefits associated with these options are essential to allow the formulation of a long-term sludge disposal policy. These investigations will include monitoring the effects of the application of composted sludge on agricultural land, particularly with respect to heavy metal content. In this latter regard, investigations into regulating the discharge of metals to the sewer have also been initiated.

A number of final disposal options for sludge disposal were evaluated, and four options were accepted:

- Co-disposal with domestic waste in a landfill
- Disposal to sacrificial land
- Composting
- Incineration.

Neither incineration nor disposal to sacrificial land were investigated further within this project. Composting showed the most promise. Experimental work revealed that it was possible to predictably achieve temperatures of over 65 to 70°C in compost heaps, thus ensuring a consistently disinfected product. The compost significantly enhanced crop or veld grass production (by 50 to 60% over controls). Concern over the contamination of the sludge by heavy metals and organics led to a reassessment of the tariff structure which the GJMC used on industrial effluents and also to investigate the option of tankering these effluents to a central treatment site.

Cost: *R342 000*
Term: *1990-1994*

Fats and oils in effluents

(No 408) Division of Water Utilisation Engineering, Department of Chemical Engineering, University of Pretoria

Levels of fats and oils in sewage in South African wastewaters are still unquantified. It also has a distinct value, and better wastewater purification practices may lead to better resource utilisation. More effective fat separation at sewage treatment plants before secondary treatment may have economic advantages. The above formed the basis for this project.

The first part of the investigation was aimed at obtaining an appreciation of oil, fat and grease problems in sewage. Questionnaires to local authorities revealed that with one minor exception, it is not seen as a major problem except for occasional spills or unlawful releases by service stations. Strict controls could therefore limit the extent of the problem.

The second part was aimed at assessing the amount of oil and fat in sewage sludge. A number of determinations showed a value of only 0.5 to 1%. These values are based on multiple Soxhlet extractions and are lower than expected compared with published data of up to 5%. It is possible that the Soxhlet extraction is not suitable for determination of fat, oil and grease in samples with such high solids concentrations.

The third part was aimed at studying the feasibility of oil production by pyrolysis of sewage sludge and to study disposal options for residues. The main findings were that about 35 to 40% of the dry sludge mass of waste activated sludge could be converted into an oil with a high calorific value – probably well suited for use as a fuel oil. Another 5% was lost as a non-condensable gas (at room temperature). The residue was tested for its potential as an adsorbent and found to approach granular activated carbon in its efficiency to adsorb methylene blue. This might find application in polishing secondary effluents after recovery of fuels.

Cost: *R13 000*
Term: *1991-1996*

Refinement of design parameters for sludge thickening by dissolved air flotation

(No 556) Laboratory for Energy, Rand Afrikaans University

Published surveys of full-scale dissolved air flotation thickening plants show wide scatter in performance and also with regard to certain critical design parameters, such as the shape and size of the contact zone, the velocity and design of the sludge-scraping mechanism, air supply and chemical dosing. These aspects were investigated more closely in this project.

In spite of the high variability of the sewage sludges and plants studied, useful results were obtained. A primary finding of the study is that three of the five plants surveyed, do not allow the float layer to accumulate sufficiently to adequately allow the drainage of water from the float layer above the water level, and to provide enough stability to protect the float layer from being destabilised by the sludge scrapers. This results in the less than optimum sludge dryness and increased suspended solids values in the effluent from the plants. Previously developed models for the thickening of sludge by flotation were also investigated and commented upon.

Cost: *R75 000*
Term: *1993-1994*

Laboratory- and pilot-plant bioreactor development for remediation of metal-contaminated wastewater using activated sludge as biosorbent

(No 688) Department of Biotechnology, Technikon Natal

The phenomenon of bioadsorption of metals by activated sludge has been well documented in the literature, both as a treatment process for removing metals and as a problem of metal contamination in sludges to be disposed of to landfill. The work carried out in this project covered three major areas, viz.:

- Laboratory-scale development and optimisation of various bioadsorption options using waste activated sludge (WAS) for treating industrial metal-containing effluents
- Conceptual design of a pilot-scale bioreactor, excluding desorption of the resulting metal-enriched sludge

- A preliminary costing of bioadsorption of metals using WAS compared to conventional physico-chemical precipitation and "hi-tech" adsorption options available commercially.

The major conclusion reached was that, on a cost basis, bioadsorption by WAS and commercial disposal of the metal-enriched sludge was significantly more expensive than other options available. The major cost factors were transportation of the WAS (55%) and disposal of the resultant metal-enriched sludge (38%). Desorption using mineral acids or sodium chloride resulted in a metal-concentrate of approximately one-third the volume of the original effluent with a relatively high concentration of organic suspended solids and the almost total de-activation of the WAS. Construction and operation of a pilot plant on site at a metal-plating company were not considered to be justified at this stage of the research.

It was concluded that, to make the process more competitive, the specific uptake rate (mg/g) needed to be increased and the desorption cycle needed to be optimised. If the basic process viability/potential could be improved, other techniques e.g. membrane processes could then be considered for further concentration and recovery of metals from the desorbing eluate, with the cost-attractiveness then depending on the particular metal concerned.

Cost: *R175 400*
Term: *1995-1997*

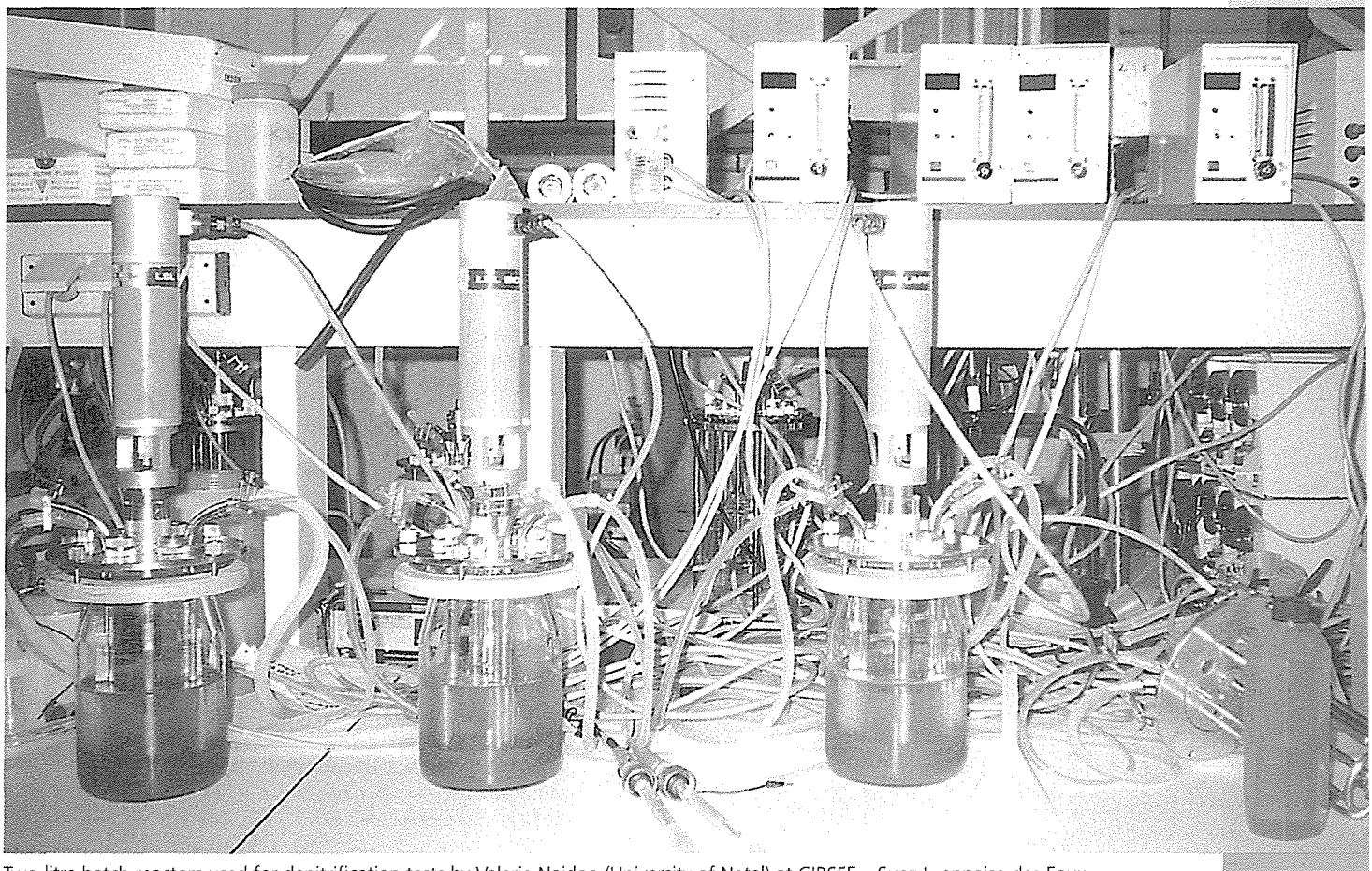
Calibration of open-channel flow-measuring systems using laboratory-calibrated velocity-head electronic measuring instruments, and by applying the continuity principle

(No 707) East Rand Water Care Company (ERWAT) through Sigma Beta (CE)

During 1992 a detailed investigation revealed that the majority of open channel flumes on South African sewer mains and at municipal wastewater treatment plants, do not comply with the generally accepted *British Standards 3680*.

In this project tests were performed on different flumes in order to establish the impact of differences in shape and surface roughness on calibration coefficients. It has been found that differences in shape led to a maximum error of 2.7% and that surface roughness caused a maximum error of 1%. It is thus evident from the laboratory test results that both shape and surface roughness play only minor roles with respect to the accuracy of flow measurement in flumes. The calibration of measuring flumes was also addressed. Information has been included on the measurement of discharges in pipes which flow partially full under uniform flow conditions. These guidelines are the product of a large number of practical tests, combined with existing standards for the measuring of fluids by flumes. The result is a set of methodologies and worked examples, which clarifies and simplifies measuring flume design to the point where plant personnel in the smaller plants will also be able to follow and utilise the guidelines to the full.

Cost: *R86 600*
Term: *1995*



Two-litre batch reactors used for denitrification tests by Valerie Naidoo (University of Natal) at CIRSEE – Suez Lyonnaise des Eaux in 1996 and 1997.

New projects

Investigation into optimisation of high-rate biological filtration for wastewater treatment

(No 929) Water Engineering Division, Wates, Meiring and Barnard (CE) Inc.

The national initiative to provide water supply and sanitation services to many rural and semi-rural communities is resulting in the production of varied sewage effluent streams. These effluents have to be treated in a reliable manner to protect our national water resources. Biofiltration has been proven to be a reliable and robust wastewater treatment technology. A large amount of research is being conducted internationally in the field of fixed-film technology, of which biofiltration is a good example. In the rural situation, biofiltration would be the preferred technology due to its simplicity and ease of operation and maintenance.

A recent research project on biofiltration funded by the WRC produced very promising results. It was demonstrated that the combination of biofiltration and activated sludge is economically more attractive than either of the technologies applied in isolation. This statement is specifically applied to situations where the special phosphate standard is not relevant. These research results have been applied on full scale at several plants serving the communities of Dundee, Nigel and Witbank, to name a few. However, further research is required to optimise a number of aspects before this promising technology could be widely applied in practice.

The research objectives all relate to the further refining and optimisation for the full-scale application of the technology, and are as follows:

- Investigation into alternative biofilter media, including natural stone and synthetic locally manufactured media
- Optimisation of the wastewater dosing pattern and frequency
- Optimisation of the recycling of biofilter effluent across the biofilter reactor
- Improvement of nitrification removal performance.

Estimated cost: *R233 000*
Expected term: *1998-1999*

Biological application in microbial diversity studies of activated sludge

(No 933) Department of Microbiology and Plant Pathology, University of Pretoria

Phosphate-rich wastewater effluents entering lakes or impoundments result in eutrophication of these water bodies. Eutrophication leads to significant changes in water quality and lowers the value of surface waters for potable, industrial and recreational uses.

The project aims to use the recently introduced "Biolog Automated Microbial Identification System" in a new role for identifying and characterising a wide variety of environmental bacteria and yeasts. The Biolog System was recently introduced, mainly for the identification of micro-organisms. However, preliminary investigations in the project leader's and other laboratories have indicated that this technique might be very useful in microbial ecology studies and specifically in microbial diversity studies of activated sludge. In this project the Biolog System will be used to provide new insights into the composition of the microbial community in activated sludge. These studies should also provide a better understanding of the biological phosphorus removal phenomenon and the microbial ecology of bulking sludge. This information could lead to process optimisation for enhanced biological phosphorus removal and improved control over the eutrophication of our surface water resources.

Estimated cost: *R174 000*
Expected term: *1998-1999*

Bio-augmentation of activated sludge for enhanced biological phosphorus removal

(No 934) Department of Microbiology and Plant Pathology, University of Pretoria

Residual phosphorus entering surface water resources from wastewaters remains a problem in terms of the eutrophication it causes – with the concomitant negative impact which eutrophication has on potable water production, industrial water and recreation. The activated sludge process frequently fails to remove phosphorus adequately to meet legislative standards. Hence, chemical treatment has to be used in order to meet those standards. Research has indicated that biomass quantity is more important than the microbial community of the biomass. Should phosphorus removal be dependent on biomass quantity, it could lead to system failure in terms of phosphorus removal. Bio-augmentation could boost and replenish depleted populations of micro-organisms, permitting rapid regrowth of the biomass.

The benefits of biomass supplementation (bio-augmentation) are: no retro-fitting of the process would be required; it is a cost-effective alternative to chemical treatment; bio-augmentation products are on-site if return sludge or waste sludge is used; and a useful application for waste sludge might be discovered. The relationship between biomass quantity and phosphorus removal, therefore, needs further investigation.

The aims of the project are as follows:

- To determine the relationship between biomass and phosphorus-removing and non-phosphorus-removing systems
- To evaluate anaerobic sludge biomass as supplement; return sludge biomass as supplement; aerobic sludge biomass as supplement; and bio-augmentation biomass as supplement
- To determine the phosphorus-removal capacity of a system based on biomass
- To determine the effect of bio-augmentation on phosphorus removal in a conventional activated sludge system by adding bio-supplements and/or anaerobic sludge in order to increase the biomass.

Estimated cost: *R336 000*
Expected term: *1998-1999*

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

(No 970) Department of Civil Engineering, University of Cape Town

Many trickling filter (TF) wastewater treatment plants (WWTP) in South Africa have been extended by building biological nutrient removal activated sludge (BNRAS) systems, particularly in the inland areas where the 1.0 mgP/*l* standard has to be met. In order not to lose the benefit of the old TF, three approaches have been followed:

- In some cases, a proportion of the influent WW is directed to the TF and the TF effluent is then discharged to the BNRAS system

- In other cases, the TF effluent is chemically treated for P removal
- Where the TF effluent is not chemically treated, it is irrigated and not returned to the catchment.

None of these approaches is desirable. The first approach is not the best utilisation of the influent WW organics because with this arrangement the AS system has to achieve BNR of the total WW flow but with a reduced organic load. This arrangement in effect increases the influent TKN/COD and P/COD ratios of the WW discharged to the AS system which reduces the BNR that can be achieved in the AS system. The second approach increases salinity, reduces alkalinity and pH, does not reduce nitrate and is expensive. The third is a loss of downstream reusable water and is a practice which is to be substantially disallowed by the DWAF in future.

The factor which governs the sludge age of the BNRAS system is the requirement to nitrify. If external nitrification could be achieved outside a TF/BNRAS plant, the sludge age could be more than halved from the usual 15 to 20 d to 7 to 10 d with improved BNR and COD removal. The reduction in sludge age increases the treatment capacity of the BNRAS system by some 50% so that the TF would not be required for COD removal. A further benefit of this scheme is that it virtually eliminates the alternating anoxic-aerobic conditions which have been identified as the major stimulus for filamentous bulking in 'conventional' BNRAS plants, and the improved sludge settleability could further increase treatment capacity of the AS system.

The aims of the project include the following:

- To examine the effect of external nitrification on BNRAS systems
- To examine N and P removal performance and sludge settleability of non- or partially nitrifying BNRAS systems at short sludge ages (5 to 8 d) and low temperatures (12 to 20°C)
- To examine biological excess P removal (BEPR) performance and sludge settleability in anaerobic-anoxic zone (i.e. no aerobic zone) BNRAS systems at laboratory scale
- To extend BNR simulation models to include anoxic P uptake/denitrification kinetics.

Estimated cost: *R665 000*
Expected term: *1998-2000*

Transforming the PETRO® process to provide for biological nutrient removal

(No 971) PGJ Meiring Konsult

In recent years, understanding of the fundamental biological principles involved in both the biological removal of phosphorus by biological nutrient removal activated sludge (BNRAS) wastewater treatment plants and of algae present in oxidation pond effluents by pond-enhanced trickling filter operation (PETRO®) plants indicates that the two systems have certain basic concepts in common. Initial studies and experiments indicate the feasibility of a successful line-up of the two processes, for which pioneering research was in both cases carried out in South Africa. The developed world was quick to accept the BNRAS concept, and the PETRO® system for algal removal (a combination of secondary biological treatment unit processes such as anaerobic reactors, facultative oxidation-ponds, biological trickling filters, activated sludge reactors and nitrifying facilities) has been hailed by engineers and scientists as one of the most significant advances in low-cost sanitation during the second half of this century. However, although PETRO® removes algae from oxidation pond effluent and can nitrify ammonia very effectively it has, until now, not been successful in removing phosphorus biologically. If the process could be extended successfully as a low-cost, simple-to-operate facility to reliably bring about P-removal, it would enjoy much wider application.

The aim of the project is to research and develop a link-up between the PETRO® process for algae removal and the BNR type of activated sludge plant (both developed in South Africa) to bring about, at little additional cost and with low operational requirements, an integrated facility which will reliably produce an effluent that will meet all the stringent nutrient and quality requirements now often laid down in both the developed and developing worlds. Conventionally, this has been approached by installing high-cost acid digesters to increase the volatile fatty acids required by P-reducing bacteria. However, acidogenesis is a relatively high-tech process in this context and is not consistent with the low-tech nature of the PETRO® process. The introduction of a number of low-cost measures which are compatible with the PETRO® concept are anticipated to solve the problem.

The measures referred to above include:

- Enhancement of organic load on the fermentation pit
- Use of submerged acid digesters in the primary pond
- Transfer of the P-release fermentation zone from the ASP reactor into the primary pond.

Estimated cost: *R889 000*
Expected term: *1998-2000*

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Research projects

Completed

- **316** Aspects of sewage sludge treatment and disposal (Greater Johannesburg Metropolitan Council (GJMC))
- **408** Fats and oils in effluents (University of Pretoria – Department of Chemical Engineering, Division of Water Utilisation Engineering)
- **556** Refinement of design parameters for sludge thickening by dissolved air flotation (Rand Afrikaans University – Energy Laboratory)
- **688** Laboratory- and pilot-plant bioreactor development for remediation of metal-contaminated wastewater using *activated sludge as biosorbent* (Technikon Natal – Department of Biotechnology)
- **707** Calibration of open-channel flow measuring systems *using laboratory calibrated velocity-head electronic measuring* instruments, and by applying the continuity principle (East Rand Water Care Company (ERWAT), through Sigma Beta (CE))

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)
- **542** Causes and control of low A/A filament bulking in nutrient removal activated sludge systems (University of Cape Town – Department of Civil Engineering)
- **554** Study of activated sludge microbial population dynamics for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **555** Limitation of convection currents in clarifiers (University of Pretoria – Department of Chemical Engineering)
- **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)
- **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 Town City Council – City Engineer's Department)
- **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) ,
- **755** Development of strategies for amelioration of bulking *by anoxic-aerobic filamentous organisms in nutrient removal* activated sludge systems (Stewart Scott (CE) Inc.)
- **776** Fingerprinting of activated sludge systems using PAGE analysis of total protein extractions for the optimisation of biological phosphorus removal (University of Pretoria – Department of Microbiology and Plant Pathology)
- **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))

New

- **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)

Water quality management

5

In terms of South Africa's constitution the State has an obligation to ensure an environment which supports the health and well-being of all its people. It is increasingly appreciated that access to water of an acceptable quality plays an important role in this regard.

In fact, impaired water quality has a negative impact not only on human consumption, but on practically all water uses. Unfortunately it is also a fact that most uses of water tend
to impact negatively on its quality. Consequently a deterioration in quality is observed after every use cycle. As water resources therefore become more fully utilised and surplus dilution capacity diminishes, the effects are usually manifested as water quality degradation. If left unchecked this deterioration in quality will continue until the stage is reached where the water is no longer suitable for use. Experts therefore warn that it may prove to be more difficult in the longer term to provide users with water of an acceptable quality on a sustainable basis, than merely providing an adequate supply.

South African efforts to manage water quality have been in force for decades. Since it is much more difficult to identify, control and manage non-point (i.e. diffuse) sources of pollution than point sources, our regulating authorities, up to fairly recently, concentrated their efforts on controlling pollution from point sources. A realisation that non-point sources are the major contributors to water pollution in many catchments, coupled with a recognition of the fact that the water quality requirements of users vary, gave rise to a shift in approach to water quality management. With the new approach, pollution from whatever source is now managed in order to maintain the quality of the water body affected by the pollution in a state which is acceptable to users of the water. These principles are embodied in the new National Water Act.

Traditionally a prescriptive regulatory or command-and-control approach was used to control water quality degradation. The cost, manpower demands and other inefficiencies inherent in this approach gave rise to the investigation of economics-based measures to achieve the same goal.

Partly as a result of these investigations the concepts of "wastewater charges" and the "polluter pays" principle have now been embodied in our new National Water Act. Researchers on WRC projects have made valuable contributions to provide the scientific foundation on which these and other water quality management principles in the Act are based. The WRC will continue to undertake research aimed at supporting the introduction of these and other approaches which are aimed at improved and more effective water quality management.

A number of projects in the field of water quality management are aimed at analysing the water quality situation, its causes, magnitude and impact on users. Other projects aim to improve our ability to predict system response to natural driving forces, disturbances, pollution incidents and management intervention or obtain a better understanding of the processes which operate in nature. Increasing attention is being devoted to study the effect of organic contaminants and using biological methods of water quality assessment.

Poor water quality often manifests itself as specific problems. Projects that address problems in the field of salinity, eutrophication, other aspects of surface water quality are being funded by the WRC in support of water quality management.

Salinisation remains one of the consequences of water pollution which is most widespread in South Africa. With increasing salinity the water becomes less fit for most users, who consequently incur additional costs. Because its effect is creeping and incremental, most of these problems go unnoticed, or remain unconnected by consumers. Salinisation is the result of the addition of a variety of salts to the water environment which almost inevitably results from the increasing use and reuse of water 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 also excrete toxins.

The gradual deterioration of water quality and the growing awareness of water quality as a factor which undermines the utilisation potential of water, have given rise to the identification of a number of research needs. **Water quality studies** are being conducted to address problems

associated with microbial pollution, organic compounds, sediments and other water constituents, as well as to improve the means to cope with them.

Completed projects

Feasibility of GIS-based integrated cadastre for point and non-point sources of aquatic pollution and its integration into multi-objective analyses and the planning of pollution control

(K8/202) Department of Civil Engineering, University of the Witwatersrand

Whereas past efforts to preserve the quality of South Africa's water resources concentrated almost solely on the control of pollution, present activities are increasingly aimed at water quality management from a holistic perspective. The integration inherent to this approach requires amongst others, databases which contain information about all the sources in a catchment and linkages to geographical and other information systems. This project investigated the feasibility of utilising a Yugoslavian developed inventory (cadastre) as a database and information system under South African conditions. The evaluation was generally positive. Adaptions proposed for its use and possible implementation under local conditions, are being considered and evaluated by the relevant authorities.

Cost: *R96 600*
Term: *1995-1997*

Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area

(No 419) The South African Sugar Association Experiment Station

This project set out to monitor the relative soil loss and water use of timber, sugar-cane, and natural grassland on steep sloping land under various erosion control measures near Umzinto in KwaZulu-Natal. Unfortunately, due to a series of catastrophic events (the longest and most severe recorded drought in the area occurred during the first years of the project term, the consequent die-back of trees, a fire which killed most of the trees and chronic vandalism of equipment), data collection could not be conducted and concluded as had been envisaged. By making use of the available data and the aid of the ACRU model for sugar-cane, realistic scenarios were simulated to supplement actual measurements. Amongst others it was found that minimum tillage dramatically reduced soil loss whilst also reducing runoff, while afforestation had a greater impact on streamflow than sugar-cane. The impact of land use on runoff was found to be more pronounced on shallow than on deeper soils.

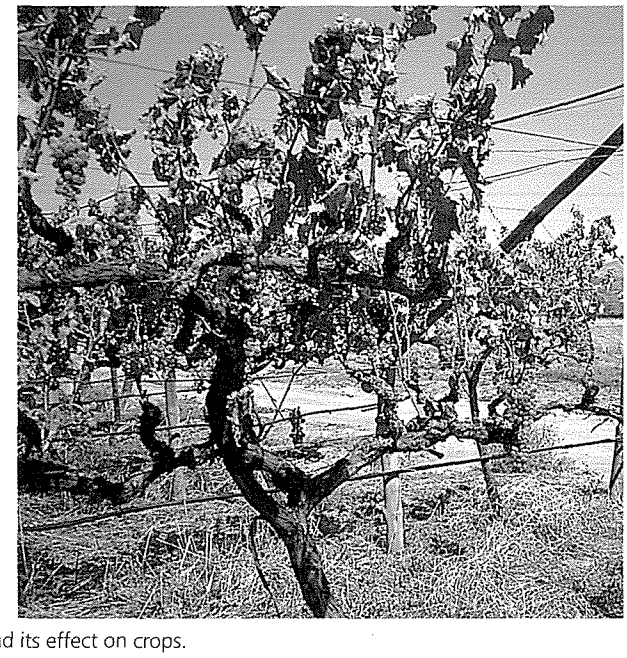
Cost: *R481 800*
Term: *1992-1996*

Collection and evaluation of runoff water quality data from a disused feedlot in Natal

(No 498) Division of Water, Environment and Forestry Technology, CSIR

A preceding project which quantified the effect of land use on runoff water quality in selected catchments in KwaZulu-Natal found that a small catchment, which had previously been used as a wintering feedlot for cattle, showed extremely high phosphorus, nitrogen and COD concentrations during stormflow runoff. This project followed on the preceding project to confirm the earlier findings which were founded on a limited data set, and to obtain data which could be used in water quality simulation models. Pollutant concentrations in high-flow (primarily surface) runoff, were of the same order of magnitude as those found in raw sewage. Baseflow concentrations were much lower. From an extrapolation of the results it was concluded that it would take 4 to 5 years before runoff water quality would return to normal levels. Pollution from similar land uses can be prevented by collecting and diverting surface runoff to holding ponds for further treatment or used for irrigation of pastures.

Cost: *R55 000*
Term: *1991-1993*



Salinisation of land and its effect on crops.

New projects

Assessment of the extent of oestrogenic activity in Western Cape water resources

(No 926) Department of Zoology, University of Stellenbosch

Human, agricultural and industrial activities are releasing large numbers of man-made chemicals into the water environment, from where they may enter the food chain and cause bio-accumulation in wildlife and humans. A wide range of man-made chemicals have been implicated in mimicking the action of oestrogens. Evidence is mounting to show that these substances can cause serious disruptions of normal physiological capabilities, and could affect the functioning of future populations and ecosystems. The reproductive disorders in wildlife reported to date involve reduced fertility, reduced hatchability, reduced viability of offspring, poor growth, impaired hormonal function, modified sexual behaviour and feminisation of males. This project will assess the extent of possible environmental pollution by biologically active chemicals (from industrial, agrichemical and sewage treatment works effluents), using the Western Cape as a test case for the rest of South Africa. This will help to ensure the effective conservation of South Africa's rich biodiversity, and most importantly, the quality of life for humans and wildlife in South Africa.

Estimated cost: R463 000
Expected term: 1998-2000

Occurrence and source of *Cryptosporidium* and *Giardia* in catchment areas and wastewater works

(No 927) Umgeni Water

At present the occurrence and distribution of the pathogenic protozoa *Cryptosporidium* and *Giardia* are largely unknown due to a lack of suitable routine testing methods. After evaluating methods to concentrate these protozoa from water and detect their presence, Umgeni Water selected a polymerase chain reaction (PCR) method with a 68% recovery from potable waters, for routine analysis. As part of this project, the suitability of the PCR method will be evaluated for wider routine use by a number of other laboratories involved in routine water testing. In order to establish to what extent diarrhoeal disease within a selected high-risk community is caused by *Cryptosporidium* and *Giardia*, each participating laboratory will conduct its own investigation on the catchment area of the community they selected. The presence, viability and removal of parasitic protozoa during wastewater treatment processes and an evaluation of the contribution of this source to their occurrence in the aquatic environment, will add to existing knowledge to prevent possible pollution from these sources.

Estimated cost: *R300 000*
Expected term: *1998-1999*

Molecular characterisation of F-RNA coliphages in South African water sources

(No 928) Department of Virology, University of Pretoria

Viruses may cause up to 80% of water-borne diseases. Because of various selective pressures, the importance of viruses as water-borne pathogens is, furthermore, increasing. Since viruses are more resistant to water treatment and disinfection processes than faecal bacteria such as coliforms, the value of using coliforms as indicators of the virological safety of water, is declining. Ideally water should thus be tested specifically for viruses. Because tests for viruses are relatively expensive and complicated, indicators which are better than coliforms are being sought. F-specific RNA coliphages (F-RNA phages) have attractive features for this purpose since they closely resemble viruses in many respects. This project aims to upgrade the techniques for the detection of F-RNA phages in water, and also to improve the typing of the phages into four serological groups. Evidence available from other parts of the world indicates that some of the types are specific for humans and others for animals. This distinction is important because the risk of viral infection from human faecal pollution is higher than that from animal pollution.

Estimated cost: *R162 000*
Expected term: *1998-1999*

Eutrophication of a water body resulting in undesirable growth of aquatic plants.

Water quality information systems for integrated water resource management: The Riviersonderend-Berg River system

(No 951) Department of Civil Engineering and Department of Soil and Agricultural Water Science, University of Stellenbosch

Impoundments and associated bulk water supply infrastructure are present in most South African river systems. Because of the disparate natural occurrence of rainfall and runoff and its mismatch with water demand concentrations, many of these schemes have to incorporate inter-catchment transfers. Water quality deterioration, furthermore, often threatens to diminish the utilisable part of the runoff in many catchments. This project aims to develop an integrated information system specifically for water quality (WQIS) as a tool to assist water managers in managing these complexities on an integrated catchment basis. The WQIS will provide diagnostic and predictive utilities to serve technical planning and operational decision-making in a river system, and at the same time also provide appropriate information to support water managers in the engagement of and communication with stakeholders and communities. The Riviersonderend-Berg River system was selected to serve as prototype for development of the WQIS approaches.

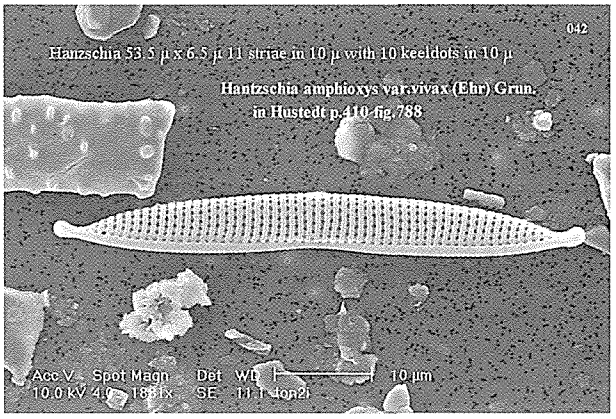
Estimated cost: *R1 367 000*
Expected term: *1998-2001*

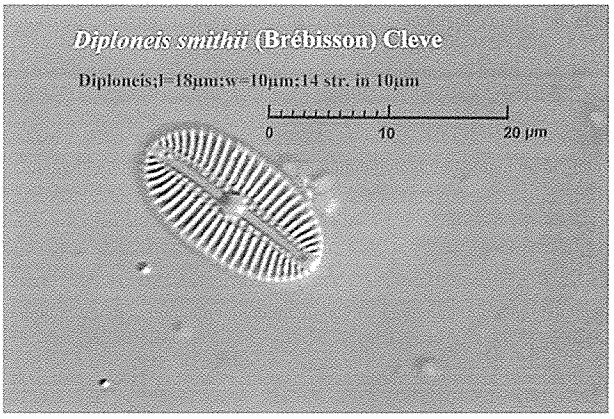
Biomarker assays for the detection of chronic toxicity in the aquatic environment

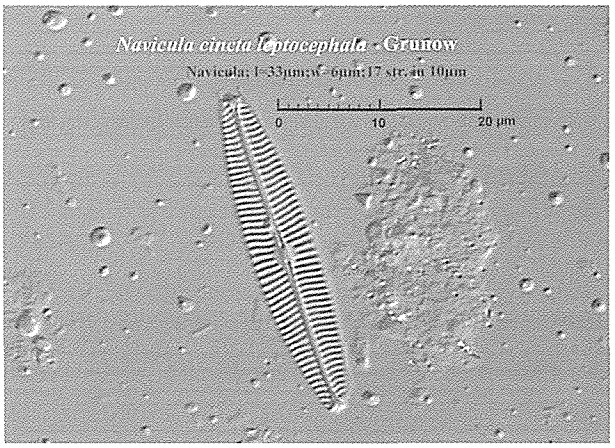
(No 952) Division of Water, Environment and Forestry Technology, CSIR

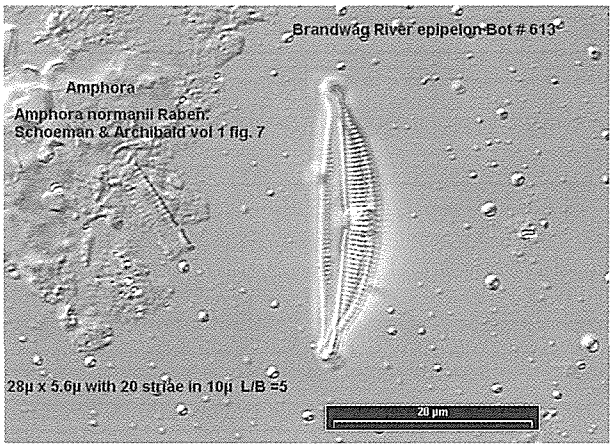
Biological toxicity tests have become an important part of water quality management in South Africa. Currently, there is a selection of aquatic toxicity tests to detect acute toxicity. However, very little attention has been given to the establishment of techniques to detect chronic toxicity. Chronic toxicity tests are very important monitoring and control tools when the toxicity of effluents is low and are also indispensable to manage ambient waters. Traditionally, these tests take very long to complete. A new approach is the use of biomarker assays which provide rapid measures of the molecular mechanisms underlying toxicity. The aim of the proposed project is to establish biomarker assays for the detection of chronic toxicity in the aquatic environment. The techniques will be evaluated by applying them to fish and other aquatic organisms (e.g. molluscs, snails, worms) collected from polluted and unpolluted aquatic environments.

Estimated cost: *R650 000*
Expected term: *1998-2000*









Rapid identification of dominant diatom species using electronic media for biological water quality monitoring. Shown above are various examples of diatom species. (Photos: Carel Hause).

Research projects

Completed

- **K8/202** Feasibility of GIS-based integrated cadastre for point and non-point sources of aquatic pollution and its integration into multi-objective analyses and the planning of pollution control (University of the Witwatersrand – Department of Civil Engineering)
- **419** Water quality and quantity assessments in catchments with changing land uses in the Umzinto coastal area (SA Sugar Association Experiment Station)
- **498** Collection and evaluation of runoff water quality data from a disused feedlot in Natal (CSIR – Division of Water, Environment and Forestry Technology)

Current

- **195** Hydrosalinity studies in the Eastern Cape (Rhodes University – Institute for Water Research)
- **266** Extension of the management-orientated models for eutrophication control (CSIR – Division of Water, Environment and Forestry Technology)
- **369** Completion of research relating to the DISA model – A daily irrigation and salinity analysis system model (Ninham Shand (Cape) Inc.)
- **411** Coastal pollution: Pathogenic micro-organisms (University of Pretoria – Department of Medical Virology)
- **421** Relationship between atmospheric deposition and water quality in a small upland catchment (CSIR – Division of Water, Environment and Forestry Technology)
- **465** Detergent phosphorus in South Africa: Impact on eutrophication with specific reference to the Umgeni catchment (University of Natal – Department of Chemical Engineering and Umgeni Water)
- **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 1: Development of a generic model (DWAF and Urban-Econ, Development Economists)
- **696** Development of a guide to assess non-point source pollution of surface water resources in South Africa (Sigma Beta (CE) Inc. and DWAF)
- **697** Modelling the long-term effect of atmospheric deposition on the salinity of catchment runoff with special reference to the Vaal Dam catchment (Stewart Scott (CE) Inc.)
- **717** The 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)
- **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.)
- **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** The 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)

New

- **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)

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6 Groundwater

Groundwater, which is widespread in occurrence though far from abundant in South Africa, has gained recognition as a major asset of national importance with the government's drive to meet basic human needs for potable water.

