



Water Research Commission

# Knowledge Review

2002/03



Water Research Commission



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## Water Research Commission



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# Introduction



**Dr R Kfir**  
Chief Executive Officer

As reflected in the WRC's mission and its various undertakings, the WRC functions as a 'hub' for water-centred knowledge. It is a networking organisation linking the nation and working through partnerships. Being an innovative organisation, it is continuously providing novel (and practical) ways of packaging knowledge and transforming knowledge into technology-based products for the water sector and the community at large, both locally and globally. The *Knowledge Review* before you aims at sharing the knowledge about the research activities of the WRC.

During the year 2002/2003 the WRC successfully implemented a new core strategy and progressed significantly towards turning the organisation into a dynamic and innovative 'hub' for water-centred

knowledge. The WRC revised and implemented its core business process of funding. A new process of funding was introduced, allowing for three funding streams and the comprehensive reviewing of research proposals and a new contracting framework.

The WRC followed various routes to discuss the new strategy, research portfolio, new operational structures, funding process and its general *modus operandi* with many of its stakeholders. These included special visits, group presentations and discussions, workshops and presentations at conferences, symposia and other gatherings. Specific interactions with key stakeholders also took place around terms of reference for proposed solicited projects. The WRC has developed strong relationships with many of its stakeholders and has adopted several approaches to improve its understanding of the water sector's needs and aspirations. It has given high priority to appropriate packaging and timely transfer of knowledge and technology products and successfully launched a number of strategic positioning and marketing initiatives. The WRC has invested in building and diversifying the water-centred knowledge base in South Africa, as reflected in the capacity-building drive carried out through the funding of various research projects and other knowledge transfer initiatives. More than 300 students are currently supported by WRC project funds. Of these, about 70% are from previously disadvantaged backgrounds (see table below). The WRC currently supports several historically disadvantaged universities and a number of technikons throughout South Africa.

	Number of disadvantaged students	Total number of students		Number of disadvantaged students	Total number of students
Council for Geoscience	2	2	Tech Wits	5	7
CSIR		1	University of Cape Town	14	22
DIT	5	5	University of	16	16
Ecosun cc		1	Durban-Westville University of Natal	5	8
Endocrine Consortium *	10	14	University of Natal (Pmb)	4	17
ERWAT	3	3	University of Port Elizabeth	5	7
Highveld Biological Association	1	2	University of Pretoria	24	31
Institute for Water Research (Rhodes)	5	9	University of Stellenbosch	7	24
Institute of Natural Resources	12	17	University of the Free State	11	23
McCracken	1	1	University of the North	4	6
MEDUNSA	0	1	University of the Western Cape	18	18
Peninsula Tech	12	13	University of the Witwatersrand	11	16
PU for CHE	3	3	University of Venda	10	10
Pulles, Howard & de Lange	9	10	Water Systems Research Group	2	4
Rand Afrikaans University	3	5	<b>Total</b>	<b>211</b>	<b>312</b>
Rhodes University	9	16	<b>% of total students</b>	<b>(68%)</b>	

\*The consortium includes the universities of Fort Hare, MEDUNSA, Pretoria, Stellenbosch, Technikon Pretoria, CSIR, ARC, Du Buisson & Partners and SABS.

The WRC was also involved in a number of other local and international drives addressing capacity-building, e.g. the Eskom/NRF drive, WARFSA (Water Research Fund for Southern Africa) and FET-Water (capacity-building and training network for the water sector). The WRC is also represented in the COHORT task team, ad-

ressing the issue of R&D capacity in South Africa, and is a founding member of the *Women in Water Awards* (a young female scientist was provided with research sponsorship following this year's event).

The research portfolio for 2002/2003 (as presented in the greater part of this *Knowledge Review*) is

concentrating on generating new knowledge, as well as the transfer and dissemination of knowledge. The WRC supported various knowledge-centred activities aimed at improving South Africa's ability to appropriately address future water problems in the short- to the long-term. It addressed issues such as water for all, quality of life, and environmental sustainability, which are part and parcel of South Africa's national priorities and require considerable attention. In addition, the WRC has led numerous studies on strategic and implementation issues arising from recent water legislation, including the strategic approach to integrated water resource management (IWRM), the recognition of water as a basic human right and the resultant free water policy, as well as the right of the aquatic environment to its sustaining share of water (the Ecological Reserve).

A new funding process was developed and implemented allowing for three funding streams, i.e. solicited and non-solicited research proposals and consultancies. This included the institution of a new review process which raises and widens the reviewer's profile and allows for extensive feedback, as well as the establishment of new project management processes supported by a new contract format. The new approach of soliciting research also emphasises the building of consortia and the transfer of knowledge between organisations and individuals.

### The WRC research portfolio: Investment in the generation and transfer of knowledge

During the year under review the WRC placed emphasis on playing a leading role in building a sustainable water-related knowledge base in South Africa by:

- Investing in water research and development
- Building sustainable and appropriate capacity
- Developing skills for the water sector
- Being adept at forming strategic partnerships in order to achieve objectives more effectively while making optimal use of the latest global information/knowledge and other technologies available.

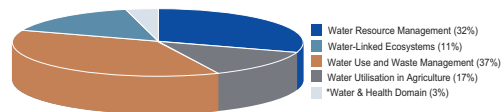
The WRC met the challenge of being adaptive and responsive to a changing, dynamic environment by maintaining relevance and providing South Africa with value for the money invested in water R&D. This is reflected in the organisation's performance as measured against its strategic and operational objectives, in the

portfolio of research projects and in other knowledge-generation and knowledge-transfer initiatives undertaken by the WRC during the year under review.

In 2002/2003 R62.4m. was invested in knowledge generation and capacity-building and a further R4.2m. in technology transfer and dissemination drives (patenting, publication of reports, workshops and conferences, knowledge reviews, publication of *Water SA*, *Amanzi* and *The Water Wheel*). The investment of R62.4m. in knowledge generation and capacity-building represents an increase of 13% from the last financial year (R55.2m. in 2001/2002).

During the reporting period the WRC financially supported 466 projects at a budgeted amount of R54.5m. Of these, 363 projects (about 78 %) were ongoing and 103 (about 22%) were new projects which commenced during the year under review. Of the ongoing projects, 35% (120 projects, or 26% of the total number of projects) were completed (finalised) during the year. In total, 121 research reports were published, some of which pertaining to projects which had been finalised during the previous financial year.

### Distribution of research project funds (%)



\* Water and Health was the only domain which was allocated research project funds

### Key strategic areas (KSAs)

The KSAs commenced operation during 2002/2003, building new working relationships and operational modalities, and supporting both the internal and the external environment. The KSAs have developed their strategic and business plans and implemented these via their new research portfolios, which place emphasis on knowledge generation, dissemination and transfer, as well as capacity-building. Through discussion and consultation, new research thrusts and programmes were established, aimed at addressing key needs and guiding future research. During 2002/2003, these KSAs initiated their leadership role in directing and supporting water-centred knowledge generation in South Africa, linking and networking with local players as well as supporting strong partnerships with global players. The

KSAs operate as strategic units, focusing on the recently-established strategic research portfolios, while investigating the need for future refinement based on stakeholder needs and feedback. The knowledge-centred KSA supports the water-centred KSAs in knowledge dissemination and information technology (IT) services.

During 2002/2003, the research portfolio of each KSA was structured on the basis of the new thrusts and programmes mentioned above. The call for research proposals (for projects due to commence in 2003/2004) was based on these KSA-specific research portfolios. Both solicited and non-solicited research proposals were invited, while KSAs also supported other initiatives such as workshops and consultancy projects. Each of the KSAs has also developed innovative processes to effectively manage its ongoing research projects. The WRC has also established a key strategic area addressing **Water-Centred Knowledge**.

#### • Water Resource Management

The strategic focus for research in this KSA is largely guided by the principles and objectives of the National Water Act (NWA) of 1998. The primary principle of the Act is that water resources should be managed to achieve optimum long-term social and economic benefits for all. This implies maintaining an optimum balance between protection of the environment and efficient water utilisation. This KSA supports the implementation of the policy by developing tools and technologies for water resource assessment and guidelines and decision-support systems to support decision-makers in achieving equitable and efficient allocation of water resources among competing needs. During 2002/2003 the research led by this KSA placed emphasis on multidisciplinary approaches that provide decision-makers and planners with appropriate tools that enable them to address social, environmental and economic factors in the planning of water resource development.

During this year, a shift in the research focus was initiated, from supporting policy-making to providing guidance for policy implementation and development of policy instruments. The research carried out during 2002/2003 enabled significant progress to be made towards the development of the necessary information systems, guidelines, decision-support systems, prediction tools and technologies/methodologies that support protection of water resources and equitable allocation of water to meet the needs of the environment and of social and economic development. The emphasis that the NWA puts on stakeholder participation in water

resource management called for a number of research projects on effective participatory tools and approaches that can support multistakeholder participation in water resource management at catchment level. The potential impacts of global climate change on water resource management are also being addressed increasingly through research within this KSA.

Thrusts:	Funds (Rm.)	No of projects	
		Ongoing	New
<b>Water Resource Management</b>			
Water Resource Assessment	9.19	45	12
Integrated Water Resource Development	1.26	7	4
Management of Natural and Human-Induced Impacts	4.36	21	10
Policy Development and Institutional Arrangements for Water Resource Management	2.76	22	5
<b>Total (126 projects)</b>	<b>17.57</b>	<b>95</b>	<b>31</b>

#### • Water-Linked Ecosystems

Water-linked ecosystems are defined as in-stream (fully aquatic), riparian (dependent on water stored in the river banks and linked to the river) and water-table dependent (dependent on a water table, but not on surface water). This KSA focuses on the protection and sustainable utilisation of the aquatic environment and biota (in-stream, riparian and groundwater). This includes addressing research needs around the international conventions on environmental management (e.g. biodiversity) as well as human needs from the aquatic environment (e.g. sustainable management for equitable ecosystem resource utilisation, recreation and ecotourism).

During the year under review, progress has been made in developing technologies and methodologies, adaptive management processes and capacity in order to protect water-linked ecosystems and to sustain the flow of goods and services in a time of both demographic and climatic change in the Southern African context. Technologies and methodologies have been developed within this KSA to support the implementation of national water policy which aims to ensure sustainable resource use.

Thrusts:	Funds (Rm.)	No of projects	
		Ongoing	New
<b>Water-Linked Ecosystems</b>			
Ecosystem Management and Utilisation	4.85	24	11
Ecosystem Protection	1.05	8	2
<b>Total (45 projects)</b>	<b>5.90</b>	<b>32</b>	<b>13</b>

• **Water Use and Waste Management**

This KSA focuses mainly on the domestic, industrial and mining water sectors and aims to proactively and effectively advance technology, science, management and policies relevant to water supply and waste and effluent management in the municipal, commercial, industrial and mining sectors. The KSA focuses on providing knowledge that ensures reliable, affordable and efficient services to enhance the quality of life and contribute to economic growth and improved public health. It addresses the management of water services in both rural and urban areas; the development of appropriate technologies for improving the quality and quantity of our water supplies for both domestic use and industrial applications; the development of new approaches to manage and enhance hygiene and sanitation practices; the provision of appropriate, innovative and integrated solutions to water and waste management in the industrial and mining sectors; the development of applications for improved treatment of wastewater and effluent and improved processes for enabling increased reuse thereof.

Thrusts: Water Use and Waste Management	Funds (Rm.)	No of projects	
		Ongoing	New
Water Services - Institutional and Management Issues	3.27	26	12
Water Supply and Treatment Technology	3.49	51	7
Wastewater and Effluent Treatment and Reuse Technology	9.41	78	19
Industrial and Mine-Water Management	3.84	22	9
<b>Total (224 projects)</b>	<b>20.01</b>	<b>177</b>	<b>47</b>

• **Water Utilisation in Agriculture**

The strategic focus of this KSA is on increasing the efficient use of water for the production of food, fibre, fuelwood and timber, ensuring sustainable water resource use, reducing poverty and increasing the wealth of people dependent on water-based agriculture. The needs and requirements of present and future generations of subsistence, emergent and commercial farmers are addressed through the creation and application of water-efficient production technologies, models and information systems within the following inter-related subsectors of agriculture:

- Irrigated agriculture
- Dryland agriculture
- Woodlands and forestry
- Grasslands and livestock watering
- Aquaculture

The challenge for applied research and knowledge dissemination is to provide solutions to practical problems which are experienced in the process of utilisation, development and protection of water resources, thereby contributing to productivity growth in agriculture.

Thrusts: Water Utilisation in Agriculture	Funds (Rm.)	No of projects	
		Ongoing	New
Water Utilisation for Food and Fibre Production	1.56	9	2
Water Utilisation for Fuelwood and Timber Production	0.13	3	0
Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture	4.56	157	
Water Resource Protection and Reclamation in Agriculture	3.11	15	3
<b>Total (54 projects)</b>	<b>9.36</b>	<b>42</b>	<b>12</b>

• **Water-Centred Knowledge**

Knowledge management in a knowledge-intensive organisation like the WRC is both a core business activity as well as a support function, while IT-based systems and tools are key enablers. This KSA focuses on key aspects of knowledge management that are of importance to the water sector. This KSA also supports the management of knowledge that affects the efficient and effective 'operation' of the WRC. The focus is on the management and creation of documents, as well as their storage and reuse in IT-based systems. This KSA supports the widest possible dissemination of knowledge and information. This encompasses knowledge created via the support of the WRC as well as from other sources of water-centred knowledge. The main focus is on knowledge as a 'value-adding component' that can be located and re-organised, supporting the creation of, capture, distribution, measurement and management of knowledge.

**Crosscutting domains**

The core strategy of the WRC calls for specific mechanisms to address key strategic issues of national importance. This has been dealt with in four crosscutting domains which were established during 2002/2003 specifically for this purpose.

The crosscutting domains focus on the role of water with regard to the following major strategic issues:

- Water and Society
- Water and the Environment
- Water and the Economy
- Water and Health.

During the year under review (2002/2003), the importance of the issues addressed by the crosscutting domains was further emphasised by the emergence of similar issues in the agenda of the World Summit on Sustainable Development (WSSD), as well as in the newly developed agenda for New Partnership for Africa's Development (NEPAD). These domains form integrating frameworks across the KSAs and draw together programmes and projects within the portfolios of each of the KSAs which also address issues relevant to the domains.

The goals, intermediate goals, purpose, and outputs of the above crosscutting domains were identified and developed further. The overarching view is given below in 'logical framework' format.