Within the rural areas especially, this need to provide water is spread over some 15 000 villages, mainly in the eastern and northern parts of South Africa. This need can often not be met from scarce surface water resources. Thus low-yielding aquifers in non-traditional groundwater areas may frequently constitute the only viable source of supply.

About 90% of South Africa's groundwater occurs in secondary aquifers consisting primarily of shallow zones of weathering and fracturing beneath a thin soil cover. In these aquifers, the problem of low yields is frequently compounded by naturally poor water quality and susceptibility to pollution. Research priorities, therefore, include more efficient exploration methods, improved characterisation of aquifers, better assessment of exploitability and safe yield, specification of groundwater protection requirements, characterisation of groundwater quality and risks associated with consumption of poor quality water, and enhancement of sustainable use through artificial recharge.

With the passing of the National Water Act in 1998 water resources (which include groundwater resources) are seen as a single, indivisible national asset. This gives a new dimension to the management of groundwater resources, as part of a hydrological systems approach. Not only is a greater emphasis placed on groundwater protection, but the interactions between groundwater, surface water and aquatic ecosystems now come strongly to the fore. The requirement in the new Water Act for assessment of the "ecological reserve" demands that these interactions be clearly understood and quantified as best as possible.

During the year the WRC facilitated two workshops designed to give better focus to research efforts with specific research areas. The one, held in July, considered the role of the vadose zone in attenuating the risk of groundwater pollution. The other, held in October, gave impetus to the planning of a research programme for facilitating the assessment of the "groundwater reserve" component of the "ecological reserve", as required for implementation of the National Water Act.

Completed

Regional investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment

(No 291) Institute for Groundwater Studies, University of the Orange Free State

Elevated sulphate and low pH levels provide clear indications that the quality of the surface waters of the Olifants River, specifically the Witbank Dam subcatchment, has deteriorated over time. At the stage when this project was initiated the origin of the pollutants was still uncertain. It was known that mining activity and power generation had expanded significantly during the preceding number of years. The impact that this expansion would have on the environment, especially for slow-reacting systems such as groundwater, was expected to become visible only over an extended period of time. This investigation was undertaken to quantify the contribution of the various activities to the groundwater quality deterioration in the area. The natural groundwater in the weathered aquifer used by farmers was found to be of excellent quality but low-yielding. A direct link was observed between the water quality in many surface streams and development (mostly mining). Of all the activities which were investigated, open-cast mining was found to have the greatest impact on groundwater quality. The project furthermore quantified the pollution generated by selected activities and identified management options to alleviate their effect.

Cost: *R1 603 000 (The Chamber of Mines of South Africa contributed a further R200 000 and DWAF about R200 000 in kind)*

Term: *1990-1994*

Development of techniques for risk analysis and groundwater management of Southern African aquifers

(No 378) Institute for Groundwater Studies, University of the Orange Free State and Division of Water, Environment and Forestry Technology, CSIR

Reasons for the inadequate management of South Africa's groundwater resources in the past include the poor understanding of the occurrence, replenishment and behaviour of groundwater, as well as the lack of groundwater management models applicable to South African conditions. This project was undertaken, firstly, to address the need for user-friendly tools for the development of appropriate management models. A second objective was to develop, for use with such models, risk assessment techniques which consider uncertainties associated with aquifer properties and recharge rates due to rainfall variability.

The research resulted in the development of the groundwater management software package called AQUAMOD. The package consists of several programs, one of which is the two-dimensional groundwater modelling program known as AQUA. The software package provides the tools needed for the development and application of aquifer-specific groundwater optimisation models for controlling groundwater hydraulics and water quality, and also for addressing the inverse problem of parameter estimation. A necessary condition, however, is the availability of sufficient, reliable geohydrological and other relevant data for the aquifer.

Both the AQUAMOD software package and the methodology for long-term risk assessment developed as the second product of the research, were successfully tested and applied in a case study carried out on the Grootfontein aquifer. Management models were developed and used to devise alternative management plans for which associated risks could be adequately assessed. The case study suggested that current abstraction rates from the Grootfontein aquifer far exceeded the long-term potential yield and that water-level recovery could not be expected under conditions of normal rainfall variability.

Cost: *R532 128*
Term: *1991-1994*

Analysis and interpretation of aquifer tests in secondary aquifers

(No 487) Institute for Groundwater Studies, University of the Orange Free State

Ever-increasing pressure is being brought to bear on South Africa's groundwater resources to meet the demands of rural communities for potable water. This has highlighted the inherent complexities of fractured-rock aquifers, which occur over some 90% of the country and, in particular, the paucity of available methods for determining the hydraulic properties of these aquifers. This project was initiated to address the need for a better understanding of the nature and behaviour of groundwater in fractured-rock aquifers, especially with regard to the applicability and reliability of hydraulic tests.

Whereas it was originally envisaged that all types of fractured-rock aquifers would be investigated, it was soon decided to restrict investigations to the special case of Karoo aquifers which occur extensively and do not conform to the behaviour of conventional fractured rock aquifers described in the literature. The research clearly revealed that the behaviour of a stressed Karoo aquifer is determined by its very complex geometry that results from the presence of bedding-plane fractures and the multi-porosity of the rock matrix. This conclusion has important implications for the operation and long-term management of borehole schemes in the Karoo where continuous lower pumping rates would appear to be more suitable than short-duration high rates of pumping. Classical primary flow models, although extensively used in the past, are totally inappropriate for modelling groundwater behaviour in these aquifers. Considerable progress has been made in adapting an existing three-dimensional groundwater flow model and developing a new two-dimensional model to describe groundwater behaviour during pumping.

Cost: *R1 406 956*
Term: *1992-1996*

Application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured-rock aquifers

(No 516) Division of Water, Environment and Forestry Technology, CSIR

In order to locate water-bearing zones in fractured-rock aquifers, a thorough understanding of the location, physical nature and orientation of these factures is required. The main aim of this project was to investigate the use of certain geophysical fracture characterisation techniques in gaining a better understanding of the physical nature of hard rock aquifers. Initially it was envisaged that seismic borehole tomography and borehole radar imaging techniques would be evaluated. During the course of the project the emphasis, however, shifted to the application of radiowave tomography (RT) and its use in conjunction with seismic tomography (ST). It was found that RT is an efficient and useful monitoring tool which gives consistent and repeatable results. It can be used in the identification and delineation of flow paths within aquifers as an aid to the development of groundwater flow models. In contrast to other more conventional geophysical techniques, RT and ST demonstrated the potential to interpolate aquifer geometry between boreholes. When used in combination, RT and ST have the ability to map different lithologies and lateral variations therein, as well as major fractures and water flow directly.

Cost: *R579 981*
Term: *1993-1997*

Extension and refinement of the AQUAMOD computer software package

(No 640) Institute for Groundwater Studies, University of the Orange Free State

The AQUAMOD groundwater management software package was conceptualised to satisfy a need for user-friendly tools to optimise the management of groundwater resources. Most of the software was developed during the course of WRC Project No 378, **The development of techniques for risk analysis and groundwater management of Southern African aquifers**. While sound, the software did not succeed in being user-friendly. This follow-on project was therefore necessary to transform the AQUAMOD software into a truly user-friendly package and to further develop the software to provide for groundwater quality modelling and the graphical presentation of data. AQUAMOD was consequently converted to the Windows environment using object-oriented programming. Two new

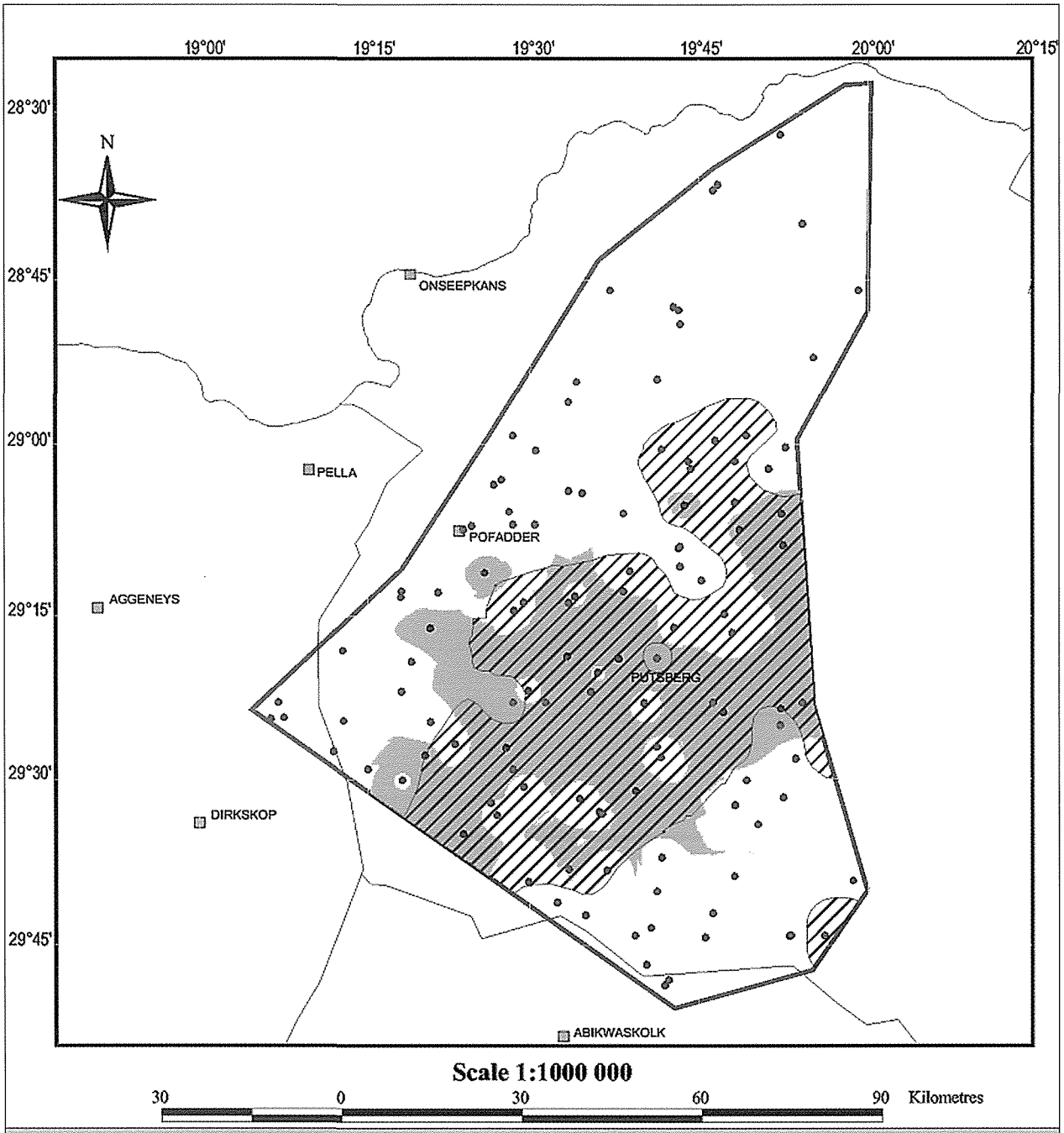
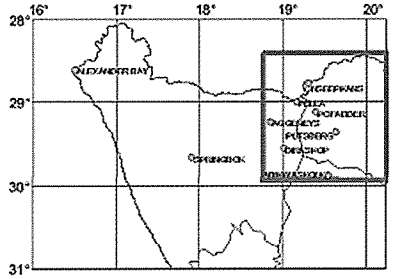


Fig. 1 : MAP INDICATING THE REGIONAL CORRELATION BETWEEN URANIUM, ARSENIC AND ATYPICAL LYMPHOCYTES

LEGEND

- Arsenic > 500 µg/l and Uranium > 70 µg/l
- Area where > 35% of the Population from whom Blood Samples were obtained have an Atypical Lymphocyte Count Above the Normal Range
- Contour Boundary
- Hydrogeological Sampling Points
- Haematological Sampling Points
- Magisterial District Boundary
- Boundary of 1:50 000 Map Sheets

LOCALITY MAP



program modules were added to address aspects of groundwater flow and pollution risk using Monte Carlo simulations. The resulting product is a comprehensive groundwater management software suite entitled AQUAMOD for Windows, or AQUAWIN. This suite of software incorporates results of many years of research into the nature and behaviour of South Africa's fractured-rock aquifers and provides South African hydrogeologists with user-friendly groundwater resource management tools which are able, among other features, to address risks associated with over-abstraction and pollution.

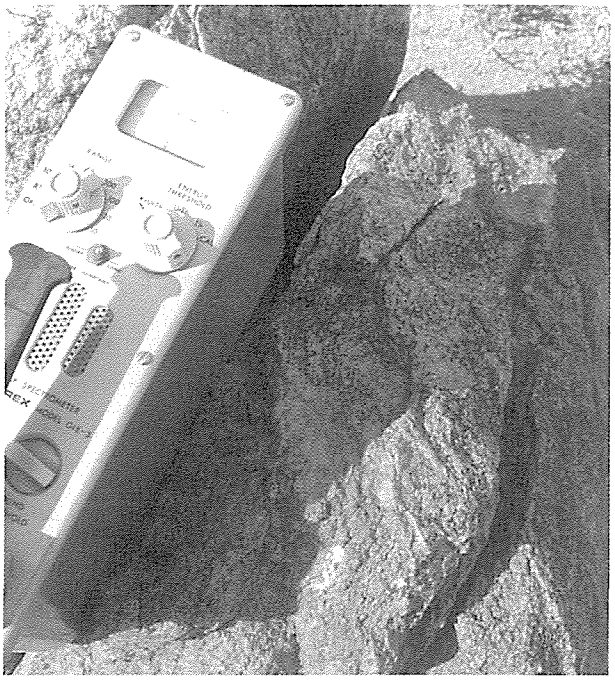
Cost: *R268 999*
Term: *1994-1996*

Correlation of high uranium, arsenic and other chemical element values in groundwater with abnormal haematological values

(No 839) Toens and Partners CC

This project was initiated following observations by medical researchers that a number of cases of haematological abnormalities, related to leukaemia, had been reported from the area around Pofadder in the north-west Cape, where relatively high values of uranium and arsenic in groundwater are also known to occur. The thrust of the investigation was to establish statistically verifiable correlations between various hydrogeological characteristics and the prevalence of haematological abnormalities of long-term residents in the area. A newly-developed GIS-based methodology was used successfully to show that a positive correlation exists between the elevated levels of uranium and arsenic in groundwater and atypical lymphocyte counts (as a proxy of haematological abnormality). Arsenic (r=0.41), uranium (r=0.57) and the combination of uranium and arsenic (r=0.60) returned positive correlation coefficients, confirming the existence of a statistical association. From a community health aspect, the availability of this methodology is important, since it makes it potentially possible to identify areas where long-term residence and utilisation of groundwater could be regarded as undesirable, or alternately, where the consumption of untreated groundwater should be avoided. It should be emphasised that this investigation dealt mainly with the earth science aspects of the relationship and that the further significance of the atypical lymphocyte counts and their relationship to the high incidence of leukaemia in the area should be addressed by medical researchers.

Cost: *R200 000*
Term: *1997-1998*



Scintillometer reading of 130 counts per second (broad band) on an outcrop of radioactive orange weathering pink quartz feldspathic gneiss. (Photograph: NJ Wullschleger.)

New projects

Evaluation of nuclear magnetic resonance (NMR) as a new geophysical technique for groundwater exploration in fractured rocks

(No 935) Division of Water, Environment and Forestry Technology, CSIR

Many rural communities in South Africa, who are largely dependent on groundwater, are resident in areas underlain by fractured-rock aquifers. The nature of groundwater occurrence in fractured-rock aquifers poses an additional challenge to locating drilling sites which can yield adequate amounts of groundwater. The use of existing geophysical tools, such as electromagnetic, resistivity and magnetic techniques, has contributed some success under favourable geological conditions. However, a technique which is specifically suitable for addressing fracture systems in South African geological environments still needs to be developed.

One promising technique, not yet tested in South Africa, is nuclear magnetic resonance (NMR). It was first used in Russia during the late 1970s and subsequently also in Australia and Israel. It is claimed that this technique is capable not only of indicating the presence or absence of groundwater, but also of providing a quantitative indication of distribution with depth. Recently, in France, NMR instrumentation has been totally redesigned and interpretation routines vastly improved. There is good reason to evaluate the use of NMR under South African conditions without delay.

The aims of the project are to:

- Intensify the literature study of the theory and application of NMR as a geohydrological tool
- On the basis of the results of the literature study, and in collaboration with DWAF, identify suitable sites in South Africa for the testing of the NMR technique
- Conduct field surveys and interpret results, focusing on the practical application of the technique in helping to select good drilling sites
- Evaluate the usefulness and cost-effectiveness of NMR as a means of improving understanding of geohydrological conditions in South African fractured-rock aquifer systems.

Estimated cost: *R385 000*
Expected term: *1998-1999*

Flow and transport characteristics of groundwater in Karoo formations

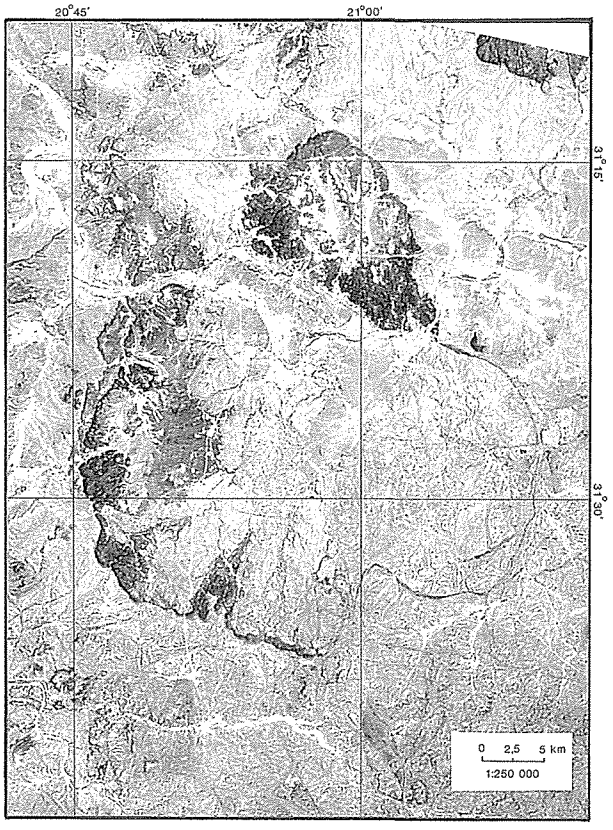
(No 936) Institute for Groundwater Studies, University of the Orange Free State

More than 50% of South Africa is underlain by Karoo formations which are dense, fractured to a greater or lesser extent, and of low permeability. Boreholes in Karoo aquifers are frequently low-yielding and have been considered to be unreliable sources of water. However, recent investigations have revealed that Karoo aquifers contain considerably more water than formerly assumed.

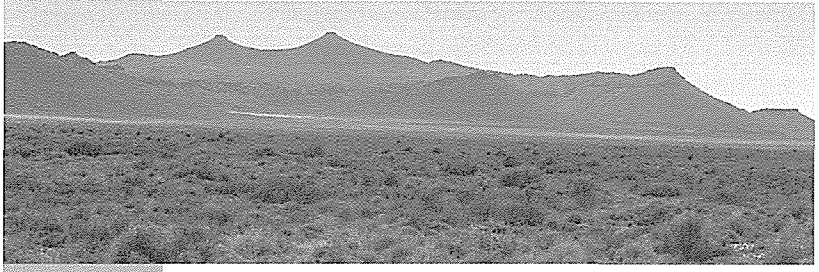
Improved insights into characteristics of Karoo aquifers have important implications for their management and use. Firstly, methods commonly employed to investigate aquifers need to be adapted to avoid obtaining misleading information concerning hydraulic characteristics. More specifically, methods need to incorporate *in situ* flow measurement and tracer tests. Secondly, Karoo aquifers are particularly susceptible to pollution and will have to be managed accordingly. Besides the need for more appropriate observational tools, it is also imperative that more appropriate computational techniques be developed for Karoo aquifers if they are to play a prominent role in the water budget of the country.

This project therefore aims to use more appropriate methodologies to confirm and expand knowledge of the physical characteristics of Karoo aquifers and influence on the dispersion of contaminants. New knowledge will be incorporated into an existing three-dimensional flow model, which will be used to revise management and protection strategies in order to improve the reliability of these aquifers as sources of potable water and protect them against pollution.

Estimated cost: *R243 000*
Expected term: *1998-2000*



A satellite photo of a dolerite ring near Williston.



The Karoo dolerite sills and rings, two levels of intrusion around Victoria West.

Influence of dolerite ring-structures on the occurrence of groundwater in Karoo fractured aquifers: A morphotectonic approach

(No 937) Council for Geoscience

Dolerite formations are intruded into the Karoo sediments over an area covering approximately half of South Africa. Dolerite dykes are well-known for their water-bearing capacity and are presently the subject of a number of research projects. Dolerite ring-structures have, on the other hand, to a large extent been overlooked as potential groundwater exploration targets, even though they form an important part of the Karoo structural framework.

Preliminary studies of the ring-structures in the central Karoo show that they display various morphotectonic features which are potential groundwater exploration targets. A more detailed investigation is now needed to assess the occurrence of groundwater associated with Karoo dolerite sills and ring-structures using three-dimensional morphotectonic models.

The aim is to approach the study at two scales. At the regional scale, detailed mapping of ring-structures is envisaged to enable description and classification according to geometry, dimension, distribution and degree of fracturing, magnetic signature, stratigraphic position, mode of emplacement and conceptual model of groundwater occurrence. At the local scale, one or two ring-structures will be selected for geohydrological investigation based on information obtained from the regional study. This will enable the refinement of the conceptual model of groundwater occurrence.

It is expected that the results will enhance the DWAF's programme of providing water to rural communities in the Eastern Cape, where dolerite ring-structures are common and well exposed in relation to other geological lineaments.

Estimated cost: *R425 000*
Expected term: *1998-2000*

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

(No 966) Council for Geoscience

The challenge of providing developing rural areas in South Africa with sufficient potable water is substantial, especially where settlement is not densely concentrated and the ability to pay is low. The water requirements of these settlements can most cost-effectively be met from locally managed groundwater systems. However, as the demand for groundwater grows and the more obvious aquifers and target features become increasingly exploited, further development will have to consider problematic and complex fractured geological environments.

Although drilling success rates in these regions have been low in the past, there are some high-yielding boreholes which suggests that suitable target features do exist. Low borehole success rates can be attributed not only to the nature of groundwater occurrence in this complex terrain but also to inappropriate exploration and/or interpretation methods resulting from an incomplete understanding of the geohydrology.

The primary objective of this project is, therefore, to investigate the development potential of groundwater and to develop guidelines for groundwater exploration and develop-

ment in problematic or complex terrain. The supporting objectives are to:

- Investigate the occurrence of groundwater and the geological and structural controls which distinguish high- from low-yielding features
- Evaluate the ability of currently used and new geophysical methods to distinguish or delineate target features
- Quantify the exploitation potential of groundwater and evaluate methods for estimating sustainable aquifer and borehole yields.

Estimated cost: *R833 000*
Expected term: *1998-2000*

Pilot artificial recharge schemes: Testing sustainable water resources development in secondary aquifers

(No 967) Water Quality Programme, CSIR

Many towns and settlements in South Africa, a large proportion wholly dependent on groundwater, face the prospect of having to supplement existing water sources. International experience has shown that artificial recharge could, through substantial savings on infrastructure, operation and maintenance, be more cost-effective in securing a sustainable water resource than upgrading surface water schemes or establishing new wellfields.

Artificial recharge to secondary aquifers has been shown, on a limited scale, to work in other countries. In South Africa, artificial recharge skills are available only in respect of primary aquifers such as the Atlantis, Cape Flats and Maun aquifers. Similar skills have yet to be developed in areas underlain by hard secondary-rock aquifers, by far the most common type of aquifer in South Africa. A current WRC-CSIR project has established factors which might affect the suitability of recharge schemes in SA's secondary aquifers and has identified suitable artificial recharge sites. The logical next step is to establish pilot projects to test the concept of artificial recharge of secondary aquifers, to refine procedures and to train operators.

The aims of this proposed project, are, therefore, to:

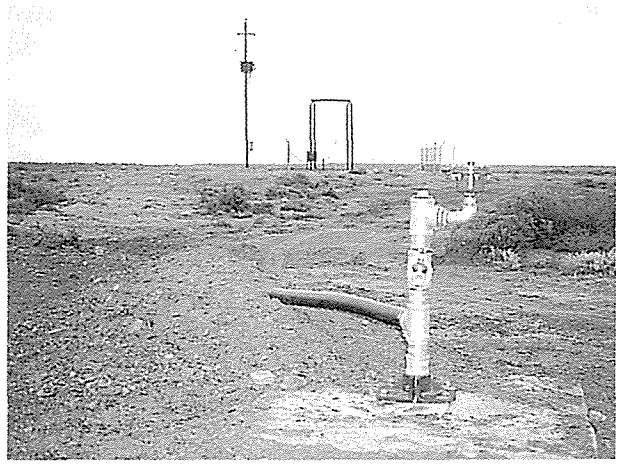
- Test the artificial recharge concept in South African secondary aquifers
- Demonstrate the potential for artificial recharge to hydrogeologists and water resource planners
- Train local water resource managers in the operation and management of pilot artificial recharge schemes.

Estimated cost: *R1 270 000*
Expected term: *1998-2001*

Amalgamation of MuniBase and WISH software into a user-friendly software package to be used by South African geohydrologists

(No 968) Institute for Groundwater Studies, University of the Orange Free State

The WRC, in close collaboration with DWAF, has sponsored two projects which are yielding valuable technology-transfer products. The one product is a database (MuniBase), designed for use at the municipal level to capture and provide access, not only to groundwater information, but to other water-related information as well. The other is a Windows-based interpretation system for geohydrologists (WISH) comprising a powerful set of geohydrological tools for processing and interpreting groundwater-related data and information. Both products have been developed with the intention of overcoming specific problems experienced by groundwater practitioners in South Africa. The intention was not that either product stand alone, but that they be used with other systems developed for the groundwater community over the past 10 years, mainly with WRC and DWAF support.



One of the injection boreholes, with the abstraction borehole in the background (near Calvinia, Karoo).

This project, therefore, aims to bring about the necessary adaptations and extensions of the MuniBase and WISH systems and their amalgamation into a user-friendly, stand-alone, Windows-based system for the benefit of the geohydrological community in South Africa. Software will be made freely available to users through the Internet. The envisaged product also fits in with DWAF's strategy for the development of a National Groundwater Information System for South Africa.

Estimated cost: *R300 000*
Expected term: *1998*

Research projects

Completed

- **291** Regional investigation into groundwater quality deterioration in the Olifants River catchment above the Loskop Dam, with specialised investigations in the Witbank Dam subcatchment (University of the Orange Free State – Institute for Groundwater Studies)
- **378** Development of techniques for risk analysis and groundwater management of Southern African aquifers (University of the Orange Free State – Institute for Groundwater Studies and CSIR – Division of Water, Environment and Forestry Technology)
- **487** Analysis and interpretation of aquifer tests in secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)
- **516** Application of seismic tomography and ground-penetrating radar for the detection of fractures and the determination of hydraulic properties of fractured-rock aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)

- **839** Correlation of high uranium, arsenic and other chemical element values in groundwater with abnormal haematological values (Toens and Partners CC)

Current

- **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)
- **565** Hydrogeological, isotopic and hydrochemical assessment of the response of a fractured multi-layered aquifer to long-term abstraction (University of the Witwatersrand – Schonland Research Centre)
- **572** Investigation of the contaminant attenuation capacity of the soil/aquifer system with special emphasis on the vadose zone (CSIR – Division of Water, Environment and Forestry Technology and the University of Stellenbosch – Department of Soil and Agricultural Water Science)
- **641** Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **653** Regional characterisation and mapping of Karoo fractured aquifer systems – An integrated approach using a geographical information system and digital image processing (DWAF – Directorate of Geohydrology, and the Council for Geoscience)
- **676** Preparation of a monograph on South Africa's groundwater resources (JR Vegter Esq.)
- **701** Relationship between the geotechnical and hydrogeological properties of residual soils and rocks in the vadose zone (University of Pretoria – Department of Geology)
- **702** Development of a Windows-based interpretation system for hydrogeologists (University of the Orange Free State – Institute for Groundwater Studies and the DWAF)
- **720** Geohydrological modelling of the Richards Bay area (University of Zululand – Department of Hydrology)
- **721** Groundwater supply assessment and strategy for the Western Karoo, Namaqualand and Bushmanland (University of the Western Cape – Department of Earth Sciences)
- **729** Modelling of groundwater flow in the Table Mountain Sandstone fractured aquifer in the Little Karoo region of South Africa (DWAF – Directorate of Geohydrology)
- **731** CFCs and groundwater age-dating in South Africa's fractured-rock aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **732** Cost-effective development of groundwater in problematic terrain and low-potential areas: The evaluation and assessment of current drilling and groundwater abstraction techniques and the modification of equipment and methods (Water Systems Management)
- **733** Utilisation of tracer experiments for the development of rural water supply management strategies for secondary aquifers (University of the Orange Free State – Institute for Groundwater Studies)
- **821** Bacterial pathogens in groundwater (University of Durban-Westville – Department of Microbiology)
- **838** A critical evaluation of groundwater monitoring in water resources evaluation and management (Water Resources Evaluation and Management CC and DWAF)
- **840** Investigation into a GIS-based methodology to determine the sustainable exploitability of South African aquifers (CSIR – Division of Water, Environment and Forestry Technology)
- **841** Assessment of ambient groundwater quality on a national scale in the Republic of South Africa (Hydromedia Solutions and DWAF)
- **842** Artificial recharge, a technology for sustainable water resource development for community water supplies (CSIR – Division of Water, Environment and Forestry Technology)
- **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)

New

- **935** Evaluation of nuclear magnetic resonance (NMR) as a new geophysical technique for groundwater exploration in fractured rocks (CSIR – Division of Water, Environment 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 morphotectonic approach (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 (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)

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Agricultural water management

7

An analysis of the current levels of water and land use shows that an estimated 53.6% of the annual water requirement of approximately 20 000 x 10^6 m^3 and an area of 1.3 x 10^6 ha are apportioned for irrigation.

Regarding future development potential it is apparent that water is relatively more limiting than land, since the officially projected available water only allows for an expansion of 178 000 ha out of an area of 283 400 ha potentially suitable for irrigation. In addition there is scope for upgrading 66 700 ha of under-utilised land on irrigation schemes with an existing infrastructure.

Because irrigation is the single largest user of water, it is very often maintained that more efficient use will lead to savings which can be released to meet increasing demands of domestic and industrial water use. This argument is emphasised further with the observation that on average only 45% of the water that is diverted or withdrawn for irrigation actually reaches the crop.

Technologies are available to reduce water losses which occur through canal and on-farm water distribution as well as through field application. These include better timing of canal releases to prevent spillages; improving the design and application uniformity of irrigation equipment; changing to irrigation methods with higher application efficiencies; implementing irrigation scheduling and specific practices such as deficit irrigation; and breeding and cultivating crops that use less water. Although water-use efficiency can be improved, in most cases water savings within agriculture will only be achieved if the area under irrigation does not increase. As has been pointed out above, only limited scope exists for this to take place. Nonetheless, a profitability analysis of irrigation farming is necessary in order to determine whether water use per hectare can be reduced without expansion of the area under irrigation. Various planning procedures can be used for this purpose such as enterprise (gross margin) budgets, partial and whole-farm business budgeting. It is also essential to evaluate the objectives of a diverse group of commercial, emerging and subsistence farmers and to consider uncertainties of e.g. climate and price variables. A major influence will furthermore be exercised by government policies on the transfer of water allocations and the adjustment of water tariffs.

The successful application of water-efficient technologies, if success is measured in terms of water saving by agricultural water users, is therefore dependent on:

- Enabling water policies and legislation
- Economic incentives to improve farming profitability
- Adoption of technology by farmers for water management.

The research projects completed and started during this report period all reflect a continued effort to provide practically useful decision-support to agricultural water users.

Completed projects

Flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches

(No 290) Department of Agricultural Engineering, University of Pretoria and Rehab Consultation

In addition to the critical evaluation referred to in the title of this project, it also attended to further development of the most suitable design procedure by means of hydrodynamic model studies and field experimentation, preceded by an investigation into the validity of hydrodynamic models in flood irrigation. Finally the design procedure which emanated from this project was field-tested.

The results of this project are being reported on in a final report of four volumes:

Volume I: *Development and Computerisation of a Suitable Flood Irrigation Design Procedure: Summary Report*

This volume provides a summarised overview of the whole project, including an introduction to the theory on which the end result – a computerised design program entitled OPTIVLOED 2.2 – is based. It discusses the utilisation of the hydrodynamics of advance and recession fronts in the devel-

opment of the design procedure. This volume is concluded with a design example illustrating the use of OPTIVLOED 2.2 in the design of a flood irrigation system.

Volume II: *Critical Evaluation of Flood Irrigation Design Procedures*

This volume contains a critical evaluation of the existing flood irrigation design approaches. The basic philosophies and a number of historical perspectives relevant to the various approaches are discussed. As far as the empirical design procedures are concerned, it is indicated that not all variables playing a role in flood irrigation are included in the procedures, resulting in generalisations impacting negatively on the achievable application efficiency. In the case of volume-balance design procedures, it is pointed out that neither the flow dynamics nor the energy balance of the irrigation event is correctly incorporated in the procedure, resulting in questionable predictions on the performance of a system. Hydrodynamic design procedures, based on the solution of St Venant flow equations by means of computer-supported numerical techniques, are tedious and require a high level of skill from the computer operator. This volume is concluded with a motivation for a design procedure based on a combination of the available hydrodynamic approaches, together with the incorporation of optimisation techniques.

Volume III: *Evaluation of Hydrodynamic Models and Features Valid for Flood Irrigation in South Africa*

Two available simulation models have been evaluated utilising data collected for this project, as well as data from other WRC projects and projects of the Department of Agriculture. Evaluation of the Sirmod model (origin: USA) indicated unacceptable results for SA conditions as far as the furrow irrigation subroutine is concerned. The local model proved to be superior in this regard. Both models proved to be acceptable for flood irrigation (border irrigation) with the Sirmod model at an advantage due to the ease with which final designs are reached. Since both models require information on infiltration and flow resistance, this volume concludes with new methods to determine these variables at an acceptable accuracy.

Volume IV: *Development and Computerisation of the Most Suitable Design Procedure for Flood Irrigation*

This volume reports on the development of the OPTIVLOED 2.2 design approach, incorporating capabilities identified during the course of the project. The eventual computerised design package provides for graphical interaction assisting the operator through the optimisation techniques to reach an optimum design for a given set of conditions. Limited tests on this approach are reported on, confirming the basic philosophy of the model. The design program is fully bilingual and can be translated into other languages relatively easily.

Cost: *R370 900*
Term: *1989-1997*

Scheduling irrigation of tuber crops with specific reference to potatoes

(No 389) Roodeplaat Vegetable and Ornamental Plant Institute, Agricultural Research Council

The effects of soil-water regimes on 14 potato genotypes were investigated during four autumn and three spring plantings. The influence of the different treatments on tuber yield and size distribution, tuber internal quality, root development and water use was studied. Two physiological parameters, namely photosynthetic rate and stomatal resistance, were evaluated as screening methods for drought tolerance in potatoes.

The influence of water stress on tuber yield and size distribution was seasonal: for all genotypes yield and size distribution was more adversely affected in spring plantings, when stress was aggravated by high evaporative demand and high temperatures. In spring the ranking of genotypes according to total yield changed for the different water regimes, indicating differences in adaptability to water stress. For the autumn plantings yield rankings did not change as a result of water regimes. Water stress shifted tuber-size distribution downwards in all genotypes, without genotypic differences.

Tuber relative density and chip colour was influenced by water regimes only in autumn, with the best quality obtained from the most stressed treatments for all genotypes. During spring, high temperature effects apparently played an overriding role, resulting in no differences. There was a high correlation between tuber yield and both seasonal mean stomatal resistance and photosynthetic rate. Changes in the magnitudes of these parameters with increasing water stress were good indicators of drought tolerance. Vast differences in water use occurred between plantings, but only minor genotypic differences were evident. In spring the highest water-use efficiencies were usually recorded for the drought-tolerant genotypes. Root development was not stimulated by drought nor was there any relationship between drought tolerance and rooting density.

Cost: *R308 000*
Term: *1991-1997*

Optimal water utilisation by turf

(No 417) Department of Plant and Soil Science, Potchefstroom University for CHE

Relatively large quantities of water are used in urban areas for irrigating turf grasses associated with sports fields and recreational areas. In order to avoid over-irrigation and wastage of water, it is important for managers of such facilities to have an adequate means of estimating actual evapotranspiration requirements associated with desirable turf condition in terms of growth rate, mowing height, health, etc. This project, accordingly, set out to measure the water usage of selected turf grasses over at least one full growing season and to relate measured usage to potential evaporation rates estimated from weather observations. Six grasses including five warm-season grasses (four Bermuda grasses and Kikuyu) and one cool-season grass (Penncross Creeping Bent) were evaluated at different mowing heights and fertilisation levels. Evapotranspiration of the grass was measured with the aid of small weighed lysimeters. Class A-pan evaporation was used as the measure of potential evaporation. The research resulted in sets of crop factors recommended for use in scheduling the irrigation of the different grasses over a range of mowing heights.

Cost: *R105 400*
Term: *1992-1995*

Use of computer models for agricultural water management at farm level

(No 625) Department of Soil Science, University of the Orange Free State

The larger the amount of rain stored in the soil, the lower the risk of crop damage due to water stress. Accurate balancing of the stored soil water with the expected crop-water deficit is a means of lowering the risk of crop failure. This requires a sound knowledge of the soil-water balance and the quantification of each component thereof.

This research focused on the need for a practical computer program, that can be run by the farmers or agricultural advisers themselves, 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 procedures can be used to estimate the amount of rain stored in the soil, from harvesting of the previous crop to planting of the present crop. This information can be used in conjunction with an input of the expected precipitation, to estimate the obtainable yield. It can also aid the farmer in making a decision, based on the economic viability and risk involved, whether to plant or not. These procedures can also be used to estimate the amount of unused plant-available water in the soil, at the end of a growing season. Values estimated by using the procedures were compared with values measured in farmers' fields, and were found to be of acceptable accuracy.

The separate estimation procedures, for each of the components of the soil-water balance, were therefore linked in a single computer program. This software package will be available to individual farmers and agricultural advisers under the title SWAMP (Soil WAter Management Programme). The distribution of this computer software package will transfer and make available technology, based on 22 years of research results and practical expertise on agricultural water management, to the dryland and irrigated crop producers.

Cost: *R736 400*
Term: *1994-1997*

Quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system

(No 644) Department of Animal and Wildlife Sciences, University of Pretoria

This project was a follow-up to Project No 310 which initiated the research into the water quality requirements for livestock production. In order to achieve this overall objective, it investigated the most important livestock production systems; the water sources utilised; the main variables of relevance in these water sources and their impact on the livestock; and developing guideline levels for the respective livestock production systems and the water quality variables in the form of an index system.

During the development and modelling of the water quality guideline index system, the need for a flexible guideline system was evident not only from the biological trials conducted (which indicated the inaccuracies of a mg/*l* system), but also from the realisation that, although the main problem with a guideline was adequately accounting for the complexity resulting from the large number of factors involved, the solution to water quality problems also lay in the opportunities for manipulation created by these complexities.

The water quality guideline index system (WQGIS) was largely designed from a modelling and programming point of view which would allow for manipulations to be made from a managerial perspective to obtain a best-fit for a given water source, achieving this without compromising its user-friendliness. The developed WQGIS attempts to lead the user in establishing which important constituent information is required for a specific water source and the livestock drinking it.

The results furthermore confirm the need for experimentation regarding specific water quality constituents (WQCs) and specific livestock species and categories for the establishment of safe exposure times coupled to ingestion rates. More complex experiments investigating interactions between WQCs are required, but during this project it was felt that the priority lies in establishing safe ingestion rates over the production phase of the particular livestock type. The core structure of the WQGIS is such that it is relatively easy to incorporate new input types (such as wildlife or multiple species production systems). From a modelling and programming approach a substantial amount of work has been completed to arrive at the current WQGIS version which not only performs the tasks intended with this project, but which can also cater for envisaged future applications. It also addresses WQCs that are normally not encountered in the natural aquatic environment, but which may be problematic in situations involving industrial pollution or chemical spills. The WQGIS also provides a means for guiding the user to find solutions to water sources with problematic constituents by indicating possible manipulations to system factors which may alleviate adverse effects, including water, animal, environmental and nutritional factors.

The biological experimentation conducted fell into three general categories, i.e. toxicological, palatability and interactions between them. The primary aim of the toxicological experiments was to investigate the effects of potentially toxic WQCs over a short exposure period on growth and health. The rationale for this is that in many livestock production systems, a large component of the herd is comprised of stock destined for slaughter. As a result, potentially toxic WQCs with a chronic mode of action reliant on an accumulation over time may be tolerated by such stock as long-term effects are not relevant because they do not adversely affect the production aims. Providing the health of the animal and product quality are not compromised, WQC levels in excess of the current recommended guidelines can be tolerated, allowing for the allocation of water sources with potentially hazardous constituents to livestock on the basis of a sensitivity index.

The palatability experimentation investigated the effects of various chemical ratios on water intake and animal performance, and the results focus on the calculation of optimal ratios in terms of acceptability to livestock. Improving the palatability of saline waters used for livestock watering is of major importance in utilising subterranean water sources more effectively, as in many cases adverse palatability is a limiting factor for livestock production in arid and semi-arid regions.

Cost: *R902 000*
Term: *1994-1997*

Integrated control of blackflies along the Orange River

(No 650) Onderstepoort Veterinary Institute, Agricultural Research Council

The problems caused by blackfly (*Simulium* spp.) stem from the fact that water resources are increasingly controlled as they are developed, and the natural flow variation which existed prior to control and exerted a degree of control, has been removed. The initial project investigated the use of the microbial larvicide *Bacillus thuringiensis* var. *israelensis* (B.t.i.) and an organophosphate larvicide. While these are effective, control was costly. Thus, this project set out to investigate ways of increasing the efficiency of using these methods of control by studying the relationship between population dynamics and variations in the ecosystem.

It was found that the timing of outbreaks was variable. In the lower (warmer) reaches of the river, outbreaks may occur in winter, while in the upper (cooler) reaches, outbreaks occurred in summer. A combination of high temperatures and high evaporation rates limited outbreaks during high summer. The life cycle of adults was estimated at 8 to 12 d under good conditions. One of the ways in which outbreaks could be predicted was by monitoring the population numbers. Farmers up and down the river routinely monitored adult numbers, which gave an indication of when an outbreak could be expected. At the same time, staff monitored larval numbers. Decisions to spray are based on numbers combined with other factors such as river flow and temperature. It was found that a flow at Upington of 70 cumecs was sufficient to cause problems, but the larval habitat increased significantly at flows >300 cumecs. Flow can only be used as a control between Gariep Dam and Prieska. Observation indicates that *Microcystis* blooms may be toxic to larvae, and the bivalve *Corbicula fluminalis* may limit larval numbers by competing for the same food source. While the alga *Cladophora glomerata* may play a role in natural control by providing habitat for predators, the reed *Phragmites* when trailing in the water, provides additional habitat for the larvae and hampers control.

This information was brought together in a model which assists in the decision of when to apply larvicide.

Cost: *R524 200*
Term: *1994-1998*

Investigation into food-plot production at irrigation schemes in the central region of the Eastern Cape Province

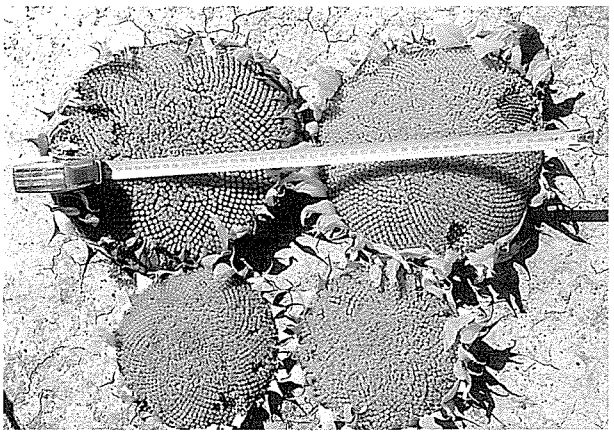
(No 719) Faculty of Agriculture and Agricultural and Rural Development Research Institute (ARDRI), University of Fort Hare

Most of the irrigation schemes developed during the 1970s and 1980s involved fairly sophisticated technology and consisted of two components, namely a social and an economic component. The economic component was designed to be farmed as an estate by external managers, while the social component consisted of food plots on which crops could be produced mainly for subsistence purposes. These food-plot sections were introduced into irrigation schemes primarily to compensate land-right holders for making available their land to the estate farm. Yet, food plots have been one of the relatively successful aspects of irrigation-scheme development in central Eastern Cape.

Six different schemes with plot sizes ranging between 0.16 ha and 2.0 ha were included in the study. The results suggested that an increase in the size of land holdings tended to be accompanied by a shift in the objectives of farmers from subsistence to market-oriented production. There was also a concomitant increase in the proportional contribution of agriculture to household income. This shift was found to expose farmers to a number of new challenges, of which production practices, marketing and financial management were the most important. The shift was also found to create new demands in terms of scheme organisation and supply of support services. Factors such as ready access to inputs, good quality land preparation, a reliable water supply and expert extension co-determine successful small-scale irrigated cropping. Well-organised farmers' organisations were found to be able to handle many of these new challenges, and their development needs to be encouraged and supported.

Whereas food-plot schemes appeared to be a suitable model of introducing irrigation on land held under communal tenure, it is not recommended for settlement schemes. The size of standard food plots (0.25 ha or less) is just too small to make irrigated agriculture a viable livelihood

Water harvesting basin tillage (WHB) plots with young sunflower after a rain event on the Glen/Swartland ecotype. Note the water accumulation in the basin.



Comparing sunflower seedheads from the WHB plots and the conventional tillage plots.

option. However, for progression to occur at these schemes, suitable institutional reforms with respect to land tenure would need to be developed and adopted by land-right holders. From the study it appeared that a minimum plot size of 2 ha is required in order for agriculture to become the main source of income for farming households.

Cost: *R196 600*
Term: *1995-1997*

New projects

Guidelines for rehabilitation of small-scale farmer irrigation schemes in South Africa

(No 891) Prof emeritus TJ Bembridge, Private Consultant

Small-scale farmer irrigation schemes in South Africa comprise only approximately 48 000 ha or 3.7% of the total area irrigated. From a rural development and socio-economic point of view such schemes are of cardinal importance since more than 223 000 people are dependent at least partially for a livelihood from small-scale irrigation schemes. Despite huge investments the performance of most small-scale irrigation schemes has been poor. Research has shown that small-scale farmer irrigation schemes are beset by varying combinations of economic, institutional and social problems.

The main motivation for this study is that large amounts of capital have been invested in schemes in all provinces. Ways and means need to be explored together with participants and the community as a whole to rehabilitate the schemes for the socio-economic advancement of the participants and the community. Rehabilitation of irrigation schemes has the potential to increase employment, household income and food security.

Before these schemes can be rehabilitated it is necessary to undertake an appropriate diagnostic analysis to pinpoint cultural, socio-economic, institutional, production and technological constraints, as a basis for innovative changes in the management and participation by small-scale farmers in the project. The proposal is that lessons gained from case studies, could provide guidelines for rehabilitating similar schemes in different provinces.

The most central aim of the research will be to identify present constraints and determine what needs to be done to rehabilitate the scheme. Such research involves investigating a number of inter-related variables such as:

- Assess present and previous institutional arrangements, including the land-tenure system
- Evaluate the impact of the project on participants and non-participants of the scheme
- Assess the managerial capacity of scheme participants
- Investigate the possibility of future participatory approaches to water management
- Investigate the research, extension and training needs of present and future participants
- Assess the suitability and acceptability of alternative irrigation technology
- Examine the present agricultural production situation
- Assess the economics and acceptability of various irrigation farming systems.

Estimated cost: *R150 000*
Expected term: *1998*

Evaluation of a model for water use in deciduous fruit orchards and scheduling of irrigation with the aid of meteorological data

(No 892) Infruitec, Agricultural Research Council

Several models to estimate evapotranspiration by means of meteorological data are already in use in South Africa. However, these models were developed for annual crops covering the full surface and under full-surface irrigation. It is therefore not applicable to orchard situations where strip irrigation is practised and crop architecture makes estimation of water use from meteorological data more difficult.

The "model" many fruit producers are presently using for irrigation scheduling is Class A-pan evaporation combined with estimated crop coefficients. A large number of producers still use long-term evaporation data in this model as a "recipe" method. Even when daily Class A-pan evaporation is used, it is often not realised that meteorological factors could have vastly different effects on pan evaporation and on crop transpiration. Evapotranspiration is also affected by soil type, soil-water content, tree size, phenological growing phase, training system, planting densities, irrigation system, irrigation cycle and various other cultivation practices.

A reliable irrigation scheduling model which is easy to use and which can be linked with automated irrigation systems should therefore find universal acceptance. The fruit industry is a major source of employment and of foreign exchange. Severe water restrictions superimposed on the announced tariff increases of water could have a detrimental effect on this industry. Improved irrigation management through a reliable model can save a substantial amount of water to the benefit of all.

The aims of the project are to:

- Develop and evaluate a mathematical model for prediction of water use of deciduous fruit trees from meteorological data
- Supply guidelines for irrigation scheduling of deciduous fruit trees
- Integrate the irrigation scheduling model with other models in a GIS based integrated farm management system and to communicate with fruit producers through the existing FRUITNET computer network.

Estimated cost: *R371 000*
Expected term: *1998-2000*

Factors which influence the acceptance of irrigation scheduling with specific reference to scheduling models

(No 893) Department of Agricultural Economics, Extension and Rural Development, University of Pretoria

The supply costs of irrigation water will increase in the near future due to the gradual phasing out of subsidies on water tariffs. This will necessitate judicious use of water in order to minimise costs of water distribution and application. The best way to achieve this is by means of irrigation scheduling with the aid of scheduling models.

Different models (e.g. BEWAB, SWB) for irrigation scheduling are available, which have been developed with WRC funding. However, if these models are not accepted by farmers, they will not be used in practice and water will not be saved. It is therefore essential to determine the degree of acceptability of scheduling models and if necessary to make adjustments to improve the acceptance of such models. These adjustments can best be made based on a scientific extension analysis of the factors which influence the accept-

ance of models as scheduling tools.

The aims of this pilot research project are to obtain guidelines for commercial and subsistence farming of the acceptability of scheduling models on two or three different irrigation schemes.

Specific aims are to:

- Determine the perception regarding irrigation scheduling in practice
- Identify the human and environmental factors which influence the acceptability of scheduling models
- Develop guidelines and make adjustments which will improve the implementation or practical use of scheduling models.

Estimated cost: *R100 000*
Expected term: *1998*

Implementation of the FARMS (firm-level agricultural risk management simulator) system for management decision-making in irrigated farming

(No 894) Department of Agricultural Economics, University of the Orange Free State

In previous WRC-funded research projects, procedures and methods have been developed for economic evaluation of irrigation scheduling strategies, analysis of the cost of irrigation equipment, such as centre pivots, and assessment of the business and financial risks on a whole-farming level. Although this research has led to the development of powerful models, it can be said that there is a lack of implementation of knowledge and tools in practice.

Successful implementation of the above-mentioned models in practice mainly depends on the following:

- Linking of various submodels to provide decision support for management of the farming business unit
- User-friendly presentation of computer programs whereby complex calculations are done
- Illustrating the usefulness of models with data under different real-life situations.

The goals of managers differ and a single measure of performance is not applicable. The modelling system must therefore be flexible and make provision for evaluation of various management alternatives.

The main aim of this research project is to integrate available computerised tools into a modelling system in support of irrigation management. In particular this will involve the following:

- Integration of crop-growth models and scheduling models in the FARMS system
- Inclusion of the SPILKOST 2.0 program for centre-pivot irrigation and further refinements to calculate the costs of e.g. flood, drip and micro-irrigation
- Incorporating risk preferences for different management profiles and quantifying price risks in the whole-farming model
- Testing the applicability of the model on irrigation schemes for varying scales of farming activity
- Establishment of a user-friendly computerised decision-support system for the economic evaluation of irrigation farming management.

Estimated cost: *R358 000*
Expected term: *1998-1999*

Investigation into the use of pathogenic organisms for the biological control of the troublesome alga *Cladophora glomerata*

(No 918) Plant Protection Research Institute, Agricultural Research Council

The alga *Cladophora glomerata* is a serious pest in irrigation and industrial canals. At times of peak demand unchecked growth of *C. glomerata* will prevent the canal from delivering its design capacity which will result in revenue loss not only to the canal owner but also to the end users of water.

Mechanical control is only successful in the short term as

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

reinvasion rapidly occurs. Chemical control is expensive and dangerous, and is becoming increasingly unacceptable where water delivered is used for crops destined for export. While the effect lasts longer than mechanical control, it is not permanent. For these reasons, research is being conducted on biological control of the algae.

In the previous project of this series, several fungi with the potential to control *C. glomerata* were isolated. Further research is, however, necessary to investigate the practical application of these organisms in irrigation schemes.

During this project, the efficacy of selected organisms to control *C. glomerata* will be investigated, as will the mass production, formulation and application of the selected organism once its host specificity has been determined.

Estimated cost: *R266 000*
Expected term: *1998-2000*

Selection for drought tolerance in the germplasm of *Vigna unguiculata* (cowpea), *Vigna subterranea* (bambara groundnut) and *Amaranthus* spp. (marog)

(No 944) Vegetable and Ornamental Plant Institute, Agricultural Research Council

Water stress is one of the most important environmental variables affecting plant growth and development. Hunger and malnutrition have given new urgency to drought research in an attempt to reduce the risk of dramatic yield reduction and to enhance food security. Hope for the future may lie in a number of unexploited and neglected species that have been largely ignored. Various studies conducted in this regard have emphasised the role of indigenous and traditional plants in providing many of the basic needs of rural people, such as shelter, fuel, medicine, dietary supplements and as a source of income. Several indigenous species are eminently suited for production in large areas in South Africa which have a low agricultural potential due to low or unreliable rainfall. Although cowpea, bambara groundnuts and marog are relatively drought tolerant, variation in tolerance exists. It will therefore be valuable to determine the variation in drought tolerance and develop a screening method for drought tolerance. Results from such research may be helpful to reduce the risk of food production for resource-poor farmers under dryland conditions.

Before any final recommendations can be made regarding the best selected lines, the laboratory results must first be compared to results obtained from field trials. The selected lines must be planted in the field under different dryland conditions to confirm their suspected tolerance/sensitivity towards drought stress. Thus, the final selection can only be done after correlation of the physiological tests with the field evaluation. This method will help to obtain the best line for the specific environment where it will be planted with participation by the communities.

The aims of the project are as follows:

- Physiological evaluation of drought tolerance
- Optimisation of tissue culture and multiplication of selected cultivars/lines
- Field evaluation after tissue culture
- On-farm trials in the communities.

Estimated cost: *R735 000*
Expected term: *1998-2002*

Two-dimensional water balance and energy interception model for fruit trees

(No 945) Department of Plant Production and Soil Science, University of Pretoria

It is estimated that 90% of the production of citrus and deciduous fruit is under irrigation. However, there is a lack of suitable tools to mechanistically describe the water balance of tree crops. This is because existing water-balance models consider a one-dimensional problem which is suitable for agronomic, vegetable and pasture crops, which cover the whole surface area uniformly. Tree crops are planted in widely spaced rows to allow access between trees to carry out necessary management practices (e.g. pest control and harvesting). Row orientation, tree size and spacing, land aspect and gradient all affect the amount and spatial distribution of intercepted solar radiation. This will influence evaporation and transpiration and needs to be quantified. Micro-irrigation used in orchards only wets a limited area under the canopy of the trees, so evaporation from the surface is not uniform. Interception of rain by trees is also channelled down the stem and drips from the edge of the canopy, so rain is also not evenly distributed on the surface. Root density varies with depth and with distance between the rows so that water uptake for transpiration will also vary in two dimensions. It is important to quantify water uptake between rows in order to estimate the effectiveness of rain and the competition for water from cover crops or weeds growing between the rows.

This project involves collaborative research between the University of Pretoria (UP) and the University of the North (UNIN) for the purpose of capacity-building. Short-term training courses for the users of water for irrigation purposes are being contemplated by the authorities of the Northern Province. Commendable as this is, it is only an emergency plan which does not offer a long-term solution. What is really needed is to create a core of expertise within the Province which can then address the long-term issues. It is envisaged that this project would be the beginning phase of developing this core of expertise.

The project aims to:

- Develop a two-dimensional fruit tree water-balance model which takes into account the unique fractional interception of solar radiation associated with hedgerow orchards as opposed to the horizontal planar interception encountered in agronomic crops
- Verify the model for deciduous fruit trees using peaches as an example
- Verify the model for evergreen fruit trees using citrus as an example
- Develop a core of irrigation expertise, within the Faculty of Agriculture, UNIN, i.e. to be of service, in collaboration with the National Community Water and Sanitation Training Institute, to agriculture in the Northern Province.

Estimated cost: *R827 000*
Expected term: *1998-2000*

Development of an integrated information system using the WAS, SWB and FARMS computer models

(No 946) NB Systems

In the current debate on water policy reform there is acceptance of integrated catchment management (ICM) with involvement of water user associations (WUAs) of different

water-use sectors. The prerequisite for successful implementation of both of these approaches is active participation by water users in water management on a local level, e.g. the individual farm and irrigation scheme. This means that WUAs or their appointed agents will require information and decision-making tools to assist in water management. In the case of irrigation schemes in particular, an accurate prediction of the quantity of water likely to be demanded is necessary in order to supply water from dams and canals on request, on time and with the least possible distribution losses.

The sequence of analysis is briefly an assessment of water required per crop according to season and growth stage. The water requirement per farm will be determined by the type and combination of crops grown as influenced by price expectations, management goals and a range of limitations such as available land, water, capital, labour, etc. The sum of water volumes required for a number of farms on different canal sections gives the total quantity according to which water releases from the dam must be calculated.

Based on three different research projects funded by the WRC in the past, the water administration system (WAS), soil water balance (SWB) and firm-level agricultural risk management simulator (FARMS) computerised models have been developed. The decision-support tools are therefore available to determine the water demand per crop and farm and calculate the required supply of water from canals. What is necessary for these tools to be used for integrated water management is a uniform database and linking of crop and whole-farming models on the demand side with canal flow models on the supply side. The total information system can be implemented on a network where it can be used by different people to capture data, generate reports, calculate water releases, advise farmers on irrigation scheduling and efficient water use for irrigation.

The main aim of this project is to integrate the WAS model, the SWB model and the FARMS model in such a way that it can be used as tools on an irrigation scheme to:

- Minimise water distribution losses
- Maximise efficiency of water use per crop by means of irrigation scheduling
- Optimise crop combinations within resource limitations.

Estimated cost: *R594 000*
Expected term: *1998-1999*

Economic impact of changing water quality on irrigation farming in the Lower Vaal River

(No 947) Department of Agricultural Economics, University of the Orange Free State

In the course of economic growth and development, there is an increasing use of water and also return flows, which can contribute to the gradual deterioration of water quality. This applies in particular to the Vaal River system, where water quality worsens as river flow reduces, but improves again after floods. Even if water quality were not to worsen progressively over time, it is expected that the irrigability of soils could still be affected, which in turn would impact on the sustainability of crop production.

Seasonal or cyclical decline in water quality contributes to both private and external costs. Private costs involve e.g. artificial drainage, amelioration and application of additional water to leach salts; external costs refer to e.g. increasing salt loads in downstream river reaches. The causes and consequences of deteriorating water quality can be managed by adapting on-farm production practices and by introducing policy instruments such as pollution charges. However, no analysis has so far been done of the long-term economic viability of irrigation farming under these conditions in the Lower Vaal River. It must be determined whether benefits can be generated which at least cover private costs and internalised external costs.

This project is an extension of a WRC-funded project on **The effect of water quality on irrigation farming along the Lower Vaal River: The influence on soils and crops** (No 740) which is currently being undertaken by the Department of Soil Science of the University of the Orange Free State. The results that will be forthcoming will be analysed further to determine the economic impact of changing water quality.

The main aim is to develop and apply models to determine the long-term financial and economic viability of irrigation farming in the Lower Vaal River area.

Estimated cost: *R417 000*
Expected term: *1998-2000*

Economic efficiency of irrigation systems for large- and small-scale farming enterprises

(No 974) Department of Agricultural Economics, University of the Orange Free State

Just as no theoretically founded instrument was available for the estimation of the cost of centre-pivot irrigation 10 years ago, similar instruments are still not available for the economic and financial evaluation of the cost of micro, drip and flood irrigation at whole-farming level, and a need therefore exists to round off the technical research by introducing economic analyses. With the implementation of the new constitutional dispensation and the concomitant land- and water-reform initiatives, the need for financial analyses with regard to the viability of irrigation on small-scale farms has become very important, because irrigation often offers the only method of survival and commercial competitiveness in agriculture.

A further need is that one should be able to use the above-mentioned program for the estimation of the cost of irrigation at whole-farm level to analyse the economic and financial position of small and large farming systems. This need has been emphasised by the Co-ordinating Committee for Irrigation Research.

The economic analysis of small-farm irrigation is also a logical continuation of completed WRC projects on the technical aspects of irrigation. Supplementing the results of these projects with an analysis of the economic and financial viability of the other irrigation methods, will be a major contribution to the financial survival of the approximately 40 000 small- and 15 000 medium- to large-scale irrigation farmers.

Against this background the objectives of the proposed project include, *inter alia*, the following:

- Economic and financial analyses of alternative irrigation systems and methods on whole-farm level for large- and small-scale irrigation farming
- Critical analysis of irrigation systems and methods in relation to each other and in terms of efficiency of water use and energy use, as well as economic profitability and financial feasibility
- Estimation of the economic profitability of irrigation systems with available financing methods.

Estimated cost: *R750 000*
Expected term: *1998-2001*

Research projects

Completed

- **290** Flood and furrow irrigation: A critical evaluation of design procedures and the computerisation of the most suitable approaches (University of Pretoria – Department of Agricultural Engineering and Rehab Consultation)
- **389** Scheduling irrigation of tuber crops with specific reference to potatoes (Agricultural Research Council – Vegetable and Ornamental Plant Institute)
- **417** Optimal water utilisation by turf (Potchefstroom University for CHE – Department of Plant and Soil Science)
- **625** Use of computer models for agricultural water management at farm level (University of the Orange Free State – Department of Soil Science)
- **644** Quality of water for livestock production with emphasis on subterranean water and the development of a water quality guideline index system (University of Pretoria – Department of Animal and Wildlife Sciences)
- **650** Integrated control of blackflies along the Orange River (Agricultural Research Council – Onderstepoort Veterinary Institute)
- **719** Investigation into food-plot production on irrigation schemes in the central region of the Eastern Cape Province (University of Fort Hare – Faculty of Agriculture and Agricultural and Rural Development Research Institute)

Current

- **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)
- **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)
- **479** Molecular approach to drought tolerance (Agricultural Research Council – Institute for Plant Biotechnology)
- **499** Effect of exchangeable sodium percentage and clay mineralogy on the infiltration capacity of soil already sealed due to cyclic irrigation (Potchefstroom University for CHE – Department of Plant and Soil Sciences)
- **573** Water-use efficiency of cultivated subtropical forage and pasture crops (University of Pretoria – Department of Plant and Soil Sciences)
- **578** Evaluation of irrigation techniques used by subsistence and emergent farmers (MBB (CE) Inc.)
- **581** Computerised weather-based irrigation water management system (University of the Orange Free State – Department of Agrometeorology)
- **600** Problem blooms of macro-algae: Investigation of causal factors, seasonality of recruitment and growth, and efficiency of control methods (University of Cape Town – Department of Botany)
- **624** Personal computer-based procedure for the estimation of irrigation requirements of crops in Southern Africa (MBB (CE) Inc.)
- **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)
- **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)
- **753** Facilitating irrigation scheduling by means of the soil water balance model (University of Pretoria – Department of Plant Production and Soil Science)
- **768** Evaluation of the appropriateness and management requirements of micro-irrigation systems in small-scale farming (MBB (CE) Inc.)
- **774** Development of guidelines for appropriate training levels and content in support of sustainable small-scale irrigation development (MBB (CE) Inc.)
- **780** Effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas (CSIR – Division of Water, Environment and Forestry Technology)
- **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)

New

- **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 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)

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Industrial water management

Nationally, sustainable development is a corner-stone policy adopted by DWAF. Accordingly, ever-increasing emphasis has in recent years been placed by the WRC on balancing research priorities in industrial wastewater management between effluent treatment technologies and source reduction.

The former includes the full range of physico-chemical and biological processes available for minimising the impact of industrial effluent discharges on the receiving environment. By contrast, source-reduction initiatives include waste minimisation, cleaner production and cleaner technology. Examples are process substitutions using more environmentally friendly methods and materials, synergistic combinations of wastes to produce additional useful products, the conversion of "problem waste" materials into more environmentally benign or valuable co-products and process integration using *inter alia* pinch technology to achieve water savings. A useful methodology for rationally deciding on the relative advantages of post-production treatment and source-reduction intervention is "life cycle assessment" whereby all the environmental impacts associated with alternative production/processing/treatment/discharge options can be quantitatively and holistically determined. The impacts assessed include material and energy considerations, with both local and remote factors being considered. Such considerations support current policy initiatives by DWAF, Department of Environmental Affairs and Tourism (DEAT) and Department of Trade and Industry (DTI) (sustainable development; national waste management strategy; cleaner production).

Regionally, the water-scarce RSA situation precludes the option of a "solution to pollution by dilution". Environmental stresses are evident in inland areas (salinisation and eutrophication from salt and nutrient discharges to receiving water bodies from domestic, industrial and mining sources), in coastal areas (excessive disposal of liquid industrial effluents to waste disposal or landfill sites) and off-shore (increasing discharge of effluents to the marine environment in commercially or ecologically sensitive situations). The national water-scarce context obviously promotes the reduction of freshwater use for industrial processing purposes, with a consequent need for recycling and (often) a concomitant increase in the concentration of industrial pollutants, even when the mass load discharged is reduced. Such trends affect both the economies of recovering additional products from "waste streams", and the treatment requirements for residual effluent discharges.

Completed projects

Transfer of wastewater management technology to the meat-processing industry

(No 239) SRK (CE) Inc. and Abakor Ltd.

This project was aimed at providing the red meat abattoir industry with a low-cost, low-risk opportunity of using and assessing in their own environment, the available membrane technology not yet utilised for this purpose.

The performance of locally manufactured membranes compared reasonably well with that of imported non-cellulosic membranes. Rejections of COD, by UF in particular, were very good, but other rejections by UF are worth noting in that they were not fully expected, including:

- An apparent salt rejection of 25%, measured as conductivity
- A typical rejection of about 85% of soluble phosphates, possibly as a result of complexation with proteinaceous materials.

As the trials proceeded, it became clear that the more gentle cleaning techniques were becoming less effective and that clean membrane fluxes were not being fully recovered. The harsher cleaning techniques were somewhat more effective, and in most cases more expensive, but promoted the risk of damaging the membranes with repeated use, potentially

shortening the life of the membranes. After some months of this declining trend in membrane cleaning efficiency, it appeared that the entire exercise may have to be aborted on the basis of high cleaning costs, excessive down-time during inordinately long cleaning runs, and membrane damage.

A series of short laboratory-controlled cleaning trials using enzymatic preparations, designed for general cleaning in the abattoir, on fouled membranes, was carried out at the Institute for Polymer Science, University of Stellenbosch, and yielded spectacular results. When chemical cleaning was assisted by sponge balling, flux improved more than threefold. No damage to the membranes was detected as a result of using these preparations.

Cost: *R169 000*
Term: *1989-1995*

Utilisation of the fungus *Geotrichum* in wastewater

(No 315) Department of Chemical Engineering, University of Pretoria

In this project, growth kinetic constants were determined for three species of *Geotrichum* which dominate in an open, selective cultivation process. Using these growth kinetic constants and Monod kinetics it was possible to explain which combinations of biomass dilution rates and effluent substrate concentrations would favour the selection of specific species.

These results are significant in that the process has now for the first time been characterised to such an extent that the conditions may be tailor-made to produce the correct species of *Geotrichum* to suit the requirements of industry. Growth kinetics have been made available to predict growth of the *Geotrichum* species under various conditions. Under certain conditions, more proteins are produced, whereas, under other conditions, another species may dominate, which does not produce so much protein biomass, but is better able to break down organics in effluents. From these results industry will now be able to specify plant operating conditions in advance, depending on whether protein production or effluent treatment is the most important objective.

Although these results still have to be verified under real operating conditions, an important step forward has been taken in the treatment of effluents with the simultaneous production of a valuable protein by-product.

Cost: *R293 000*
Term: *1990-1992*

Improvement in water usage control and wastewater treatment in the sorghum beer industry

(No 342) Department of Chemical Engineering, University of Pretoria

The sorghum beer industry in South Africa daily consumes approximately 10 000 m^3 of water. The specific water consumption per unit of beer is considerably higher than that of the malt beer industry. Sixty per cent of the water intake ends up as an acid effluent with high loads of suspended, colloidal and discharged organic matter. Most of the effluent is discharged to the municipal sewerage system after little, if any, pretreatment. This project was aimed at reducing water consumption in sorghum beer brewing and at reducing the acidic and organic load of effluents discharged via municipal sewers.

A pilot-scale study demonstrated that the filter-bag system, incorporating simple installation and operation, produced unparalleled results in terms of the prevention of pipe blockages and concomitant operational problems, and that it is a cost-effective solution.

A wedge-wire screen showed further improvement in wastewater quality with the possible production of a usable by-product. The wedge-wire screen also serves as effective forerunner to subsequent treatment processes such as coagulation and/or sand filtration. The use of a wedge-wire screen with openings smaller than 0.45 mm will also result in increased solids removal. The decision of whether to use a screen or not, should, however, rest with the results of a particle characterisation analysis.

The upflow sand-filter runs, with or without coagulation, proved that the method is viable for producing reusable wastewater in the sorghum industry.

A possible process design for the effective treatment of mainly sorghum beer-brewery wastewater is the following:

- Four disposable bag filters (10 mm openings) positioned at the outlet of wastewater pipes
- A wedge-wire parabolic screen with at least 0.45 mm openings and large enough to accommodate the maximum wastewater flow
- Controlled effluent pH neutralisation with lime and upflow sand filtration of sufficient effluent to serve the specified reuse needs of the plant.

Cost: *R47 000*
Term: *1990-1996*

Phenols in the steel industry wastewater: Origin, prevention and removal

(No 409) Department of Chemical Engineering, University of Pretoria

Phenols are generally found in the steel and stainless steel production industry, especially where coking is used. They end up in the water during slaking and from slag dumps find their way into storm- and groundwater. Phenols can import a bad taste to water even at low concentrations, causing problems in mainly water purification as chlorination aggravates the taste problem. The objectives of the project were to quantify the problem regarding phenols in the steel industry and to create a management programme which will prevent phenols from ending up in effluents.

The first part of the investigation was aimed at determining the amount of pollution with phenolic compounds from Iscor's Pretoria works. Phenolic compounds were released by old dumpsites in leachates from this site. The concentrations were low and diminishing over time and it would appear that they will dwindle to very low levels within the next 15 to 20 years.

The second part of the investigation was conducted at wastewater "evaporation" ponds belonging to stainless steel manufacturers in Middelburg. It was found that these ponds contained extremely high concentrations of phenols, in fact high enough to consider recovery of the phenolic compounds rather than its destruction. Unfortunately research in this regard could not be initiated.