<b>Goals</b>	<ol style="list-style-type: none"> <li>1. Sustainable social and economic development is achieved at national and catchment levels</li> <li>2. Poverty and water-associated diseases are alleviated</li> <li>3. Degradation of the water-linked environment is arrested and reversed.</li> </ol>
<b>Intermediate goals</b>	<ol style="list-style-type: none"> <li>1. A balanced, mutual understanding and appreciation of societal, economic, environmental and transboundary water roles and requirements have resulted in a reduced potential for conflict and greater potential for co-operation and sustainability.</li> <li>2. There exists general awareness, understanding and appreciation of the various roles and responsibilities that water managers, water institutions and water users need to assume, in the interests of achieving both environmental/community health and equitable, sustainable, social and economic development.</li> <li>3. Knowledge, pertaining to best uses of available water resources for achieving sustainable social and economic development and community and environmental health targets, is available to managers and users, and can be effectively applied.</li> </ol>
<b>Purpose</b>	<ol style="list-style-type: none"> <li>1. The WRC and partner organisations are able to facilitate, among stakeholders, awareness creation of key water-associated health, developmental and environmental issues, in the interests of resolving inter-sectoral and transboundary conflict and promoting co-operation (<i>Outputs 1, 6</i>).</li> <li>2. The WRC and appropriate development agencies focus on developmental and environmental issues of real need/concern, and use this strategic focus to guide investment in further research, development and implementation along paths of high priority (<i>Outputs 2, 3</i>).</li> <li>3. Planners and decision-makers use developed analytical and decision-making tools (e.g. water valuation, risk assessment, multicriteria decision-making, social-economic-environmental modelling tools, etc.) to assist in making informed choices concerning water-linked social, economic, environmental and health issues which need to be addressed (<i>Outputs 4, 5, 6</i>).</li> <li>4. The work of planners and decision-makers is facilitated by having decision-making tools which are integrative, i.e. tools which appropriately weight and combine necessary data and information from a variety of relevant sources (<i>Outputs 5, 6</i>).</li> <li>5. Practitioners are able to use appropriate "best practice" guidelines for any water-linked development task at hand (e.g. for obtaining stakeholder/community participation, for providing water services within the context of an integrated approach to poverty alleviation, etc.) (<i>Outputs 6, 7</i>).</li> <li>6. Policy-makers are provided with material to be used for refining water policy, water institutions and co-operative governance, in the combined interests of the health and well-being of society, the economy and the environment (<i>Output 8</i>).</li> </ol>
<b>Outputs</b>	<ol style="list-style-type: none"> <li>1. State-of-art reviews pertaining to water as a key factor in sustainable social and economic development as well as community and environmental health.</li> <li>2. Needs analyses/assessments relating to optimising roles and usage of water in helping to achieve integrated developmental and environmental targets.</li> <li>3. Strategic research and development portfolios tailored to identified needs.</li> <li>4. Analytical tools, e.g. integrated risk assessment, tools for valuation of water, modelling tools, etc.</li> <li>5. Tools for integrated decision-making, e.g. multicriteria decision-making tools, socio-economic modelling tools, etc.</li> <li>6. Information dissemination and knowledge-transfer strategies for awareness creation and application, respectively.</li> <li>7. Best-practice guidelines relating to water-linked societal, economic and environmental practices within the context of sustainable development.</li> <li>8. Policy analyses/assessments and proposals for policy improvement and filling of policy gaps.</li> </ol>

# KSA 1

## Water Resource Management



Mr K. Pietersen  
Director:  
Water Resource Management

### Scope

The strategic focus for research in this key strategic area (KSA) is largely guided by the principles and objectives of the National Water Act (NWA) of 1998. The primary principle of the Act is that water resources should be managed to achieve optimum long-term social and economic benefits for all; this implies maintaining an optimum balance between protection and effective utilisation. The research supports the implementation of the policy by developing tools and technologies for water resource assessment, guidelines and decision-support systems to support decision makers in achieving equitable and efficient allocation of water resources among competing needs. The research puts emphasis on multidisciplinary approaches that provide decision

makers and planners with appropriate tools that enable them to take cognizance of social, environmental and economic factors in the planning of water resource development.

The research focus is shifting from supporting policy-making to providing guidance for policy implementation and development of policy instruments. The challenge for research in this KSA is to provide the necessary information systems, guidelines, decision-support systems, prediction tools and technologies/methodologies that support protection of water resources and equitable allocation of water to meet the needs of the environment, social and economic development. The NWA puts emphasis on the stakeholder participation in water resource management; this requires effective participatory tools and approaches that can support multistakeholder participation in water resource management at catchment level. The potential negative impact of global climate change on water resource management is also being addressed through research within this KSA.

### Objectives

The primary objective of research in this KSA is to ensure that water resources of South Africa are protected, utilised, developed, conserved and managed to achieve environmental, social and economic sustainability. Sustainable water resource management requires a

holistic approach that balances competing demands of the different user groups.

The secondary objectives are to:

- improve policy for promoting equitable, efficient and sustainable allocation of water resources among competing needs
- develop a systems approach, supported by necessary management tools and institutions to integrate environmental, economic and social issues within a catchment or water management area into an overall management philosophy
- provide scientific explanation and adequate quantitative understanding of the soil-water balance dynamics and streamflow-generating mechanisms for any spatial and temporal scale and their relationships with the physical and chemical transport of matter
- acquire adequate understanding of atmospheric processes and develop appropriate atmosphere-based technologies needed for the satisfactory assessment, management and augmentation of South Africa's water resources
- refocus groundwater characterisation towards integrated water resource management in line with national needs and priorities
- promote better utilisation of South Africa's limited water resources by supporting research, development and technology transfer actions aimed at improving the management (assessment, prediction, control and utilisation) of quality of South Africa's surface and groundwater resources.

The research portfolio of current projects has been grouped into strategic thrusts and programmes which directly address the above-mentioned objectives and are summarised as follows:

### Thrusts and programmes

#### Thrust 1: Water Resource Assessment

- Groundwater occurrence in fractured-rock aquifers
- Catchment hydrology
- Understanding and predicting rainfall variability
- Development of appropriate techniques for evaporation monitoring
- Water quality assessment studies and information systems
- Real-time mapping of daily rainfall over South Africa

#### Thrust 2: Integrated Water Resource Development

- Integrated catchment management
- Groundwater resource development

#### Thrust 3: Management of Natural and Human-Induced Impacts on Water Resources

- Predicting the impact of global climate change
- Groundwater protection
- Pollution of surface water
- Human-induced impacts

#### Thrust 4: Policy Development and Institutional Arrangements for Water Resource Management

- Decision support for water policy formulation and implementation
- Development and implementation of water policy instruments
- Institutional arrangements for integrated water resource management (IWRM)
- Transboundary water resource management

### Budget for 2002/03 and 2003/04

The approved funding of the research portfolio for 2002/03 leads to a committed funding budget of **R11 453 648** in 2003/04. Funding for **new projects of R8 800 000** in 2003/04 is requested to support new projects within the four thrusts. The proposed new projects will continue to develop tools, technologies and guidelines necessary to support sustainable water resource management. The consolidated budget for the research portfolio is presented below:

Research portfolio	Approved 2002/03 R	Committed and requested 2003/04 R
Current projects	10 457 279	11 453 648
New projects	9 523 100	<b>8 800 000</b>
Total	19 980 379	20 253 648

## CORE STRATEGY

### Strategic context

South Africa has scarce water resources due to its location in the semi-arid part of the world; its climate varies from desert and semi-desert in the west to sub-humid along the eastern coastal area, with an average rainfall of about 450mm per year. This is way below the world average of approximately 860mm per year. Due to poor spatial and temporal distribution of rainfall, the natural water availability is also highly variable. In most parts evaporation exceeds rainfall; on average 90% of water balance is "green water" and only 10% is "blue water".

Water resource managers and policy makers are faced with many challenges as they strive to achieve water security for the needs of the different groups of water users and water-related ecosystems. These challenges include the following:

- Ensuring adequate water for basic needs and aquatic ecosystems.
- Improving food security, particularly for the poor and marginalised, through more equitable allocation of water for food production.
- Managing risks: Better prediction and management of floods and droughts in order to mitigate the negative impacts of these disasters.
- Valuing water: To manage water and all its uses in a way that reflects its economic, social, environmental and cultural values, and to move towards pricing water services to reflect the cost of provision; this approach should take account of the basic needs of the poor.
- Governance: Ensuring good governance through the development and implementation of policies that support sustainable water resource management. This requires participatory institutional mechanisms for involving all stakeholders in the management of water resources.
- Sharing water resources: To develop synergies between different users of water at local, national and international levels; this requires the establishment of appropriate institutions such as river-basin management authorities and catchment management agencies.

These challenges have forced the WRC to review its traditional approach to research within water resource management which has been mainly based on disciplines rather than problem-driven approaches. In the past, WRC research on water resource management was addressed through six different research fields, namely Water Policy; Integrated Water Resource Management; Catchment Hydrology; Groundwater; Hydroclimatology; and Water Quality Management. The WRC has taken a strategic decision to integrate research in these fields into one KSA in order to provide its stakeholders with integrated solutions to water resource management problems. This approach will allow researchers to address problems in a multidisciplinary manner and will enable the WRC to provide information and knowledge which will guide decision makers in ensuring that their decisions about water resource management take resource issues, social, economic and environmental factors into consideration. Strategic focus for this KSA is largely guided by the principles and objectives of the National Water Act (NWA).

### Needs analysis

The primary drivers for water resource management in South Africa are population growth, economic growth and poverty eradication. The national water policy affords the highest priority to providing water for basic needs, safeguarding and sustaining aquatic ecosystems.

The South African NWA of 1998 and the Water Services Act of 1997 provide a legislative framework for addressing the above-mentioned challenges. The primary principle of the NWA is that water resources should be managed to achieve optimum long-term social and economic benefits for all, which implies maintaining an optimal balance between protection and effective utilisation. Other important objectives of the NWA include the following:

- To achieve sustainable use of water by striking a balance between legitimate water requirements and water availability and by implementing measures to protect water resources.
- To ensure that water use is as efficient as possible, by implementing equitable pricing strategies and applying water conservation and demand management measures.
- To create suitable regional and local institutions, with appropriate community, racial and gender representation, and progressively decentralise the responsibility and authority for water resource management to the lowest appropriate level.
- To establish systems for the collection and dissemination of water-related data and information.
- To ensure public protection from water-related disasters such as floods and droughts.

Water research must provide the necessary information base, guidelines, decision-support tools and technologies that will support the implementation of the national water policy so that we can achieve the objectives of the NWA. There is a need for tools/technologies for equitable allocation of water to meet the needs of the environment, social and economic development. There is also a need for effective tools that can support multi-stakeholder participation in decision making on water resource management issues.

### Overview of technological trends

Numerical simulation modelling, geostatistics and GIS are indispensable technologies for spatial characterisation of water resources in terms of all the important attributes. These technologies require continuous

refinement to overcome data-poor situations and to meet ever-increasing demands for resource information for management purposes. The effective application of GIS as a spatial analysis tool requires further research in order to produce more useful information for catchment management without necessarily having to perform more basic measurements.

Evaporation measurement/monitoring/estimation is the weakest link in the water resource assessment chain. Micrometeorological approaches which are at the heart of the only viable technologies, require high levels of skill and produce results which are expensive and site-specific. Alternative approaches which produce measurements of spatially integrated evaporation need to be developed. Sound measurements would provide the basis for refinement of models for reliable estimation of evaporation losses from all land surfaces.

Numerical modelling suitable for simulating impacts of climate variation and change on water resources and water-sensitive land uses has reached a reasonably advanced stage in South Africa. Hence the NWA has introduced "Stream Flow Reduction Activities" as a water use. This hydrological modelling technology should be immediately applicable to assessing climate-change impacts once atmospheric modelling technology has succeeded in generating probable climate-change scenarios for different parts of South Africa.

The development of integrated classification systems to protect water resources by linking delineated hydrogeological systems with eco-region classification systems is improving our understanding of the environmental functions of groundwater. New knowledge created in assessing fractured-rock aquifers is leading to the improvement of conceptual understanding of groundwater occurrence, i.e. greater validity of theoretical assumptions and sounder data interpretation techniques (pump testing and modelling). Knowledge on the integration of techniques such as geophysics, remote sensing, GIS and structural geology has resulted in significant successes in targeting groundwater in what has been traditionally considered to be low-yielding aquifers.

### Key stakeholders

Major stakeholders fall within two groups:

- Water resource managers and planners, i.e. all those entrusted with developing and allocating water resources to meet the needs of the environment and various users

- Major water users including farmers, industries, water service providers and civil society.

South Africa shares many rivers with neighbouring countries, therefore, the governments and major water-user groups from these countries constitute the 3rd group of key stakeholders. South Africa is also a signatory to several international conventions that govern water resource management at all levels.

The research conducted within this KSA contributes to better water resource management for the benefit of all the key stakeholders.

### Other players

Most water research conducted in South Africa is supported by the WRC; however, government departments such as DWAF are receiving large sums of money from international donor agencies who are keen to promote the implementation of the national water policy because South Africa is seen by the international community as a leader in having a legislative framework that guarantees water allocation for basic needs and water-related ecosystems and also promotes an integrated approach to water resource management. Major international players include DANCED, DFID, USAID, the Dutch Government, the International Water Management Institute and IUCN.

### Providers

Most of the research supported by the WRC is conducted by Universities (about 75%); science councils and consulting firms are responsible for approximately 25% of the research and there is limited participation by DWAF, Water Boards and Eskom.

### Links to Vision and Mission of the WRC

The research conducted within this KSA will produce innovative solutions for water resource management and will enhance capacity building in different aspects of integrated water resource management. Research outputs will be disseminated as widely as possible to make sure that our research not only benefits South Africa, but also contributes to the improvement of water resource management globally. Research outputs will be packaged appropriately to meet the needs of diverse stakeholder groups. To achieve this vision the KSA will

actively foster partnerships with major international players in the field of integrated water resource management (e.g. IWMI, World Water Assessment Programme and IHP of UNESCO, World Water Council, Global Water Partnership, DFID, DANCED and the Dutch Government)

## RESEARCH PORTFOLIO FOR 2002/2003

### General aims

- To improve policy for promoting equitable, efficient and sustainable conservation and allocation of water resources among competing needs.
- To develop a systems approach, supported by necessary management tools and institutions, to integrate environmental, economic and social issues within a catchment or water management area into an overall management philosophy.
- To provide a scientific explanation and adequate quantitative understanding of the soil-water balance dynamics and streamflow-generating mechanisms for any spatial and temporal scale and their relationships with the physical and chemical transport of matter.
- To acquire adequate understanding of atmospheric processes and to develop appropriate atmosphere-based technologies needed for the satisfactory assessment, management and augmentation of South Africa's water resources.
- To refocus groundwater characterisation towards integrated water resource management in line with national needs and priorities.
- To promote better utilisation of South Africa's limited water resources by supporting research, development and technology-transfer actions aimed at improving the management (assessment, prediction, control and utilisation) of the quality of South Africa's surface water resources.