Cost: *R39 000*
Term: *1991-1996*

Development of procedures to assess whole effluent toxicity

(No 453) Division of Water, Environment and Forestry Technology, CSIR

The complexity of effluents produced by modern society cannot be successfully monitored by conventional chemical tests. However, various biological tests are cost-effective ways to determine the toxicity and dilution requirements of effluents. DWAF has identified whole effluent toxicity (WET) testing as an appropriate tool to assess the suitability of hazardous effluents for discharge to receiving waters.

During this project a variety of tests were evaluated and their methods described. While many of these were identified as suitable for acute tests, the need for short-term chronic tests was identified especially for use on low-toxicity effluents. This aspect is being addressed in a follow-up project (WRC K5/952) being carried out by the same research institution (see **Water Quality Management**).

This report is accompanied by a set of guidelines on WET testing.

Cost: *R359 700*
Term: *1992-1998*

Development of an expert systems approach to water management in the fruit- and vegetable-processing industry

(No 458) SRK (CE) Inc.

Measures to improve water management in the fruit- and vegetable-processing industry (the Industry) have generally focused on line-specific actions. It was originally envisaged that a practicable expert system for water management in the Industry would be based on monitoring and reporting the water use for individual commodities or processing activities in a format which would transparently identify problem areas. Appropriate remedial actions could then be taken by the Industry to maintain water-use efficiency at or close to the minimum target levels identified, improving compliance with the water management objective(s) selected, e.g. more conservative, more consistent or more cost-effective use of water to achieve the commercial production aims of the Industry.

During the execution of the project, the seasonally orientated nature of the Industry was found to exert a more significant influence on water-use efficiency than previously realised. At high levels (>50%) of factory capacity utilisation the factory specific water intake (SWI, kl/t) tended to a minimum level (7 to 8 kl/t) and at low levels (<10%) of factory capacity utilisation, the factory SWI rose to much higher values (up to 40 kl/t). The factory capacity utilisation was not uniquely associated with one or more particular commodities, indicating that the commodity SWI-values generally ascribed to line-specific factors were influenced also by the overall factory production rate. Factories in the Industry could thus usefully define initial water management targets based on historical production/capacity utilisation, before embarking on a more ambitious water-metering programme in which detailed processing water uses are exhaustively monitored. The results obtained and the conclusions reached provide a valuable basis for an expert systems approach in which realistic water management objectives in the industry can be sensibly set in relation to production.

Cost: *R227 000*
Term: *1992-1995*

Use of filamentous micro-organisms for the purification of industrial effluents

(No 535) Department of Chemical Engineering, University of Pretoria

A promising effluent treatment method had previously been developed by the Division for Water Utilisation Engineering of the University of Pretoria. In this method a cross-flow sieve bio-reactor system, running at low pH, is used to select for filamentous fungal micro-organisms. The effluent is purified, while single-cell protein is produced simultaneously by harvesting the filamentous organisms. In this project, the research team aimed to select a thermotolerant filamentous fungal organism for the treatment of pulp and paper effluent.

They succeeded in selecting a thermotolerant fungus, *Aspergillus fumigatus*, on the specific effluent used in this study. The organism, which has not yet been exploited elsewhere in the world in such an application, is able to grow well at 45°C in suspension, resulting in eliminating the need for any further cooling of the effluent. Since concern exists regarding the safety of process workers due to possible contamination of the air with spores or viable fungal material, tests have been conducted to quantify the amount of viable fungal material in the environment around the laboratory reactor. No significant amounts of fungal material could be detected in the working area of the laboratory-scale process. The only two possibilities for the recovery of by-products that were explored for commercial exploitation are single-cell protein and cellulase. However, there are strong indications that the biomass can be used in secondary steps for the production and extraction of various other metabolites.

Cost: *R194 000*
Term: *1993-1995*

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

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

In this project the extraction of polluting heavy metals and other chemicals from a feed solution through a membrane into a strip solution was investigated, using supported liquid membranes. This concept comprises a capsule containing the so-called strip solution, impregnated with the correct extractant which would effect the extraction.

The extraction of nickel with suitably formed membrane capsules gave extraction rates and total extraction values which were dependent on the following five variables:

- Temperature
- Speed of agitation on the feed side (Reynolds number)
- Acid concentration in the strip (inside) solution
- Special ligand concentration in the feed-side solution
- Extractant concentration in the membrane.

Each of the variables increased the extraction rate and the combined nett effect was an increase of at least 100 times greater extraction than reported in literature. Furthermore, an empirical rate equation was developed which yielded a polynomial expression in terms of all the independent variables mentioned. This rate equation is a powerful tool to predict and determine the required size of a plant using this technology.

Cost: *R100 000*
Term: *1996*

New projects

Development of bioreactor systems for the conversion of organic compounds in industrial effluents to useful products

(No 939) Department of Biochemistry and Microbiology, Rhodes University

Toxic organic compounds in industrial wastewaters represent an environmental hazard to the community and an expensive material waste to the producer. The fields of biotransformation and bioremediation offer the potential both for limiting or neutralising the toxic effects of various organic compounds which are present in the industrial water/effluent cycle, as well as the possibility of converting some of these compounds to economically valuable by-products (the latter aspect obviously enhances the prospects for implementation of such bioprocesses by industry). Major advantages of biotransformation methods over chemical synthesis are the mild, environmentally friendly conditions required, the efficiency and specificity of biological catalysts (not easily achieved by conventional chemical methods), and the ability of enzymes to catalyse reactions where unreactive molecules (e.g. benzene, xylene) are converted to more reactive molecules (e.g. cyclohexene-diols) which also have chirality (optical activity). Such selectivity (stereospecificity) is extremely important in the pharmaceutical and fine chemical industries, where different optical isomers can have very different biological activities.

Specifically, the project aims at:

- Further development of fundamental understanding of the oxidative enzymatic processes involved in the bio-conversion of toxic organic pollutants present in certain major industrial effluents to saleable products which can off-set the costs of water reclamation
- Applying this fundamental knowledge to the design of practical bioreactor systems.

Estimated cost: *R595 000*
Expected term: *1998-2000*

Electrochemical treatment of water and effluents

(No 940) Department of Chemical Engineering, Potchefstroom University

Electrochemical (EC) treatment of wastewaters has some significant technical advantages over chemical dosing methods, particularly in that counter-ions e.g. chloride are not produced while generating cations e.g. ferric ions for flocculation. It has also been shown that very high phosphate and fluoride concentrations, up to thousands of mg/*l*, can be reduced to guaranteed levels below 1 mg/*l* using EC treatment. Such benefits have previously been negated by the high cost of EC processes.

The project aims to "revisit" EC treatment of wastewater, using modern electric, electronic and control technology. The approach proposed is to employ sacrificial scrap-electrodes, allied with the potential for using solar or wind energy, which could result in a "clean technology" treatment option which is also cost-competitive. Promising initial results have been obtained from preliminary pilot trials on various industrial effluents, acid mine drainage, sewage and potable water using an existing pilot plant (1 Ml/d). In addition to the use of scrap sacrificial electrodes, further cost advantages could also be derived by the development of a generic EC-reactor which could handle scrap. A sophisticated generic EC-reactor with a range of sacrificial scrap metal electrodes and geometries will be thus be developed and tested as a parallel objective of the project. Objectives for this research are thus to exploit the existing pilot-scale EC-reactor, to establish its performance characteristics and optimise operating costs in the applications indicated, and to develop a more generic reactor which could handle scrap metal.

Estimated cost: *R335 000*
Expected term: *1998-1999*

Research and development of electronic distance-learning methodology for the education and training of industrial wastewater treatment personnel

(No 941) LIRI Technologies, Rhodes University

A recent WRC study estimated that of some 5 000 workers in the wastewater treatment industry, many have little formal training in the jobs in which they are employed. The education of adults already in employment and vocational training for those entering the field requires specific, sustained inputs. The diversity of wastewater treatment plants and their spread through companies and towns across South Africa creates almost insurmountable obstacles for any programme of conventional education targeting a meaningful impact on the development of personnel working in the field. There is also a growing need for knowledge to be transferred to communities as they are drawn into water-care issues, which implies the acquisition of both technical and communication skills by workers in this field.

The project aims at:

- The structuring of an education- and training-based career path for human resource development in the wastewater treatment industry, providing progress from operative through to plant management qualifications
- The research and development of an effective, low-cost electronic distance-learning technology focused on the education and training requirements and the specific delivery needs associated with the diverse and widely spread wastewater treatment industry
- The research, development and piloting of course materials required for the delivery of the education and training programme
- The evaluation of the performance of adult learners and the provision of feedback into both the course development and electronic delivery processes.

Estimated cost: *R432 000*
Expected term: *1998-2000*

Solid stabilisation of soluble wastes from the ferro-alloy industry

(No 942) Mineralogy and Process Chemistry, Council for Mineral Technology

Local industries endeavour to reuse and recover pure water from industrial effluent by desalination, e.g. reverse osmosis (RO). However, RO processes produce concentrated brines which have to be stored in expensive lined dams to prevent the contamination of natural river courses. In addition to the shortage of and unproductive use of available land, these dams become more difficult to manage in the longer term and require expensive maintenance to prevent spills and leakages. The potential of RO and other water-recovery options for the enhancement of existing water resources can only be fulfilled in the longer term if a suitable option for the disposal of brines can be found.

In 1996 Mintek embarked on a preliminary study to investigate the solid stabilisation of brines by forming new mineral phases in cement-based composites which act as

internal barriers to contain the soluble salts. The results of the study using local brines and ashes were very encouraging, with some soluble components in the brine stabilised up to 50%. This approach is to be extended to wastes generated in the ferro-alloy industry, which is expected in the future to compete with the gold industry in terms of exports. The project aims are to:

- Optimise the production of solid stabilised soluble wastes generated in the production of ferrochromium and stainless steel, by the manufacture of cement bricks/blocks using wastes available on site: low-quality recycle water, slag and baghouse dust
- Evaluate the leachability of soluble salts and toxic components (Cr(VI)) from the manufactured bricks/blocks by internationally accepted procedures to access this disposal route in terms of the potential impact on the environment
- Assess the solid stabilisation products as potential building construction materials, including evaluation of the economic potential for the manufacture of these products and their utilisation in the national Reconstruction and Development Programme (RDP).

Estimated cost: *R205 000*
Expected term: *1998-1999*

Process development and system optimisation of the integrated algal trench reactor process for sulphate biodesalination and heavy metal precipitation in mining and industrial effluents

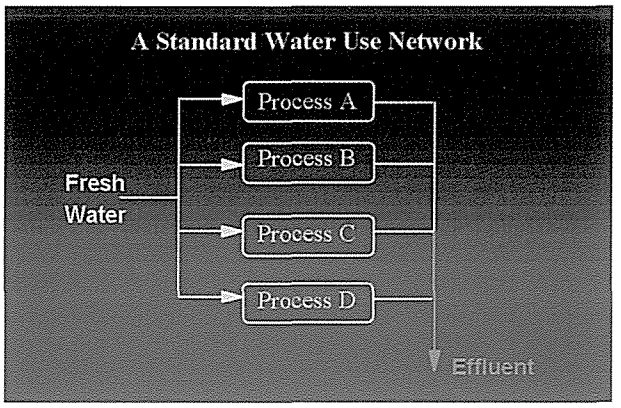
(No 972) Department of Biochemistry and Microbiology, Rhodes University

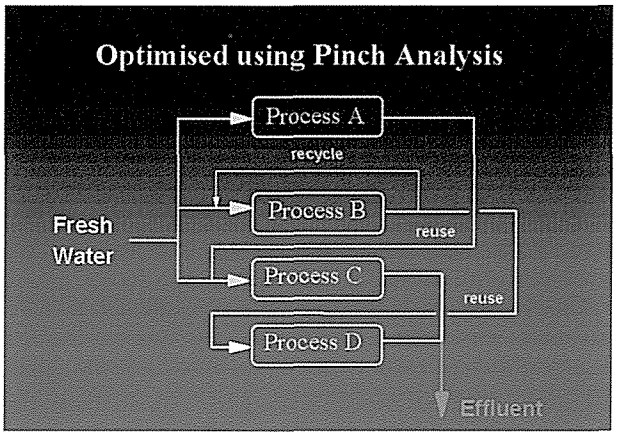
Mine drainage waters and certain industrial effluents containing heavy metals and high sulphate levels present urgent and intractable environmental impact problems which have reached critical proportions on the East Rand ("the Grootvlei crisis") and are also widespread elsewhere in mining areas both in the RSA and abroad. Apart from the adverse environmental impacts associated with large volumes of acid mine drainage (over 100 Ml/d currently contaminate the ecologically sensitive Blesbokspruit RAMSAR site with metals and salts), this represents a large untapped resource of low-grade water (e.g. up to 50 x 10^6 m^3 annually in the Nigel area).

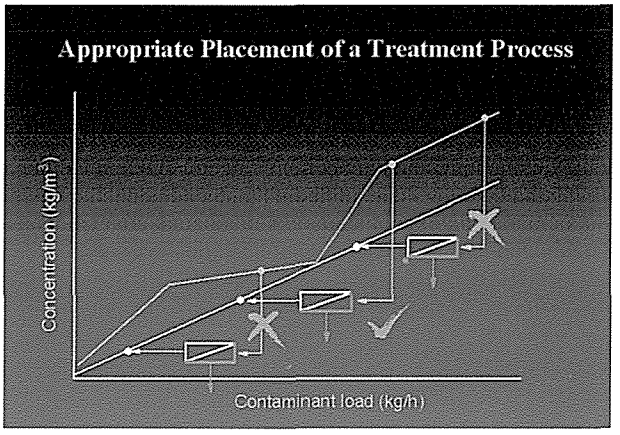
WRC-sponsored research on algal ponding technologies, undertaken in the Department of Biochemistry and Microbiology at Rhodes University over a number of years, has resulted in the development and patenting of a novel process for effecting the linked removal of heavy metals and sulphate from such wastewaters. The progress in algal integrated ponding systems (AIPS) includes development from fundamental and laboratory studies, through piloting, to construction of full-scale and demonstration plants applied to a range of wastewaters at a number of sites. The development of the novel double-deck trench digester integrated together with the AIPS is an innovative contribution to the field providing both potentially high-rate sulphate reduction and photosynthetic conversion of sulphide to elemental sulphur (WRC provisional patent).

Due to the urgency of the situation, empirical evaluation of the process has been accelerated despite the relatively early stage reached in developing a fundamental understanding of the biological processes involved. The broad objective of the project is to expand the knowledge base, and develop the fundamental design principles necessary for rationalising process development and functional performance optimisation of the algal trench reactor process for sulphate biodesalination and heavy-metal precipitation in these effluents.

Estimated cost: *R922 000*
Expected term: *1998-2000*







Application of pinch technology as a strategic tool in the rational management of water and effluent in an industrial complex. (Project No 851).

Waste minimisation and effluent treatment clubs – Phase 1: Initial assessment and pilot study

(No 973) Pollution Research Group, University of Natal

There is a national development programme to promote and support the establishment of industrial small, medium and micro enterprises (ISMMEs) in the RSA. International experience has indicated that cumulatively these organisations are significant sources of pollutants (air, water and solid waste). These diverse and intermittent discharges have a detrimental effect on the operation of sewage treatment

works and impact negatively on downstream water users. Individually members of this sector do not have the knowledge or resources (financial or technical) to address these issues. The usual sources of information on effluent treatment (engineering consulting services, equipment vendors, local authorities) are generally beyond the reach of such enterprises or are otherwise precluded.

An alternative approach, which has been successfully applied internationally, is to incorporate ISMMEs into regional waste minimisation and effluent treatment clubs, in which cleaner production practices can be cost-effectively established. Experience from Europe has indicated that it takes time to establish the culture of waste minimisation clubs, but once established, large savings (financial and environmental) can be achieved. In the RSA, the development of a framework for such a waste minimisation programme would enable similar exercises to be repeated in all the major industrial areas of the country using local expertise.

The overall objective of the project is thus the preservation and improvement of water quality through the prevention of industrial water pollution and the reduction in the demand for industrial water by implementing cleaner production principles.

Aims to achieve these objectives are:

- The development of the concept of waste minimisation clubs in South Africa
- A contribution to the establishment of competitive ISMMEs in South Africa
- The promotion of the concepts of waste minimisation, cleaner production and sustainable development among ISMMEs, tertiary educational institutions, local authorities, government agencies and professional consultants
- The promotion of energy efficiency and indirectly reducing the impact of the power industry on the aquatic environment.

Estimated cost: *R1 150 000*
Expected term: *1998-2000*

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Research projects

Completed

- **239** Transfer of wastewater management technology to the meat-processing industry (SRK (CE) Inc. and Abakor Ltd.)
- **315** Utilisation of the fungus *Geotrichum* in wastewater (University of Pretoria – Department of Chemical Engineering)
- **342** Improvement in water usage control and wastewater treatment in the sorghum beer industry (University of Pretoria – Department of Chemical Engineering)
- **409** Phenols in the steel industry wastewater: Origin, prevention and removal (University of Pretoria – Department of Chemical Engineering, Division for Water Utilisation Engineering)
- **453** Development of procedures to assess whole effluent toxicity (CSIR – Division of Water, Environment and Forestry Technology)
- **458** Development of an expert systems approach to water management in the fruit- and vegetable-processing industry (SRK (CE) Inc.)
- **535** Use of filamentous micro-organisms for the purification of industrial effluents (University of Pretoria – Department of Chemical Engineering, Division for Water Utilisation Engineering)
- **761** Extraction of ionic and chemical species from water by capsulated membrane extraction (Potchefstroom University for CHE – Department of Chemical Engineering)

Current

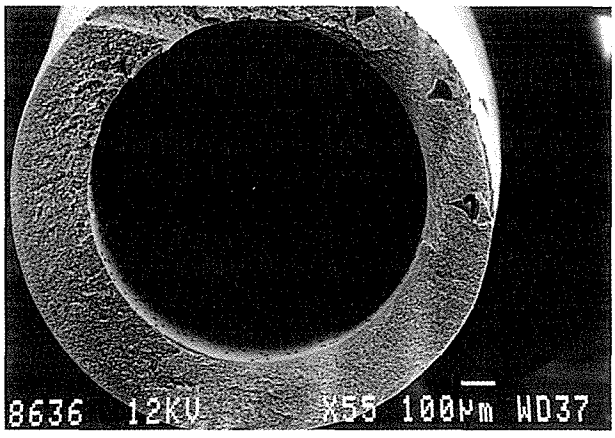
- **241** Dewatering of compressible filter cakes (University of Natal – Department of Chemical Engineering)
- **308** Recovery of water and chemicals from ion-exchange regeneration effluents (University of Natal – Department of Chemical Engineering)
- **331** Improved oxygen transfer for high biosludge concentrations (University of Pretoria – Department of Chemical Engineering)
- **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)
- **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)
- **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)
- **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 – Pollution Research Group, and Eskom)
- **687** Membrane-based biotechnological systems for treatment of organic pollutants (Rhodes University – Department of Microbiology)
- **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 – 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 – 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 – 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 – 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)

New

- **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 of water and effluents (Potchefstroom University for CHE – Department of Chemical Engineering)
- **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-alloy 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 – Pollution Research Group)

9 Membrane technology



Membrane technology development in South Africa has again progressed definitively over the past year.

Innovative research and development are continuing on a number of potential applications and new patents have been registered or are pending. Fields of application for these innovations include the desalination of sea and brackish water, purification of surface and polluted waters for potable use, and the treatment of industrial effluents. Membrane separation processes are increasingly being developed and evaluated for water supply to rural and peri-urban communities. Further development is continuing on the all-important control of membrane fouling. Noteworthy results in fouling control are being obtained with electromagnetic, physical, membrane surface modification, *in situ* enzymatic, and "defouling-on-demand" enzymatic methods. Exciting new developments in affordable ceramic and catalytic membrane technology are being followed up and evaluated. Manufacturing techniques have not been lagging. New capillary membrane cross-flow modules and improved 200 mm diameter parallel-flow modules have been successfully manufactured. Studies on the use of new spherical supported liquid membranes for heavy metal removal from mining effluents show considerable promise.

Attention is increasingly being given to the building 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 not only resulted in exciting technical developments, but have also 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.

In October 1997 a three-day membrane technology workshop of the Membrane Technical Division of WISA was held. In a strategy-planning session held by the WRC during this workshop, some specific research and development needs were elicited and subsequently prioritised, with a view to supplementing the general strategies of the Strategic Plan for Water-Related Membrane Research in South Africa.

Completed projects

Development of specialised cross- and transverse-flow capillary membrane modules

(No 618) Institute for Polymer Science, University of Stellenbosch

This project was aimed at the further development and industrialisation of specialised cross- and transverse-flow capillary membrane modules for application in the large-scale treatment of surface water to potable standards, and the upgrading of industrial and secondary treated effluents. The results obtained from this project show promise with regard to the commercialisation of membrane technology in South Africa.

The following products resulted from the research:

- A 3 x 50 mm diameter cartridge capillary membrane module (3 x 1.5 = 4.5 m^2 membrane area) was laboratory bench-tested over an extended period of time and successfully field-tested.
- Three 90 mm diameter modules (3 x 5 m^2 = 15 m^2 membrane area), requiring a manifold, were installed and tested for 23 months. Further field trials are being conducted and pilot plants are operating with six modules at two other sites.
- A large 200 mm diameter module cartridge (18 to 25 m^2 membrane area) has been developed as it makes a manifold superfluous. This module has been bench-tested and has exceeded all expectations. Delivery of pure water was measured at over 1 000 $l/h \cdot m^2$ at a trans-membrane pressure of only 50 kPa. The manufacturing method is being patented and much larger modules are now possible.
- A patent, *Capillary Membrane Modules*, has been filed and granted for an epoxy encapsulation method, SA Patent 96/1580, developed under the project.
- Modules have been developed for containment in larger tanks. 200 mm cartridges can now be housed in a multi-cartridge or tank-type module, creating plants of up to 1 375 m^2 membrane area.

Cost: *R558 700*
Term: *1994-1996*

Development of transverse-flow membrane modules for use in bioreactors

(No 847) Institute for Polymer Science, University of Stellenbosch

The transverse-flow membrane modules developed in this project entail an arrangement of capillary membranes in a cross-flow mode with regard to the flow. Transverse-flow membrane modules may be used for many commercial and industrial applications, because of the higher mass-transfer coefficient modular design, individual stacking freedom and possible uses as bioreactors.

A working transverse-flow, capillary membrane module of 24 m^2 membrane area has been developed which has potential for a variety of uses. In addition to the normal separation role, the module may be used to add gases (O_2, CO_2, H_2S) to or strip them from the liquid, thereby providing compelling reasons for its use as a bioreactor. Unfortunately the module is still somewhat sophisticated and might be expensive to manufacture at this stage.

However, the project has paved the way for the production of very large modules, with 200 capillary membranes per layer, 333 layers high (1 m high) which would have surface areas of 250 m^2 for externally-skinned membranes, which can be constructed using the same methods as those used for the present 24 m^2 model. This product is seen to have good potential for a wide range of water-related applications.

Cost: *R217 000*
Term: *1997*

New projects

Water desalination and clarification by electronically enhanced membrane defouling

(No 930) Mineral Water Development (Pty) Ltd.

Desalination has a critical role to play in water treatment, especially along coastlines, in brackish water areas as well as in the treatment of industrial wastes. Low fluxes experienced through reverse osmosis desalination membranes because of the concentration of salts on the membrane surface is an international problem. This project intends using a novel, patented, electrical method to remove the salt concentration layer on a continuous basis, thereby enhancing the flux through the membrane and significantly reducing the required membrane surface area and treatment costs. Mineral Water Development (Pty) Ltd. perfected aspects of this technology and has produced electrically enhanced spiral-wrap desalination elements which are able to treat both brackish and sea water. There is, however, a range of different size spiral wrap elements as well as elements of hollow fine fibres that have not yet been evaluated using this technology. In addition, studies are required to further investigate fundamental mechanisms of this technology, and using the technology to enhance fluxes on both ultrafiltration and microfiltration processes.

Estimated cost: *R549 000*
Expected term: *1998-2001*

Transverse-flow module fabrication technology development

(No 931) Institute for Polymer Science, University of Stellenbosch

A membrane bioreactor can be defined as a membrane device which allows bio-transformations to be conducted within a confined space, in which the membrane interface can be used for the immobilisation of enzymes or whole cells. The membranes can also be used for transferring gases into the reaction medium, or to extract gases which could inhibit biocatalytic conversions. The membranes can furthermore be used as filters, separating unwanted components from the feed stream.

The combination of immobilised organisms secreting beneficiary enzymes (or immobilised enzymes themselves), and a filtration capability, is very powerful for the removal of organic pollutants and other unwanted components from water and effluents. In full realisation of this, the Universities of Rhodes (Department of Biochemistry and Microbiology) and Stellenbosch (Institute for Polymer Science) have teamed up, and with funding from the WRC, have entered into research on bioprocess development using membrane bioreactors. This project is required to take the initial developments a step further toward commercialisation by the implementation and evaluation of some novel concepts to improve the efficiency and cost-effectiveness of the existing membranes and modules.

Estimated cost: *R308 000*
Expected term: *1998-1999*

Development of a "defouling on demand" strategy for the operation of bio-active membranes

(No 932) Department of Biochemistry, Rhodes University

Membrane treatment has found application in a wide range of industries for water and effluent purification. Fouling of membranes is the single biggest reason for membrane replacement, and the biggest problem in membrane plant operation. This project proposes to combine the oxidative "defouling" power of enzymes secreted by certain fungi, with the capability to trigger the enzyme to be activated at the will of the plant operator. It is a novel concept which, if successful, will enable the defouling of membranes on demand of the operators at the correct moment when cleaning is required due to fouling from organic components in water. In this manner, a thin fouling layer (which assists filtration) may be kept on the membrane. Only when the fouling layer becomes too thick, is the defouling action of the enzymes on the membrane activated by the operators. This fouling control strategy could find application in all pressure-driven membrane processes. The concept has recently been patented.

The overall aim of this project, therefore, concerns the development and application of degradative enzymes from white rot fungi for membrane defouling in terms of the "defouling on demand" principle.

Estimated cost: *R389 000*
Expected term: *1998-2000*

Electromembrane reactors for desalination and disinfection of aqueous solutions

(No 964) Department of Chemistry, University of the Western Cape

Disinfection processes are of vital importance for adequate protection of the health of South Africa's people. The use of electroconductive ceramic membranes opens up possibilities for significant improvement of disinfection installations based on the processes of on-site sodium hypochlorite generation by electrolysis from table salt, and "luminescent electrolysis" (the formation of peroxides and oxygen-containing radicals with extremely high anti-bacterial activity). The ceramic-based membranes will combine the following four functions into one: serving as electrode; separation of

unwanted components from the water; serving as a dosing system; and catalysing the reactions.

The project will be aimed at the development of a generic electromembrane reactor system for desalination and disinfection that will find application in virtually all water-related areas. Economic benefits of the electromembrane reactors will be based on the following advantages of these systems, thereby also rendering them applicable to small and rural communities:

- Low maintenance cost
- Minimum chemical pretreatment and regeneration required
- Maximum water recovery
- High reliability and stability.

Estimated cost: *R874 000*
Expected term: *1998-2000*

Capillary ultrafiltration membrane process systems R and D

(No 965) Institute for Polymer Science, University of Stellenbosch

There are examples in South Africa of water not meeting the SABS standards set for potable water supplied to small coastal and inland towns, communities, schools and clinics. In these small- to medium-scale applications, ultrafiltration could offer a technology for point-source treatment of water. Other applications in the rural and peri-urban environment are:

- Farming and other settlements situated near rivers
- Communities dependent on highly coloured runoff water from the mountains in the Southern Cape
- Communities dependent on subsurface water containing high levels of aluminium, iron or micro-organisms.

Brackish water and sea-water desalination is a further area in which ultrafiltration could be useful as a prefiltration step before direct desalination by reverse osmosis or any other applicable desalination technology.

The project's aims are mainly to develop and evaluate capillary ultrafiltration membrane processes to produce a high-quality filtered product from coloured surface water, high-turbidity waters, eutrophic water and sea water before desalination by reverse osmosis, without the addition of chemicals. Furthermore, operating and cleaning protocols will be investigated, and a set of conceptual design for a reliable, robust, cost-effective and marketable product will be produced.

Estimated cost: *R1 245 000*
Expected term: *1998-2000*

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Research projects

Completed

- **618** Development of specialised cross- and transverse-flow *capillary membrane modules* (University of Stellenbosch – Institute for Polymer Science)
- **847** Development of transverse-flow membrane modules for use in bioreactors (University of Stellenbosch – Institute for Polymer Science)

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 *macromolecular engineering for membrane development* (Vista University – Department of Chemistry (Port Elizabeth Campus))
- **728** Computer program for cross-flow module and potable water plant design (University of Stellenbosch – Institute for Polymer Science)
- **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)
- **791** Defouling of ultrafiltration membranes (Rhodes University – Department of Biochemistry and Microbiology)
- **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)

New

- **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)

Hydroclimatology

Hydroclimatology is the term employed by the WRC to designate that part of atmospheric science and related technology which can be brought to bear on improving the assessment and management of our water resources.

In its broadest sense, water resources management (most effective at catchment scale) includes facets such as water resource development, augmentation, conservation, protection, and effective and efficient utilisation – not all of which are mutually exclusive.

More briefly stated, hydroclimatology is seen by the WRC as atmosphere-related science and technology in service of the water industry and the community of water users. Together with its sister disciplines, geohydrology and surface hydrology, which aim to serve the water industry and the community in a similar fashion, hydroclimatology completes the list of disciplines which make up the study of the all-important hydrological cycle.

It goes without saying that, at certain fundamental levels, hydroclimatology will have much in common with atmosphere-related science and technology practised for the benefit of other industries such as agriculture and power generation and for the benefit of the community at large.

It is also to be expected that fundamental research advances in areas of hydroclimatology where there are serious, progress-limiting gaps in knowledge, will not necessarily bring about immediate improvements in water resources assessment and management. Nevertheless, the quest for such improvements provides the sole justification for undertaking fundamental hydroclimatological research. Hydroclimatological research would, therefore, remain incomplete if fundamental research advances were not extended in the direction of, and ultimately integrated into, water resource assessment and management processes.

During 1998 revision of the strategic plan for hydroclimatological research was set in motion. There is general consensus among stakeholders that the goals of hydroclimatological research may be stated as follows:

- To acquire an adequate understanding of:
  - The statistical nature of climate (especially precipitation) variability over space and time, including inter-scale relationships
  - Mechanisms governing climate variability
  - Human influences on atmospheric processes and climate change
  - Mechanisms associated with precipitation and evaporation processes.
- To develop appropriate techniques, technologies and systems for:
  - Climate monitoring (mainly precipitation and evaporation)
  - Climate information management
  - Expressing space-time characteristics of precipitation
  - Inferring past, and predicting future, climate variability and change
  - Sourcing additional quantities of atmospheric water, through for example, rainfall enhancement and fog harvesting.
- To integrate atmosphere-based technologies into specific procedures or programmes for water resource assessment and management.

There is little doubt that the development of a reliable, cost-effective precipitation monitoring system with the necessary areal coverage and space-time resolution to satisfy a range of water resource requirements, a worthy goal in itself, is also fundamental to the achievement of many other goals of hydroclimatological research. The most promising means of achieving this ideal is through the use of weather radar. In November 1998 the South African Weather Bureau and the WRC joined forces in arranging a successful workshop to promote such applications of weather radar.

Completed

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

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

Previous investigations have revealed that the oceanic environment of Southern Africa plays an important regulating role in the climate of the subcontinent. In particular, statistical teleconnections between oceanic temperature anomalies and precipitation over South Africa's summer rainfall region have been demonstrated. This project was designed to investigate the physical mechanisms of ocean-atmosphere inter-

action as a means of contributing to a better understanding of the role of the oceans in affecting the weather of the subcontinent. The Agulhas Current region was selected as the study area.

The first task was to assemble and test a portable micrometeorological instrumentation system required to make the necessary on-board ship measurements in order to quantify the turbulent exchanges of water vapour, heat and momentum above the ocean surface. Measurements obtained at ship level could then be linked to measurements at other levels in the atmosphere through the use of radio sondes. Considerable difficulties had to be overcome before the instrumentation could be used successfully to obtain the necessary high-quality data. A large volume of data were collected during several cruises undertaken over the five-year research period. Among the many results was the finding that the core of the Agulhas Current, about 50 km wide, transfers about 5 times as much water vapour to the atmosphere as the surrounding water, all year long.

The instrumentation and expertise developed during the course of this project, when used in conjunction with satellite remote sensing, should provide the means of extending the quantification of air-sea interactions to much larger surrounding ocean areas than have up to now been investigated. This will greatly benefit the further development of atmospheric circulation models and add to the understanding of the mechanisms whereby the surrounding oceans affect the climate of South Africa.

Cost: *R905 484*
Term: *1991-1997*

Development of models to stochastically generate spatially distributed daily rainfields

(No 550) Department of Civil Engineering, University of Natal

Water resource engineers often require information on how rainfall associated with storm and prolonged rain events is distributed in space and time. The limited and declining number of rain gauges which report daily as part of the national network cannot satisfy this need. Radar rainfall-measurement technology has the necessary potential, but cannot yet fulfil the need because of its restricted availability. In the absence of routinely observed data, the alternative has been to investigate the modelling of simultaneous spatial and temporal behaviour of rainfields to enable the space-time occurrence of rainfall to be simulated realistically for training and design purposes.

This project was split into two tasks corresponding to the two main objectives of the research. The first was to continue with the previously-started development of a rain-day model, based on sequential occurrences of dry, scattered and general rain days, for simulating the distribution of daily rainfall amounts over a large area. Special attention was given to accurate representation of seasonal variations over the year. The second task was to investigate the modelling of spatial distribution of rainfall at given time slices to enable the variability and clustering nature of the rainfall process as observed by radar to be replicated.

The first of the two main objectives was successfully achieved. The second was achieved with partial success, sufficient to provide good insight into the prerequisites for higher resolution space-time modelling to be undertaken in a follow-up project.

Cost: *R55 895*
Term: *1993-1997*

New projects

Development of optimum statistical long-range forecast models of summer climate and hydrological resources over Southern Africa

(No 903) Department of Geography, University of Zululand

The availability of water in Southern Africa is constrained by annual fluctuations in summer rainfall. Accurate long-range forecasts of areal rainfall and streamflows could play a useful role in mitigating the effects of climate variability. Previous WRC-supported research has given rise to the development of several multivariate models for seasonal lead-time forecasting of summer rainfall and streamflow. These statistical models employ oceanic and atmospheric predictors and display forecast skills which, although still limited, are nevertheless able to reduce risk associated with climate variability if forecasts are correctly used.

Despite the expectation that major advances in long-range forecasting of climate will ultimately result from the use of dynamic general circulation models (GCMs) rather than statistical models, there is potential for further refinement of the statistical models by lengthening the training/calibration period in order to capture most recent patterns of global ocean-atmosphere coupling. Furthermore, new data sets have become available which can be beneficially exploited.

The aims of this project are, therefore, to undertake:

- Historical analysis of streamflow and rainfall-evaporation indices over Southern Africa with emphasis on inter-annual variability of water resources
- Meteorological analysis of new monthly atmospheric and sea surface temperature data sets, with the object of extracting appropriate climate and hydrological predictors
- Development of statistical long-lead forecast models for hydrological targets which can address varying influences of the El Niño Southern Oscillation (ENSO)
- Assessment of long-lead forecasts in the hydrological decision-making process
- Development of research skills at a historically disadvantaged university.

Estimated cost: *R560 000*
Expected term: *1998-2000*

Seasonal climate predictions with a coupled atmosphere/ocean general circulation model: A contribution to water resource management over Southern Africa

(No 904) Department of Civil Engineering, University of Pretoria

Seasonal climate prediction is an emerging technology which has potential for improving water resource management and minimising vulnerability to drought. In recent years climate forecasting skills have improved substantially with the identification of reliable predictors and the improvement of conceptual understanding of the roles of such predictors within the general circulation of the atmosphere.

At present statistical forecasting models are the preferred tools for seasonal forecasting of climate. However, the greatest potential for major advances lies in the continuing development and use of dynamic general circulation models (GCMs) for this purpose. Researchers at the University of Pretoria have, through two years of close contact with the Australian CSIRO, become well-acquainted with the latest version of the CSIRO GCM. It is a fully coupled ocean-atmosphere GCM, which is important because of the role of

oceanic factors in driving atmospheric circulation and hence the region's climate.