### Expected outcomes

The knowledge base generated in this KSA will help South Africa move away from a sectoral approach to water resource management to a more integrated approach that promotes co-ordinated development of water, land and related resources in order to achieve social equity and economic growth. The research will

Table 1: Overview and description of KSA1 thrusts and programmes for 2002/03.

Thrust 1: Water Resource Assessment	
<p><b>Scope:</b> This thrust focuses on researching the quantity, reliability, quality and fitness-for-use of water resources (at various applicable spatial scales) and their trends over time resulting from both natural and human (land-use) influences. The recognition of groundwater as public water (as opposed to private water) means that the integration of groundwater into a broader water resource management framework is a key strategic directive in South Africa. A programme to update the water resources of South Africa is vital to achieve this end. Accurate information on the quantity and quality of freshwater in relation to present and future demands is the basis for resolving issues of equitable sharing of water amongst competing uses/users and for assessing risks associated with water quality, scarcity and excess. Steps towards acquiring the necessary information will include the review and refinement of national monitoring and information systems and the development of effective assessments techniques and predictive tools.</p>	
Programme	Scope
1. <i>Groundwater occurrence in fractured-rock aquifers</i>	This research programme focuses on better understanding of groundwater resources in fractured-rock aquifers; 90% of aquifers found in South Africa occur in these domains. The programme attempts to characterise various geological provinces in terms of groundwater occurrence and development potential; develop techniques and protocols for groundwater exploration; estimate aquifer parameters using innovative techniques; and develop systems for better resource management.
2. <i>Catchment hydrology</i>	Essentially this programme establishes how much water is naturally available in South Africa and the impacts that human activities may have on this resource. The hydrology of South Africa is characterised by very high natural variability in space and time and for management purposes research needs to provide a scientific explanation and adequate quantitative understanding
3. <i>Understanding and predicting rainfall variability</i>	The ability to better forecast rainfall variability (including rainfall events and amounts), the ultimate goal of this programme, is of great importance for water resource management. At very short time scales (48 down to a few hours ahead) the ability would greatly benefit flood management and disaster mitigation activities. At longer time scales (e.g. interannual or seasonal scales) the ability would greatly assist decisions concerning seasonal water allocation to various users and the environment. Forecast models range from the empirical (based on statistical relationships using various oceanic and atmospheric predictors) to the mechanistic (based on the use of dynamic models encapsulating best understanding of influential atmospheric and oceanic processes). The latter are usually scale-specific. Therefore, because rainfall at local scale depends on processes operating at scales, forecasting by means of the dynamic modelling approach depends on learning, through projects in this programme, to use different-scale and different-type models interactively, while ensuring that local forcing factors such as topography, soil moisture, etc. are adequately accounted for.
4. <i>Development of appropriate techniques for evaporation monitoring</i>	Actual evaporation (transpiration included) is the most poorly quantified and, after rainfall, the largest single component of South Africa's water budget. Variations in evaporation greatly influence the amount of water available for all uses. Uncertainties in measuring or estimating evaporation have a profound effect on the reliability of water resource assessment. In this programme, research which investigates and delivers improved methods of evaporation measurement and estimation, will be undertaken.
5. <i>Water quality assessment studies and information systems</i>	Because of the developmental phase in which South Africa is at present, it is necessary to timeously identify emerging water quality issues and how to deal with them, and furthermore continuously improve the tools available to assess and manage water quality.
6. <i>Real-time mapping of daily rainfall over South Africa</i>	Rainfall, the primary input into South Africa's water budget, is poorly estimated by the current national rain-gauge network which provides an insufficient (and steadily declining) number of point measurements, also inadequately distributed over South Africa's surface. Recognising these serious inadequacies, the WRC, in 1993, initiated investigations into the feasibility of integrating rain-gauge and remote sensing (radar, satellite) technologies in developing a national system for the spatially continuous measurement of rainfall in real time, which would satisfy all water resource assessment requirements. With several pilot studies successfully completed, this programme now researches the implementation of a country-wide rainfall monitoring system.
Thrust 2: Integrated Water Resource Development	
<p><b>Scope:</b> Research in this thrust focuses on providing information to support integrated water resource development. It seeks to find a balance between approaches to improve supply (e.g. artificial groundwater recharge and interbasin transfer schemes), and optimisation tools for cost-effective, sustainable exploitation of available water sources. It also seeks to find a balance between supply-side consideration and the demand management side. Integration of social, economic and environmental considerations which are key to sustainable water resource development and management will be reflected in the outcomes of research within this thrust. The integration of groundwater into the planning process will be facilitated through providing better information to planners about the linkages between groundwater and surface water and attributes of this resource will be highlighted.</p>	
1. <i>Integrated catchment management</i>	The programme establishes understanding of links and connectivities between the different biophysical components of the water resource system at a continuum of scales. The NWA requires water management to address the whole hydrological cycle as a single system. To do this properly, knowledge on how an intervention in one part of the system impacts elsewhere in the system must be acquired.
2. <i>Groundwater resource development</i>	Understanding the processes involved in surface- and groundwater interactions is becoming increasingly more important for protection and management of water resources. These linkages are crucial for implementation of legislation which requires setting of Resource Directed Measures (RDM).

Table 1: Overview and description of KSA 1 thrusts and programmes for 2002/03 (continued).

Thrust 3: Management of Natural and Human-Induced Impacts on Water Resources	
<p><b>Scope:</b> Research in this thrust focuses on developing tools and methodologies for managing the impacts of climate variability and change and human interventions on the hydrological cycle and related water resources. This includes development of systems (e.g. river flow and inundation forecast models, drought impact monitoring systems) for managing floods and droughts. It also includes developing the ability to recognise and address, in an integrated way, human-induced impacts on inter-related components of the hydrological cycle, e.g. river systems and underlying aquifers over a range of relevant space and time scales. Research also supports improvement in water quality management with special reference to non-point sources, as well as chemical and biological pollution impacts on surface and groundwater. Research will be done to identify the greatest threats to groundwater quality, this will include the documentation of existing data on the extent, spatial distribution, propagation and types of contaminants and their associated sources. The research will also provide guidelines for moving away from the traditional "command-and-control" approach to a more oriented approach with "stick and carrot".</p>	
Programme	Scope
1. Predicting the impact of global climate change	The ability to better forecast rainfall variability (including rainfall events and amounts), the ultimate goal of this program, is of great importance for water resource management. At very short time scales (48 down to a few hours ahead) the ability would greatly benefit flood management and disaster mitigation activities. At longer time scales (e.g. inter-annual or seasonal scales) the ability would greatly assist decisions concerning seasonal water allocation to various users and the environment. Forecast models range from the empirical (based on statistical relationships using various oceanic and atmospheric predictors) to the mechanistic (based on the use of dynamic models encapsulating best understanding of influential atmospheric and oceanic processes). The latter are usually scale-specific. Therefore, because rainfall at local scale depends on processes operating at global scales, forecasting by means of the dynamic modelling approach depends on learning, through projects in this programme, to use different-scale and different-type models interactively, while ensuring that local forcing factors such as orography, soil moisture, etc. are adequately accounted for.
2. Groundwater protection	This programme focuses mainly on urban areas, where intensive land-use as a consequence of increased human settlement and economic development, can have a serious negative impact on groundwater quality. The programme outputs will establish an improved understanding of the relationship between polluting activities (sources) and quality effects in the groundwater, i.e. understanding the origin of pollutants, the pathways which these pollutants could follow into the environment and the ultimate fate of these pollutants. The programme also investigates the natural occurrence of hazardous constituents in groundwater.
3. Pollution of surface water	<p>Eutrophication is strictly defined as the enrichment of water with plant nutrients. This leads to increased productivity and nuisance growth of algae and macrophytic water plants, which in turn give rise to problems with water purification, potential release of toxins, decrease in oxygen levels, deteriorating aesthetics, etc. Research in this programme is aimed at improved management of the eutrophication problem, by determining its extent and trends, its causes (sources and levels of nutrients entering the aquatic systems), studying specific problems caused by it, determining the associated social and economic costs and improving methods for addressing specific symptoms.</p> <p>Increased industrialisation/ development leads to the exposure of the water environment to a whole range of micro-pollutants. Improved analytical techniques, furthermore, lead to continual improvement in their detection limits. It is necessary to ascertain if and to what degree water resources are affected by those contaminants which give rise to concern locally and internationally. Micro-pollutants identified as cause for concern need to be further investigated in order to gain the ability to deal with (manage) the resulting problems</p>
4. Human-induced impacts	This programme attempts to quantify human-induced impacts in water resources with a view to assessing the need for management and mitigation of negative impacts.
Thrust 4: Policy Development and Institutional Arrangements for Water Resource Management	
<p><b>Scope:</b> Research in this thrust focuses on supporting policy developments, implementation processes and evaluation of policy impacts. The concept of co-operative governance with respect to water resource management must be studied so that practical guidelines can be developed. The development of tools for stakeholder participation is receiving increasing attention in line with the growing emphasis on social, environmental and political components as compared with the past emphasis on techno-economic issues. Institutional arrangements for the management of both surface and groundwater in a catchment based approach remains a major challenge. Research should support the development of guidelines and tools for managing water resources that transcends water management area. The research also investigates tools and institutional arrangements for resolving potential water-centred conflicts and for the management of shared international rivers and transboundary aquifer systems.</p>	
1. Decision support for water policy formulation and implementation	Acquiring and interpreting information on the impact of water-related public policy and disseminating related knowledge and information to officials in government departments and representatives of water users in different use sectors.
2. Development and implementation of water policy instruments	Determining how to influence the quantity of water use and maintain the quality of water through a combination of economic and legislative measures as well as through education and persuasion.
3. Institutional arrangements for IWRM	The programme focuses on ways in which stakeholder participation in integrated water resource management can be organised more effectively around benefits and costs associated with goods and services provided by water
4. Transboundary water resource management	This programme will provide tools and guidelines for resolving potential water-centred conflicts for the management of shared international rivers and transboundary aquifer systems

also contribute to the development of a skilled and competent pool of experts who can support the implementation of the national water policy and also provide leadership for the sector at regional and global levels.

An overview of KSA1 research thrusts and programmes for 2002/03 is presented in Table 1.

## Research projects

The findings of projects completed during the year under review are given, as well as a summary of current projects and the motivation and objectives for new projects which commenced between 01 April 2002 and 31 March 2003.

## COMPLETED

### Thrust 1: Water Resource Assessment

#### Programme 1: Groundwater occurrence in fractured-rock aquifers

**Hydrogeochemical evaluation of groundwater in fractured-rock aquifers using trace elements and stable isotopes at Loxton in the Central Karoo**  
 Department of Geology, University of Stellenbosch  
 (WRC Reference No 1037)

By employing a trend that was identified in terms of groundwater type distribution in the study area, subareas with distinctive groundwater chemistry that vary in space and time, could be delineated. Groundwater characteristics of the aquifers found in the study area were found to be controlled mainly by factors determining groundwater composition, viz. geology (dissolution, precipitation and ion exchange), topography, aridity (evapotranspiration), residence time and anthropogenic activities. Vertical stratification plays a significant role. Geological materials were found to be the major source of solutes. Exchange reactions conform to those previously found in the Karoo by Tredoux and Kirchner (1981).

Based on the results of the study the following recommendations are made:

- Drilling of deeper boreholes should be considered in future geohydrological studies in the Karoo for

the positive identification of a "layered aquifer system" which could provide better water quality.

- The potential of environmental isotopes has not been properly exploited in the main Karoo Basin, and their use in groundwater investigations is being encouraged. The use of isotopes could lead to the formulation of more accurate groundwater models to be of value in efficient groundwater management.
- Unravelling the geological influence on groundwater chemistry is possible only if precise geological profiling and sampling of boreholes within specific lithological units are conducted.
- The use of natural energy has great potential and the sun-powered submersible pump proved to be a step in the direction of harnessing clean natural energy for an effective groundwater sampling technique. Development of a sun-powered pump is encouraged so that it can be used even on slightly cloudy days and at deeper sampling depths with a better yield potential.

Cost: R111 000  
 Term: 1999 - 2000

#### Programme 2: Catchment hydrology

**Analysis of streamflow generation mechanisms in a wide range of small catchments**  
 Division of Water, Environment and Forestry Technology, CSIR (Stellenbosch)  
 (WRC Reference No 1193)

The complexities of predicting catchment flow regimes are great especially where changes in land use are anticipated and alterations to the flow regime need to be assessed. The ACRU hydrological model is widely used in Southern Africa, and is particularly well suited to scenario analyses of the hydrological impacts of various land-use options.

The goal of this project was to search for links between catchment physical descriptions, patterns of streamflow, and ACRU input parameter values required to simulate these flows. The research strategy adopted was to model runoff from a range of small catchments (< 100 km<sup>2</sup>) displaying a variety of physical features. A selection of 14 catchments (13 from South Africa, 1 from the USA) was eventually chosen to represent a broad range of climate, topography, vegetation and geology. Those parameter values most directly controlling the characteristics of flow were varied, both manually and with the parameter estimation software PEST, to obtain an acceptably good fit between simulated and observed flows.

COMPLETED

The study has confirmed the importance of soil/subsoil depth and profile storage capacity in determining streamflow characteristics. Hill-slope studies, such as those in progress in the Weatherly research catchment in the North-Eastern Cape, provided clearer insight into streamflow generation processes than we have at present, and should ideally be duplicated over a broad range of geomorphology situations when opportunities arise.

Cost: R495 800  
Term: 2000 - 2003

### **Programme 3: Understanding and predicting rainfall variability**

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

*Department of Geography, University of Zululand (WRC Reference No 903)*

The climate of Southern Africa often exhibits large departures from average; these unexpected events impact on water resources and economic activity. Previous research suggested that climate fluctuations are related to nearby tropical ocean-monsoon conditions and associated atmospheric circulations; the fluctuations could to some extent be simulated using various climate and oceanic indices; and regression equations could be formulated at useful lead-times to predict the climate. Based on the above, this research project sought to develop improved prediction models for climate and water resources. The approach followed was to build upon results of previous research, using previously identified predictors and expanded rainfall and streamflow information as departure points. Associations between rainfall and streamflow anomalies and various sea-surface temperature and atmospheric circulation indices were identified and the underlying mechanisms investigated in order to obtain physical as well as statistical justification for the selected climate predictors. The project ultimately succeeded in studying, formulating and implementing promising statistical models to predict the variability of Southern African climate and streamflows. Forecasts using these models have been made public via the Internet website: [http://www/1stweather.com/forecasts/cip\\_seasonal\\_outlook.shtm](http://www/1stweather.com/forecasts/cip_seasonal_outlook.shtm)

Cost: R560 000  
Term: 1998 - 2002

#### **Short-term weather forecasting techniques dedicated to flood management systems**

*Department of Earth Sciences, University of Pretoria (WRC Reference No 1011)*

Devastating floods occur in South Africa, causing serious loss of life and damage to infrastructure. Despite recent advances in numerical weather prediction models, tools available to the weather forecaster are at present still unable to provide accurate predictions of exactly where heavy rainfall will be concentrated and how much will be recorded. This project set out to improve heavy rain forecasting techniques by focusing separately on tropical and baroclinic systems, evaluating their predictability and developing a forecast verification system for operational use. The project succeeded in developing a system which delineates areas where heavy rain can be expected with a good degree of accuracy. The system is made up of three distinct subsystems: A model for identification of tropical weather systems (MITS); a tropical heavy rainfall identification system (THERIS) and a baroclinic rainfall system for the coastal zone (BARCOZ). While the system proved very successful in isolating areas of heavy rain at the synoptic scale, data limitations still cause some difficulties in resolving local scale severe rainfall events, such as may occur in the vicinity of the escarpment, and in making significant progress towards truly quantitative precipitation forecasts. Despite this, the research has made a significant contribution to severe storm forecasting through the provision of user-friendly recognition and verification tools not previously available to forecasters.