The objectives of this project are to:

- Successfully couple a CSIRO-developed Indian Ocean model, crucial for the Southern African region, to the CSIRO GCM
- Install and run this model locally as a forecasting tool in order to investigate its ability and skills in providing seasonal climate predictions as well as Indian and Pacific Ocean sea-surface temperature outlooks
- Exchange output data with other South African and other Southern Hemisphere research institutions to identify areas of potential improvement in the model's ocean and atmosphere dynamics.

Estimated cost: *R252 000*
Expected term: *1998-2000*

Aerosols, recirculation and rainfall experiment (Arrex)

(No 938) Climatology Research Group, University of the Witwatersrand

South Africa's precipitation research programme has clearly demonstrated that modifying the nature of cloud condensation nuclei (CCN) ingested by convective storms at cloud base can have a marked effect on precipitation formation processes.

Variability of CCN in the atmosphere could therefore have profound effects, both positive and negative, on precipitation. Such variability may be natural, but can also be strongly influenced by human activity. Dusty conditions during droughts may, for instance, cause droughts to persist because of the abundance of small CCN which make precipitation processes less efficient. Conversely, CCN size distributions dominated by larger particles, as found in maritime situations or following prolonged rainy condition, could make precipitation processes more efficient. The effect of anthropogenic aerosols will depend on their chemical composition, concentration and size distribution relative to naturally-occurring CCN.

Recent research by the University of the Witwatersrand Climatology Research Group has greatly clarified the manner in which aerosols of local origin are transported and recirculated in the atmosphere over the Southern African region.

This project aims to investigate the physical properties and chemical composition of aerosol particles and cloud condensation nuclei over the South African highveld and escarpment, their transport and recirculation over the eastern seaboard and to draw initial inferences regarding their possible influence on precipitation development over the region.

Estimated cost: *R250 000*
Expected term: *1998*

The ocean's role in South Africa's rainfall

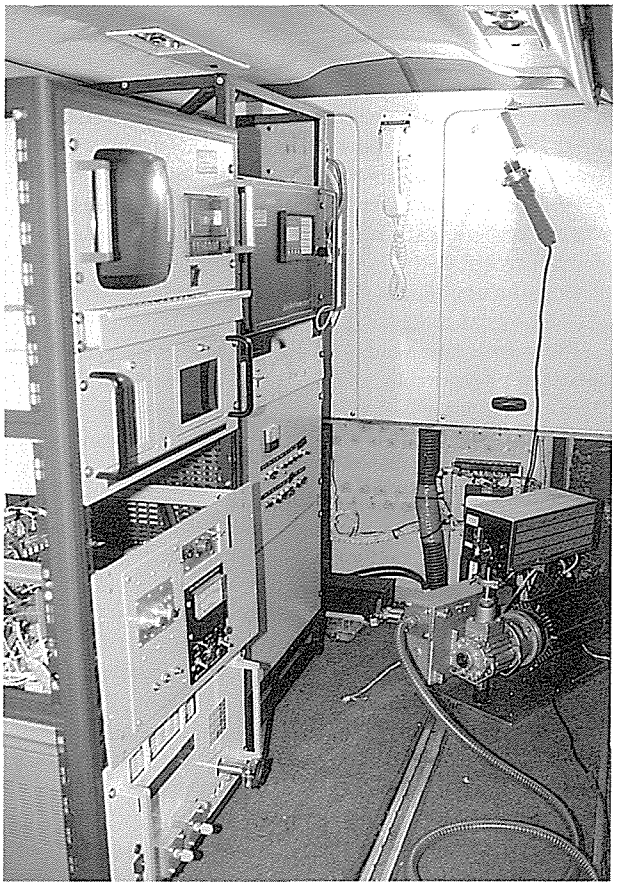
(No 953) Department of Oceanography, University of Cape Town

Knowledge of how the climate system operates, at global but more importantly also at the regional scale, depends on being able to quantify energy, water vapour and momentum exchanges between the ocean and the overlying atmosphere. A research project by the University of Cape Town has resulted in successful measurements of such exchanges, mainly in the Agulhas Current region.

The proposed new project aims to build on these achievements and also capitalise on opportunities to extend results to the larger expanses of the Indian and South Atlantic Oceans, which have a much greater influence on rainfall over Southern Africa than the Agulhas Current area alone. This will be done via a programme of judiciously-selected field experiments to be undertaken in the surrounding oceans using available ships fitted with appropriate instrumentation. Data will be used to validate satellite remote-sensing products and to develop algorithms for the modelling of air-sea interactions in the Southern African region.

Particular aims of the project are to:

- Gain a greater understanding of the role of ocean-atmosphere interactions in regulating rainfall and drought in South Africa
- Develop a satellite-based methodology to study and monitor the hydrological cycle from ocean evaporation to the advection of water vapour above South Africa
- Carry out an *in situ* measurement programme in order to validate satellite observations and model outputs which are useful for predicting rainfall over Southern Africa



The data acquisition system and some instruments inside the aircraft ZS-JRA. This is related to Arrex (Aerosol Recirculation and Rainfall Experiment).

ZS-JRA being prepared for a research flight.

- Gain more information on the mechanisms causing sea-surface temperature variability in those regions where anomalies are linked to drought in Southern Africa.

Estimated cost: *R1 191 000*
Expected term: *1998-2002*

Integrated radar-based precipitation observing system for the Vaal Dam catchment to facilitate water resource operations and research

(No 954) Weather Bureau, Department of Environmental Affairs and Tourism

The development of river-flow forecast models for optimising dam operation and managing floods is high on the priority list of water resource management objectives in South Africa. For management models operating in real time to be effective, however, there must be adequate real-time access to appropriate catchment data. In as far as areal rainfall data are concerned, this is a facility which currently does not exist for any catchment in South Africa.

The Vaal Dam catchment is, however, already served by three meteorological radars, two of which are sited near Bethlehem and one at Ermelo. One of the Bethlehem radars is the WRC-owned Russian MRL-5 S-band radar, while the other two are C-band radars, typical of the type used by the Weather Bureau in its national radar network.

Weather Bureau personnel at Bethlehem have been actively researching the use of radar for rainfall measurement in recent years. In the process, they have developed skills in the upgrading of radar hardware and software and in radar-signal processing.

These skills now need to be applied in an integrated real-time rainfall reporting system first for the important Vaal Dam catchment, which may thereafter serve as a prototype system for other catchments of concern. The aims of the project are to:

- Further exploit the capabilities of the MRL-5 radar and other infrastructure at Bethlehem to refine radar-based techniques for areal rainfall measurement
- Adapt and transfer this radar-rainfall measurement technology to C-band radar installations in the Vaal Dam catchment
- Locate and calibrate other useful rainfall-measuring devices in the catchment
- Develop appropriate software and communications systems for managing data acquisition and integration and ensuring reliable, real-time data transmission to water resource managers
- Design a spatial database in which data, appropriately processed, can be stored and accessed in near-real time for hydrological purposes
- Ensure long-term sustainability of observing systems through appropriate training.

Estimated cost: *R1 875 000*
Expected term: *1998-2000*

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Research projects

Completed

- **374** The Southern Agulhas Current and its influence on the weather and climate of Southern Africa (University of Cape Town – Department of Oceanography)
- **550** Development of models to stochastically generate spatially distributed daily rainfields (University of Natal – Department of Civil Engineering)

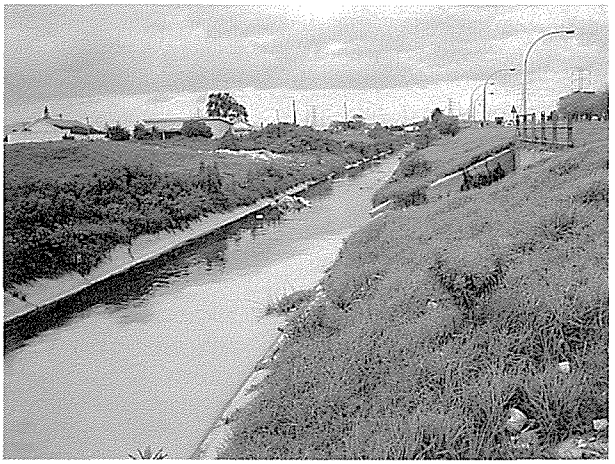
Current

- **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)
- **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)
- **804** Acquisition of off-shore marine sediment samples for palaeoclimatic and hydrological record reconstruction (University of the Witwatersrand – Climatology Research Group)
- **805** Modelling of extreme rainfall over Southern Africa (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)

New

- **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)

Integrated water resource management



The meaningful implementation of the new Water Act will create enormous challenges for the water resource management community and the adequacy of the nation's information base and management skills (wisdom) will be tested over a wide front.

The Act makes provision for a wide variety of different stakeholders to participate fully in negotiating processes relating to catchment management. This will inevitably lead to the questioning of the validity of data, assumptions and interpretations. The research community will also have to become much more involved in the real world of continuously finding compromises and adapting to new circumstances.

Simple-sounding terms like "streamflow reduction activity" and "ecological reserve", which are corner-stones of the new Water Act, will not be static, unambiguous and nationally acceptable values. They will depend on the regional and even local context of the water situation. This poses a true challenge to the research community to focus on generic principles while not losing site of the complexity imposed by local socio-economic and hydrological conditions. The WRC will have to play a more active role in the continuous development, expansion and meaningful synthesis of newly gained knowledge and understanding. Isolated initiatives and findings need to be evaluated in an integrated manner in order to be able to make a significant contribution towards wise and sustainable use of our limited water.

This is one field where a people-orientated approach is required at all times. Tools and procedures need to be robust and transparent and above all lead to decisions that are acceptable to the majority of the stakeholders and people. But, at no time should the scientific correctness of underlying understanding be compromised.

Completed project

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

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

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

Owing to a lack of knowledge regarding the overall magnitude and distribution of the problem and of uncertainty concerning the most rational approaches to address the problem at a policy level, this project undertook to:

- Determine the nature, extent and distribution of alien invaders in South Africa at a national scale
- Identify gaps in the national knowledge base, and to determine research priorities.

Invasions of alien plants were mapped and digitised and stored within a GIS (Arc/Info) at a scale of 1:250 000 for almost the entire country. The results made it possible to estimate the total area impacted by alien invasives, the consequent reduction in runoff and the approximate costs of clearing, at both a national and provincial scale.

Recommendations for action are focused on the use of the compiled information, the need to maintain and update the database, and the establishment of an open information line to the *Working for Water Programme*, which manages clearing operations. Specific recommended tasks include the mapping of areas cleared of invaders, the standardisation of data-capture methodology, and the use of the Internet as a mechanism for information sharing.

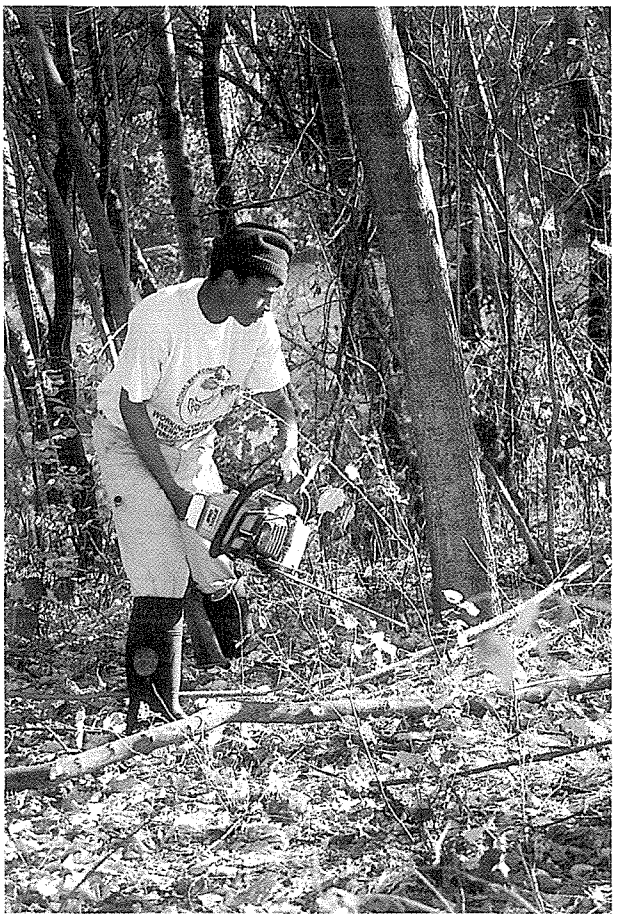
Cost: *R390 000*
Term: *1996-1997*

New projects

Socio-economic impact of the Komati River basin development, with special reference to irrigation agriculture

(No 888) Conningarth Consultants

Under circumstances of increasing costs of water supply to meet growing demand, it is imperative that the best possible use is made of scarce water resources, to achieve the required social and economic development. Water for irrigation, in particular, is in severe competition with industry, mining, forestry and domestic uses. It is therefore important to re-assess the role of irrigated agriculture in broader rural



Actively clearing alien invading plants.

development.

Various studies to assess the developmental impact of irrigated agriculture have been undertaken internationally. In South Africa, however, with the exception of cost-benefit analysis, only two previous studies have been done in which the broader developmental impact of a project was analysed by means of input-output tables. In this project the social accounting matrix (SAM) will be used to calculate the contribution of irrigation in relation to other water-use sectors. Although much more comprehensive, the SAM is based on the same principles as the conventional input-output table and to some extent is a logical extension of it. However, it lends itself much more to quantifying the income-distributional effect in respect of various sectors and income categories within the context of a specific development initiative such as an irrigation expansion project. The Komati River Basin Development Project is such a development initiative, currently being undertaken jointly by South Africa and Swaziland.

The main aim of this project is to establish the importance of irrigated agriculture in the development of rural areas and communities by:

- Analysing the socio-economic impact of irrigation in the Komati River Basin Development Project in both the Kingdom of Swaziland and the Republic of South Africa
- Compiling a SAM
- Establishing a methodology which could be used for the analysis of future projects of a similar nature.

Estimated cost: *R370 000*
Expected term: *1998-1999*

Aids for flood-damage assessment and flood-damage control planning in irrigation and urban areas

(No 889) Department of Agricultural Economics, University of the Orange Free State

An extensive project to determine the actual damage caused by floods in various river reaches of South Africa, commenced after 1974. The floods of 1988 led to further research on loss functions to estimate flood damage in advance, for floods of different probabilities of occurrence and to enable flood-damage control planning in urban and irrigation areas. During the first phase of this project, models were developed and loss functions were compiled. The aim of the second phase was to refine the computer models and to generalise them for application on a wider range of flood plains.

For successful implementation, details of actual case studies on flood remediation and their benefits need to be obtained. In this way the importance of flood control and associated major financial benefits, due to reduced flood risk, can be highlighted and quantified. The second-phase study did not make provision for determination of actual engineering solutions and their benefits in monetary terms. It will therefore be very difficult, if not impossible, to transform the research product into a commercially usable and viable tool. The real benefit can only be achieved if actual engineering solutions are utilised to demonstrate the advantages of the current research results to potential users of the products, such as local authorities or their agents who are responsible for flood management.

The main aims of this project, which will represent the third and final phase of flood-damage research, are as follows:

- Completion and release of a set of flood-damage management aids for application on local, provincial and national level
- Establishment of the usefulness and benefit of flood-control measures along major watercourses.

Estimated cost: *R350 000*
Expected term: *1998-1999*

Development of a hydrological economic model based on the Mvoti catchment

(No 890) Umgeni Water

Currently, sophisticated hydrological models are being used to predict the effects of current and expected levels of catchment development on the quantity and reliability of water available to satisfy current and expected demand for bulk water supply. Such information has traditionally been used to guide the planning, development and management of water resources. Economic evaluations have usually entered into the picture only at the end stage, such as in the cost-benefit analysis of water infrastructure.

It is clearly recognised, however, that such use of economics does not allow one to select strategies for water resource management which address the most important objective underpinning government policy, i.e. to achieve optimum long-term social and economic benefits to society.

This project proposes to develop an integrated ecological-economic modelling approach, as this would be an objective, scientific way in which the complex dynamic interdependencies between the economic and natural systems can be taken into account when making decisions on resource management.

The aims of the project are to:

- Integrate hydrological and economic information on the Mvoti catchment into a dynamic ecological-economic model to simulate various scenarios of land use and allocations of water resources in the Mvoti catchment
- Use the model to assess the impact of various water resource management approaches in terms of the benefits and costs they create in different parts of the catchment and for different stakeholders.

The research findings will make it possible to assess the potential of using an integrated hydrological economic model as a tool for guiding integrated catchment management in other important catchments.

Estimated cost: *R159 000*
Expected term: *1998*

Model for water-demand management planning and monitoring

(No 905) BKS (Pty) Ltd.

The System Integration of Development Options project, of the Vaal Augmentation Planning Study commissioned by DWAF, revealed that the implementation dates of development options could be extended by up to eight years with demand management in place. Subsequent analyses performed by BKS (Pty) Ltd. under assignment from DWAF showed that the estimated potential saving, with demand management implemented, is R4.1 bn., expressed as net present value with 1996 as base year. This has resulted in a major initiative by DWAF as well as water boards to implement demand management as a matter of priority.

Apart from the water demand projections that are influenced by demand management initiatives, the return flow from urban areas may also decrease depending on the implemented demand management measures. In the Crocodile River catchment for example, the return flows from the Northern Gauteng region constitute 45% of the available yield of the resource.

The aim of this project is therefore to develop a generic database model which will apply a systematic systems approach to planning and monitoring of demand management initiatives.

The model will assist planners in evaluating original assumptions and projections in order to improve on future projections. Use of the methodology will ensure that certain errors in projections are not repeated in perpetuity. The research will also enhance the understanding of the interdependency of demand management activities on the supply- and return-flow components of the relevant water systems.

Estimated cost: *R456 000*
Expected term: *1998-1999*

Development of a decision support system for the Mhlatuze catchment in Zululand

(No 906) Department of Hydrology, University of Zululand

Environmental impact assessment (EIA) and strategic environmental assessment (SEA) for proposed developments requires the participation of all interested and affected parties in identifying and evaluating the impacts of the development. This procedure is critically dependent on the existence and availability of information to the public. Whereas EIA focuses on the effects of development on the environment, SEA examines the effect of the environment on development. The development of a decision support system (DSS) which maintains a database of catchment information and incorporates expert systems on catchment resource processes, will provide very valuable information for decision-makers if it can be used effectively and easily.

This project has five broad aims which will be implemented in several phases:

- To develop a DSS for integrated environmental management (IEM) of the Mhlatuze catchment
- To create a relational database management system (RDBMS) in the DSS to incorporate the information requirements of the various IEM functions
- To investigate the possibility of developing the RDBMS and DSS for access by users through computer-based communications systems such as the Internet
- To investigate the application and transferability of the DSS to other regions of Southern Africa
- To enhance our understanding and prediction of IEM and to develop the capacity, at the University of Zululand, to provide appropriate training of hydrologists and water resource managers for South Africa, particularly the Zululand region.

Estimated cost: *R502 000*
Expected term: *1998-2000*

Technique for modelling scenarios for alien plant control

(No 907) Division of Water, Environment and Forestry Technology, CSIR

The CSIR has recently undertaken a project to estimate the impact of invading alien trees on the water resources of South Africa. This project showed that invading alien plants have a very significant impact on surface water resources.

However, it is not known what rate of expenditure will be required to halt or reverse the current invasion, how the problem can be tackled most efficiently, and how long it will take.

Further, the allocation of resources to the different operations involved in alien tree removal is not a simple process. As clearing takes place, more money has to be allocated to the maintenance operations which are an absolute requirement for permanent alien tree eradication. At some stage therefore, maintenance operations must take priority over clearing operations, thereby allowing uncleared areas to continue to increase in density and extent. It is necessary to develop a model in order to understand how best to schedule operations and expenditure.

The aim of this project, therefore, is to develop modelling techniques for estimating:

- The amount of money required to achieve effective control of water-using invasive plants in the different provinces and South Africa as a whole
- The time it will take to achieve significant reductions in water lost due to alien invasion resulting from varying rates of expenditure on control
- The impact of the introduction of biocontrol on control costs in the long term.

The monitoring programme and database presently being developed in the Working for Water Programme will be extensively used in this project.

Estimated cost: *R298 000*
Expected term: *1998*

Framework for state-of-the-catchment report for developing a catchment management plan using as basis Palmiet River, Western Cape

(No 913) Groenland Irrigation Board (for the Palmiet River Catchment Management Steering Committee)

The Minister of Water Affairs and Forestry has approved Phase 1 of the Palmiet scheme on condition that an integrated management plan for the Palmiet River catchment be drawn up. He committed DWAF to the process, but their input in this catchment will be limited to assessing the instream flow requirements of the river system. Catchment management plans (CMPs) are required under the new Water Act, but the protocols are still being developed, and this project will contribute towards the development of these. A CMP will be developed as part of this project.

The CMP will specifically address SA's commitment to biodiversity; water quality; sustainable and equitable use of the resource to ensure sufficient water for all needs including the estuary; to ensure proper land-use management and sanitation requirements; to ensure active and informed participation by all stakeholders; to encourage collective responsibility and ownership for the management of the catchment and to develop an effective and efficient management plan and implementation strategy.

Estimated cost: *R250 000*
Expected term: *1998*

Feasibility of using a risk-based approach to setting integrated environmental objectives for protection of water resources

(No 914) Institute for Water Research, Rhodes University

A significant feature of the new water legislation in South Africa is the commitment to protect water resources in order to ensure their capacity to support sustainable utilisation into the long-term future. Over the next five years DWAF will develop and implement a protection-based classification system for water resources, accepting that a level of protection for a resource should be concomitant with the use of the particular resource. This protection-based system will eventually be extended to cover all water resources, and pilot implementation is planned for 1999.

The general aim of this project is to investigate the feasibility of using a risk-based approach to setting integrated objectives for the protection of water resources. More specifically, the following aims will be addressed through this project:

- To review and consolidate current research into the setting of objectives for the water quantity, water quality, habitat integrity and biotic integrity requirements of water resources, as these relate to the designation of the reserve
- To investigate new and emerging trends in the use of risk concepts in setting environmental objectives
- To identify possible approaches to incorporating the concepts of risk into the setting of integrated objectives for protection of water resources
- To produce a report outlining potential approaches for setting integrated objectives for the protection of water resources.

Estimated cost: *R125 000*
Expected term: *1998*

Inflow of polluted stormwater into the Lotus River from Philippi East (construction work/paint). Note polluted stormwater, dumping and littering, and unnecessary and unsightly service conduit for electricity which could have been routed along pedestrian bridge.

Research projects

Completed

- **748** Impacts of exotic plants on the water resources of South Africa, with special reference to economics and policy options for effective management of the problem (CSIR – Division of Water, Environment and Forestry Technology)

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)
- **640** Extension and refinement of the AQUAMOD computer software package (University of the Orange Free State – Institute for Groundwater Studies)
- **642** Development of a water information management database system for data capture and processing at local authority level (University of the Orange Free State – Institute for Groundwater Studies and DWAF)
- **666** Holistic, catchment-scale, comparison of water-use efficiency of crops, focusing on the comparison between forest plantations and key irrigated agricultural crops (CSIR – Division of Water, Environment and Forestry Technology)
- **690** Continued research on flood-damage functions, models and computer programs for irrigation and urban areas in South Africa (University of the Orange Free State – Department of Agricultural Economics and the DWAF)
- **702** Development of a Windows-based interpretation system for hydrogeologists (University of the Orange Free State – Institute for Groundwater Studies and the DWAF)
- **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)
- **855** Econometric and institutional economic analysis of water use in the Crocodile River catchment, Mpumalanga Province, South Africa (European Science and Environment Forum – Economics Unit)
- **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)

New

- **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)

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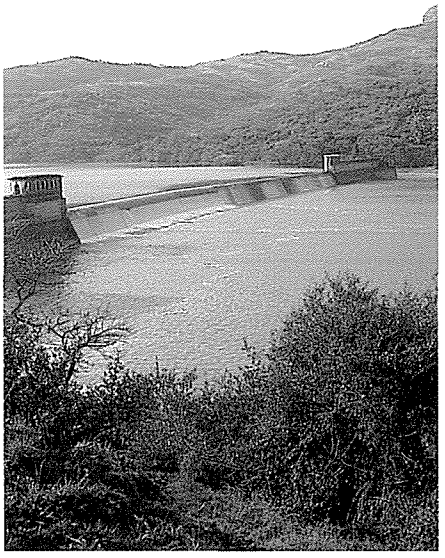
12 Surface hydrology



From a planning meeting of hydrologists held early in the year, certain themes emerged on which research efforts should concentrate in the near future.

A need to determine baseline hydrological characteristics

It is well-known that hydrological regimes in the South African landscape are changing. However, to systematically and correctly quantify change, baseline information is needed. Recent research in the Cathedral Peak catchments on the hydrological characterisation of a non-impacted area is a good example. However, virgin or pristine flows may be less useful as a reference than, for instance, flow regimes at certain development levels which can themselves be objectively and quantitatively assessed.

Assessment of all impacts of different land uses on hydrological characteristics with special reference to the interaction of ground- and surface water

This issue has been high on the research agenda for the last 10 years but much work still needs to be done, especially with regard to best management practices and the impact of poor management. Building of dams is a land-use activity the impact of which is not much different from any other human interference in the hydrological cycle. However, a systematic assessment of its impact has never been seriously considered.

Other issues are the need for a National Information System on a large variety of hydrologically important variables. Research methodology itself needs attention, especially with regard to acquisition of field data on the hydrological cycle in complex landscapes (hillslopes, riparian zones, wetlands, etc.) which are highly influential in determining the state of our water resources. Data on the interaction between ground- and surface water, especially, are seriously lacking.

Completed projects

Monitoring the effect of catchment development on urban runoff and water balance

(No 319) Water Systems Research Group, Department of Civil Engineering, University of the Witwatersrand

Urbanisation is proceeding at a rapid pace and important catchments may be affected by this development. The Witwatersrand in particular is being increasingly populated, which affects the runoff to its own water source, that is the Vaal Barrage.

This research took place in well-instrumented paired catchments in Sunninghill, Sandton where experiments with detention storage and stormwater diversion were also carried out. In one of the two adjacent catchments, intensive townhouse development took place, the effects of which were monitored during the research period. The main results of the research can briefly be summarised as follows:

- **Detention storage**

  With the co-operation of the Sandton Municipality a 1 400 m^3 detention basin was constructed. The resulting ratio of outflow to inflow varied from 0.5 to 0.9, generally decreasing with increasing inflow.

  Optimisation of detention storage will depend on the region, the size of the outflow pipe and the volume of the detention basin itself.

- **Dual drainage**

  Surface stormflow can be discharged by a combination of road surface and storm drain. The more water that is allowed to run on the road for a while, the cheaper (smaller) the storm drain is expected to be. Although no actual field observations were made, the real-life situation was modelled showing only small effects on peak discharge reduction if more water is allowed to run on the road.

- **Disconnecting impervious areas**

  Observations on a townhouse complex, half of which was connected directly to the storm drains and the other half discharged onto lawns, indicated a reduction in flood volume from 52 000 *l* to 800 *l* for an average storm as a result of discharge to lawns.

- **Water quality**

  Measurements showed the large difference in the quality of runoff between a middle-class suburb and an area of low-cost and informal housing, namely Alexandra. The observations clearly showed the build-up of pollutants in the catchment during dry periods and the heavy wash-off at the beginning of the rainy season.

- **Mass water balance**

  In the natural grassland catchment the runoff was less than 1% of the rainfall while in the comparable urban catchment the runoff was 18% of rainfall. Both input and outflow are larger for the urban catchment and the difference is largely due to the additional piped water supply and the subsequent greater total evaporation.

Cost: *R1 820 490*
Term: *1990-1996*

Effect of the agricultural environment on water resources

(No 492) Department of Agricultural Engineering, University of Natal

Through fieldwork, collaborative research, information synthesis and model development, this project aimed at enhancing the simulation modelling capabilities of the ACRU agrohydrological modelling system to help make it an objective planning tool to address those questions and challenges of the water-related agricultural environment for which decision-makers are currently, or will in the near future be, seeking answers.

In accordance with the project's objectives the following aspects were the focus of research, viz.:

- Afforestation-related systems
- Irrigation-related systems
- Crop-related systems
- Agrohydrological model development
- Information bases.

Most of the results of this research will be incorporated in updates of various chapters of a previous report entitled: *Hydrology and Agrohydrology* (WRC Report No TT 69/95). The forest hydrology component of ACRU, in particular, has been improved culminating in a first version of the software "Acruforest". This software enables preliminary estimates of the impacts of afforestation on quaternary streamflow to be made at a national scale. Other enhancements include simulation capabilities for deficit irrigation and generalised crop yield: soil water stress relationships for 13 different crops.

After several years of research and data collection for modelling the impacts of the agriculture on water resources the project team has assembled the *South African Atlas of Agrohydrology and -Climatology* comprising 276 pages and including 141 high-resolution colour maps, in sufficient detail to be useful in regional planning. Accompanying each set of maps is a text providing background information, scientific methodology and statistical summaries.

Cost: *R1 560 436*
Term: *1992-1996*

Development and testing of a water-balance model for a grassland catchment in the summer rainfall area of South Africa

(No 493) Division of Water, Environment and Forestry Technology, CSIR

A large proportion of our surface water resources is derived from our mountain catchment areas. Grasslands in these areas form an important baseline for natural evaporative losses with which the evaporative losses of other land uses and vegetation covers can be compared. This project aimed to provide an in-depth understanding of grassland water use at the catchment scale.

Near-continuous measurements of evaporation using the Bowen ratio technique were obtained over a few seasons (1990/91 to 1993/94) which included two very dry ones and one rather wet one. The study showed that despite the low rainfall in some years, actual evaporation remained fairly similar, showing that even in dry years in this normally wet part of South Africa (MAP 1 299 mm) soil moisture is not a main limiting factor in evapotranspiration of grassland. Evapotranspiration from the wet riparian zone was nevertheless still higher than from the uplands.

It was clearly established that the streamflow was fed by moisture moving slowly downslope under conditions of unsaturated flow. The saturated zone surrounding the riparian area varied in size with rainfall and season.

Hydrological models would need to account for this kind of spatial distribution of soil moisture within a catchment if they are to simulate reality satisfactorily.

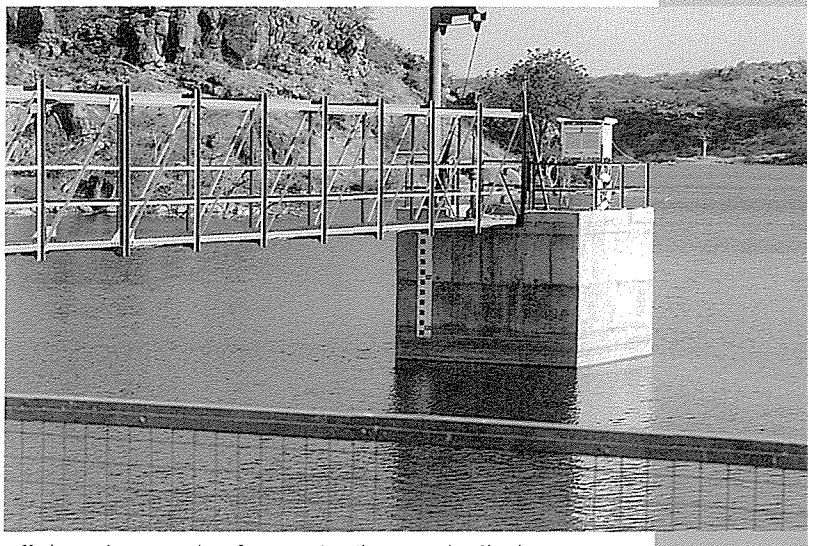
This project provided South Africa with probably the most complete data set on hydrological conditions in a typically wet part of the country. The data set will prove invaluable for more detailed analysis in time to come (for instance to evaluate the impact of climate change).

Cost: *R1 172 025*
Term: *1992-1997*

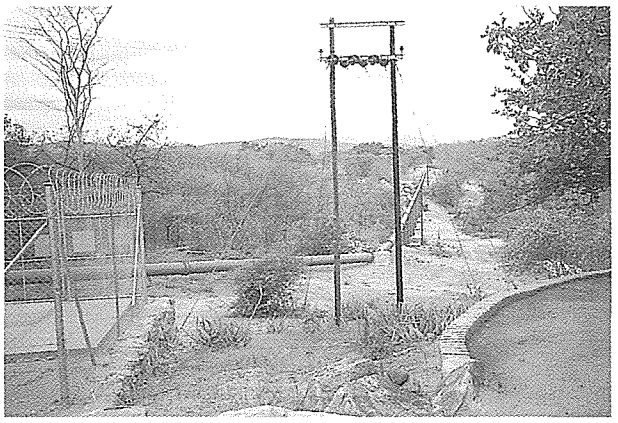
Development of a research strategy on the interaction between vegetation and groundwater

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

There is a growing appreciation in South Africa that the separation of surface- and groundwater resources is artificial, and that these systems are but expressions of a single limited



Off-channel storage dam for Venetia Mine near the Shashe confluence: Stores water from the Limpopo River during floods only.



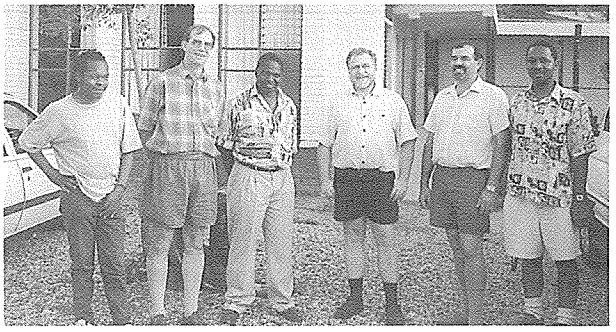
Pipes carrying water pumped from the Limpopo River bed for the supply of the town of Messina.

resource. A better understanding of how these two phases of our water resources interact is consequently required.

Through a process of workshopping, literature study, gathering of the so-called grey literature and intensive discussions with a large number of experts in the field it was concluded that:

- A change in vegetation can have a large effect on recharge. The size of this effect is dominated in South Africa by the transpiration component and, to a lesser degree, by interception.
- Vegetation will largely determine the net amount of net rainfall available for recharge, and may also influence infiltration, percolation and deep drainage, and the available storage capacity of systems.
- Recharge modelling (estimates) ought not to assume that vegetation is a constant factor; the nature of the land cover can have a large influence on recharge.
- In the higher rainfall (eastern seaboard) regions of South Africa, base flow in streams is a fairly direct indicator of groundwater levels, and thus groundwater and surface water systems are inextricably intertwined. Groundwater exploitation in these regions can be expected to have immediate effects on surface-water yields.
- Of the natural biomes of South Africa, it is probably within the savanna biome that the largest changes may be effected by changes in biomass.
- Environmental concerns may limit the development of large groundwater exploitation schemes because of our inability to satisfactorily predict "downstream" impacts. To assess environmental impacts, it is necessary to develop an understanding of the flow paths and residence times of groundwater, so that effects of groundwater abstraction can be predicted. It is also necessary to understand the extent to which plants, especially in riparian situations, rely on groundwater.
- The ecological requirement of systems that depend on groundwater is poorly understood, and this issue will increasingly have to be addressed.

Cost: *R205 000*
Term: *1996-1997*



International co-operation: These participants in the project for the **Development of a hydrological model for the upper and middle Limpopo River** (Project No 746) represent DWR – Zimbabwe, DWAF – RSA, FS University – Jena, Germany and the University of Stellenbosch – RSA.