Cost: R239 000  
Term: 1999 - 2001

### **Programme 5: Water quality assessment studies and information systems**

#### **Field testing of real-time continuous flow and water quality monitoring instrumentation**

*Wates, Meiring and Barnard (CE) Inc (WRC Reference No 1004)*

The successful implementation of water quality management schemes such as the managed release of saline mine-water during flood conditions (which has been implemented in the Olifants River), is increasingly dependent on a real time on-line communication system linked to continuous water quality and flow monitoring equipment. Although there are a number of instrumentation manufacturers and suppliers as well as communication systems available that claim to be suitable for this purpose, very little hard evidence exists regarding their performance under field conditions and

the adequacy of service backup. There is also a lack of general guidelines on the operational requirements and costs associated with continuous monitoring equipment. As part of this project, equipment manufacturers and suppliers were identified and invited to participate in the project. Five suppliers participated in the evaluation of equipment measuring pH, electrical conductivity, temperature and flow depth at DWAF weirs in the Witbank and Middelburg Dam catchments. Capital and operating costs were recorded. The results generated by the continuous monitoring equipment were assessed by comparing them with samples collected manually at regular intervals. The continuous monitoring equipment generally performed well when suitably maintained and powered. The depth and EC readings compared particularly well for most suppliers. The results for temperature and pH were more variable, with pH probes requiring more maintenance than other probes. Fortnightly manual measurements were found necessary to check on instrument readings for calibration purposes. The use of batteries as the sole power source was found to be problematic, while vandalism and theft of solar panels and communication equipment presented a major stumbling block. The technologies that are available for communicating data from the field were assessed as part of a stand-alone investigation. In practice cell phone networks were found to be the more favourable communication system with about 90% availability. A radio communication system could not be evaluated because of practical considerations such as the need for a repeater station network. However, it was recommended that its implementation be re-evaluated if a full-scale real-time monitoring system was to be installed.

Cost: R300 000  
Term: 1999 - 2000

## **Thrust 2: Integrated Water Resource Development**

### **Programme 1: Integrated catchment management**

#### **An estimation of the value of water in the commercial forestry sector for selected areas in South Africa**

*School of Economics and Management, University of Natal (WRC Reference No 1133)*

The main objective of this project was to determine the value of water use for forestry in selected areas of South

Africa. Two valuation methods were chosen:

- Residual value (RV) method
- Marginal value product (MVP) method.

The RV method is based on the premise that the residual value obtained as total revenue minus total cost, including the compensation for capital and management, is attributed to water. On the other hand, the MVP method is based on the assumption that water is rewarded according to its marginal productivity. Under this framework, the water values can be derived from the area under the MVP curve. Both approaches were used to estimate water values to selected sites of eucalyptus and pine on the eastern coast of the KwaZulu-Natal Province of South Africa. The four eucalyptus sites included: Kia-Ora, Baynesfield, Tanhurst, and KwaMbonambi. The three chosen pine sites were: Richmond, Greytown, and Usutu. These two species were selected as they dominate South African forestry, especially on the east coast. Furthermore, although both species can be grown on pulpwood and saw-wood regimes, only the pulpwood regime-based rotations were selected for computing water values.

The estimated evapotranspiration (ET) water values by the RV method for eucalyptus vary from 4c to 13 c/m<sup>3</sup> of water; 4 c/m<sup>3</sup> in a low rainfall area such as Baynesfield and 13 c/m<sup>3</sup> in high rainfall areas such as the KwaMbonambi Site. The average value comes to 8c/m<sup>3</sup>. The ET value estimates by the MVP method vary between 4 and 60 c/m<sup>3</sup>, i.e. 4 cents for the low-rainfall Baynesfield Site and 60 cents for the high-rainfall KwaMbonambi Site - the average being 31 c/m<sup>3</sup>. The ET value estimates by the MVP method are roughly 4 times the estimates by the RV method.

The RV method measures the residual net value attributed to water after paying for all other inputs in the production process; on the other hand, the MVP measures the value before other costs are paid off. The streamflow reduction (SFR) values of water for eucalyptus vary between R1.90 and R4.44/m<sup>3</sup>, the average being R3.42/m<sup>3</sup>. These values are roughly 10 times the ET value estimated by the MVP method and 40 times the ET values by the RV method. Water value estimates for pine species are much lower than those estimated for eucalyptus. For example, the average ET value by the RV method comes to 1.7 c/m<sup>3</sup> and 15 c/m<sup>3</sup> by the MVP method. The average SFR value for pine is R1.79/m<sup>3</sup>. Interestingly enough, the water values for pine are well below the values for eucalyptus. The difference can be explained in terms of the growth pattern of two tree species; eucalyptus grows much faster and uses water more efficiently.

In brief, the value of water in commercial forestry depends upon the type of use - be it ET or SFR. The SFR use value is about 10 times that of the ET use value. The results of this study can be used in multiple ways:

- Firstly, results can be used to evaluate whether tariffs charged or proposed are reasonable. For example, the calculated catchment management charge, which comes at between 0.5 and 2.5 c/m<sup>3</sup>, is in line with the estimated values of water in this study.
- Secondly, water values can be used to decide on allocation of water for expansion of forestry as compared to expansion of other land uses. Here, water values for other crops or other land uses are needed.
- Thirdly, water values can also provide guidelines to evaluate which tree species should be located where for new projects (site selection).
- Fourthly, the information could also be used toward evaluating which tree species should be used for expansion at which sites (species selection).

Cost: R276 000  
Term: 1998 - 2000

### Programme 2: Groundwater resource development

**Component projects of the research programme on the determination of the groundwater component of the Reserve:**

- **A modelling decision-support system for the groundwater Reserve**
- **Delineation, reference conditions and classification**
- **Classification of critical groundwater-dependent terrestrial ecosystems**

*Collaborating Institutions: CSIR; Institute for Groundwater Studies, University of the Free State; Groundwater Group, Department of Water Affairs and Forestry; Department of Earth Sciences, University of the Western Cape.*  
(WRC Reference Nos 1090, 1091 and 1092)

It is generally accepted that groundwater plays a role in the ecological Reserve determination if there is a hydraulic connection between groundwater and surface water bodies that jointly sustains the aquatic ecosystems. In such situations the often complex role of groundwater (in terms of water level, volume and water quality) in supporting the ecosystem and human population, has to be ascertained, so that groundwater is not subsequently misallocated.

This research presents a framework for protection of groundwater using resource directed measures (RDM) as contained within the National Water Act, i.e.:

- **Ecological Reserve:** A groundwater contribution is determined where there is a linked aquatic ecosystem that requires protection.
- **Basic Human Needs Reserve:** A Reserve is determined where people take water from or are being supplied from the groundwater resource. This process is not dependent on whether the groundwater contributes to an Ecological Reserve.
- **Classification:** Classification should be used in combination with the determination of both Reserve components, as well as for the protection of the groundwater resource where neither of the Reserve components is relevant.
- **Reserve Quality Objectives:** These should be set for each of the three above measures to express the management requirements for the groundwater resource in more specific and executable terms. For a combination of measures (higher level objectives), resource quality objectives should be prioritised and combined into one RWQ.

This report presents a conceptual understanding of RDM for groundwater and presents methodologies for classification and setting of the Reserve.

The classification system prescribed under the NWA provides guidelines on how to set appropriate levels of protection for water resources. The report presents guidelines based on the generic procedure for classification. A chapter of the report focuses on understanding ground - surface water interaction process. This relationship is crucial for setting the Reserve. Typical scenarios of groundwater contribution to streams are discussed under generalised hydrogeological settings. A hydrogeomorphic approach to quantification of groundwater contribution to streamflow was developed. A water balance model was developed to set the groundwater component of the Reserve. Software was developed to assist in the water balance calculations as part of the research programme.

Cost: R1 889 000  
Term: 1999 - 2002

### A continuous flow airlift groundwater pump for rural application

Green Energy Systems cc  
(WRC Reference No 976)

Groundwater provides a large percentage of the water requirements of especially rural communities. Very often

water supply to such communities is characterised by the problems associated with providing suitable energy sources to drive the pumps extracting water from the groundwater sources. These problems are:

- Although electric motors usually are very reliable power sources, availability of electricity in remote rural areas may be non-existent.
- In the case of liquid fuel engines to drive pumps, regular maintenance and repair when needed, may be problematic, as well as supplying clean fuel on a regular basis.

The solution would therefore be a pumping mechanism, with very simple and infrequent maintenance requirements, driven by a readily available, low-cost energy source.

Early in the project the decision was taken to "harvest" energy as and when wind is available, and to store this energy as compressed air, rather than to pump water when wind is blowing, and to store the pumped water. This approach eliminated pollution of stored water, as well as evaporation losses. Having stored compressed air available on demand also promoted more efficient water use and was more convenient to water users.

The modified pumping mechanism, the compressor and storage unit operated satisfactorily when installed on boreholes up to 70m deep. The advantage of being able to position the compressor unit for optimal wind capture rather than at the borehole was demonstrated since it was relatively easy to take compressed air to the pumping unit. Furthermore, maintenance of the system proved to be easy and not requiring highly-skilled operators. Both the compressor and pump consist of off-the-shelf parts, and one compressor unit serves a multi-borehole system. The main disadvantage of the system is the compressed air storage tank (the mast on which the compressor was mounted) since these have to be tested and certified at predefined intervals by accredited authorities.

The project achieved its objectives and demonstrated the potential of the system to pump water in areas where conventional energy sources would be problematic. To some extent, parts of the system appeared to be over-designed and eliminating - these would further reduce production costs.

Cost: R352 000  
Term: 1998 - 1999

## Thrust 3: Management of Natural and Human-Induced Impacts on Water Resources

### Programme 2: Groundwater protection

**Decision tool establishing a strategy for protecting groundwater**

*Institute for Groundwater Studies, University of the Free State*  
(WRC Reference No 969)

The aim of this project was to develop a decision tool (DT) to assist groundwater resource managers in optimising the utilisation of groundwater. A fuzzy logic-based risk assessment methodology was used to develop the DT. The DT is divided into three tiers namely a rapid, intermediate and comprehensive assessment. For each of the tiers, the following risk assessment can be done:

- A groundwater risk assessment can be defined as the probability of an adverse effect or effects on the quantity and/or quality of groundwater associated with measured or predicted hazards (for example chemical spills).
- A groundwater health risk assessment can be defined as a qualitative or quantitative process to characterise the probability of adverse health effects associated with measured or predicted levels of hazardous agents in groundwater. The health risk assessment is divided into a carcinogenic, a radiogenic, a non-carcinogenic and microbial assessment.
- Ecological risks of interests differ qualitatively between different stresses, ecosystem types and locations. The groundwater ecological risk assessment quantifies the impacts of groundwater quantity and quality on ecosystems.

The DTs are also able to determine a cost-benefit risk analysis. The DT developed relies heavily on the expertise of geohydrologists, expertise assumptions and approximations. Together with the heterogeneities present in groundwater systems the application of the tool will be complex. Nevertheless, it is an advancement in developing a systems approach to groundwater management.

Cost: R650 000  
Term: 1999 - 2003

#### Programme 4: Human-induced impacts

**An investigation into the impacts on Witbank Dam catchment associated with saline mine- water releases**  
Wates, Meiring and Barnard (CE) Inc  
(WRC Reference No 900)

During the summer of 1996/97 DWAF 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 support the decisions which are made. This project aimed to fill this need and aimed 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 were to be tested, using field observations of flow and quality, with the intention to integrate and use them to compile a rule-based approach to the future management of saline mine-water releases in the Witbank Dam catchment.

A two-dimensional, laterally averaged, hydrodynamic and water quality simulation model (CE-QUAL-W2) was selected to model the response of the Witbank Dam to variable salinity inflow from its catchment. Several models were considered for simulating the processes related to routing salinity through the catchment. Because of difficulties with linking the CE-QUAL-W2 model to some of these, the WITSKM/WITQUAL modelling system was selected for this purpose. Considering the accuracy of the available information, a reasonable calibration of the flow and pollutant routing methods was achieved.

The monitoring time step was found to determine the accuracy with which the hydrograph and pollution graph (e.g. salinity) could be described. The longer the time step the less accurate the representation of the event and the larger and more variable the flow, the bigger the discrepancy. The performance of a controlled release scheme is thus sensitive to the decision making time step. The longer the time step the poorer the performance of the scheme. Application of the dam model showed that the autumn floods tended to enter the dam on top of the thermocline. However, the later the flood occurred in autumn, the easier the thermal

stratification is broken down and the deeper the mixing that occurs. The Witbank Dam cannot be considered as completely mixed. The model indicates both a depth and a longitudinal variation in concentration.

The software developed to operate the controlled release can operate in both operational mode (to address the daily operation of the scheme) and in scenario mode (to look at possible future scenarios that may occur in the dam). In scenario mode it can be used to merely view the historic flow, dam capacities and water quality information at the control points or to predict what the sulphate concentration in the Dam can be expected to be at some time in the future. In operational mode, the model can be used to predict the impact of flood releases into Witbank Dam. The system is designed to predict the state of the dam two weeks in advance of the current state. The user can then examine whether any of the water quality objectives set for the dam will be violated during that period. If so, the model can be re-run for different starting conditions.

The model is currently being utilised by DWAF to manage the controlled saline mine-water release scheme.