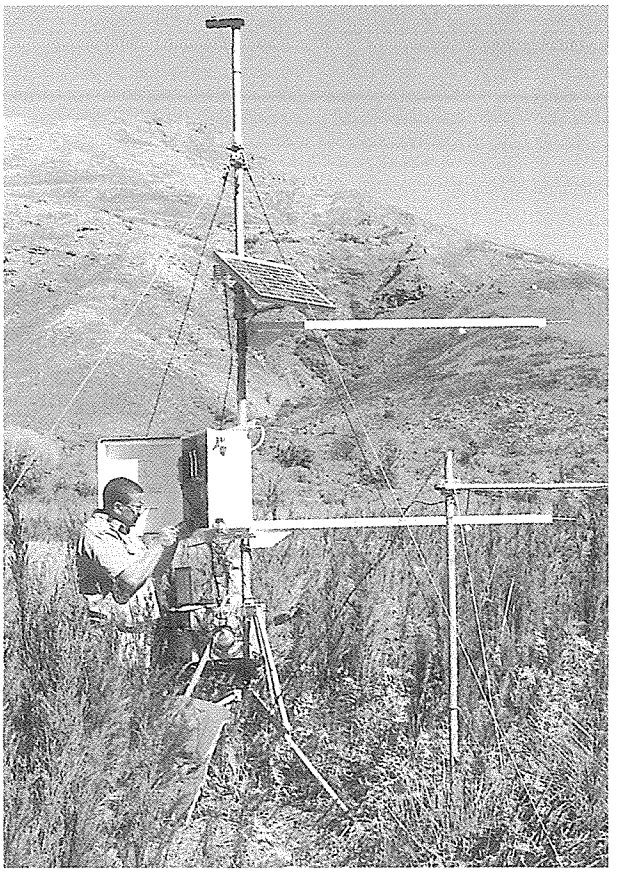
New projects

Flood-forecasting system for Vaal Dam

(No 908) DWAF

In early 1995, the USA-RSA Binational Commission was formed to explore opportunities for future technological co-operation between South Africa and the United States. Under the auspices of the Binational Commission, it was proposed to establish a project to examine the flood-forecasting system for the Vaal River system in South Africa and to determine whether the USA's National Weather Service (NWS) River Forecast System could be implemented for the catchment.

Responsibilities for project tasks will be distributed among the NWS and South Africa's DWAF and Weather Bureau. Successful execution of the project will involve purchase of scientific workstation computers, installation of existing NWS Forecast System software, initialisation of the forecast



Mr Godfrey Moses from the Stellenbosch office of the CSIR doing maintenance work on the Bowen ratio system, installed in the Jonkershoek valley. The purpose is to measure rates of evaporation from riparian fynbos, and compare these to estimates of water use by riparian thickets of wattle at another site in the Stellenbosch area.

system parameters and variables, a workshop, calibration of hydrological models, the utilisation and interfacing of existing hydrometeorological data including radar data, while the WRC will contribute to the budget of the project, costs will be borne mainly by the participating organisations.

Estimated cost: *R150 000*
Expected term: *1998-1999*

Monthly multi-site streamflow model

(No 909) BKS (Pty) Ltd.

In 1985 the Vaal River System Analysis (VRSA) was started by BKS Inc. for DWAF. One key aspect of the VRSA was the inclusion of stochastic hydrology in the analysis process. This was required due to the relatively short streamflow records available, together with the relatively long critical periods experienced in South Africa. A stochastic streamflow generator was consequently incorporated into the main system models where it remains today as a crucial component of the full system model.

The stochastic streamflow model has been continually improved, tested and refined since 1985 and this has now resulted in a stochastic generator which is considered to be one of the best in the world. However, its performance is not matched insofar as presentation and ease of use are concerned. As part of the larger system analysis model it is very difficult and cumbersome to produce stochastic streamflow sequences without using the full model.

This project, therefore, aims to re-structure and re-write, where necessary, the stochastic streamflow generator in order to produce a self-contained model which is suitable for widespread distribution and use. The model will be accompanied by a suite of verification and validation routines which will enable users to ensure that the streamflow sequences they generate are realistic and acceptable.

Estimated cost: *R300 000*
Expected term: *1998-1999*

Research projects

Completed

- **319** Monitoring the effect of catchment development on urban runoff and water balance (University of the Witwatersrand – Department of Civil Engineering, Water Systems Research Group)
- **492** Effect of the agricultural environment on water resources (University of Natal – Department of Agricultural Engineering)
- **493** Development and testing of a water balance model for a grassland catchment in the summer rainfall area of South Africa (CSIR – Division of Water, Environment and Forestry Technology)
- **730** Development of a research strategy on the interaction between vegetation and groundwater (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)
- **636** Hydrological systems modelling research programme: ACRU model development and user support (University of Natal – Department of Agricultural Engineering)
- **637** Hydrological systems modelling research programme: Hydrological process research (University of Natal – Department of Agricultural Engineering)
- **638** Studies on river losses: Phase 2 (BKS (Pty) Ltd)
- **681** Short-duration design rainfall estimates for Southern Africa (University of Natal – Department of Agricultural Engineering)
- **683** Evaporation from the Orange River: Quantifying open water resources (CSIR – Division of Water, Environment and Forestry Technology)
- **744** Experimentation and laboratory measurement for hydrological processes research (University of Natal – Department of Agricultural Engineering)
- **746** Development of a hydrological model for the upper and middle Limpopo River (University of Stellenbosch – Department of Civil Engineering)
- **747** Assessment of the MIKE SHE hydrological model for application in South African catchments (Rhodes University – Institute for Water Research)
- **781** Long-term monitoring of streamflow and weather in the Cathedral Peak catchments (CSIR – Division of Water, Environment and Forestry Technology)
- **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 – Department of Agricultural Engineering)
- **867** Integration and application of daily flow analysis and simulation approaches within Southern Africa (Rhodes University – Institute for Water Research)

New

- **908** Flood-forecasting system for Vaal Dam (DWAF)
- **909** Monthly multi-site streamflow model (BKS (Pty) Ltd.)

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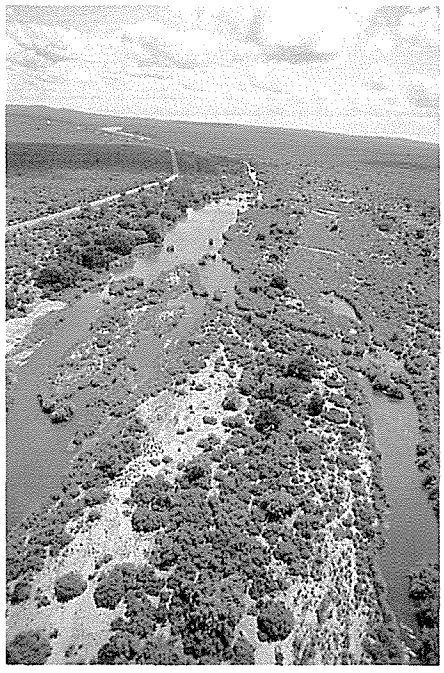
13 Conservation of water ecosystems



Three of the WRC activities in this research field during 1998 need to be highlighted:

- *Estuarine ecosystems*
- *Continued impact of the building-block methodology*
- *National rivers initiative*

Estuarine ecosystems

Almost half of South Africa's estuaries are situated on the eastern coast of the Eastern Cape. While the estuaries in the rest of the country have been studied, there is almost nothing known about these estuaries beyond the fact that many of them are scenically very beautiful and the catchments relatively undeveloped. Much of the coastal development that has occurred in South Africa has been centred on estuaries. Realising that ecotourism has the potential to create employment in a poor area of the country, but that estuarine ecosystems are fragile and easily disturbed, the WRC has initiated a research programme aimed at creating the capacity to sustainably manage estuaries in this part of the country. The stakeholders in the region have expressed their commitment to the programme, which was launched in April this year, and will aim to create both research and management capacity for estuaries in the region.

Continued impact of the building-block methodology

The building-block methodology (BBM), developed through WRC-funded research and practical application by DWAF, was specifically designed to estimate the flow required by a river to maintain the ecosystem. It was developed to enable managers to balance the abstraction and impoundment of water to the requirements of the riverine ecosystem and has been used initially in the pre-feasibility studies for proposed impoundments. However, it has also been included in the new Water Act as a requirement for all significant catchments, and this will create a large demand for people familiar with the process. The methodology has also been exported to Australia, and is attracting interest from other countries such as Taiwan, Portugal and Italy.

National rivers initiative

During the year a working conference was held to formulate a national rivers initiative to address research needs in rivers nationally. The conference was held under the auspices of the Southern African Society of Aquatic Scientists (SASAQS), and was well attended. A task group was mandated to develop the proposals made at the conference, and this group will report back firstly to a reference group, and then to the conference attendees.

Completed projects

Key to phytoplankton species

(No K8/83) Department of Zoology, University of Cape Town

This project was initiated to address the need for workers in the field to be able to identify non-filamentous phytoplankton. The photomicrographic record was developed from the algal taxa record during a 2-year study during which water bodies in the Western Cape were sampled at 14 d intervals, and represents a comprehensive record of the taxa found. The occurrence of individual taxa is related to the physico-chemical variables of the water bodies, providing information on the phytoplankton assemblages in water bodies of differing trophic states.

The report consists of high-quality photomicrographs and scanning electron micrographs of the taxa found during the study. The season and water quality conditions under which each taxon occurred are also presented, giving insight into their requirements.

The final product can be accessed via the Internet (accessible from the WRC home page).

Cost: *R14 500*
Term: *1992-1998*

Potential for the biological control of the floating aquatic weed *Azolla filiculoides* Lamarck (red water fern/rooivaring) in South Africa

(No K8/229) Plant Protection Research Institute, Agricultural Research Council

The red water fern (*Azolla filiculoides*), a South American native, was first recorded in South Africa in 1940. The lack of natural enemies and the presence of enriched waters have contributed to dense infestations which cause severe degradation of aquatic ecosystems and limit their utilisation. The effective absence of damage from indigenous herbivores, made it necessary to look to the importation of an agent for biological control.

The frond-feeding weevil *Stenopelmus rufinasus* was imported for quarantine testing. Favourable biological characteristics of this weevil include a high rate of increase, long-lived adults, a high *per capita* feeding rate and it would be capable of several generations per year. Host specificity of the insect was determined by adult starvation and oviposition tests on 26 plant species in 15 families. Feeding, oviposition and larval development were only recorded on other *Azolla* spp., and at significantly lower levels, particularly so for *A. nilotica* and *A. pinnata* (from Namibia). The weevil did survive (at approximately 50% of its success of *A. filiculoides*) on *A. pinnata* from Natal which is cause for concern. The phenology of the Natal *A. pinnata* is much more weedy than that of the Namibian one, and one of the recommendations coming out of the project is that the taxonomic status of these two populations be clarified.

Cost: *R14 100*
Term: *1996-1998*

Geomorphological response to changing flow regimes of the Sabie and Letaba River systems

(No 376) Department of Botany, University of the Witwatersrand

The demands on the surface water resources of South Africa are such that competition between the various interested sectors is inevitable. In order to enable the optimal development of the country's water resources, reliable quantification of both the consumptive and non-consumptive water requirements of river systems is essential. It was suspected that these non-consumptive requirements exceed the consumptive, and with the changes which have occurred in the Sabie and Letaba Rivers in ecologically relevant time-scales as a result of developments, and with more developments planned, upstream from the Kruger National Park (KNP), these needed to be defined. This project aimed to develop predictive models for geomorphological change taking into account the established temporal pattern of change in channel morphology, and so identify management interventions to maintain ecological functioning.

In working with complex bedrock-dominated rivers the researchers developed a channel classification system of three scales: morphological units (1 to 100 m), channel types (10 m to 1 km) and reaches (100 m to 1 km) on which further work could be based. Aerial photographs from 1940 to the present showed progressive sedimentation of both the Sabie and Letaba Rivers, apparently as a combined result of both increased sediment production and reduction of flow. Using two time-scales, a path of geomorphological change has been proposed using a model which links quantitative research findings with qualitative spatial data for the Sabie River.

The morphological associations within these channels may be structured to reveal five principle channel types on the Sabie River: bedrock anastomosing, mixed pool-rapid, mixed anastomosing, alluvial-braided and alluvial single-thread channels. In addition, four main dynamic catchment controls on channel form were identified: catchment sediment production rate, local channel transport capacity, flow variability and flow magnitude. Changes to the catchment-control factors are occurring in both catchments as a result of climatic variability and anthropogenic influence. A model is presented that links the various channel types along the Sabie River in a semi-quantitative sense, predicting annual sediment deposition and erosion in response to a daily average flow regime. Predictions using the model agree well with changes observed on the Sabie River.

Cost: *R1 273 000*
Term: *1991-1998*

Rapid biological assessment of water quality impacts in streams and rivers

(No 422) Division of Water, Environment and Forestry Technology, CSIR

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.

The English system has been modified to suit South African conditions, widely tested and renamed SASS (South African Scoring System). The SASS index offers a cost-effective method for assessing the health of the macro-invertebrate community in a river. During the development of the SASS, the methodology was widely discussed, and it is now routinely being used as part of the biological monitoring of river health. It is also one of the indices which form the basis of the National River Health Programme.

Cost: *R483 000*
Term: *1992-1998*

Diversity and productivity of biotic communities in relation to freshwater inputs in Eastern Cape estuaries

(No 463) Department of Zoology, University of Port Elizabeth

Estuaries are, by their very nature, unique environments, but the freshwater inflow is critical to their functioning. Thus, the quantity of freshwater that reaches an estuary determines, to a large extent, the composition of the floral and faunal components of the ecosystem, as well as their productivity. In the absence of freshwater inflow, estuaries do not generate the primary production necessary to support life, and become hypersaline and unproductive. This study involved three Eastern Cape estuaries, the Sundays (continuous freshwater inflow), the Swartkops (reduced freshwater inflow) and the Kromme (deprived of freshwater). The food-chain in the Sundays is based on phytoplankton, while that of the Kromme is based on detritus from marine benthic macrophytes which have encroached up the estuary as a result of increasing salinities. Without being flushed by floods, the Kromme is in danger of becoming a marine lagoon and being choked up by marine sediments.

The diversity was greatest in the Sundays, the estuary with the largest freshwater input.

Cost: *R28 000*
Term: *1992-1998*

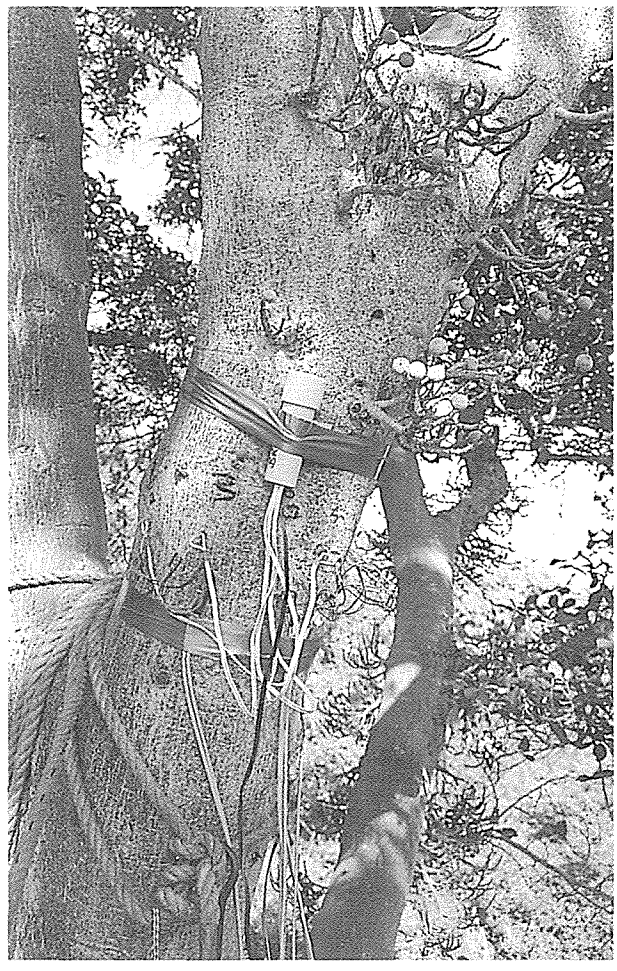
Developing an integrated approach to predicting the water use of riparian vegetation

(No 474) Department of Botany, University of the Witwatersrand

The natural riverine biota are now recognised as a legitimate demand sector in water resource management with a significant demand, and a part of this project addressed that demand. The second part of this project addressed the translation of river discharge into local hydraulic conditions. This latter aspect enabled the stage-discharge relationships to be reliably estimated. It did show, however, that neglecting bank storage led to unrealistic estimates of the rating curves for any sampling point. A model predicting bank storage was developed using information on the interaction between surface flow, groundwater, soil moisture in the saturated and unsaturated zones of the alluvial bank and losses to evapotranspiration. Evapotranspiration was found to vary seasonally, with bank seepage estimated to provide 95% of water use in winter (total 0.25 m^3/s for the Sabie River within the KNP boundaries) and 74 to 80% of water use in the late summer (total 1.5 m^3/s within the KNP boundaries).

Existing models of hydraulic conditions are based on empirical calibrations, and proved inaccurate for natural channels. Thus it was necessary to quantify flow resistance for various vegetation communities and channel geometry, bed and bank characteristics. A 'non-horizontal' model was developed to address sections with multichannel flow where the levels in the channels differ. Where the levels do not differ, the conventional methods can be used for estimating flow.

Cost: *R1 209 000*
Term: *1992-1998*



Instrumentation utilised to measure water consumption by riparian vegetation in the Kruger National Park.

Environmental status of the Orange River mouth as reflected by the fish community

(No 505) Department of Zoology and Entomology, University of the Orange Free State

Fish-wise the Orange River estuary is neither particularly rich in estuarine species nor is it important as a nursery area. However, the nearest significant functional estuaries are the Cunene (>10° of latitude to the north) and the Olifants (3° of latitude to the south). A major concern is that the planned development of the resource upstream is going to result in both lower low flows and reduced levels at high flows. It was anticipated that reducing the flow would also negatively impact on the tidal marsh which is a designated Ramsar wetland.

Investigations showed that the marine component of the estuarine fish fauna was small, as were the other components, but the fish were healthy, and those fish that were there were surviving well under the increased flow management. The research team made the recommendation that a long-term monitoring programme should be instituted, together with further research to better understand the ecosystem, given its Ramsar status, and to improve management guidelines.

Cost: *R64 300*
Term: *1993-1998*

Effects of different magnitude flows on riverine ecosystems

(No 576) Freshwater Research Unit, University of Cape Town

South African rivers mirror the world-wide trend in their deteriorating condition. This is largely due to general catchment degradation and increasing manipulation of flow regimes to provide water for the ever-increasing population. One of the ways in which this is being addressed is through the emerging science of environmental flow assessment. The flow regimes recommended by this process are designed to contain or mitigate the impacts of such water resource developments. The cost of poorly functioning rivers is high, with much of the cost being borne by those least able to withstand them – the rural poor.

This report is the definitive work on the building-block methodology (BBM), a process developed to assess flow requirements of rivers. It also covers the considerable amount of research done by the team to complement the development of the BBM. The principal aim of the research programme was to improve understanding of the relationships between the magnitude, duration, timing and frequency of different categories of flow and the structure and functioning of riverine ecosystems. Such aspects as base flows, specifically dry-season low flows, freshes and floods are cov-

ered with specific research investigating topics such as sediment transport, the effect of base flows on macro-invertebrate assemblages and triggers for fish breeding.

Cost: *R776 000*
Term: *1993-1998*

Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa

(No 608) Department of Zoology, Rand Afrikaans University

The Olifants River, Mpumalanga Province, has been described as 'the battered river' because it is so heavily impacted by the activities in the catchment. Disturbances in the upper catchment are largely caused by agriculture. In the middle reaches activities such as coal-mining, industry, urban runoff, informal settlements, poor agricultural infrastructure and sewage treatment works each impact on the health of the river. A serious problem associated with coal mining activities is the low pH of the effluent. One of the effects of a low pH is that metal ions are mobilised, making them available in the food-chain. The result is that metal toxicity becomes a greater problem than it would be in alkaline waters.

The Olifants River upstream from Loskop Dam was widely sampled over a 2-year period for an extensive range of constituents, and the results are summarised graphically by their conforming or otherwise to guideline levels. At the same time, the metal levels in fish tissue (gills and liver) were also monitored, and the sublethal influence of Cu, Zn, Al and Mn on fish was determined using fish haematology as the measure of the organisms' response to pollution by heavy metals. This enabled the researchers to predict the effect of water quality found in the upper Olifants River on the fish population. The influence of deteriorating water quality on the macro-invertebrate populations of the area was also recorded, and the more resistant species noted.

Cost: *R549 700*
Term: *1994-1998*

Water quality requirements for riverine biotas

(No 626) Department of Zoology, University of Cape Town

A Biological/Chemical Database was developed as part of this project, incorporating virtually all the ecological studies done on South African rivers which include both taxonomic and chemical data. Using SASS4 (South African Scoring System, version 4), several of the water-quality variables in the DWAF guidelines for environmental water quality were tested for each of the four regions (mountain, foothills, transitional and low-land rivers). The correlations obtained indicate that this is not only a viable method for testing the acceptable range of water quality variables, but also for verifying the SASS4 score of individual taxa.

Using the Western Cape endemic amphipod *Paramelita nigricolus* as a test organism, the synergistic/antagonistic effects of Mn, Al and Cu were investigated. It was found that Mn opposed both Al and Cu.

In addition, physical, chemical and biological conditions in the Breede River catchment were investigated. The main causes of degradation were found to be changes in conductivity, pH and NO_2 and NO_3-nitrogen.

Cost: *R359 700*
Term: *1994-1998*

Water quality modelling of estuaries

(No 664) Division of Water, Environment and Forestry Technology, CSIR

The development of estuarine water quality monitoring expertise was identified as a priority research requirement by the Co-ordinated Programme on Decision Support for the Conservation and Management of Estuaries. This project investigated the suitability of the one-dimensional Mike 11 Water Quality Model to predict water quality in South African estuaries. The two estuaries selected were the Berg and the Swartkops, both of which are relatively long and narrow with permanently open mouths which suit one-dimensional modelling. In addition, both are data-rich by South African standards. The model showed good correlation between measured and simulated temperature and dissolved oxygen (DO), even predicting the low DO levels in the upper reaches of the Berg Estuary in the summer, although the high variability near the mouth was underestimated. This is possibly due to insufficient data on the inshore marine environment. One area of difference between these estuaries and those of the Northern Hemisphere is the sediment oxygen demand. It was postulated that this could be the result of a relatively small freshwater input. The effect of the 'black tide' on the Berg Estuary was modelled successfully. This indicates that Mike 11 can also be used for linking water quality to biological processes.

Nutrients such as soluble reactive phosphate and silicate were strongly correlated to salinity, but total dissolved nitrogen showed no correlation to any parameter either measured or modelled. Another current limitation is that the model cannot, in its present form, simulate bacterial water quality.

Cost: *R165 500*
Term: *1995-1998*

Tadpoles as bio-indicators of stream quality

(No 718) Department of Biochemistry, University of the Western Cape

Tadpoles are known to be sensitive to toxins in the environment and their numbers are declining. Once the tolerances of individual species are known, the composition of the tadpole community of a waterbody will indicate the quality of the water in which they are living, and so the fitness of the water for use as a drinking and household source.

The results of the research are presented in two sections. The first section covers the classification of tadpoles, their distribution and seasonality. The distribution maps, descriptions and an identification key for 36 species of tadpoles are clearly presented and easy to follow. The second section deals with a number of locally-used insecticides, fungicides and a herbicide, describing their use, known ecotoxicology and environmental fate, as well as the effect of each on the development of *Xenopus* (platanna) tadpoles using the FETAX (frog embryo teratogenesis assay – *Xenopus*) test.

The sensitivities of tadpoles to the test chemicals obtained in the second part are revealing, especially when the quantities of these chemicals marketed in the country are considered. Two examples taken from the chemicals tested are:

- Deltamethrin (used for locust control)
  LC_{50} 0.19 mg/*l* (concentration at which 50% of the embryos fail to develop)
  EC_{50} 0.006 mg/*l* (effective concentration at which 50% of the embryos show developmental abnormalities)

- B.t.i. (used for blackfly control)
  LC_{50} 163.2 mg/*l*
  EC_{50} 0.02 mg/*l*

indicating that even low concentrations of chemicals in the environment are cause for concern.

Cost: *R160 200*
Term: *1995-1997*

Development of a production facility for test organisms to be used in flowing water ecotoxicological research

(No 755) Institute for Water Research, Rhodes University

The WRC has supported a suite of projects investigating the tolerance of indigenous organisms to variations in water quality. One of the constraints identified is availability of standard organisms of known age and origin for use in ecotoxicological tests. Without this, the variability of the results obtained is likely to be increased by an unknown amount. This is the second project in a series which investigated the possibility of rearing suitable animals in the laboratory for use in water quality testing. The first project screened a series of organisms and this project has enabled the researchers to investigate two candidate species in some depth. The two candidate species are the freshwater limpet *Burnupia stenochorias* and the mayfly *Adenophlebia auriculata*. Another aim of the project was the design of a facility dedicated to rearing invertebrates of use in ecotoxicological work.

Further fieldwork was conducted on both the organisms. In the laboratory, progress has been made with the culture of *B. stenochorias*, particularly in the realms of feeding, growth rate and fecundity determinations. Handling of the limpets, which had proved difficult, was overcome successfully. *A. auriculata* proved easy to rear in the laboratory, but the constraint is in the breeding. Some success was achieved in the artificial fertilisation of the eggs, but these did not hatch. However, the organism is readily available in the field and so field-caught nymphs may be used experimentally.

Cost: *R395 800*
Term: *1996-1998*

Scenario modelling for the Kruger National Park Rivers Research Programme (KNPRRP) decision support system

(No 782) Centre for Water in the Environment, University of the Witwatersrand

Volume I of the final report on the above-mentioned research project, entitled *Geomorphological Change Models for the Sabie River in the Kruger National Park (KNP)* was finalised during 1998. The following objectives were addressed in this part of the project:

- Refinement, verification and testing of a suite of hydraulic and geomorphological change models developed by the Centre for Water in the Environment (CWE) for use in the KNP decision support system (DSS)
- Modelling of geomorphological change in the Sabie River since the early 1900s in order to isolate the effects of past climatic change and anthropogenic influences
- Integration of the results with other research conducted within the KNPRRP.

During the course of the project, geomorphological change was modelled under scenarios specified through the DSS. The understanding of and ability to predict the direction and magnitude of geomorphological change was enhanced through an investigation of the influence of flow regime on sediment transport characteristics; a study of the influence of flooding on the erodability of cohesive sediments; and the development and testing of a rule-based geomorphological unit change model which operates at spatial scales that can realistically be integrated with ecological studies. The results have been integrated with other research conducted under the auspices of the KNPRRP, particularly the abiotic-biotic links project (No 777) and the instream flow assessment project (No 874).

Key findings of the study were:

- The reduction of dynamic sediment storage resulting from reduced flooding influence is likely to impact significantly on the spatial and temporal assemblages of geomorphological features, since under conditions of reduced flooding progressive sedimentation will systematically reduce the bedrock influence. The biodiversity of the system is a consequence of the mixed bedrock alluvial character of the river and will be severely affected if there is a loss of bedrock influence.
- In order to achieve a new dynamic equilibrium in response to a reduced flooding regime, alluvial channel types display a tendency to erode whilst pools and (to a lesser degree) mixed anastomosing channel types show a tendency to aggrade. Loss of storage within braided channel types is likely to result in a smaller active channel incised within the macro-channel infill deposit.
- The riparian vegetation along the Sabie River needs to be adequately managed to ensure that it continues to afford protection to the cohesive bed during extreme flood events.
- There is encouraging evidence in support of the further development of rule-based modelling as a tool for predicting change at the morphologic unit spatial scale that can realistically be integrated with ecological studies.

Cost: *R599 800*
Term: *1996-1997*

New projects

Impact of herbicides used in water hyacinth control on natural enemies released against the weed for biological control

(No 915) Plant Protection Research Institute, Agricultural Research Council

The water hyacinth (*Eichornia crassipes* (Mart.)) is a pest world-wide, and is South Africa's worst aquatic plant pest. Its detrimental effects include out-competing other plant species, adverse habitat alteration, increase in evapotranspirational losses, clogging of water courses and harbouring disease vectors. Nutrient enrichment of our surface waters stimulates vigorous growth, and a stand of the plant can double its area in 6 to 15 d under certain conditions.

Mechanical harvesters have been designed which are suitable for work on canals (Europe and USA), but not on South African rivers. Chemical control is effective in the short term, and the herbicide Glyphosphate is registered in this country for use on water courses. Research elsewhere has indicated that while the herbicide itself may not harm the biocontrol agents, the surfactant may be toxic to the biological control agents. This country has released six biological control agents against *Eichornia*, and the researchers anticipate that a substantial measure of control will be achieved within the next decade.

However, the plant is so vigorous that outbreaks are likely

to continue to occur under suitable conditions. To this end, the scientists see the need for an integrated control strategy in which the biological control will be backed up by chemical control when necessary.

This project aims to quantify the impact of the different formulations of herbicides used in the chemical control of the water hyacinth on the biological control agents, and formulate an integrated control strategy for South Africa.

Estimated cost: *R107 000*
Expected term: *1998-1999*

Invertebrates of South Africa – Identification keys

(No 916) Umgeni Water (for the South African Society of Aquatic Scientists)

Over the past decade a number of keys for the identification of groups of aquatic invertebrates have been produced by aquatic scientists, but these have not been published as a suitable publisher could not be found. At the time this national collaborative project was initiated, the need for the keys was almost entirely within the aquatic scientist community, and many of the keys have been circulated in unpublished form for use by other scientists and as teaching resources.

However, the wide acceptance of the SA Scoring System (SASS) (a water quality assessment method based upon the size and diversity of invertebrate populations) as a biomonitoring tool during the last few years has made the need for the publication of these keys a matter of priority. The reasons for this are:

- SASS is now being used by technicians as well as scientists
- The need for people skilled in aquatic invertebrate identification will increase substantially in the foreseeable future as the need for biomonitoring is included in DWAF's policy on resource protection.

Questionnaires were sent to scientists currently active in the invertebrate field and substantial comment was received motivating for the publication of the keys.

This project will produce a series of identification keys to cover all of South Africa's freshwater aquatic invertebrates.

Estimated cost: *R185 000*
Expected term: *1998-2001*

Promotion of scientifically based estuaries management through the development of an estuaries management handbook

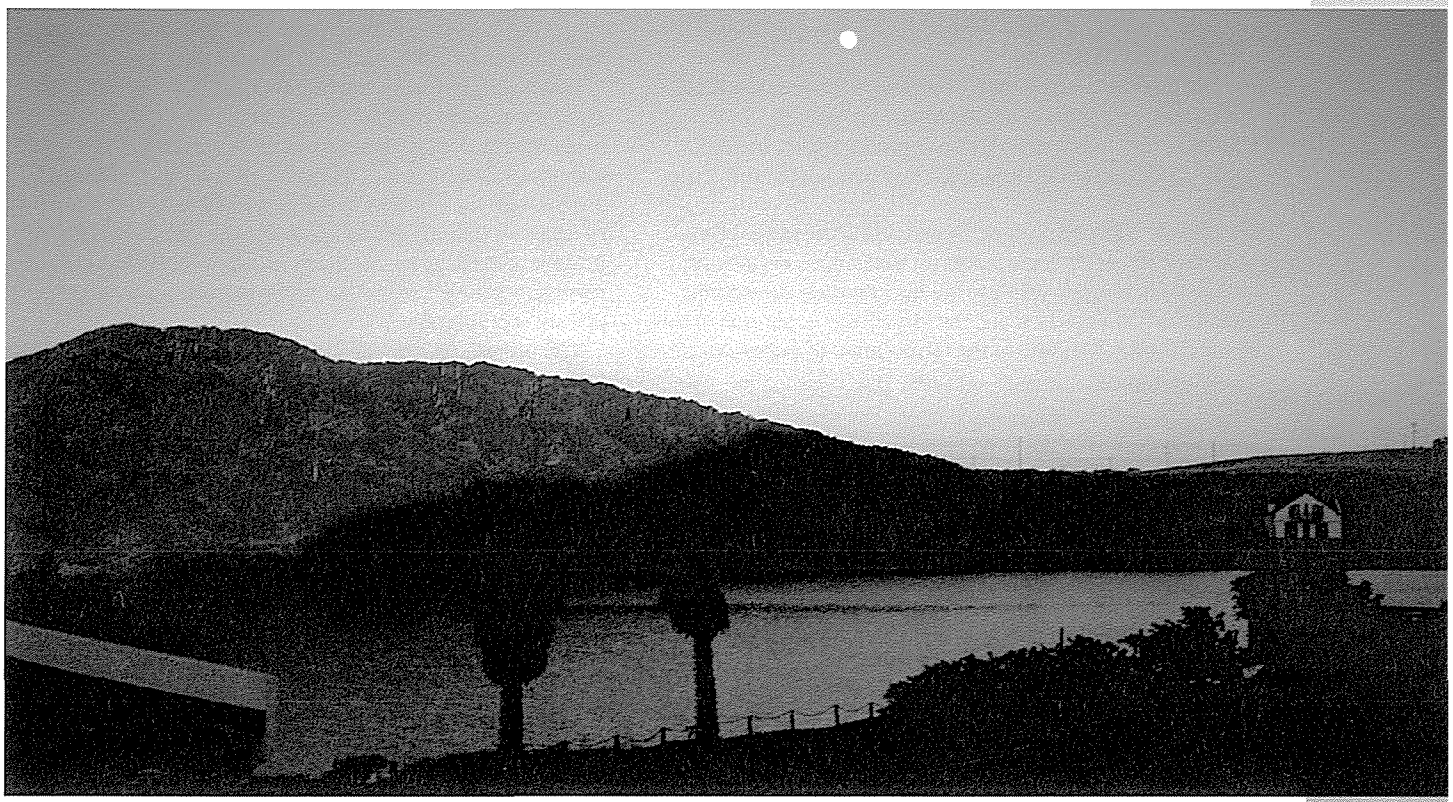
(No 917) Institute for Natural Resources, University of Natal

The importance of South Africa's estuaries is out of all proportion to their area. From a marine point of view they are breeding grounds and nursery areas for some of our important marine resources; from a terrestrial point of view, they are in high demand for many types of recreation. Urban or holiday coastal developments often centre on estuaries.

At the moment, however, there is no 'one-stop-shop' where the people who make the day-to-day decisions on the management of the country's estuaries can obtain information on how to plan and execute their developments while sustaining the essential estuarine functions. A good deal of scientific knowledge exists within CERM (scientists of the **C**onsortium for **E**stuarine **R**esearch and **M**anagement), and the handbook developed during this project will translate this knowledge into management principles, so that this may be applied where the need is. The handbook will be written in such a way that it can be used as a resource for an institutional training and support system.

Specifically, this will be achieved through:

- Collaborative (scientists and managers) development of a practical introduction and guide to the structure, functioning and management of estuaries



Mpekweni Estuary in the Eastern Cape. Decision-support systems for the management and conservation of estuarine systems are being developed.

- An institutional (coastal universities and institutions) system which provides training and support for local managers and interested and affected parties
- An information network and management system which sustains interest and promotes management based on current understanding
- Provision of practical guidelines for monitoring and data collection necessary for enhanced management.

Estimated cost: *R250 000*
Expected term: *1998*

Use of indigenous riverine organisms in applied toxicology and water-resource quality management

(No 955) Institute for Water Research, Rhodes University

Initial motivation for this programme came from the realisation, early in the Kruger National Park Rivers Research Programme, that there was very little information on the water quality tolerances of riverine invertebrates. Substantial progress has been made in this area, and the approach has proved itself in contributing to the setting and refining of both general and site-specific water quality guidelines for the protection of aquatic ecosystems. Quantitative data on the tolerance of local riverine organisms to either individual water quality parameters or whole effluents are few. These data, which are relatively simple, need to be interpreted in the context of complex problems in a complex environment for the development of meaningful guidelines. This interpretation will allow the data to be incorporated in the setting of effluent-discharge criteria in permits. The information generated by toxicological work also provides an important link between biological monitoring, which is becoming established in the country, and chemical monitoring which has been widely used for some years.

To address the above, the overall aims of this project are to:

- Apply eco-toxicological methods using indigenous riverine taxa as test organisms
- Continue the development of methods to apply results to the development and refinement of guidelines
- Further develop water-resource quality policy, including the application of toxicological end-points in permit criteria.

Specifically, this will be done by extending the range of variables and whole effluents tested on indigenous organisms, and initially to apply this knowledge to setting site-specific guidelines. On a wider scale, the knowledge generated in this research will contribute to the formulation of policy on resource quality.

Estimated cost: *R926 000*
Expected term: *1998-2001*

Development of numerical methods for assessing water quality in rivers, with particular reference to the "instream flow requirements" process

(No 956) Department of Zoology, University of Cape Town

Management of water quality is one of the major issues facing water managers in South Africa. Three aspects of water quality in relation to 'the environment' (particularly aquatic ecosystems, but in fact all users of water) concern the development of guidelines for aquatic systems; biomonitoring and the assessment of the impact on water quality by proposed new water resource development. On the first of these the Biological-Chemical Database developed during the previous project (No 626) will be verified for South Africa as far as data availability will allow. Regarding the second concern, the Biological-Chemical Database has the potential for objectively verifying the scores allocated to invertebrate taxa by the South African Scoring System (SASS) biomonitoring tool. Currently these scores are based solely on expert opinion. The third point outlined above, forming the major thrust of this project, will address the lack of any protocol for incorporating water quality considerations into the assessment of instream flow requirements (IFR) for the baseflow required in terms of the new Water Act for both basic human needs and the environment.