Cost: R300 000  
Term: 1998 - 2000

#### Modelling the impact of land-cover and land-management practices on streamflow reduction

School of Bioresources Engineering and Environmental Hydrology, University of Natal  
(WRC Reference No 1015)

The South African Water Act (Act No. 36 of 1998) provides for certain land-use practices to be declared as streamflow reduction activities (SFRAs). A number of land-cover and management practices have been suggested for inclusion into this classification as SFRAs. Research studies have since been done to investigate the impacts of forestry on streamflow in South Africa. These studies included WRC projects reported in the WRC reports TT 173/02 and 494/1/97. These studies have facilitated the verification and enhancement of hydrological models under forested catchments and to some extent catchments under other agricultural land uses (non-forestry).

In this study, land use, which comprised land-cover (crops) and land-management practices (tillage, contouring, water harvesting, strip cropping, etc.) were considered as potential SFRAs. The ACRU model was

enhanced through the application of the collected data in model verification at various sites. Data on land use were obtained from different sources which included the University of the Free State, the Directorate of Engineering and Soil Conservation and the South African Rainfall Simulator Programme. The ACRU model was configured and applied to selected sites to simulate the impacts of different land use/s. The model results were verified against the relative sequences and orders of magnitude of observed runoff responses generated under the different tillage practices.

This project resulted in the development of new algorithms for the ACRU model to handle tillage practices. A new modelling approach for maize and wheat in the different tillage practices in the ACRU model was also developed in this study. This study resulted in the acquisition and collation of historical field data that focuses on land use related hydrological processes which have been added in electronic format to the report.

It was noted in this study that the implementation of the SFRAs in the National Water Act needed careful conceptual re-consideration to address the dynamic nature of land cover and land management which characterise typical land uses (the variable spatial and temporal scales non-forestry land uses included). Another recommendation that came from this study was the possibility of assessing hydrological impacts using the concept of changes in total evaporation. The WRC is currently funding two projects (K5/1219 and K5/1319) that take into account this concept.

Cost: R571 000  
Term: 1999 - 2002

#### Hydraulic analysis of tunnel ageing and possible remedial measures

Ninham Shand (Pty) Ltd  
(WRC Reference No 1088)

Concrete-lined tunnels could lose as much as 30% of their hydraulic capacity over a period of 30 years due to ageing. There was, however, a need for a better understanding of the tunnel ageing process in order to plan for future tunnelling requirements as water demands increase.

The aims of the project, therefore, were:

- To provide a reliable hydraulically based methodology by means of which concrete-lined tunnel ageing and the associated decrease in hydraulic capacity can be predicted (i.e. effects of sliming, sediment deposition and soft water corrosion).

- To establish whether remedial measures can be implemented to reverse or contain the ageing process.
- Development of tunnel design and operational guidelines to limit tunnel ageing.

The project consisted of laboratory and field tests, the latter including the Orange-Fish Tunnel, Roode Elsberg Tunnel and the Theewaterskloof Tunnel. The results of the project indicated the following:

- Hydraulic ageing is caused by sediment deposition consisting of fine cohesive sediment, at times containing some organic material. Hydraulic flushing by means of high flows effectively reduces hydraulic roughness by flushing out sediment deposits, but bacterial action may require other measures.
- A relationship was developed and calibrated to determine the effective hydraulic roughness of a segmentally lined tunnel, including joint step losses. Furthermore, a hydraulic rate of ageing equation was developed and calibrated on UK and RSA data and pH turned out to be the dominant variable. An ultimate hydraulic roughness equation was also developed and calibrated. A probable and maximum probable roughness formulation has been proposed.
- Mechanical cleaning of tunnels in soft water conditions is not recommended due to damage to the tunnel surface. For soft water conditions, tunnel linings, e.g. poly-urethane, may be considered, but need to be applied during construction.

Design and operational guidelines for the determination of tunnel ageing and selection of tunnel diameter during design, have been proposed. The LHWP Delivery Tunnel North has been used as a case study.

Cost: R571 000  
Term: 1999 - 2002

#### Tier 1 risk assessment of radionuclides in selected sediments of the Mooi River

Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 1095)

An investigation into the fate of radioactive metal releases into the Mooi River conducted by the Department of Water Affairs and Forestry (DWAF), indicated that the radionuclides in the water column dissipate with distance from the source - presumably because the radionuclides bind to sediments. The

implication is that large quantities of radionuclides which have been removed from the water phase in this way may be remobilised under a different set of conditions. It is important to know under which conditions these radionuclides may be remobilised, and if this occurs, how much of a risk to human health they may pose.

The Mooi River catchment has received the impacts from mining operations for more than 60 years. The river of interest is the stream called the Mooi River Loop and the Wonderfontein Spruit. This stream provides input into the Boskop Dam, from which the town of Potchefstroom derives its drinking water.

The aims of this project were:

- Determination of the concentrations of selected radionuclides (<sup>238</sup>U, <sup>235</sup>U, <sup>234</sup>U, <sup>223</sup>Ra, <sup>232</sup>Th, <sup>210</sup>Pb and <sup>210</sup>Po) in the sediments of the Mooi River at three sites
- Determination of the risk represented by the radionuclides in the Mooi River sediments to man

In all of the scenarios, modelled by chemical equilibrium modelling, there was the possibility of uranium being solubilised by environmental processes that fall within the bounds of reason. The scenario under which uranium is least likely to be mobilised is that of strongly reducing environmental conditions. The scenario under which uranium is most likely to be solubilised is that of high oxidation potential and low-to-intermediate pH. This scenario is likely if the sediments of an impoundment are exposed by drainage, or by dredging operations. Increased oxidation potential automatically enhances the potential for low pH conditions. Thorium is expected to remain in the chemically inert fraction, and transport of thorium is most likely to be as a particulate with comparatively limited migration potential.

In all of the sediments tested, uranium was mobilised during sequential chemical extraction, by reaction with a weak acid. Uranium was also mobilised by both an increase in oxidation potential, and by a decrease in oxidation potential. There is evidence that uranium is transported in a soluble form along the length of the Wonderfontein Spruit and the Mooi River Loop.

It was concluded that:

- Radionuclides do accumulate in the sediments of the Mooi River catchment
- The main radionuclide of interest, being uranium, seems to be adsorbed to the environmental phases: Carbonate, iron and manganese oxyhydroxides, and organics (with a slight

possibility of being included in sulphide components)

- Uranium may be remobilised into the water column by perturbation of TDS, pH and oxidation potential
- Because they had <sup>238</sup>U levels higher than the Nuclear Energy Act stipulation, six of the study sites had a positive Tier I Risk Quotient.

Cost: R115 000  
Term: 1999 - 2000

**Sediment transport through hydraulic structures in rapidly varied open channel flow**  
*Department of Civil Engineering, University of Cape Town (WRC Reference No 1098)*

This research investigated and analysed scouring and deposition as the principal causes of failures in many bridges and other hydraulic structures. In this study a 3D modelling approach was pursued in analysing scouring and deposition.

The modelling process utilised incipient motion - the conditions under which sediment movement commences were analysed in terms of flow velocity, bed shear stress, and stream power. Analysis of sediment transportation data revealed that it is possible to link the "intensity of motion" to a Movability Number. Further analysis of transportation data showed that there is no specific value of Movability Number at which movement can be said to have begun or ceased. In the model presented in this study, equations were used to describe the Movability Number criteria at which scour becomes appreciable. In the proposed scour model the sediment transport through a hydraulic structure was simulated mainly by the upstream and downstream conditions, i.e. the supply and removal of sediment respectively.

On simulation the model appeared to give good results when applied to the prediction of scour upstream of a weir. The results were not as impressive when the model was applied to the prediction of scour around piers and abutments although the general scour pattern was clearly visible. Approximation of the free surface could have resulted in the poor results. Coding is now available that gives a better determination of the free surface which can lead to an improvement of this modelling process in future.

After considering the use of numerical and empirical models this study came to the conclusion that physical models are the most reliable in representing scouring and deposition, provided that they are constructed at a sufficiently large scale. Major shortcomings in physical

models were that they are time-consuming to construct and test, and therefore expensive.

The unit stream power model presented in this investigation shows considerable promise for the prediction of scour and deposition, but extensive development will be required before the model will be able to solve the entire range of problems facing engineers in this field.

It appeared that the method developed in this investigation has the potential to predict scour and deposition in any situation given the correct boundary conditions. The main limitations at present are:

- An inadequate free surface routine
- The lack of an unstructured mesh in the CFD package to facilitate corrections to the boundary as scour and / or deposition takes place. In this investigation, only the initial and final states were modelled
- No facility for the program to make continuous corrections to the boundary in response to the scour potential calculations without further input from the user
- The limited capacity of the current generation of machines.

Cost: R440 000  
Term: 1999 - 2002

**Removal and disposal of sediments from pump intakes in rivers by means of permanently installed jet pump type dredge systems**  
*Prestedge Retief Dresner Wijnberg (CE) (WRC Reference No 1187)*

The problem of sediment removal from pump intakes is characterised by the fact that local conditions often differ from those in regions where many of the classical extraction layouts have been developed, and that discharges in Southern Africa are highly variable, often carrying heavy loads of suspended sediments. Intake structures to solve the problem require complex three-dimensional flow patterns, investigation of which requires expensive physical model studies to ensure optimal sediment removal efficiency.

The project set out to develop an efficient reliable and cost-effective sediment removal and discharge system for the removal of sediment deposition outside and inside of pumping stations on rivers by utilising the jet-pump type dredging system.

Based on a national survey of intakes on rivers (which confirmed the need for effective sediment removal at a large number of intakes on rivers, the excessive abrasion

to pumps caused by sediment, and the fact that both major and minor floods cause disruption of water supply due to sedimentation), the approach followed was to design and assemble a fixed system (dedicated to one intake), and a mobile, trailer mounted unit, both for evaluation in alleviating sedimentation problems.

Both units were evaluated over a period of 12 months. The mobile unit was utilised for 80 cleaning operations at eight sites. The fixed unit successfully created "craters" at the raw water pump intakes and required 15% of the pump discharge (only intermittently), for sediment removal. Operating cost was, therefore, minimal. The mobile unit was as effective, but depending on circumstances, may require the services of divers to ensure effectiveness.

Based on the performance results obtained during the evaluation period with the fixed and mobile units, it was concluded that the main objectives of the project have been achieved. Consequently DWAF decided to utilise both units for a further two years at sediment-prone intakes in Mpumalanga and Northern Province. Furthermore a permanently installed jet-pump system has been incorporated into the new water intake structure at Hoxani on the Sabie River.

This project's results provide a technology (fixed or mobile, but the cost/benefit ratio was in favour of fixed systems) that ensures maintaining an intake in operational condition and therefore, ensuring continuous water supply. This benefit is, however, difficult to quantify.

Cost: R469 000  
Term: 2000 - 2002

## Thrust 4: Policy Development and Institutional Arrangements for Water Resource Management

### Programme 1: Decision support for water policy formulation and implementation

The development of a methodology to determine the true value of water in the Berg River basin  
*Department of Agricultural Economics, University of the Free State*  
(WRC Reference No 943)

Water shortages are a looming threat for agricultural as well as urban users in South Africa, mainly for the following reasons:

- The high cost of new water supply infrastructure
- The high percentage of unaccounted-for water
- The pricing of water below its real value
- Central water allocation instead of transferable water rights (water market) systems.

The primary objective of this project was to develop a methodology to determine water values and the impact of a potential water market on efficiency. This included the methodology to analyse water values and water markets as well as the quantification of variables, which will be influenced by the implementation of water markets as an alternative for administrative water allocation in the Berg River basin.

The literature abounds with models for analysing alternative water allocation mechanisms. The positive mathematical programming (PMP) technique, which was introduced in this study, to calibrate a regional water market model, is a relatively new approach. The most important finding with regard to modelling is that in similar studies, without the PMP technique, response to policy and other external impacts on farmers' behaviour was probably overstated. The PMP technique causes a regional model, with incomplete information, to respond more smoothly to a change in parameters. Most of the previous studies also used regional linear programming models instead of typical farms to represent the water demand function for agriculture. In this study, typical farms are embedded in the spatial equilibrium model, and are aggregated to represent irrigation regions. This renders it possible to model farmers' behaviour more accurately.

This study clearly pointed out that there exist huge inefficiencies in the Berg River catchment. Without a water market the capitalised marginal value of agricultural water ranged between R0 and R20.2 with a median value of R1.6/m<sup>3</sup>. The capitalised marginal value for urban water is estimated to be R10.1/m<sup>3</sup>. When there is relatively low water scarcity and a water market is introduced, the marginal value of water for all agricultural water users declines to either zero (typical irrigation farms where there is an infrastructure transfer restriction) or to 30c/m<sup>3</sup> for all other irrigators. The marginal value for agriculture to agriculture and agriculture to urban water transfers. The reduction in the marginal values for water when a water market is introduced indicates a huge increase in efficiency of the allocation system.

When a water market is introduced the market sends price signals to users, informing them about the scarcity situation. The value of water increases and the opportunity cost of inefficient users becomes too high to carry on with their inefficient practices. They react by using water more efficiently. The net disposable income per m<sup>3</sup>, which was used as measurement of efficiency, rises in response to the introduction of a water market. This creates "surplus" water, which can be traded to higher-valued uses. When a water market is introduced farmers change to lower-intensity irrigation as water becomes scarcer. When water trade is possible, farmers manage to keep a larger area under optimal irrigation than when it is not possible.

Water markets themselves tend to evolve over time. Even very simple water markets, if structured well, can be a stimulus for more efficient water use and can lead to continual refinements in the trading system. This concept was clearly indicated in this study. Even if the trade volume is low initially there are immediate gains in efficiency when water trade is permitted. The Berg River CMA can gain experience by instituting a relatively simple water market (only internal trade within for example the agricultural sector) and develop over time into a sophisticated market with trade between all user sectors and even trade with other catchments (e.g. the Breede River and possibly the Olifants River).

Cost: R664 500  
Term: 1998 - 2001

### The value of water as an economic resource in selected catchment areas in South Africa

*Department of Agricultural Economics, University of Natal*  
(WRC Reference No 987)

As water scarcity increases, the need for a framework to judge beneficial use becomes more pressing. The answers provided by such a tool are the basis on which society decides who gets access to the resource and who does not.

This study analyses the economic efficiency of water allocation on the Fish-Sundays Scheme in the Eastern Cape Province of South Africa. The objective was to develop a basin-wide model of water use that calculates total and marginal water value. Estimates of total value were used to confirm financial feasibility while marginal values measure the efficiency of current allocation as well as gains from reallocation. A linear programming model shadow prices commercial irrigation, which controls 97% of available water on the scheme. The value of water to commercial irrigation is interpreted as the opportunity cost of reallocating water to an ecological Reserve, irrigation equity and municipal demand. Value in these sectors is typically hard to quantify but the method developed here constitutes an easy procedure for obtaining a first estimate of the cost of meeting equity objectives.

Total water value is defined as residual farm profit after all fixed resources have been remunerated at their opportunity cost. Assuming the perfect competition of the Ricardian framework, residual profits are interpreted as payments to irrigation water, which pre-1998 was not sold in a separate market but traded as part of the bundle of resources associated with (irrigated) farmland. An accurate estimate of water value critically depends on identifying all other factors of production. Hence, risk is introduced through MOTAD, which penalises the objective function by an exogenous weighting according to risk preference. Accounting for risk reduces total and marginal water values, which are also sensitive to the value of crops and input prices.

Total water value for the scheme is estimated to be R27m. in 1999 Rand ( $\pm$  \$2.24m.) and irrigation shadow prices range from zero to R0.2115/m<sup>3</sup> ( $\pm$  \$0.0176/m<sup>3</sup>). Results indicate that 77x106 m<sup>3</sup>/year can be transferred away from irrigation at zero opportunity cost. Two thirds of the current allocation to irrigation can be bid away at a price of R0.0352/m<sup>3</sup> ( $\pm$  \$0.003/m<sup>3</sup>). Thus equity objectives can be satisfied at zero or very low opportunity cost to commercial irrigation.

The typical model of water value relies on a vast array of assumptions that all influence final values. While orders of magnitude and directions of reallocation are therefore meaningful, one should not attach too much meaning to any particular result. Administered prices are too data-intensive to be practical. Water markets represent a more reliable and cost-effective institution to derive subjective willingness to pay.

Cost: R443 190  
Term: 1998 - 2001

### Updating of 1989 manual for cost benefit analysis in South Africa to 2000

*Conningarth Consultants*  
(WRC Reference No 1132)

The evaluation of water resource development projects is often a difficult task since costs and benefits occur over time. Furthermore, costs and benefits are often hidden, making them difficult to identify, and are also frequently difficult to measure. These problems are not limited to capital projects; they also occur when decisions have to be made regarding the merits of current expenditure programmes. The cost benefit analysis (CBA) method, also known as benefit cost analysis, provides a logical framework by means of which projects can be evaluated, serving as an aid in the decision-making process.

The primary aim of this CBA manual is to provide the decision maker with practical guidelines and procedures to apply the CBA methodology. The secondary aim of this manual is to provide the user with an extensive and up to date data bank of shadow and surrogate prices in South Africa.

To ensure that this manual provides guidelines for the CBA practitioners the research was conducted in close cooperation with the research manager at the WRC, members of the project steering committee, the Development Bank of Southern Africa, the Department of Water Affairs and Forestry and leading CBA practitioners. As part of the process, four major workshops were held during the course of the project. At these workshops valuable inputs were given.

The main subjects discussed in this manual are the following:

- applications and limitations of CBA
- methodology of CBA
- criteria for project assessment
- shadow and surrogate prices for South Africa
- issues relating to water development
- practical examples.

As far as possible a practical approach is followed in this manual. This applies specifically to the guidelines for shadow and surrogate prices. In this regard the following shadow/surrogate prices are provided:

- shadow wages for unskilled labourers per province
- estimated annual remuneration for occupational categories in South Africa per province
- index of projected real effective exchange rate of the Rand
- index of projected prices for petrol and diesel
- index of estimated relative changes in electricity prices
- estimated time cost according to income groups
- economic value of productive life.

The researcher is assisted in the application of the guidelines in this manual by providing him or her with practical examples which appear on the website of the WRC ([www.wrc.org.za](http://www.wrc.org.za)). These examples include electricity, potable water, roads and municipal vs. irrigation water schemes.

Cost: R419 000  
Term: 2000 - 2002

### **Programme 2: Development and implementation of water policy instruments**

#### **Framework for state of the catchment reports for developing a catchment management plan and using as a basis the Palmiet River, Western Cape**

Groenland Irrigation Board  
(WRC Reference No 913)

The publicly elected steering committee formulated the vision for the catchment as "To manage the Palmiet River Catchment Area so that optimal use is made of the total resource to sustain the ecological, social and economic requirements and to maintain the unique conservation status and scenic beauty of the area." Nowhere in South Africa has this type of transparent, grassroots-level participation in the planning of resource utilisation been attempted. This process could form a precedent for other similar initiatives and provide valuable experience to government departments on the

involvement of local communities and interested and affected parties in decisions concerning the utilisation of natural resources. On a regional level it also addressed certain aspects of catchment management within a political and environmental framework that are unique to the south-western Cape.

To achieve this vision the key goals (with local, regional and national relevance) were drafted by the committee:

- ensure that the CMP conforms to SA's international commitments on the preservation of bio-diversity
- ensure high quality of water (prevent pollution) and optimal sustainable and equitable use of the resources (prevent waste)
- ensure sufficient water to meet all needs (basic, environmental, social, recreational and economic)
- ensure that the estuary and river keep functioning as viable ecological units (e.g. instream flow requirements)
- reduce erosion through proper land-use management
- meet sanitation requirements
- ensure active and informed participation by all stakeholders
- encourage collective responsibility and ownership for the management of the catchment
- develop an effective and efficient management plan and implementation strategy.

The plan has been submitted to DWAF for approval and acceptance in terms of the National Water Resource Strategy.

Cost: R250 000  
Term: 1998 - 2001

### **Programme 3: Institutional arrangements for IWRM**

#### **Development of a hydrological economic model based on the Mvoti catchment**

Umgeni Water  
(WRC Reference No 890)

The motivation for this research was the realisation that the increased water scarcity in South Africa, and the

implementation of the NWA (1998), which requires the equitable, efficient and sustainable management of water resources, requires the integration of hydrological and economic thinking, especially with regard to the assessment of water use efficiency.

The objective of this research was to build a Hydrological Economic Agricultural Model (HEAM). The model is to be used to assess the economic and hydrological impact of different water management options, targeting land-based water use (irrigation and SFRAs) with the purpose of evaluating the efficiency and equity implications of these options.

The Mvoti catchment was selected to undertake this research due to the water scarcity in the catchment (during the dry months of the year) and due to the availability of good hydrological data. After investigating various modelling options, it was decided to adopt a hydrological economic optimisation modelling approach at farm level. The HEAM is a linear programming (LP) model that operates on a farm level. Unique features of the approach adopted in setting up the LP model are that the economic component was simplified, and a hydrological component was added.

The HEAM was set up for 3 different farms, referred to as Farm A, B and C respectively. Farm A is a privately owned, small mixed farming operation. Farm B is a large company, which adopts mixed farming operation and Farm C is a relatively large, independent timber growing operation.

The water available in the stream during each of the 4 periods available for abstraction, the crop irrigation requirements and yields associated with the different irrigation land-use management practices (LUMPS), as well as the runoff for all LUMPS were modelled with ACRU.

It was found that the farms have vastly different marginal costs for increasing the flow during the low-flow months of dry years. Marginal costs are defined as the cost which the farmer would incur if he were to generate one additional unit of low flow by changing his LUMP mix. Marginal costs of producing low flows during dry years differ significantly across farm types.

A further test was undertaken in order to assess the merits of the afforestation permit system (APS), which was implemented during the previous Water Act, mainly out of a concern for low flows. As can be expected from the previous results, it has been very costly to protect low flows. The calculations showed that the current low flow from all 3 farms (which are currently regulated by the old APS) may be achieved by adjusting irrigation crops while at the same time giving rise to additional average farm income per annum.

The results generated by the study show that the cost of meeting Reserve requirements will be influenced by the strategy adopted. Irrigation seems to offer the most cost-effective options to generate more streamflow during critical dry periods (dry months during dry years). Pushing back forestry on non-arable land is prohibitively expensive. Clearing riparian zones seems to be a relatively cost-effective option but more economic and hydrological data would be required to conclude this with more certainty.

Within this report a definition of efficiency (which relates in this context specifically to the water use of land-based activities) has been proposed, and indicators for this efficiency have been developed. When it comes to assessing water-related policies targeting land-based water uses (i.e. irrigation and SFRAs), the impact of policy options on the land-use decisions of the holders of land-based water-use licenses needs to be known, and following this the consequent impact of the new land-use on the hydrological cycle needs to be quantified. If this cause-and-effect relationship is known, one can evaluate the impact on efficiency of each policy option. Furthermore, if the requirements for the Reserve are known, an indicator can be developed regarding the sustainability of each policy option.

In this framework, the need for hydrological economic thinking is clear: One can only assess costs and benefits of policy options (i.e. the impact on efficiency) if both the economic and hydrological impacts are known.

Cost: R159 000  
Term: 1999 - 2000

## CURRENT

### Thrust 1: Water Resource Assessment

#### Programme 1: Groundwater occurrence in fractured-rock aquifers.

##### Reliability of small spring water supply systems for community water supply projects, and the enhancement of flows from springs

Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 859)

In the eastern parts of South Africa many small-scale rural water supply schemes have been based on protected springs. This projects aims to determine the factors affecting the flow from small springs with potential for use as water supplies to rural communities and to evaluate spring protection and flow enhancement techniques for their effectiveness and practicality.

Estimated cost: R650 000  
Expected term: 1997 - 2001

##### Flow and transport characteristics of groundwater in Karoo formations

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

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. It is becoming apparent that their physical properties in fact differ from those generally described. This project aims to use more appropriate methodologies to confirm and expand knowledge on the physical nature of Karoo aquifers.

Estimated cost: R 598 000  
Expected term: 1998 - 2001

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

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

Knowledge of the age of recharged groundwater and of recharge rates is important for evaluating groundwater resources in terms of sustainability and exploitability. Chlorofluoro-carbon (CFC) levels in groundwater have been shown to provide a means of accurately estimating the age of unmixed groundwater. This research develops a method of integrating and analysing groundwater age data provided by isotopes, so that groundwater mixing ratios can be determined. It further investigates the application of these mixing ratios to groundwater resource evaluations so that the reliability of these evaluations can be refined.

Estimated cost: R354 000  
Expected term: 1999 - 2000

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

Groundwater Group, Department of Earth Sciences, University of the Western Cape  
(WRC Reference No 1093)

An important aspect of sustainable management of groundwater resources is the quantification of recharge. Investigating recharge in basement aquifers is important not only on account of the small storage of basement aquifers, but also to obtain a better understanding of the processes and quantities involved which increases knowledge of the aquifer potential. This research project will assist in developing methodologies for the estimation of recharge in basement aquifers.

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

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

Faculty of Dentistry, University of the Western Cape  
(WRC Reference No 1094)

Contributing to the poor domestic water supply and quality in the Northern Cape are high fluoride levels. This study, through systematic analysis, is investigating the impact of poor water quality, high in fluoride, and the potential for low-cost treatment.

Estimated cost: R318 000  
Expected term: 1999 - 2001

##### Geomechanical modelling as a tool for groundwater exploration of fractured-rock aquifers (A component project of the Research Programme on Sustainable Groundwater Management and Utilisation in the Northern Cape)

Groundwater Group, Department of Earth Sciences, University of the Western Cape  
(WRC Reference No 1117)

This project is to apply a geomechanical modelling technique for the location of optimal groundwater resources. This is because the development of fractured rock is the result structural deformation, which is in turn driven by tectonic stresses. The project will:

- Develop a structural model for groundwater flow in basement aquifers
- Contribute to the quantification of groundwater in the region for community water supply purposes.

Estimated cost: R560 000  
Expected term: 2000 - 2002

##### Importance of groundwater in the hydrological cycle and the relationship to surface water bodies

Department of Hydrology, University of Zululand  
(WRC Reference No 1168)

Understanding the processes involved in groundwater-surface water interactions is becoming increasingly important for protecting the integrity of ecosystems. This projects aims to develop models of typical groundwater-surface processes in South Africa and also to establish compatible methods for estimating time series of surface and groundwater rates for comparative analyses.

Estimated cost: R770 000  
Expected term: 2000 - 2002

##### A strategy for future investigations of deep groundwater systems in South Africa

Directorate Geohydrology, Department of Water Affairs and Forestry  
(WRC Reference No 1237)

Present knowledge of fractured-rock aquifers in Southern Africa is mainly restricted to the "shallow" (i.e. upper 100m) of the earth's surface, where the ubiquitous role of erosional unloading/weathering is an important factor controlling the occurrence of groundwater. There are, however, a number of key indicators pointing to the existence of deep groundwater systems within many of these hard-rock terrains, e.g. thermal springs and artesian boreholes. With the shift in emphasis of groundwater resource assessment from the

localised to the catchment scale, there is a need to assess the role of deep groundwater systems in the hydrological cycle.

Due to a lack of information on and the complexity of the deep groundwater flow system, as well as the requirement of a multidisciplinary approach, a strategy for conducting such research has to be formulated as a prerequisite to detailed investigations.

The results of this research will provide guidelines to the groundwater community in terms of the conceptualisation, exploration and development of deep aquifer systems, and will also identify key areas for future research.

The aims of the project are to:

- Develop a conceptual framework for assessing the significance of deep groundwater systems
- Increase the level of awareness and understanding of deep groundwater systems in South Africa

Estimated cost: R195 000  
Expected term: 2001 - 2002

##### Hydrogeology of fractured aquifers and related ecosystems within dolerite ring- and sill systems of the Eastern Cape

Council for Geoscience  
(WRC Reference No 1238)

Dolerite rings and sills control most of the second-order geomorphological features and drainage systems of the main Karoo Basin. They also control, together with dolerite dykes, the springs and seepages of the Karoo Basin. On a regional scale, these features display a great degree of variability in size, geometry, shape, level of stratigraphic emplacement and structural complexity. They form an important part of the structural framework of the Karoo Basin, and outcrop over an area approximately half of South Africa. This project is a follow-up to a project that has recently been completed. The results are promising, indicating that ring structures are potentially excellent targets for groundwater, provided that the associated hydrogeological domains are well understood. This project will investigate the ring structures in the Eastern Karoo in the vicinity of Queenstown and King William's Town.

The aims of the project are:

- To assess the occurrence of groundwater associated with the dolerite rings and sills in the Eastern Cape area, i.e. Queenstown and King William's Town 1/250 000 sheets, using:

- Morphological and tectonic 3D analysis
- Drainage systems
- Detailed investigation of the dolerite ring structures on a local scale for explorative drilling and selection of springs for detailed studies of their ecosystems
- To define hydrogeological domains and the effects on ecosystems, spring recharge and water quality:
  - By compiling ecosystem maps from available data and remote sensing on a regional scale
  - By completing specific fieldwork on a detailed study area
  - By selecting a specific spring for a detailed study parallel to the drilling programme.