The aims of this project are to:

- Manage and update the Biological-Chemical Database developed during Project No 626, verify SASS scores and identify water quality requirements for taxa
- Investigate water quality requirements for taxa
- Examine specific aspects of the influence of water quality on invertebrates endemic to the South-Western Cape
- Establish the relationship between water quality and water quantity with particular reference to IFR assessments.

Estimated cost: *R800 000*
Expected term: *1998-2000*

Ecological risk assessment in water resource management: Research priorities, process development and implementation guidelines

(No 957) Division of Water, Environment and Forestry Technology, CSIR

Ecological risk assessment (ERA) is a recently developed methodology which permits people whose activities influence the environment, such as industry or decision-makers, to gauge the probability of their actions or decisions having undesirable effects. The methodology is becoming widely used in the USA and Europe, and in our interactions with these countries we are being required to show that we conform to their requirements.

Water resource assessment, management and policy formulation were in the past mainly in the areas of biological assessments, chemical measurements and modelling, and toxicity evaluations. The advent of ERA as an assessment process and the changes in policy and focus of the regulatory agencies (mainly DWAF) provides the climate for the integration of existing technologies into a product that can more adequately address the needs at both government and private-sector levels.

The overall objective of the proposed project is to focus the techniques for ecological assessment of water resources within the new regulatory context. The developed ERA process should facilitate and co-ordinate the ecological contributions towards predictive assessments, regulatory processes, sustainable development issues and retrospective analyses.

Estimated cost: *R825 000*
Expected term: *1998-2000*

Assessment of the implications of inter-basin water transfers for the genetic integrity of donor and recipient river basins using selected taxa

(No 975) Department of Zoology, University of Cape Town

Southern Africa is a leader in the development of inter-basin water transfer (IBT) technologies. Across the region, water is seen as one of the greatest constraints to increased socio-economic development and as with many dryland regions across the globe, IBTs are increasingly being used to rectify the problems posed by the uneven distribution of surface waters. In South Africa, the growing use of IBTs has seen them listed as one of the major threats to the integrity of river and stream ecosystems. One of the main concerns voiced thus far is the transfer of species and individuals between river basins. More recent concerns however, have focused attention on the transfer of species, as well as that of individuals from different populations between river basins.

The very nature of river basins provides natural isolating mechanisms which safeguard genetic diversity. However, already in South Africa there are a number of extant IBTs which cross not only adjacent river catchments but which move water, and potentially individuals and species, across biogeographic boundaries. The objective of this project is to examine the integrity of river basins by assessing the levels of genetic differentiation between rivers in the Western Cape Province.

The aquatic insects proposed for assessment during this project reflect different dispersal potentials across a gradient at both the larval and adult stages. With this in mind, this project aims to examine the integrity of river basins and to assess the implications of IBTs for the conservation of river ecosystem functioning and riverine biodiversity using selected taxa and to contribute to the development of a management protocol for use in the assessment of the ecological effects of IBTs on both donor and recipient river basins.

Estimated cost: *R115 000*
Estimated term: *1998-2000*

Development of methodologies to promote interaction between the Kruger National Park Rivers Research Programme (KNPRRP) and catchment stakeholders

(No 986) Centre for Water in the Environment, University of the Witwatersrand

The Sub-Programme: Research of the KNPRRP has identified as priority the need for further development and application of the desired state objectives hierarchy protocol (DSOHP), with particular reference to integrated catchment management and incorporating the needs and values of previously excluded communities. Two specific needs, to be addressed in this project, are the following:

- Development and testing of a training programme and manual for transfer of the DSOHP:

  Phase III of the KNPRRP has the dominant theme of technology transfer to stakeholders and river forums. One of the factors limiting the effectiveness of forums and their interaction with the KNPRRP, is the difficulty experienced in integrating the objectives of the various participants into a common and cohesive strategy for river basin management. The KNPRRP DSOHP can provide a framework for developing such a strategy, but it is difficult for many people who are unskilled in strategic management to adopt the strategy merely by reading the relevant documentation. The intention is for the developers of the protocol to assist conservation and environmental management groups to develop their own objectives hierarchies.

- Development of appropriate instruments to survey community perceptions of their needs and values for river management, and to incorporate these into the relevant objectives hierarchies, thereby empowering previously excluded communities in river management.

  The DSOHP is underpinned by negotiation processes aimed at incorporating the needs and values of involved parties into a strategic, scientifically sound, management plan. In instances of multi-party catchment management it is essential to engage all parties at the start to ascertain their "desired state" of a river. In most catchments this will entail dealing with a very wide range of social and economic groups and the current protocol is too coarse for this purpose. In particular there is a need to understand the values and needs of communities previously excluded from the decision-making processes.

Estimated cost: *R95 000*
Expected term: *1998-1999*

Development of a programme for water-quality research and technology transfer on the rivers flowing through the Kruger National Park (KNP)

(No 988) Centre for Water in the Environment, University of the Witwatersrand

Despite the fact that there are many pressing water quality problems in the KNP rivers, the Rivers Research Programme has up to now not been able to effectively engage this issue. The Sub-Programme: Research of the KNPRRP in its planning confirmed two priority research and technology transfer needs for the remainder of Phase III of the programme. One of these is to generate an explicit thrust to improve the understanding of water quality issues in the catchments of the KNP rivers, and to transfer existing knowledge to catchment forums. The strategy to engage other parties in the catchments in explicit integrated catchment management activities requires that there is a solid grasp of what the issues are, what can be done with existing information and where future research should focus. Much information is available, but is fragmented and requires integration before it can be used to generate a clear and achievable plan of action for the future.

Against the above background, the project will have the following objectives:

- Review the existing knowledge of current water quality issues of the perennial rivers flowing through the KNP, and the available technology for dealing with water quality issues
- Compile an annotated list of the main interested and affected parties and their information and management needs
- Develop a strategy for effective transfer of existing knowledge and technology for managing the rivers of the KNP
- Develop a strategy by which the KNPRRP can effectively contribute to the enhancement of the knowledge base and its application.

Estimated cost: *R70 000*
Expected term: *1998*

Research projects

Completed

- **K8/83** Key to phytoplankton species (University of Cape Town – Department of Zoology)
- **K8/229** Potential for the biological control of the floating aquatic weed *Azolla filiculoides* Lamarck (red water fern/rooivaring) in South Africa (Agricultural Research Council – Plant Protection Research Institute)
- **376** Geomorphological response to changing flow regimes of the Sabie and Letaba River system (University of the Witwatersrand – Department of Botany)
- **422** Rapid biological assessment of water quality impacts in streams and rivers (CSIR – Division of Water, Environment and Forestry Technology)
- **463** Diversity and productivity of biotic communities in relation to freshwater inputs in Eastern Cape estuaries (University of Port Elizabeth – Department of Zoology)
- **474** Developing an integrated approach to predicting the water use of riparian vegetation (University of the Witwatersrand – Department of Botany)
- **505** Environmental status of the Orange River mouth as reflected by the fish community (University of the Orange Free State – Department of Zoology and Entomology)
- **576** Effects of different magnitude flows on riverine ecosystems (University of Cape Town – Freshwater Research Unit)
- **608** Lethal and sublethal effects of metals on fish physiology in the Republic of South Africa (Rand Afrikaans University – Department of Zoology)
- **626** Water quality requirements for riverine biotas (University of Cape Town – Department of Zoology)
- **664** Water quality modelling of estuaries (CSIR – Division of Water, Environment and Forestry Technology)
- **718** Tadpoles as bio-indicators of stream quality (University of the Western Cape – Department of Biochemistry)
- **755** Development of a production facility for test organisms to be used in flowing water ecotoxicological research (Rhodes University – Institute for Water Research)
- **782** Scenario modelling for the Kruger National Park Rivers Research Programme (KNPRRP) decision support system (University of the Witwatersrand – Centre for Water in the Environment)

Current

- **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)
- **525** Natural and unnatural factors regulating the structure and functioning of estuarine systems (University of Natal – Institute of Natural Resources)
- **577** Decision support system for the integrated management and conservation of estuaries (University of Natal – Institute of Natural Resources)
- **601** Freshwater requirements of plant communities in different types of estuaries (University of Port Elizabeth – Department of Botany)
- **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 – Roodeplaat Grassland Institute)
- **665** Assessment of the ecological impacts of inter-basin transfer schemes in dryland environments (University of Cape Town – Department of Zoology)
- **669** Survey for potential biological control agents for the troublesome alga *Cladophora glomerata* (Agricultural Research Council – Plant Protection Research Institute)
- **686** Application of an artificial stream system to investigate macro-invertebrate water quality tolerances (Rhodes University – Institute for Water Research)
- **716** Water quality and aquatic faunal studies in the Umzimvubu catchment, Eastern Cape, with particular emphasis on species as indicators of environmental change (University of the Transkei – Department of Zoology)
- **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)
- **813** Rule-based modelling for management of riparian systems (University of the Witwatersrand – 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 the 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)
- **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)
- **884** Hydrological modelling to manage the environmental reserve within the KNP (University of Natal – Department of Agricultural Engineering)

New

- **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)

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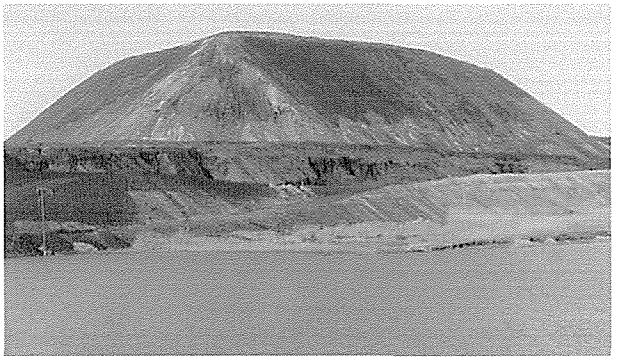
14 Mine-water management



By its very nature and scale, South African mining has a marked and visual impact on the environment.

Although mining is not regarded as a major consumer of water, it is implicated as a significant polluter of our water resources. Acid mine drainage (AMD), which is the main type of water pollution emanating from mining activities, originates from the pyrites which occur in most of the geologic formations which are being mined. Mining activity goes hand in hand with the disturbance and shattering of previously undisturbed material, thereby exposing pyrites and other minerals to accelerated weathering. When exposed to air and water, pyrites oxidise to produce sulphuric acid – the main constituent of AMD. Metals, such as iron, which dissolve under acidic conditions, are further constituents of mine drainage. In water-rich countries the low pH and metals associated with AMD are the main causes of concern – the reason being that these countries mostly have surplus capacity to dilute the accompanying salinity. In water-poor South Africa, with our limited dilution capacity, the high salinity associated with AMD is an additional cause for concern. Although much can be learned from the experience of other countries concerning mine-water management, our specific conditions mostly require that we adapt their findings to our situation.

Most of the impact mining has on the water environment is of a diffuse (i.e. non-point) nature. Because of the complexity of dealing with non-point pollution, the effort to regulate this impact is of fairly recent origin. Government and the mining industry have come to an agreement that the necessary regulation will largely be satisfied by the precondition that a mine prepare an Environmental Management Programme which, after consideration and possible modification, would be accepted by Government. Acceptance of the Programme is followed by Government's monitoring of the Programme's execution by the mine. The mining industry has herewith accepted that environmental rehabilitation will form an integral part of mining operations. By keeping to the letter and spirit of environmental management programmes, it is expected that individual mines will keep the negative environmental impact of their operations to within acceptable limits. The implementation of environmental programmes has given rise to many new research needs in the mining industry. These and other research activities are being co-ordinated by the WRC's Co-ordinating Committee for Mining-Related Water Research (CCMRWR) comprising representatives and individuals from Government, mining and the research community.

The CCMRWR identified the the following six problem areas as those in which technology is either not available or inadequate to deal with the water-related problems being experienced:

- Water treatment
- Water management
- Prediction of environmental impacts at source level on a mine
- Quantification of the effect of mining operations on surface- and groundwater resources
- Data acquisition systems, databases and information systems
- Policy regarding the effect of mining on the water environment.

Specific research and technology-transfer needs within these problem areas have been identified. New needs and their relative priorities are reviewed on an annual basis to give guidance to researchers and funding agencies.

Excellent co-operation exists between the different mining houses, government departments and the WRC concerning the execution of projects. Several projects funded by the WRC are being co-funded from other sources.

Completed projects

Use of vegetation in the amelioration of the impacts of mining on water quality – An assessment of species and water use

(No 413) Division of Water, Environment and Forestry Technology, CSIR

Mining activity at, or close to, the soil surface goes hand in hand with the disturbance of surface soils and the shattering of bedrock. This in turn results in increased infiltration of water while surface runoff is decreased. The exposure of hitherto unweathered surfaces furthermore mostly causes the water quality of the percolate from these areas to deteriorate markedly in comparison to the undisturbed condition. This project investigated the feasibility of using trees with a deep root system and high transpiration requirement, to reduce flow of water through mine material, thereby reducing the associated water quality degradation. Measurements at mine sites indicated that trees (mostly eucalypts) do grow well under the harsh environmental conditions associated with mines and that they generally use considerably more water than grass covers.

Cost: *R746 000*
Term: *1991-1996*

Development of an integrated and generic water quality simulation model for open-cast coal mining water circuits

(No 528) Wates, Meiring and Barnard (CE) Inc.

Several very large open-cast collieries are operative on the Mpumalanga Highveld and these are contributing a substantial salt load to the water resources in the area. One of the problems facing regulating authorities and mines is the lack of tools by means of which to predict how mining operations affect water quality over time. This project contributed to the development of a generic mine-water model which can be used to predict the water balance on an open-cast mining operation, including runoff, seepage, and groundwater recharge. The model simulates the water flow and associated water quality over the operational life of an open-cast pit. The simulation is done for a selected hydrological sequence and operates at a monthly time-step. The open-cast pit is subdivided into a number of individual mining blocks to allow the mine scheduling to be incorporated into the model. Each mining block is further subdivided into up to 10 horizontal layers. This allows the simulation of the vertical spatial variation of oxygen and water migration.

Cost: *R388 600*
Term: *1993-1995*

Screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines

(No 582) Department of Plant and Soil Science, University of Pretoria

Plants can play an important role in ameliorating the negative effects of poor-quality mine drainage water. They are being used in wetlands designed for water treatment, or to utilise water (which otherwise would be only a liability) for the irrigation of suitable crops. Many plants will, however, not survive exposure to mine drainage and, therefore, suitable plant species for this purpose need to be selected. This project aimed to identify plant species which would be suitable for cultivation under irrigation with polluted mine waters, or as wetland species, in order to either improve the water quality or put it to beneficial use. Selected crops and pastures suitable for cultivation under prevailing climatic conditions and under irrigation were investigated under applicable glasshouse, growth-chamber and field conditions for their tolerance to lime-treated acid mine drainage (AMD). Other high-sulphate and sodic-saline waters were also investigated under controlled conditions. In addition, some wetland species were investigated, and some tentative studies were conducted on possible soil-physical and -chemical changes associated with application of treated AMD. The latter were conducted in soil columns, as well as through modelling of the soil-chemical changes observed in the field trials. It is now clear that neutralised AMD can be used for irrigation of a large range of crops.

Cost: *R329 000*
Term: *1993-1996*

Development of an information transfer, extraction and management system for mine-water management and treatment

(No 750) Pulles, Howard and De Lange Inc.

Millions of rands are spent annually on mining-related research in South Africa and many times more is spent internationally. Despite this level of effort and financing, most local users remain unaware of the information which is available to assist them in managing mine-water systems and resources. Users, such as mines, furthermore, seldom have the capability to keep up to date with all these developments. This project developed a computerised Information Transfer, Extraction and Management System (ITEMS) which enables users to gain access to local and international information on mine-water quality, management, treatment and research. The six modules incorporated in ITEMS, viz. literature, water quality guidelines, contaminant properties, research results, an impact assessment manual and a mine-water management manual, and the options available in each of the modules, render ITEMS an extremely versatile information tool. The total computer file size of the databases is 87 Mbytes. ITEMS is available on CD-ROM.

Cost: *R172 900*
Term: *1996-1997*

New projects

Quantitative evaluation of water utilisation in different rehabilitation methods for slimes dams

(No 899) Envirogreen and Freegold

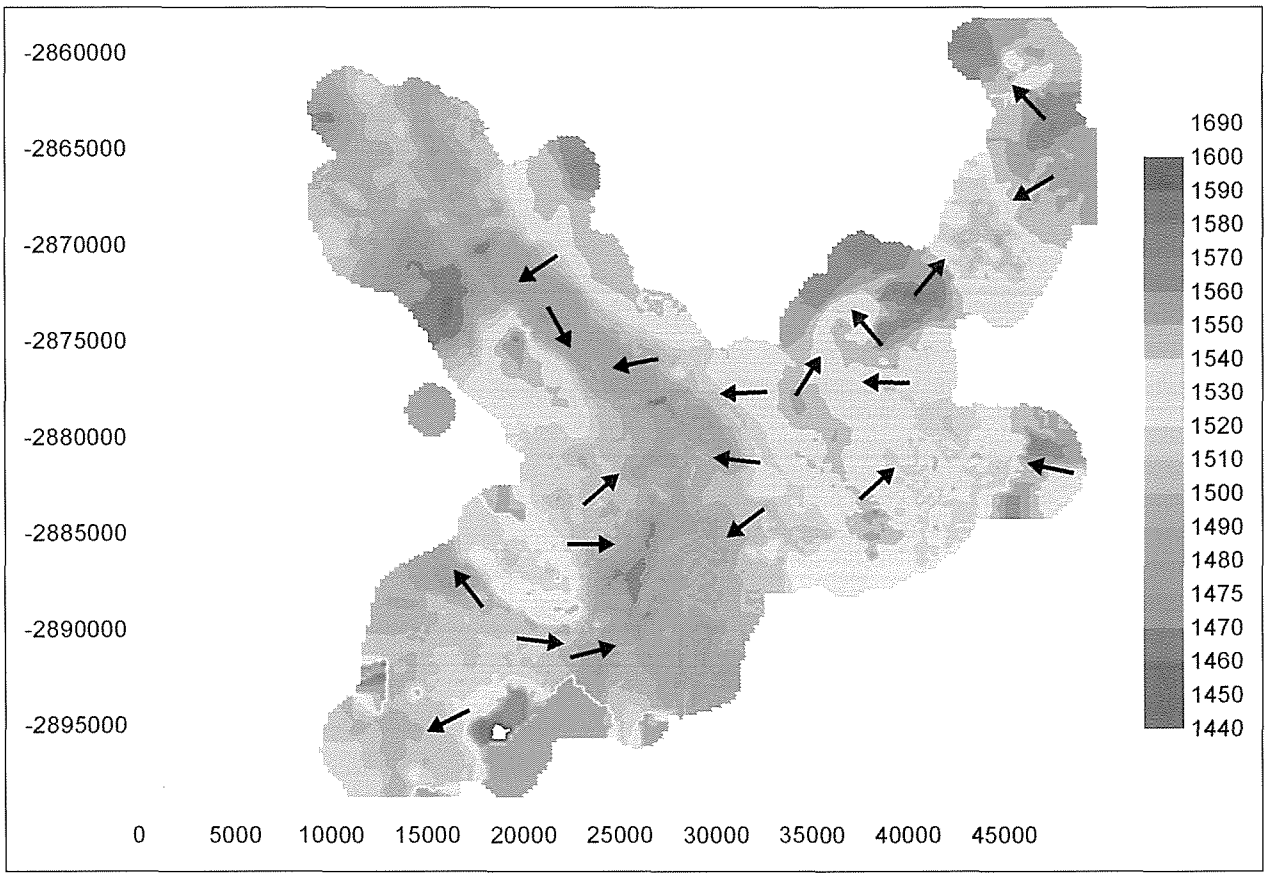
The rehabilitation/stabilisation of slimes dams at gold mines is important not only from an aesthetic point of view, but also to impede detrimental impacts on the water and general environment. Indications are that the irrigation requirements of the various rehabilitation methods currently in use can differ substantially, and are largely governed by the need to leach excess salts and acidity from the slimes-dam "soils" and the required water quality and quantity of the vegetation cover. Of importance here is the vegetation cover used; the more sustainable the vegetation is, the less water is needed to maintain it. Exotic vegetation often needs more water than indigenous plants, and it is thus important to identify the most suitable vegetation for slimes dams. Moreover, the sustainability of the vegetation without the need for further irrigation must be reached as soon as possible in order to save more water in the long term. This project aims to determine which of the present rehabilitation methods require the least water during the initial vegetation stage, and identify the method of slimes-dam rehabilitation which requires the minimum amount of water for the most sustainable end-product.

Estimated cost: *R123 000*
Expected term: *1998-2001*

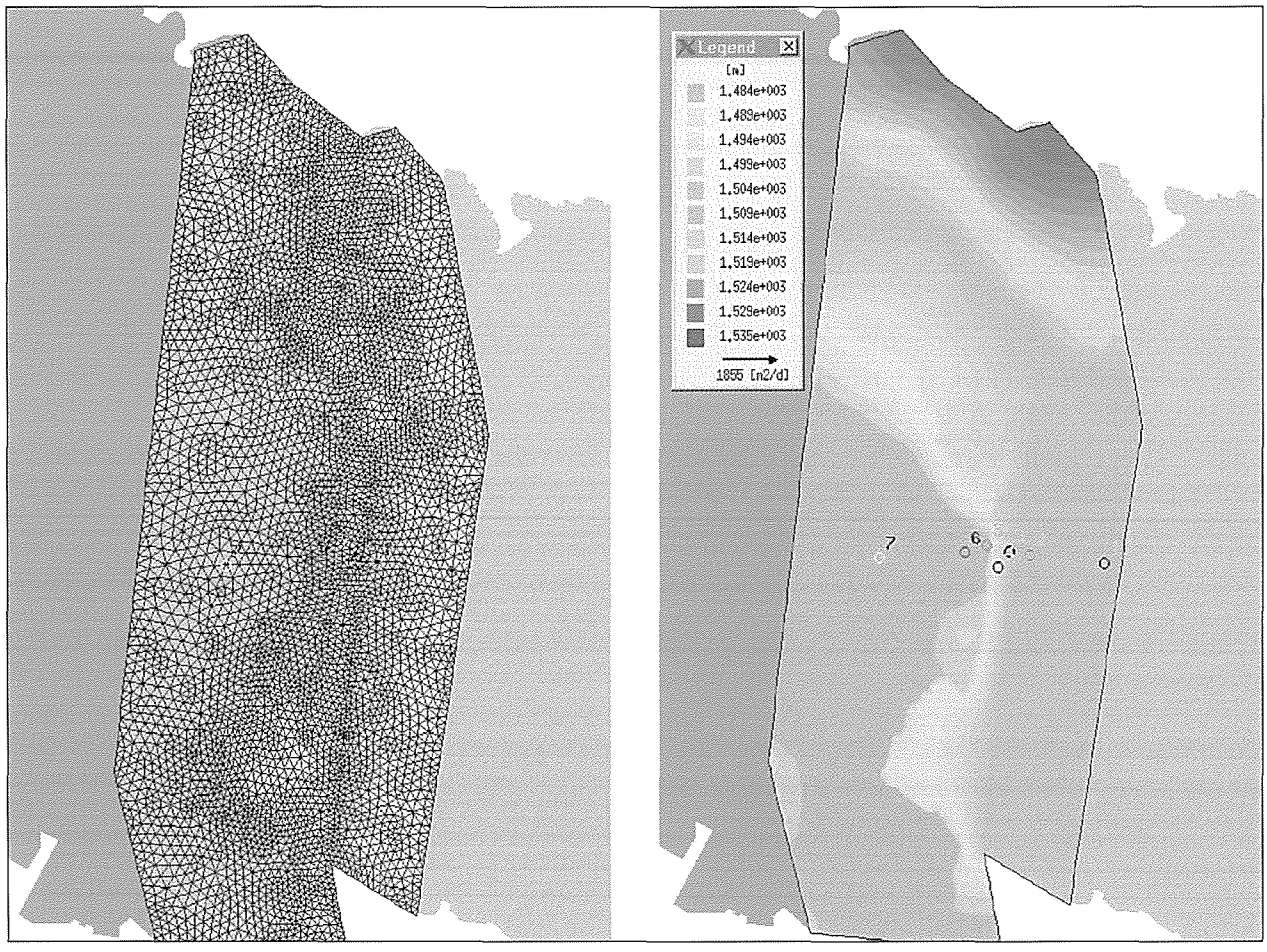
Development of a management strategy for the controlled release of saline mine water during flood conditions in the Witbank Dam catchment

(No 900) Ninham Shand (Cape) Inc. and Wates, Meiring and Barnard (CE) Inc.

DWAF recently undertook a pilot project to assess the viability of allowing controlled saline mine water releases during flood conditions as one of the water quality management tools in the Upper Olifants River catchment. The project gave some encouraging results, but concerns were expressed about the prediction and management of impacts at abstraction points within Witbank Dam and local impacts immediately downstream of mine-water releases. A continuation of the controlled release of saline mine water, would therefore be dependent on the availability of modelling tools to sup-



Floor contours and mine-water migration directions in a selection of coal mines for the Mpumalanga coalfield.



Finite element network and modelled results, demonstrating the degree of mine-water interflow between two mines.

port the decisions which are made. The project aims to achieve two linked objectives; viz. the simulation of water and salinity profiles in the upstream catchment and establishment of a hydrodynamic salinity simulation model of the Witbank Dam. Both these models will be tested, using field observations of flow and quality. The models will then be integrated and used to compile a rule-based approach to the future management of saline mine-water releases in the Witbank Dam catchment.

Estimated cost: *R300 000*
Expected term: *1998-2001*

Development of an Internet Service Centre on water-modelling systems for the mining industry

(No 901) Pulles, Howard and De Lange Inc.

The use of predictive models is becoming more commonplace to assist with a wide range of issues, from mine planning through to decommissioning. Water resource modelling covers the fields of hydrology, water quality, geochemistry, groundwater, water and salt balances, and radiation. As the available models for a specific task multiply, all users find it increasingly difficult to select the most appropriate model for a specific task. This project aims at providing users with information which will assist them in the selection process by describing those models which are currently in use in South Africa, as well as those models which could be used, but which are currently only used in countries abroad. An Internet Service Centre (ISC) will be established which will provide details on various aspects of each model as well as its availability and use locally and internationally. Links will be established to local and international studies. The ISC will be housed at the CCWR in Pietermaritzburg. Although not directly responsible for the maintenance of the site in the future, the CCWR will provide technical support to the maintenance team.

Estimated cost: *R300 000*
Expected term: *1998*

Research projects

Completed

- **413** Use of vegetation in the amelioration of the impact of mining on water quality – An assessment of species and water use (CSIR – Division of Water, Environment and Forestry Technology)
- **528** Development of an integrated and generic water quality simulation model for open-cast coal mining water circuits (Wates, Meiring and Barnard (CE) Inc.)
- **582** Screening of crop, pasture and wetland species for tolerance of polluted water originating in coal mines (University of Pretoria – Department of Plant and Soil Science)
- **750** Development of an information transfer, extraction and management system for mine-water management and treatment (Pulles, Howard and De Lange Inc.)

Current

- **454** Occurrence of bacteria causing acid mine drainage in the outer layers of coal waste dumps (University of Stellenbosch – Department of Microbiology)
- **575** Calibration of models for the design of covers for open-cast mine and waste dump rehabilitation (Wates, Meiring and Barnard (CE) Inc.)
- **647** Application of isotope chemistry to quantify the contribution of gold and coal mines to salt pollution load in groundwater and rivers (CSIR – Division for Earch, Marine and Atmospheric Science and Technology)
- **699** Prediction techniques and preventative measures relating to the post-operational impact of underground mines on the quality and quantity of groundwater resources (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., the 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)

New

- **899** Quantitative evaluation of water utilisation in different rehabilitation methods for 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 (Ninham Shand (Cape) Inc. and Wates, Meiring and Barnard (CE) Inc.)
- **901** Development of an Internet Service Centre on water-modelling systems for the mining industry (Pulles, Howard and De Lange Inc.)

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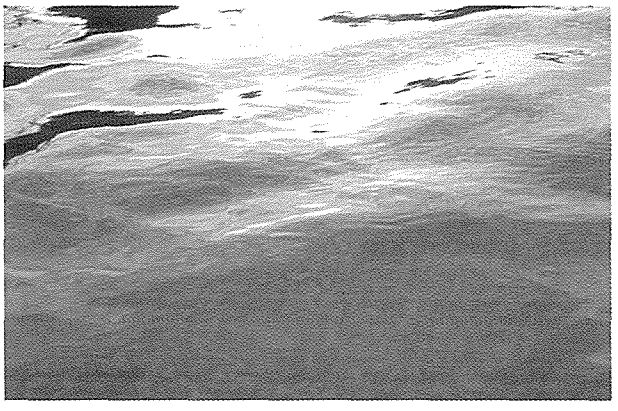
15 Water policy



In recent years dynamic and purposeful policy changes have been brought about in the water sector.

This has involved public consultation, release of various discussion documents, publication of the White Paper on a National Water Policy and promulgation of the Water Services Act and National Water Act. Indications are that the emphasis has now shifted from formulation to the implementation of policy. The issues under consideration for the effective management of the demand and supply of water are:

- Taking the value of water into account when calculating cost
- Measuring water use and relating use to actual cost of supply
- Recovering cost partially or fully from direct beneficiaries.

The implication for policy research is that priority attention must be given to guidelines that will promote active participation of water users in water resource management. Experience in South Africa and internationally has already demonstrated that transferring management responsibilities from a central to a local level leads to an improvement in water delivery services and a reduction of operation and maintenance cost. Since a government department usually retains control over water resources and the main storage and distribution network, communication lines must be established between representatives of private water users and public authorities. The strategies, functions and structures of organisations such as Catchment Management Agencies and Water User Associations must therefore be investigated in more detail.

Another area of research is the application of economic and legal or regulatory policy instruments for the integrated management of the quantity and quality of surface and underground water. The social, economic and ecological impact of various water tariffs and pollution charges which can be combined with quotas and licences or public education and persuasion, must be analysed further. Effective policy advice requires, amongst others, information on the value of water for ecological, domestic, agricultural and industrial uses; the elasticity of demand and the response of water users to tariff increases; the appropriate levels of tariffs and charges to influence the quantity and quality of water used; and the recovery of water supply cost without creating additional tax burdens which are disincentives for productivity growth and economic development.

Having specified the information requirements in the previous annual report, the ongoing and new research projects focus predominantly on valuation of water resources and various aspects relating to water tariffs and pollution charges. Although a start has been made to develop management guidelines for local service providers, more research needs to be done on water organisations.

Completed projects

Establishment of a research framework for local authorities and the preparation of the first part of a series of management guidelines for water and waste departments in local authorities

(No 758) Palmer Development Group

The output from this study is a set of guidelines entitled *Management Guidelines for Water Service Institutions*. These Guidelines emanate from a need identified by local authorities to deal with:

- Tariff-setting
- Dealing with consumers
- Reporting procedures
- Determining need and demand for services
- Structuring effective water and waste agencies.

The Water Services Act, Act 108 of 1997, can be considered to be one of the most important pieces of water legislation in our history. The development of the Guidelines came at a very opportune time coinciding with the drafting of the Act. Hence, many of the principles of the Act have been incorporated into the Guidelines. The Guidelines do not represent statutory requirements and have to be used at the discretion of the user. However, the Guidelines have been prepared with input from key national government departments and senior representatives of local governments. Thus it represents a 'reasonable consensus' with regard to an approach to the key activities addressed in the series.

The Guidelines are intended to assist those who are responsible for providing water services (water supply and

sanitation). The approach used is as far as possible, to identify best practice and to provide a methodology for carrying out various key activities. It has been written primarily for people with some experience in the field of water services provision and may also be of use as an educational tool for those who are new to the water services field.

As mentioned, central to the Guidelines are principles of the requirements of the Act. The Guidelines comprise seven modules, representing a first step towards a comprehensive series of guidelines, which cover key activities of a water services provider being:

- Governance
- Management and administration
- Finance
- Planning
- Projects
- Customer relations
- Operations.

The seven modules deal with only three of the activities listed.

The Guidelines are supported by two related but separate user manuals and software, i.e. the *Sanitation Services Model* (SSM) and the *Water Supply Services Model* (WSSM). These models and their associated manuals, the *Water Supply Services Model Manual* and the *Sanitation Services Model Manual*, have been developed in a user-friendly format to assist water service authorities in financial planning of their services and for tariff-setting. They are written in a format that will eventually provide the user with a Water Services Development Plan (WSDP).

It is envisaged that the Guidelines and its components are a first step towards assisting local authorities to operate and function in a financially viable and sustainable manner which will ensure continued services to all consumers. In doing so they also fulfil many of the principles as set out in the Act.

Cost: *R380 000*
Term: *1996-1997*

Development of a legal framework to provide for the effective management and sustainable utilisation of South Africa's groundwater resources

(No 789) DWAF

This project was commissioned to contribute to the South African Water Law Review process. Its goals included formulation of a coherent national groundwater policy and development of a broad enabling legal framework and practical procedures to give effect to this policy.

The point of departure, as reflected in the final report, was to ascertain the problems currently being experienced in relation to the management and allocation of groundwater. This involved two stages. The first outlined the existing legal framework governing groundwater management in South Africa and highlighted some of the legal problems encountered, while the second stage dealt with practical problems experienced in the management of South Africa's groundwater resources. The latter information was obtained from responses to questionnaires and the outcome of a workshop involving a range of both public and private groundwater managers and experts. Having ascertained the problems, the next step was to review international trends in groundwater law and management. The focus was on developing and examining international solutions to local problems. This was undertaken essentially as a desktop study and thus necessarily had shortcomings. While recognising the need for investigating the enforceability and applicability of foreign legislation under South African conditions, this review of foreign legislation did provide a firm foundation for a local legal framework.

Cost: *R80 400*
Term: *1997*

Seen at a seminar on the Introduction of the WRC *Management Guidelines for Water Service Institutions*, hosted in association with WISA (Institutional Affairs and Management Technical Division) and DWAF, held on 2 October 1998, were, from left: John Mokhele (Central District Council), BA Dandashe (Magalies Water) and NF Mokumo (Springs City Council).

Speakers at the panel discussion, from left: Fred van Zyl, Helgaard Muller, Joanne Ferreira and Hendrik Best, all from the Department of Water Affairs and Forestry.

Upgrading of the *Water Supply Services Model* (WSSM)

(No K8/294) Palmer Development Group

and

Upgrading of the *Sanitation Services Model* (SSM)

(No K8/316) Palmer Development Group

From a review commissioned by the WRC of institutional and financial facets of water-supply and sanitation services in the urban areas of South Africa, the invest-tariff model was developed with the purpose of assisting the agencies responsible for water supply in urban areas in the development and evaluation of investment scenarios and tariff policy. This model was further developed and extended and included the sanitation aspects. This revised model has been tested and is widely used by a number of water services institutions.

In the light of recent developments, it was necessary to upgrade this initial investment tariff model, to make it more user-friendly, allowing for inflation and making full use of the experience gained in the development and application of the model. The output is the *Water Supply Services Model* (WSSM) and *Sanitation Services Model* (SSM) software and associated manuals. These new models and manuals have been developed in a user-friendly format to assist water services authorities in financial planning of their services. The models also complement the *Management Guidelines for Water Service Institutions*, providing a systematic and standard format towards developing a Water Services Development Plan (WSDP), as required by the Water Services Act, Act 108 of 1997.

The User Manuals are intended to facilitate understanding and use of the WSSM and SSM. The key assumptions of the models are discussed, the structure and data inputs required are described and model results explained.

Cost: *R70 000 and R15 300*
Term: *1998*

New projects

Development of a tool for evaluating the effect of alternative funding options (with different risk profiles) on water tariffs

(No 887) PAA Ramsden, Private Consultant

Previously, funds for water supply infrastructure were provided mainly from treasury allocations. In future, however, government policy will be to encourage the mobilisation of private sector funds for the development of water supply projects. This policy has been confirmed with the Department of Finance and in policy meetings with DWAF. Proposals to restructure the water industry to enable the greater use of private sector funding are already in preparation.