Estimated cost: R485 000  
Expected term: 2001 - 2003

**Deep artesian groundwater exploration for Oudtshoorn (Dageos) municipal supply**  
Umvoto Africa (Pty) Ltd  
(WRC Reference No 1254)

The thick orthoquartzitic sandstone formations of the Table Mountain Group (TMG) in South Africa constitute a significant aquifer (aquifer volume of at least 200 000 km<sup>3</sup>). Aquifer permeability is due to a pervasive set of fractures, including bedding-parallel and bedding-normal fractures, as well as jointing and faulting at various scales. Traditionally boreholes have been drilled to maximum depths in the range of 90 to 150m. Over the past few years, limited deep drilling below 150m has resulted in boreholes yielding >32ℓ/s. This implies a deep circulation of groundwater within the TMG fractured-rock aquifer. This study will use a multidisciplinary approach (remote sensing and geophysics and structural geology) for optimal site selection. This will be followed by groundwater verification of selected targets and finally deep drilling and pump-testing. The wells will be utilised by Oudtshoorn Municipality.

The aims of the project are:

- To explore and quantify the deep artesian groundwater resource potential in confined fractured-rock aquifers of the Table Mountain Group (TMG) within a water-stressed catchment through the integrated application and further enhancement of structural-geological and remote-sensing/geophysical methods
- To develop and prove the technical capacity for drilling deep (>350 to 400 m) wells at selected sites of potentially high water resource yield >35ℓ/s

- To complete and pump-test at optimum yield an experimental deep groundwater well at two or more target sites for the purpose of constraining the aquifer parameters (e.g. permeability and storativity) and proving a sustainable and environmentally acceptable augmentation of the Oudtshoorn municipal water supply
- To develop and implement modern methods of technical and financial risk assessment as a scientific-technical guide and decision-making tool, and to determine the overall project financial risk.

Estimated cost: R550 000  
Expected term: 2001 - 2002

**Groundwater in the Olifants River basin: Assessing viable alternatives for small-scale irrigation**  
School of Environmental Sciences, University of Venda  
(WRC Reference No 1278)

Groundwater in the Olifants River basin presents a suitable opportunity for smallholders. If accessible, it will be a much more cost-effective way of implementing small-scale irrigation systems. Operation and maintenance costs associated with flood and sprinkler irrigation systems that are widely used will be drastically reduced when groundwater is used.

There are several drawbacks to the use of groundwater by small-scale farmers in the Olifants River basin. The Olifants catchment is characterised by highly variable rainfall, spatially as well as temporally, resulting in groundwater recharge episodes that are non-uniform, too far apart, and not predictable. This makes planning difficult by farmers and results in poor yields. Secondly, the potentially utilisable groundwater occurs in non-contiguous water-bearing formations. It is in these isolated pockets that groundwater potential for irrigation lies. Thirdly, there is a general lack of knowledge of the basin-level hydrological potential in order to estimate the potential area that can be irrigated using groundwater available in the catchment. This project brings about the opportunity to address all these issues through:

- Quantification of available groundwater and more realistic recharge estimation in the high groundwater potential areas of the Olifants River basin
- Quantification of the demand of water by smallholder agriculture from underground sources and an assessment of the impact of such abstraction on overall water resources in the basin
- Development and application of conceptual recharge-runoff models for the typical aquifers in the basin

- Development of abstraction base flow-rate relationships in order to establish the impact of groundwater development and use of small-scale irrigation, and assess sustainability.

The aims include:

- To explore the potential and sustainability of small-scale irrigation using groundwater in the Olifants River basin.
- To develop decision support tools, including guidelines, for sustainable use of groundwater for small-scale irrigation, and for policy makers, which address the problems and needs of smallholders.

Estimated cost: R420 000  
Expected term: 2001 - 2002

**The application of Internet-based interactive mapping technologies for geohydrological research purposes GEOSS**  
(WRC Reference No 1290)

The broad project aim is to use leading Internet-based mapping technology for the delivery of spatial and attribute data to a wide audience from students to authorities and decision makers.

The specific aims include:

- Definition of the case study area and the collection of all relevant data.
- Establishment of a well-structured database both with spatial and attribute data, in a common format and projection and in accordance with the Spatial Entity Classification Standard (SpECS) developed by the National Spatial Information Framework.
- Migration of the database to the ArcIMS (Internet Map Server) and minor restructuring of the database as required by ArcIMS.
- Design and development of the ArcIMS interface.
- Completion of training of both researchers and staff in the use of the geohydrological ArcIMS.
- Development of database maintenance protocols and identification of research projects.

Estimated cost: R79 670  
Expected term: 2001 - 2001

**Programme 2: Catchment hydrology**

**Model of the Orange River**  
BKS (Pty) Ltd  
(WRC Reference No 865)

This project provided a basis for the operations of Vanderkloof and Gariep Dams to determine a discharge

release pattern to ensure that the various water-demand points downstream are satisfied efficiently. The use of the Orange River operational model developed here can be enhanced by developing an additional routine for automatic calibration. This routine will utilise real-time telemetry data from the river, compare them with the simulated flows and then automatically adjust the model parameters to improve model calibration. With these routine enhancements the model can be utilised for flood management.

Estimated cost: R968 000  
Expected term: 1997 - 2000

**Flood forecasting system for the Vaal Dam**  
Department of Water Affairs and Forestry  
(WRC Reference No 908)

As a result of the Gore-Mbeki Binational Commission, South Africa received an offer of a flood forecasting system based on USA technology. At the time the WRC decided, together with DWAF, to accept the offer rather than invest in costly development locally. The system has been installed for the Vaal Dam system. The WRC contribution is to be towards meeting training and installation costs.

Estimated cost: R150 000  
Expected term: 1998 - 2001

**Monthly multiple site streamflow model**  
BKS (Pty) Ltd.  
(WRC Reference No 909)

Stochastic streamflow generation to deal with South African's variable flow regimes has been in use since 1985. The existing model is not user-friendly and runs under DOS. It cannot handle records of variable length. This project will develop, restructure and rewrite more user-friendly streamflow generator software under Windows that can accommodate variable record lengths.

Estimated cost: R300 000  
Expected term: 1998 - 2001

**Sediment-induced density current formation in reservoirs**  
Department of Civil Engineering, University of Pretoria  
(WRC Reference No 911)

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. Mahale 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.

*Estimated cost:* R91 000  
*Expected term:* 1998 - 1998

**A field study of two- and three-dimensional processes in hill-slope hydrology for better management of wetlands and riparian zones**

*School of Bioresources Engineering and Environmental Hydrology, University of Natal*  
(WRC Reference No 1061)

Most high rainfall- and runoff-producing areas in South Africa are characterised by relatively shallow soils over more or less weathered bedrock with variable topography. This project addresses the lateral movement of infiltrated rainfall on the hill-slope as a key element of the rainfall-runoff process that needs quantitative understanding for the management of wetlands and baseflows in rivers.

*Estimated cost:* R1 809 000  
*Expected term:* 1999 - 2002

**Experimental and laboratory measurements of soil hydraulic properties for improved modelling of catchment processes**

*School of Bioresources Engineering and Environmental Hydrology, University of Natal*  
(WRC Reference No 1086)

The movement of water in the soil mantle of the earth plays an important role in many aspects of catchment management. Soil hydraulics is important when

investigating waste sites, irrigation and drainage and water infiltration of natural surfaces in general. This project is to develop robust field and laboratory measurement techniques to characterise soil hydraulic properties on a consistent and scientifically sound basis as an input into modelling.

*Estimated cost:* R646 300  
*Expected term:* 1999 - 2002

**Design and testing of an installed hydrological modelling system**

*School of Bioresources Engineering and Environmental Hydrology, University of Natal*  
(WRC Reference No 1155)

One of the main needs in integrated water management on a catchment basis is the requirement to achieve vertical integrity between the detail of the individual field scale and the broader view of the larger catchment scale. It is believed that a GIS-based installed modelling system covering a catchment or entire water management area is one of the tools required in this regard. Together with DWAF and BKS Inc. the ACRU modelling system is being tested in the upper Olifants River catchment. DWAF has made additional funds available in excess of R1m.

*Estimated cost:* R2 104 000  
*Expected term:* 2000 -2002

**Flow measurement at natural river controls and the provision of fish-ways**

*Department of Civil Engineering, University of Stellenbosch*  
(WRC Reference No 1270)

South Africa measures its flow in rivers by means of constructed weirs and these impose an obstruction for the movement of fish in the rivers. This project will find hydraulically acceptable ways of continuous flow measurements with fish-ladders.

*Estimated cost:* R840 000  
*Expected term:* 2001 - 2004

**Programme 3: Understanding and predicting rainfall variability**

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

*Department of Civil Engineering, University of Pretoria*  
(WRC Reference No 904)

Ultimately, the key to better seasonal climate forecasts for management purposes lies in an improved understanding of coupled ocean-atmosphere processes as captured in models, operating at the global scale, which interactively drive nested models cascading through regional and ultimately catchment scales. This project represents a major collaborative initiative with the CSIRO in Australia aimed at coupling leading global atmospheric and ocean models, with the emphasis on those ocean areas which are meaningful for Southern Hemisphere climate, and using the model outputs to improve forecasting skills.

*Estimated cost:* R252 000  
*Expected term:* 1998 - 2001

**The ocean's role in South Africa's rainfall**

*Department of Oceanography, University of Cape Town*  
(WRC Reference No 953)

The investigation of ocean processes impacting on South Africa's rainfall is being assisted through development of satellite-remote-sensing methodologies, firstly to observe, study and monitor the hydrological cycle from ocean evaporation to advection of water vapour over South Africa and secondly to further elucidate mechanisms causing sea-surface temperature (SST) variability in those regions where SST anomalies are linked to drought in South Africa.

*Estimated cost:* R1 395 000  
*Expected term:* 1998 - 2002

**Climatology of water vapour sources, sinks and transport in Southern Africa**

*Department of Environmental and Geographical Sciences, University of Cape Town*  
(WRC Reference No 1012)

To be relevant and useful within the context of climate forecasting, atmospheric models have to be able to accurately represent (simulate) flows of water vapour over Southern Africa. This project uses all available data and especially developed trajectory models to establish a unique and important climatology of water vapour sources, sinks and pathways which will be used to further elucidate rainfall processes over Southern Africa and to serve as a diagnostic frame of reference for analysing the performance of regional atmospheric models.

*Estimated cost:* R562 000  
*Expected term:* 1999 - 2002

**Reconstruction of long-term, high-resolution records of summer rainfall and its variability on South Africa from cave speleothems**

*Department of Archaeology, University of Cape Town*  
(WRC Reference No 1013)

As a further contribution to climatic record reconstruction, cave speleothems in the Northern Province have been sampled and are being analysed in order to establish long-term changes in moisture availability, temperature, rainfall and vegetation responses. Unprecedented temporal resolution (sub-decadal or 5-year time scales) appears achievable using this technique.

*Estimated cost:* R 375 000  
*Expected term:* 1999 - 2002

**Regionalisation of rainfall statistics for design flood estimation**

*School of Bioresources Engineering and Environmental Hydrology, University of Natal*  
(WRC Reference No 1060)

Most design rainfall methodologies of the past were based on individual stations' records. The regionalisation approach, being addressed in this project, will allow us a more robust processing of all observations of different record length and observation period. Since the last comprehensive processing of data on flood-producing rainfall took place in the mid 1980s, the project also presents the opportunity for a much-needed update.

*Estimated cost:* R1 072 700  
*Expected term:* 1999 - 2001

**Dynamic modelling of present and future climate system variability at inter-annual and inter-decadal time scales**

*Department of Environmental and Geographical Sciences, University of Cape Town*  
(WRC Reference No 1154)

Outputs from general atmospheric circulation or global climate models must be "down-scaled" before results can be meaningful for prediction of impacts of climate change at regional or catchment scale. This project continues to investigate, and build capacity in the nested use of global and regional-scale dynamic atmospheric models for down-scaling purposes in order to complement and refine empirical techniques already developed and in use. It does not attempt to refine regional models, developed overseas, for South African conditions.

Estimated cost: R1 616 000  
Expected term: 2000 - 2003

#### Development of an improved gridded database of annual, monthly and daily rainfall

School of Bioresources Engineering and Environmental Hydrology, University of Natal  
(WRC Reference No 1156)

The gridded (one minute by one minute) database of monthly and daily rainfall produced in 1987 is being updated to accommodate all recent data. In the process, refined methods of data infilling and extension are being used, revised maps of rainfall statistics are being produced and automated input into simulation models is being provided for.

Estimated cost: R2 277 600  
Expected term: 2000 - 2002

#### Regional model development for simulating atmospheric behaviour and rainfall over Southern Africa

Department of Earth Sciences, University of Pretoria  
(WRC Reference No 1261)

There is an increasing demand by hydrologists, the agricultural community, disaster managers and the public for more accurate spatial projections of anomalous rainfall. The complex distribution of surface characteristics over Southern Africa such as topography, coastlines, inland water bodies and vegetation, induces atmospheric circulation and rainfall patterns unique to the region. To better simulate local circulation patterns and rainfall over the Southern African region, it is necessary to develop or adapt a regional atmospheric model to suitably capture the unique surface characteristics of the region. An issue as important as the development of a regional atmospheric model for Southern Africa is the broadening of the skills base needed for continuous refinement and use of such models. It is intended to use this project to create opportunities for interested scientists and students from various institutions to familiarise themselves with atmospheric modelling concepts and practices.

The aims of this project, therefore, are to:

- Modify the dynamic formulation and physical parameterisation schemes of an internationally competitive regional atmospheric circulation model (DARLAM from Australia) in order to improve the simulation of water-related atmospheric variables over Southern Africa

- Equip scientists and prospective students from the Southern African community with the necessary knowledge and skills to develop, maintain and use such regional atmospheric models.

Estimated cost: R678 000  
Expected term: 2001 - 2003

#### Programme 4: Development of appropriate techniques for evaporation monitoring

##### Improving the basis for predicting evapotranspiration from dry-land crops and veld types in South African hydrological models

Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 1219)

Evapotranspiration or "green water" represents between 50 and 99% of our natural water balance in South Africa. Hydrology, rain-fed agriculture and irrigation have in the past followed somewhat different methods to estimate evapotranspiration of plants and plant covers. This project aims at building a common base from which the integration of the various catchment management activities (afforestation, wetland rehabilitation and alien vegetation control) can be quantitatively understood and prioritised.

Estimated cost: R530 600  
Expected term: 2001 - 2003

#### Programme 5: Water quality assessment studies and information systems

##### WQ90: Development of an interactive surface water quality information and evaluation system for South Africa

Stewart Scott (CE) Inc.  
(WRC Reference No 950)

Development mostly leads to an increasing susceptibility to salinisation and other forms of water quality degradation of the country's water resources. Sustained development requires the early anticipation of associated water quality problems so that these effects can be rectified or obviated. This project is developing a prototype water quality planning tool for the Vaal River system (similar to *Water Resources 90* which provided assistance with water resource planning)

Estimated cost: R775 000  
Expected term: 1999 - 2001

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

Department of Civil Engineering and Department of Soil and Agricultural Water Science, University of Stellenbosch

(WRC Reference No 951)

Water quality deterioration threatens to diminish the utilisable part of the runoff in many catchments. This project has developed an integrated information system specifically for water quality (WQIS) as a tool to assist water managers with managing these complexities on an integrated catchment basis. The WQIS provides diagnostic and predictive utilities to serve technical planning and operational decision-making in a river system, and at the same time also provides 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

#### Pilot study to demonstrate implementation of the National Microbial Monitoring Programme (NMMP)

Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 1118)

The NMMP and manual were developed in a previous project and consultancy. A pilot study to demonstrate the implementation of the NMMP was regarded as an important link between the concepts described in the manual and a full-scale implementation of the monitoring programme.