The Development Bank of Southern Africa (DBSA) and commercial lenders have indicated their willingness to provide funding for infrastructure in future. Many local authorities, however, still lack the organisational capacity at this stage to evaluate and negotiate loans of the scale required to upgrade water infrastructure. The lenders are also not comfortable with their own ability to evaluate all the risks to which they may be exposed.

The primary aim of the project is to develop a computerised tool, for use by water service providers (the borrowers), to evaluate alternative sources of finance.

Each source of funds and available financial instrument (such as a water bond) has its own cost variability or risk profile, depending on parameters such as the variability of the interest rates, the foreign exchange component (movement in exchange rates), the life of the instrument (i.e. how many times it must be rolled over) etc. Risk can, however, be managed through hedging operations such as forward cover on future foreign exchange transactions. Hedging operations also have cost implications. The risk profile of the selected financial instruments therefore translates into a statistical distribution of the cost of capital over the life of the project, which in turn directly impacts on the financial break-even tariff which is passed onto the water user.

The proposed computerised tool will provide the decision-maker with the capability of stochastically modelling the distribution of the financial outcomes, in terms of the break-even water tariff.

Estimated cost: *R192 000*
Expected term: *1998-1999*

Financial planning and modelling for regional water-supply service providers

(No 896) Palmer Development Group

The provision of water-supply services to rural communities is perhaps the most important objective of the government, given the extent to which the service can improve the health, quality of life and economic opportunities of people in these communities. In providing such services proper financial arrangements are of central importance: technical and level-of-service decisions need to be taken in a context of financial constraints and the ability of the service provider to generate sufficient income to manage the service in the long term.

The aims of the project are to:

- Develop a model which is useful to service providers such as water boards and district councils
- Promote the provision of water-supply services to unserved or underserved people in rural areas in a financially sustainable way
- Develop a financial planning model which assists with decision-making with regard to service levels, investment, pricing and financing options related to water supplies
- Apply the model to two case studies in South Africa and thus directly assist two organisations who are involved with water supply to rural areas
- Identify factors affecting the viability of regional water service providers.

Estimated cost: *R144 000*
Expected term: *1998*

Improved management of assets in the water-supply industry with regard to possible privatisation

(No 897) Water Systems Research Group, University of the Witwatersrand

Very few standardised data are available on the assets held by water boards, water service authorities and local governments concerning the value and condition of their technical assets. These assets range from pipelines and human resources, to purification works and water sources. In order to ensure continuation of the work which water authorities have done in the past and to enable South Africa to continue to receive good and reliable water at minimum cost, the documentation of the assets and methods of evaluation thereof

are of great importance. These assets include not only historically installed capital items, but also management systems and planning and design methodology and teams.

The project will investigate the necessity for asset management in the water-supply and sanitation sector. This will include methods of evaluation, condition, lifespan and value of assets. Information technology, accounting and GIS-based data collection systems will be investigated.

The intended output will be recommendations for a National Asset Management strategy and the tools to assist local authorities in managing their assets. The project addresses some of the principles and requirements of the Water Service Act, Act 108 of 1997, and the draft Water Regulations.

Estimated cost: *R400 000*
Expected term: *1998-1999*

Development of a methodology to determine the true value of water in the Berg River basin

(No 943) Department of Agricultural Economics, University of the Orange Free State

Public policy must clearly specify the rules and processes according to which the reallocation of water resources is to be negotiated in order to reduce uncertainty in a competitive economic environment. Individual entrepreneurs must be enabled to continue creating wealth through private initiative. Balanced economic growth must be achieved through a combination of increased productivity, reallocation of rights to water resources and redistribution of income. Improved efficiency and equity can be achieved by combining the discipline of the market process with responsible governance.

So far water management has been mainly supply-driven by determining the cost of providing water. No water system analysis has been done on the demand schedule for water and the value of water for current levels of consumption of different water uses. The approach in this project is therefore threefold: Firstly, evaluation of the economic consequences of competition for water, which involves issues of technical and economic feasibility, pricing of water rights and social welfare. Secondly, assessment of rules for improving the outcomes of allocation, that is, the principles and standards that guide policy choices. Thirdly, formulating proposals for an integrated water management system that will improve performance of the existing allocative mechanisms. The latter includes the problem of reallocation to serve changing consumer demands while remaining sensitive to existing lawful rights, basic human needs and third-party interests such as maintaining the ecological balance.

The main aim is the development of methodology to determine the value of water for different uses in the Berg River basin, an ideal test area because of its complexity in terms of its high agricultural potential, alternative water uses and contrasting supply management options.

The specific aims are to:

- Quantify the impact of different supply quantities and competition between different uses of water (i.e. agricultural and urban use) on the value of water
- Quantify the impact of a potential water market on different agricultural systems in the Berg River basin
- Quantify the impact of the re-allocation of water from agricultural use to urban use, in order to relieve the pressure on water supply for urban use and consider the possible postponement of the construction of the Skuifraam Dam.

Estimated cost: *R665 000*
Expected term: *1998-2000*

Development of a framework for the introduction of waste discharge charge systems in South African catchments

(No 949) Stewart Scott (CE) Inc. and Development Planning and Research

The National Water Act makes provision for a system of economic incentives to encourage reduction in pollution. Charges will be introduced for the discharge of waste into water bodies. Funds raised in this way will be used for resource quality management and protection activities. A current WRC project is aimed at the **Development of a philosophy and methodology for the implementation of "the polluter pays" principle in the context of the receiving water quality objectives** (No 793). This new project will build on the findings of this study by including a wider range of pollutants and focusing on implementation issues. The investigation of overseas charge systems revealed that only a few countries have developed their charges to the point where they form a significant deterrent to polluters. In designing a possible charge system for pollution reduction from the outset, SA is, to some extent, pioneering this type of instrument.

Estimated cost: *R400 000*
Expected term: *1998-1999*

Human resources needs assessment – tertiary level: South African water sector up to 2015

(No 977) Department of Civil Engineering, University of the Witwatersrand

SA is facing a major water-development task in the coming years. To a large extent these developments flow from the RDP and one of its highest priorities, namely to meet basic water needs. Human resources (HR) is one of the most important factors in the implementation of water projects. There are two facets to this, both of which are critical, i.e. sufficient numbers and appropriate skills.

Availability of HR suitably qualified at tertiary level (university or technikon) will determine to what extent SA will be able to meet the challenges of its future water developments. HR in adequate numbers at this level will form the basis of water-related research, water resource development and water resource management, and need to be planned for proactively. However, very little information is currently available on our HR requirements in the medium and long term.

The results of the proposed investigation will be of great value to tertiary training institutions, allow proactive steps by HR developers and will hopefully stimulate the water community at large to encourage water-related disciplines as career opportunities. The aims of this project include *inter alia* the following:

- To evaluate and establish the tertiary level HR needs of the water sector (government, industry, education, etc.) in SA over a period of 15 to 20 years and longer
- To examine the content of the current tertiary level education in the water sector and determine what the deficiencies are with respect to the needs of the country
- To propose an action plan for tertiary level education to ensure that HR do not become limiting to the advancement, delivery and development in the water sector in the future.

The project will address the important issues at the national, provincial and community levels, with the necessary interlinkages of the HR needs of industries, agriculture and other public or private (utility, consultancy, etc.) services.

Estimated cost: *R259 000*
Expected term: *1998-1999*

Incorporation of economic considerations into quantification, allocation and management of the environmental water reserve

(No 978) Institute for Natural Resources, University of Natal

Acknowledging that rivers are a resource, DWAF has made provision for a portion of the mean annual runoff of rivers to be reserved to sustain river systems. Instream flow assessment provides a process whereby the environmental reserve from an ecological perspective is quantified and characterised. This proposal is aimed at introducing economic criteria into this process. Government is also seeking to promote efficient use of water. To this end it is moving towards a water allocation system in which the value of water is acknowledged and taken into account. Being such a scarce commodity one can appreciate the importance of optimising economic return from water use.

The notions of an environmental water reserve and valuation of water are on converging paths. Citizenry has a right to understand the financial implications of allocation of the environmental water reserve for the environment and of how this will be managed given the vagaries of our rainfall. Without this knowledge and understanding, one cannot anticipate responsible stewardship of the resource.

This project, therefore, aims at evaluating the utility of a resource economics approach in contributing to the determination of the environmental water reserve. This will be achieved by:

- The development of a framework for incorporating economic criteria into the quantification, allocation and management of the environmental water reserve for rivers
- The application of the framework in a case study to provide a practical example of the applicability of the approach
- The enhancement of current methodologies for establishing the environmental reserve through the incorporation of the economic value and services of water
- An analysis of the policy implications of adopting the framework.

Estimated cost: *R488 000*
Expected term: *1998-1999*

Modelling the value of water as an economic resource in selected catchment areas in South Africa:

Great Fish and Sundays Rivers

(No 987) Department of Agricultural Economics, University of Natal

Great Letaba River

(No 989) Economic Project Evaluation (Pty) Ltd.

Vaal River

(No 990) Greengrowth Strategies CC

The emphasis in the economic aspects of water management in the past was on the cost of supply. Increasing competition between alternative uses requires that the attention must now focus on the value of water for ecological, domestic, irrigation, industrial and power-generation uses. Information on water values is essential for correct investment and production decisions by water users and policy decisions by national, provincial and local governments. This will contribute to efficient and equitable utilisation and allocation of scarce water resources.

Apart from separate sectoral analyses in defined subregions, no comprehensive comparison of the value of water for different uses has been undertaken in South Africa. In the absence of an active water-rights market and with the lack of a long-term database, a statistical analysis of price trends is at this stage inconclusive. The best option under these circumstances is to estimate water values through economic modelling. Substantial progress has been made overseas to develop and apply models for this purpose. It involves generating demand schedules and deriving the value of water (in c/m^3) for e.g. potable, irrigation and industrial water. These available models must be tested and applied and expertise must be built up amongst local researchers.

In view of the research backlog and the unacceptability of generalisations regarding water values, tenders were invited and approved according to specified guidelines. These projects will enable the determination of the value of water in different catchment areas, for various combinations of water-use sectors, following different modelling approaches by a number of competent research organisations. Within the strategic research plan as stated in the *1997 WRC Technical Report*, the objectives will be to:

- Determine the water balance
- Generate a demand schedule for water
- Quantify the value of water
- Compare the economic value with economic costs
- Explore a variety of scenarios with changing water values.

Estimated cost: *R2 046 000*
Expected term: *1998-2001*

Research projects

Completed

- **K8/294** Upgrading of the *Water Supply Services Model* (WSSM) (Palmer Development Group)
- **K8/316** Upgrading of the *Sanitation Services Model* (SSM) (Palmer Development Group)
- **758** Establishment of a research framework for local authorities and the preparation of the first part of a series of management guidelines for water and waste departments in local authorities (Palmer Development Group)
- **789** Development of a legal framework to provide for the effective management and sustainable utilisation of South Africa's groundwater resources (DWAF)

Current

- **512** Development of procedures for decision support in water resources management (University of Cape Town – Department of Statistical Sciences)
- **678** Pricing water as an economic resource (Palmer Development Group)
- **790** Estimation of the residential price elasticities of demand for water by means of a contingent valuation approach (Economic Project Evaluation (Pty) Ltd.)
- **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.)
- **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)
- **870** Pricing of water resources in South Africa with specific reference to riparian surface water (University of Natal – Department of Agricultural Economics)

New

- **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)

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16 Hydraulics

Although hydraulics featured for the first time as a research field in its own right in the WRC's 1997 Technical Report, *the first hydraulics-related research project funded by the WRC dates back to 1975.*

However, scrutiny of the approximately 1 000 completed and current projects funded by the WRC since 1971 reveals that about 70 research projects dealt with or are dealing with facets of hydraulics research. Furthermore, it may be stated without fear of contradiction that well-established hydraulics theories and principles are wittingly or even unwittingly being applied in most of the balance of WRC-funded projects.

The above serves the purpose to emphasise that hydraulics (by definition that branch of science and technology concerned with the mechanics of fluids, especially liquids) essentially forms an integral part of just about all facets of water-related research. Hydraulics research, therefore, has been, is and will always be important to any water-related research. There is, in addition, also general agreement that South Africa has a dearth of suitably qualified experienced hydraulics researchers who could substantially and significantly contribute not only to the solution of hydraulics problems, but who could also participate in multidisciplinary research teams as and when the need arises.

Against this background the WRC considered it necessary to take steps to address the problems requiring hydraulics research inputs, thereby establishing a proactive approach in formulating what could be considered a framework for a master research plan. A workshop in this regard was held in March 1998 and paved the way for a guide aimed at assisting researchers in developing research proposals concentrating on priority issues.

Hydraulics research workshop

An analysis of previous WRC involvement in this research field, indicated that the majority of completed hydraulics research projects addressed the **Water Conservation** concern, whilst (in line with current priorities) at this stage more projects are addressing the **Water Resource Development, Community Water Supply**, and **Protection of the Water Environment** concerns. There was general agreement that hydraulics research needs to contribute meaningfully and effectively to addressing the WRC's national water-related concerns. Discussions at the workshop culminated in the formulation of the following primary goal of hydraulics research in South Africa:

> *To acquire adequate understanding of all facets of hydraulics in order to develop appropriate technologies required for the solution of those problems impacting on the assessment, management and sustainable equitable utilisation of Southern Africa's water resources.*

In order of priority the workshop identified the following secondary goals which, on achievement, would all be instrumental in solving those issues incorporated in the above primary goal:

- Sediment properties, sediment transportation, sedimentation in reservoirs and dams, and desilting
- River hydraulics with special emphasis on river morphology and flood routing
- Eco-hydraulics, i.e. the requirements of the natural environment (e.g. rivers and estuaries) as far as hydraulics and associated issues are concerned
- Surface and subsurface drainage especially regarding impacts of structures, functional requirements of these structures and design guidelines
- Optimisation of storage facility design, construction and management, focusing on reservoirs, dams and weirs
- Conveyance and distribution infrastructure: Economic and functional optimisation of canals, tunnels, pipelines, distribution systems, pumps and other relevant equipment
- Flow measurement in pipes, canals, tunnels and rivers: Construction, cost and reliability
- Flow and pressure regulation, and associated problems
- Hydraulic problems associated with water and wastewater treatment infrastructure e.g. settling tanks and filtration plants
- Hydro-informatics and data processing required for *inter alia* integrated catchment management, flood management and computational fluid mechanics
- Hydraulic facets of beach erosion, disposal at sea sites and coastal engineering.

These secondary and associated tertiary goals are currently being consolidated into a strategic research plan for hydraulics research in South Africa, which will hopefully be a guide, not only to the hydraulics research community, but also to the WRC and other funding agencies.

Completed projects

Development of improved flow-gauging structures for South African rivers

(No 442) Sigma Beta (CE)

This project has been executed in two phases:

During the first phase, upgrading and standardisation of existing flow-gauging structures were attended to in order to improve the quality of runoff data. In addition, development of a structure requiring little maintenance and yet being able to provide accurate data on a sustainable basis, was also researched. Both these facets were reported on in the WRC's *1994 Annual Report*.

The first phase, however, also identified the following additional research needs which were subsequently attended to during the second phase:

- Calibration of larger-scale models in order to determine the extent of possible scale effects, especially under low-flow conditions
- Calibration of the sluicing flume developed during the first phase, when incorporated into other gauging structures currently in use by DWAF
- Under conditions where the sluicing flume forms an integral part of other gauging structures, information is required on its performance under submerged conditions.

Research during the second phase resulted in various recommendations regarding sluicing flume lay-outs with d/b ratios of 0.25, 0.5 and 1.0, and when combined with sharp crested weirs (d = depth of the flume; b = bottom width of the flume). The research confirmed these flumes' good characteristics with respect to handling heavy sediment loads. It displayed stable calibration characteristics, unaffected by variations in the adjacent weirs. In the case of higher flows which overtop the abutment walls, the recorded water level is converted to a corresponding energy level in the upstream pool which is not seriously affected by sediment deposition in the pool, thereby providing for more accurate estimates under these conditions. Flow gauging with these flumes is possible up to 95% drowning. Furthermore, the flumes, being relatively short in comparison with previous recommendations, are easy to construct, but still have stable calibration characteristics.

Cost (second phase): *R209 000*
Term (second phase): *1995-1997*

Control of dam siltation in South Africa

(No 580) BKS (CE) Inc.

Dam siltation has always been and still is a serious problem in South Africa.

Much has been written and done to solve the problem proactively, but the end result is that the sediment production rates are still high and vary from 37 to 740 $m^3/km^2 \cdot$year for the different areas in Southern Africa. Sediment production rates of this magnitude cause an annual decrease in the storage capacity of reservoirs in the different areas of between 0.2% and 0.9% (average for the country as a whole: 0.52%).

The project investigated different techniques which would control and manage dam siltation in South Africa. Control methods which have been investigated, include:

- Allowing incoming sediment through during peak flow periods
- Flushing of reservoir basins by decreasing water levels
- Diversion of incoming flow with high sediment loads
- External canal storage
- Density flow
- Sediment removal with piping
- Dredging of silt deposits.

The following key results have been obtained from the study:

- An extensive field reservoir monitoring programme during high-flow conditions and operations varying from storage to drawdown flushing, made it possible to establish a general sediment transport relationship through reservoirs for South African conditions. This relationship can be used in future planning of reservoir sedimentation.
- The sediment transport through reservoirs was found to be significantly underestimated by any of the well-known sediment transport equations used internationally if such an equation was calibrated on flume and/or river data only. This explains the typical delta formation in the upper reaches with almost no transport into the reservoir area as simulated by most computer models based on such models.
- A new total load sediment transport equation was derived based on applied unit streampower principles. This relationship was calibrated with laboratory, river and reservoir data and its accuracy was found comparable with other often used international equations.
- Recommendations regarding water resource planning and development for control of reservoir sedimentation in selection of measures as well as guidelines for operation have been proposed for South African conditions based on international experience.
- Environmental beneficial or adverse impacts of various sedimentation control measures have not been addressed in detail, but certain aspects have been highlighted with case studies.

Cost: *R736 600*
Term: *1993-1997*

Removal of floating and suspended materials from streams

(No 691) Department of Civil Engineering, University of Stellenbosch

Basically the objective of this project was to thoroughly analyse the designs for trash and sediment removal currently available, and to investigate the various possibilities to improve the performance of these designs in order to provide local authorities with design criteria to eliminate or at least reduce a problem which has far-reaching environmental and aesthetic impacts.

A two-pronged approach was followed during the execution of this project. One attended to trash removal and was reported on during 1998. The other attended to sediment removal, the final report on which should be available during 1999. As far as trash removal is concerned, some of the results were as follows:

- Amount of litter coming off urban catchments: This part of the project was a desk study which evaluated the various approaches followed in South Africa and mainly in Australia and New Zealand. Although these two countries are the closest to the South African situation, the problem is still much worse here than in these two countries – approximately two orders of magnitude worse. Based on

observations in Springs and Johannesburg, a tentative formula for calculating the total litter load in waterways is proposed.
- Section 3 of the report focuses on some ways of preventing litter from getting into the drainage system in the first place, and then goes on to describe the ideal litter trap and some of the difficulties experienced in the trapping of litter.
- A series of model studies into the optimum design of litter traps was conducted at the Universities of Stellenbosch and of Cape Town. These experiments emphasised the complexity of the problem since the size, shape and density of the litter play a role in the effectiveness of litter traps. Further complicating factors are the fact that very often the behaviour of a single item changes as it moves through the drainage system, and the fact that the flow rate in channels changes continuously. During the model studies certain design principles were identified which warranted further investigation.
- Based on the above-mentioned model studies, further experiments were conducted, aimed at the development of self-cleaning structures. From the research it is concluded that for a litter-trapping structure to be self-cleaning, it has to have a thin sheet of high-velocity flow directed down a steeply inclined screen with a relatively small velocity component through the screen. Some form of surging flow would greatly improve the self-cleaning action. Screens *per se* should offer as little resistance as possible to litter sliding along their surfaces, and litter that does penetrate the openings of the screen, should not get caught on the bars. Even meeting these specifications, these screens still require considerable head for their operation which often is not readily available. Under these conditions compromises are required.
- The problems associated with a number of in-line screens were analysed. The properties of the more successful designs in this regard are being evaluated.

Cost (trash removal): R205 000
Term (trash removal): 1995-1997

Flume constructed for experiments related to research on sediment-induced density currents (University of Pretoria).

New projects

Monitoring reservoir-induced crustal deformation using satellite-borne interferometric imaging radar

(No 910) Department of Electrical Engineering, University of Cape Town

The usual methods used for monitoring crustal deformation associated with a new reservoir involve using a benchmark network and conventional geodetic techniques. These techniques require on-site repeat measurements to be made by land surveyors, and furthermore, the measurements can only be obtained in a discrete number of positions. The terrain surrounding the Katse Reservoir, and many others like it, is inaccessible by four-wheeled vehicle, thus making such surveys either difficult or expensive.

Recent studies on Differential Interferometric Aperture Radar (InSAR) have shown it to be a potentially useful tool for precise measurement of small ground deformations over large areas. It has been tested successfully in various situations including areas of ground subsidence due to mining activities, deformation associated with earthquakes, landslides, and also in regions of ice movement.

The principal purpose of this particular study will be to test the applicability of InSAR to the monitoring of crustal deformations due to the loading effects of a new reservoir. If successful, the results of this study will be used to infer some fundamental rheological and geophysical properties of the earth's lithosphere in the vicinity of the reservoir chosen for study.

Mainly for reasons of timing, the area of the Katse Reservoir in Lesotho has been chosen as the test site. The impoundment of the reservoir, and the first filling phase happened to coincide with the European Space Agency's (ESA) tandem ERS1/2 mission which provides a unique opportunity for interferometric work of this nature. It also provides an opportunity to test the capability of InSAR to provide information which is of cardinal importance for dam safety.

Preliminary modelling of the loading effects of the Katse Reservoir on the lithosphere have suggested that the vertical ground displacement will be in the order of 10 to 20 cm in the immediate vicinity of the dam, and as much as 1 mm 50 km from the dam. For the purposes of this modelling exercise, various assumptions had to be made with regard to

the physical properties of the lithosphere in the Lesotho region. So, by reversing the model, and entering the deformational information, it is expected that the lithospheric properties such as flexural thickness will in effect be measurable quantities.

As the Katse Reservoir also happens to be situated in mountainous terrain, this will provide a useful test for the generation of digital elevation models which are produced as a by-product of SAR interferometry.

Estimated cost: *R211 000*
Expected term: *1998-1999*

Sediment-induced density current formation in reservoirs

(No 911) Department of Civil Engineering, University of Pretoria

Density currents in reservoirs form one of the means of sediment transport through a reservoir and can be utilised to pass high sediment loads through a reservoir, thereby limiting reservoir sedimentation. It is important to know under which conditions a sediment-induced density current will form, since this will determine the mode of sediment transport through the reservoir which will affect the sediment deposition process. Tunnel intakes (e.g. Mohale Reservoir, Lesotho), intakes at the dam, pump stations in the reservoir (e.g. Tienfontein at Welbedacht Dam) and purification plants can be severely affected by sedimentation.

The main purpose of this work will be to prove the theory developed in WRC project No 580 **Control of dam siltation in South Africa**, completed in 1997, for predicting the formation of density currents induced by sediment transport in reservoirs. This will be achieved by:

- Use of data provided by various Chinese research organisations
- Use of Chinese reservoir data
- Use of laboratory data acquired at the University of Pretoria with a view to confirming the wide range of applicability of the prediction method
- Possible modification of the theoretical assumptions according to the results.

Finally, tests will be conducted to establish whether it would be possible to "force" density current formation in a reservoir, based on the new calibrated theory. Such an option would mean a tremendous breakthrough in the control of reservoir sedimentation.

This proposal addresses one of the recommendations for further research made in the final report of the previous WRC project. Past research in RSA has elevated theoretical know-how on the subject of density current formation to a level which is the state of the art in the world today. Confirmation and calibration of this theory will not only solve the RSA's problems when modelling reservoir sedimentation processes, but will also make a substantial contribution to international research and development.

Estimated cost: *R91 000*
Expected term: *1998-1998*

Hydraulic characteristics of ecological flow requirement components in winter rainfall rivers

(No 979) Department of Civil Engineering, University of Stellenbosch

The ecological flow requirements of SA rivers, provided for in the principles of the new Water Act, have been the focus of three major research projects in recent years:

- A rapid assessment approach known as the building-block methodology (BBM) for in-stream flow requirement (IFR) assessments: The ecologically important components of the natural flow regime in a river that ensure a thriving river ecology are determined by expert assessment of the geomorphological, hydrological, hydraulic, riparian vegetation, aquatic biota, water quality and human social needs at a few critical reaches.
- Studying primary abiotic and biotic linkages conceptually for different types of rivers, using generic models to identify priority field and laboratory research, in the KNPRRP: The generic understanding of habitat-plant-organism interactions is used to derive predictive rule-based models for predicting biotic responses to abiotic changes.
- Linking empirically abiotic and biotic patterns on a regional basis: Intensive mapping of aquatic organisms and plants is being overlaid with individual fine-scale classifications of geomorphological units and of flow types in selected river reaches. By comparing pristine reaches with reaches subject to varying degrees of human impact, predictive knowledge on biotic responses to abiotic changes is acquired.

Due to the complexity of ecosystem dynamics, the advances of these projects are still subject to degrees of uncertainty. This project is intended to initiate research in the hydraulics field in winter rainfall rivers, thereby reinforcing the BBM-IFR approach and providing detailed inputs to the biotic-abiotic links research. To achieve this, depth-discharge relationships are needed for monitored reaches. The cobble-bed rivers of the winter rainfall area have energy losses which are not friction-dominated, but transition-dominated. No practicable methodology exists for the calculation of flow depths in these streams.

This project, therefore, aims to:

- Determine regional patterns in hydraulic characteristics of the individual components of ecological flow requirements in rivers of the winter rainfall region
- Derive a universally applicable methodology to calculate energy losses in streamflow in cobble-bed rivers of the winter rainfall region in order to determine stage-discharge relationships
- Determine the hydraulic characteristics of winter rainfall region monitoring sites used in the WRC project on biotic-abiotic links conducted by the Freshwater Research Unit of the University of Cape Town.

Estimated cost: *R450 000*
Expected term: *1998-2000*

Measurement of high flows in rivers

(No 980) Sigma Beta (CE)

In a previous project, entitled **Development of improved flow-gauging structures for South African rivers** (No 442), this research team concentrated on the upgrading of existing gauging stations and standardisation thereof, and the development of a gauging structure which requires minimum maintenance but ensures flow gauging of adequate accuracy. The results of this project (published in two reports) were well received by DWAF and implemented.

Subsequent to the publication of these reports, the Directorate of Hydrology of DWAF identified further research needs as far as flow gauging is concerned, especially regarding the performance of compound weirs under submerged conditions. Accuracies attainable by applying complex calibration theories to these structures when experiencing submerged conditions, are largely unknown. In a number of cases the Directorate of Hydrology compared theoretical cal-

ibrations with actual flow measurements or hydraulic models and these comparisons quite often indicated inaccuracies of up to approximately 20%. This procedure, however, is very time-consuming.

Accurate measurement of high flows is necessary not only as far as flood peak statistics are concerned, but also for water resources analyses. Large percentages of total runoff are often discharged during floods of short duration, and then it is imperative to measure not only the peaks of the floods as accurately as possible, but also their volumes. This project, therefore, aims to develop guidelines on how to improve the accuracy of high flow measurement by means of compound gauging structures, especially under submerged conditions.

Estimated cost: *R460 000*
Expected term: *1998-1999*

Development of a stochastic technique for the optimisation of pipe and reservoir systems

(No 985) Department of Civil and Urban Engineering, Rand Afrikaans University

Stochastic analysis of systems is a technique that has been applied with great success in numerous fields, including water supply. The technique which has been developed at the Rand Afrikaans University over the last few years, however, is unique and has been recognised internationally at conferences and in journals. It has also been recognised as one of two important South African "emerging technologies" in the water field by the International Water Supply Association.

The main advantage of the technique is that it is possible to link the risk of a bulk water supply system failing to the cost of the system. This means that if the acceptable risk of system failure is known, as is the case with design guidelines for developing communities, the optimum reservoir capacity might be determined using the stochastic technique. Experience with the technique has shown that in many cases the "48 h of annual average daily demand"-rule, specified in the "Red Book" for the sizing of reservoirs, results in over-estimation (with resulting over-spending) of the required reservoir capacity.

The aims of the study are as follows:

- To compile a comprehensive report on the state of knowledge regarding stochastic analyses of water supply systems and reservoir optimisation techniques.
- To develop an algorithm to use stochastic analysis techniques for the optimal design of pipe and reservoir systems. It is specifically aimed at optimising the bulk pipeline(s) from the water source to the storage reservoir, including the reservoir itself.

The algorithm is to have as optimisation variables the pipe diameter, pipe configuration and reservoir capacity. The goal of the algorithm will be to find the best combination of optimisation variable values to provide water to a given level of reliability. The technique will provide engineers with a tool for the analysis and optimal design of bulk water supply systems and provide the following benefits:

- Ensure that bulk infrastructure is supplied at the lowest possible cost by linking the risk of failure of the system to the reservoir capacity and pipe configuration
- Ensure that money is not spent unnecessarily on the upgrading of bulk water supply systems.

Estimated cost: *R82 700*
Expected term: *1998-1999*

Research projects

Completed

- **442** Development of improved flow-gauging structures for South African rivers (Sigma Beta (CE))
- **580** Control of dam siltation in South Africa (BKS (CE) Inc.)
- **691** Removal of floating and suspended materials from streams (University of Stellenbosch – Department of Civil Engineering)

Current

- **433** Engineering properties of important Southern African rock types with special reference to the shearing strength of concrete dam wall foundations (Technikon Pretoria – School for Civil Engineering)
- **502** Plunge pool scour reproduction in hydraulic models (CSIR – Division of Water, Environment and Forestry Technology)
- **643** Development of rigorous engineering methodology for designing vegetable 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.)

New

- **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)

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Research support services

WATERLIT

During the past 23 years WATERLIT has built up an excellent reputation as a bibliographic database of high standard, especially with its coverage of African (and South African) publications.

1998 was a special year for WATERLIT. On 1 April 1998, free Internet access to the database became available to all South African residents. The response exceeded all expectation, with people from all walks of life registering as users.

The existing contract with SilverPlatter Information, to publish WATERLIT on CD-ROM will not be renewed after November 1998. However, NISC will continue to publish the database as part of their *Water Resources Worldwide* CD-ROM product. Since April 1998, Sabinet Online (Pty) Ltd., the local on-line information provider, has added WATERLIT to their total database package offered to subscribers.

During the past year WATERLIT continued to grow at an average rate of 1 500 items per month. The total number of references included in the database now exceeds 300 000, covering more than 550 journals as well as conference proceedings, reports and other publications.

With the growing importance of the Internet as medium for information packaging and retrieval, the future of WATERLIT needs to be planned carefully. The unique information needs and demands of the local water research community will at all times be the most important factor determining the future of the database.

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
- To establish water research needs and priorities
- To fund water research on a priority basis
- To promote effective transfer of information and technological knowledge.

These strategic actions support and simultaneously depend on one of the key principles of the new Water Act, namely, integrated catchment management. The WRC's establishment and continued support of the CCWR is an embodiment of the WRC's belief that integrated science is an essential foundation for integrated catchment 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 for these experts need to specialise but at the same time they also need to integrate their highly complex, multifaceted 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. 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.

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 catchment management for sustainable water resources 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 CCWR's small staff of six professionals serves the on-line, medium- and long-term needs of 332 registered users who are based at no fewer than 119 departments within 77 institutions including 19 overseas institutions in the USA, Britain, Germany, Australia and New Zealand. A further breakdown of users reveals approximately 61% from universities, 16% from state or parastatal institutions, 17% from private consulting firms and 6% from what could be termed direct stakeholders in water issues.

These users are working on every conceivable aspect of water. The CCWR strives to work in a complementary and facilitary relationship with all the WRC funded research which potentially requires collaborative computing. The CCWR has made particularly good progress this past year in developing technology and processes to support the implementation of the new Water Act.

New project

An archiving system for research projects on crop water-use systems

(No 912) NB Systems

It is expected by the WRC that potentially useful data sets originating from a research project are suitably archived for future use at the end of the project. This has in many cases proven to be somewhat unsuccessful when data sets are kept by the original researchers in a form which cannot be readily accessed by other interested researchers. Many become inaccessible in this way and it is at best a very time-consuming process for a researcher to get hold of such products of previous WRC projects.

A centralised database located at either the WRC or CCWR, that is accessible to all researchers, should solve this problem. In order to investigate the feasibility of such an approach, a pilot project initially focusing on bringing together, under a common umbrella, all data sets resulting from research into crop water-use systems including forestry, should be undertaken.

The detailed aims of this project will be:

- To develop a database that can be used by WRC researchers to archive potentially useful data sets produced during the course of WRC projects
- To ensure that the database has the following capabilities:
  - Runs on the Windows 95 or higher operating system
  - Runs on a single PC
  - Runs in a client/server environment
  - Handles large amounts of data
  - Easily uploads and downloads data sets
  - Comprises extensive querying facilities for retrieving data from the database.
- To implement a master database at a site specified by the WRC where all research results will be kept
- To investigate the possibility of using the Internet to query and/or download results from the master database
- Depending on the outcome of the previous point, to implement a query-and-download facility through the Internet.

Estimated cost: *R142 000*
Expected term: *1998*

Research projects

Current

- **K 6/1** Ongoing development and maintenance of the WATERLIT bibliographic database (CSIR – Division of Information and Communications Technology)
- **K 6/3** Computing Centre for Water Research (University of Natal – CCWR)
- **735** Promotion of the Internet as a source of information on water and sanitation (University of Natal – Department of Chemical Engineering)
- **843** Implementation of appropriate information technologies for the WRC, for the more effective transfer of research results. Phase 3 (CSIR – Division of Information and Communications Technology)

New

- **912** An archiving system for research projects on crop water-use systems (NB Systems)

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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)

During the past year, the IS group succeeded in marketing the aims, activities and products of the WRC through the Internet. The organisation's web page was redesigned to become more user-friendly and several new features were added. Titles of project research reports which were published on the Internet, resulted in a substantial increase in requests for copies of these reports. Working with an outside consultant, the IS group also launched the first version of an electronic project proposal submission system on the Internet.

The water-related research projects database was redesigned and updated and made available for free access on the Internet. Together with the *Guidebook for Project Leaders* and the *Strategic Master Plans* (focusing the research requirements in all water-related fields), the database provides strategic assistance and support to all water researchers in the country. In January 1998, the IS group took over the responsibility of managing the WRC's computer network. A strategy for managing hardware and software demands in the organisation has been developed and implemented.

New web address: *http://www.wrc.org.za*

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.

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.

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 1998 51 articles were published in *Water SA* of which 15 were from overseas authors, i.e. almost 30%, and 135 authors were involved (See Table 1 on following page).

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

Manuals, guidelines and reports

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

List of Commission publications

The **Annexure** to this annual report contains a list of publications (articles, papers and published reports) which appeared during 1998 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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Table 1

Articles (51) published in *Water SA* in 1998: Breakdown of author nationalities and affiliation

Universities		Technikons		DWAF	CSIR	Water Boards		Private/Consultants	Weather Bureau	City Councils	Other Councils	Overseas	
Potchefstroom University for CHE:	1	Natal:	9	5	3	Rand:	5	6	2	2	1	Argentina:	2
Rand Afrikaans University:	5	Pretoria:	2			Umgeni:	3					Australia:	1
Rhodes University:	8											Austria:	1
University of Cape Town:	1											Brazil:	6
University of Durban-Westville:	3											Canada:	3
University of Fort Hare:	3											England:	5
University of Natal:	5											Finland:	2
University of Port Elizabeth:	2											France:	1
University of Pretoria:	11											Spain:	12
University of Stellenbosch:	5											Sweden:	1
University of the North:	2											Taiwan:	2
University of the OFS:	4											Ukraine:	1
University of the Western Cape:	1											Zimbabwe:	1
University of the Witwatersrand:	8												
	59		11	5	3		8	6	2	2	1		38

Annexure

Publications emanating from research financed wholly or partially by the WRC

This Annexure contains a list of publications released in 1998, as well as a complementary list of 1997.

Requests for articles and papers should be directed to the authors.

Developing communities

Articles and papers (1998)

- Bility K (1998) Starting young: Training primary school scholars in hygiene and sanitation. Paper presented at the 9th ITN Afr. Conf., Pretoria. 1-4 December.
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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.*