- Through the first project the implementation of the NMMP is being demonstrated in 8 high-priority health risk areas and involves the community and other stakeholders.
- The existing NMMP for surface waters also needs to be extended to include groundwater. The specific aim of this phase is to develop a prototype manual that formally describes the detailed groundwater monitoring system design and all aspects of subsequent implementation of the programme.

Estimated cost: R303 000  
Expected term: 2000 - 2001

#### A guideline for the selection of toxicity tests in support of the information requirements of the National Water Act

Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 1211)

An important implication of the National Water Act (NWA) is that the introduction of both source-directed controls and resource-directed measures aimed at improving water quality will be based on the effect of these measures on the resource. Biological toxicity tests are ideally suited to assess these effects for stressors. Toxicity assessments can be used to set the standards used in source-directed controls, or to elicit a site or situation-specific response to a stressor. A large number and variety of biological tests are available internationally for aquatic toxicity assessment. A range of toxicity tests has also been established for South African use. Most of the local tests are presently applied in hazard assessments to establish toxicity at the source level. However, in order to implement the requirements of the NWA, methodologies appropriate for resource-directed measures and source-directed controls are required, as well as knowledge on how methodologies for one application relate to the other. The purpose of this project is, therefore, to establish a guideline for the selection of toxicity tests that would support the information requirements of the NWA. This will be compiled in a user-friendly document that will facilitate the application of toxicity assessment in water resource management.

Estimated cost: R450 000  
Expected term: 2001 - 2002

#### Extension of the South African National Microbial Water Quality Monitoring Programme (NMMP) to include groundwater

Division of Water, Environment and Forestry Technology, CSIR, DWAF and the Department of Health  
(WRC Reference No 1277)

The link between the concepts described in the *Manual for the National Microbial Water Quality Monitoring Programme* and a full-scale pilot implementation has been undertaken in 8 high-priority health-risk areas and involves the community and other stakeholders. There is a need to extend the existing NMMP for surface waters to include groundwater. The specific aim of this phase is to develop a prototype manual that formally describes the detailed groundwater monitoring system design and all aspects of subsequent implementation of the programme.

Estimated cost: R600 000  
Expected term: 2001 - 2003

### **Programme 6: Real-time mapping of daily rainfall over South Africa**

#### **Spatial interpolation and mapping of rainfall: Maintenance and upgrading of radar and rain-gauge infrastructure**

SA Weather Services  
(WRC Ref No 1151)

This project addresses the needs for the upgrading, networking, maintenance and operation of existing weather radars in order to render them suitable for routine, precision rainfall measurement in addition to their intended usage for severe weather warning purposes. The project also addresses the need for supporting rain-gauge networks required for radar calibration.

Estimated cost: R1 647 000  
Expected term: 2000 - 2002

#### **Spatial interpolation and mapping of rainfall: Radar and satellite products**

Meteorological and Technology Systems, SA Weather Bureau  
(WRC Reference No 1152)

This project contributes to the programme by refining and extending procedures whereby radar and satellite signals are converted into best-possible rainfall measurements in areas of radar and satellite coverage. Special procedures and algorithms are being developed in order to reduce the effects of "noise" superimposed on the rainfall signals, thereby enhancing data reliability.

Estimated cost: R318 000  
Expected term: 2000 - 2002

#### **Spatial interpolation and mapping of rainfall: Optimal integration of rain-gauge, radar and satellite-derived data in the production of daily rainfall maps**

Department of Civil Engineering, University of Natal  
(WRC Reference No 1153)

This project optimises the merging of data from different rainfall data sources (point data from rain gauges and spatially distributed data from radars and satellites). Merging (integration) procedures take into account that there will be instances where availability and/or reliability of data from some sources are greater than from others, and that data selection should be preferentially based on reliability and requirements for best spatial and temporal resolution.

Estimated cost: R270 000  
Expected term: 2000 - 2002

#### **Caledon River catchment rainfall data linked with streamflow data**

Eskom  
(WRC Reference No 1199)

An existing research programme on real-time spatial interpolation and mapping of rainfall addresses the infrastructural needs of a national real-time daily rainfall monitoring and mapping system, the refinement of radar and satellite rainfall-estimation technologies, and the merging of rain-gauge, radar and satellite data to provide the best possible integrated product from the point of view of resolution (both spatial and temporal) and reliability. The programme also makes provision for pilot applications of the real-time spatial rainfall outputs, in order to test and demonstrate their efficacy and promote technology transfer. Use of digital rainfall products from the mapping programme is being tested and promoted through this small pilot implementation project which aims to link areal rainfall data in the Caledon River catchment to streamflow, thereby fulfilling a need for inflow prediction into the Gariep Dam for optimising water releases for hydropower generation by Eskom.

Estimated cost: R76 000  
Expected term: 2001 - 2002

#### **Umgeni flood nowcasting using radar - An integrated pilot study**

Department of Civil Engineering, University of Natal  
(WRC Reference No 1217)

An existing research programme on real-time spatial interpolation and mapping of rainfall addresses the infrastructural needs of a national real-time daily rainfall monitoring and mapping system, the refinement of radar and satellite rainfall-estimation technologies, and the merging of rain-gauge, radar and satellite data to provide the best possible integrated product from the point of view of resolution (both spatial and temporal) and reliability. The programme also makes provision for pilot applications of the real-time spatial rainfall outputs, in order to test and demonstrate their efficacy and promote technology transfer. This project, which addresses the issue of early flood warning as an aid to disaster management, is not only a pilot study linked to the above-mentioned research programme, but is also an extension of WRC-sponsored research on the development of a real-time flood forecasting model undertaken in the Department of Civil Engineering at the University of Natal. Umgeni Water and Durban Metro

will participate, with a view to immediate implementation of the research products.

The aims of the project are to:

- Draw together new rainfall data sources and flood forecasting methodologies resulting from recent WRC-sponsored research and demonstrate their usefulness within the context of flood management
- Provide decision-makers in Umgeni Water and Durban Metro with tools which will allow them to be more pro-active and effective within the same context.

Estimated cost: R350 000  
Expected term: 2001 - 2002

## **Thrust 2: Integrated Water Resource Development**

### **Programme 1: Integrated catchment management**

#### **The model for water demand management planning and monitoring**

BKS (Pty) Ltd.  
(WRC Reference No 905)

Water demand forecasting is a critical element in medium- to long-term planning. In the past projections were mainly based on extrapolations of broad historical data on actual water use. This project combines population growth and service level considerations to provide a more accurate and verifiable methodology of demand forecasting in urban-industrial complexes.

Estimated cost: R456 000  
Expected term: 1998 - 1999

### **Programme 2: Groundwater resource development**

#### **The determination of recharge and the contribution of groundwater to baseflow (Phase 1)**

Division of Water, Environment and Forestry Technology, CSIR (Stellenbosch)  
(WRC Reference No 1234)

The determination of groundwater recharge and the contribution of groundwater to streamflow are crucial to

the implementation of resource directed measures. Implementation of these measures is a requirement of the National Water Act and in the interests of using water resources sustainably while affording them adequate protection. It is generally assumed that baseflow in surface water resources is largely derived from groundwater resources. However, the separation of the different components of the flow hydrograph is problematic and methodologies are required to determine the actual groundwater contribution to baseflow in rivers. This study proposes to use isotopes and major ions to develop an understanding of flow-paths and the contributions of different flow-paths to streamflow. Stable isotopes of water and other conservative chemicals are increasingly being used to investigate the relative sources (contributions) of water in stream discharge, determine the extent of groundwater resources and estimate residence times. Intensive sampling of rain, soil water, groundwater, baseflow and stormflow will be done. The isotopic (and chemical) signatures will be used in mixing models to resolve the size of the different fluxes. Further, the study will focus on recharge determination, through analysing the hydrograph. This study will be an additional case study to study the hydrological interaction between groundwater and surface water in a well-defined catchment.

The research aims of the study are to:

- Improve process hydrological modelling in headwater catchments based on a proper understanding of flow paths, residence time and reservoir size
- Develop a predictive capability for aquifers of the Table Mountain Group, based on an understanding of flow mechanisms and flow paths in headwater catchments.

Estimated cost: R270 000  
Expected term: 2001

### **Guidelines to set resource quality objectives for groundwater**

Division of Water, Environment and Forestry Technology, CSIR (Stellenbosch)  
(WRC Reference No 1235)

This project intends to support the implementation of the National Water Act. The setting of resource quality objectives (RQOs) is an essential part of the process and also an important mechanism to protect groundwater. The "Reserve" as it is currently defined has a focus which is primarily on surface water and does not adequately protect groundwater. RQOs have a broader

definition under the Act than the Reserve, and therefore have the potential to protect groundwater more effectively and extensively. The need for this project was identified at various forums, as the current WRC-funded programme on **Determining the groundwater component of the Reserve** does not embrace the complete suite of resource-directed measures, i.e. classification, Reserve setting and RQOs. This project will complement the programme and provide significant input into developing groundwater protection measures. The project team will attempt to develop guidelines on setting RQOs for intermediate (medium-term, intermediate confidence) and comprehensive (long-term, high confidence) resource-directed measures. The approach will be consultative, and many key figures from DWAF, research institutions, consultancies and (proto) CMAs will be consulted. The guidelines need to be robust and applicable in a range of South African scenarios - fully covering both the biophysical and management spectra. It is envisaged that the guidelines will provide a procedural framework to select key indicators measuring the functioning of the groundwater resource.

The aims of the project are:

- The establishment of guidelines on setting RQOs
- Contribution of a representative groundwater perspective to the **Resource-directed measures programme**, particularly delineation of eco-regions, classification and monitoring requirements
- A worked example of setting comprehensive groundwater RQOs in a catchment.

Estimated cost: R200 000  
Expected term: 2001

### Thrust 3: Management of Natural and Human-Induced Impacts on Water Resources

#### Programme 1: Predicting the impact of global climate change

Statistically based regionalised flood frequency estimation study for SA, using systematic, historical and palaeoflood data

SRK (CE) Inc  
(WRC Reference No 1260)

The need for flood management and flood protection planning has intensified within the context of the Government's Disaster Management Policy. This project will compile a regionalised flood frequency estimation based on observed flood data in a key water management area in the Eastern Cape. If successful the study can be extended into the rest of South Africa.

Estimated cost: R773 200  
Expected term: 2001 - 2002

#### Programme 2: Groundwater protection

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

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

Groundwater exploitation in many respects forms the cornerstone of water supply to rural communities in South Africa. A problem frequently faced is that of high nitrate concentrations in groundwater. This project determines the extent and severity of high nitrate in groundwater (and associated anthropogenic pollution) in selected study areas in the community water supply context. It also identifies and interprets environmental conditions aggravating the situation.

Estimated cost: R450 000  
Expected term: 1999 - 2001

**The assessment of short-, medium- and long-term impacts on groundwater quality associated with the filling of dolomite cavities**

Metago Environmental Engineering  
(WRC Reference No 1122)

De-watering of the dolomitic aquifers overlying ore-bearing reefs has, since the 1960s, resulted in the formation of a large number of cavities in the dolomitic compartments on the West Rand. These cavities need to be filled both for safety reasons as well as to prevent further inflows of surface water which would lead to aggravated ground instability and accelerated recharge of the mine void. The State Technical Committee for Sinkholes had raised the alarm about the potential for groundwater contamination when the cavities are filled with various mine waste materials including slimes and waste rock. This investigation will focus on the impacts arising from the future filling of cavities and assess the effectiveness of alternative fill materials and methods, in reducing those impacts. Impacts will be assessed over the short-, medium- and long-term. The investigation

will furthermore assess the relative significance of the filling of sinkholes as a source of groundwater contamination in comparison to other sources of contamination such as tailings dams, waste rock dumps, return water dams and streams, and assess the provisions of both current and pending legislation to ensure that proposals arising from the project comply with the requirements of such legislation.

Estimated cost: R440 000  
Expected term: 2000 - 2002

**Mapping of naturally occurring hazardous trace constituents in groundwater**

Council for Geoscience  
(WRC Reference No 1236)

Groundwater is normally considered a safe, viable option to untreated surface water, especially in rural areas of South Africa where funds and expertise to operate treatment facilities is limited. In some cases this can result in the supply of water of unacceptable or hazardous quality due to the presence of trace elements not detected by routine analytical procedures. Arsenic, whose origin is often geological, is an example of such an element and the cause of an environmental disaster such as is currently unfolding in West Bengal and Bangladesh.

South Africa has an "old" geology. As a result the groundwater in these formations has a large potential to assimilate trace constituents due to long residence times of groundwater. These trace constituents, which apart from arsenic, may include uranium, selenium and fluoride, may pose a health risk to the community supplied from this source. The project will delineate potentially hazardous areas and provide decision-makers with information for planning purposes. Identification of problem areas and the awareness of risks may lead to the development of safe alternative sources and possible treatment, where no other sources are available.

The principal aims of the study will be to:

- Produce a GIS map on CD-Rom informing South African experts and decision-makers of the locations of naturally occurring hazardous constituents which pose a risk to groundwater potability
- Identify the hydrochemical processes involving these problem constituents and the field conditions under which they remain in solution.

Estimated cost: R190 000  
Expected term: 2001

#### Programme 3: Pollution of surface water

**Cost-effective methods for monitoring pesticide pollution in water systems: Technologies and procedures for field use in rural areas**

Department of Community Health, University of Cape Town  
(WRC Reference No 1120)

There is emerging evidence of widespread pesticide contamination of water at relatively low concentrations. As part of a recently completed project, pesticide analytical approaches as used at the Peninsula Technikon, have become sufficiently sensitive and consistent to detect small quantities of primary and breakdown products on a regular basis. Little pesticide monitoring takes place in South Africa because of limited capacity, high costs and the dependence of local communities on distant experts. This project is evaluating two promising new technologies that could reduce the costs of, and practical obstacles to, analyses for pesticides in water. It also aims to develop monitoring guidelines for stakeholder groups and identify the training, technical support and other needs to implement monitoring.

Estimated cost: R500 000  
Expected term: 2000 - 2001

**Water-related impacts of small-scale mining - Nature of the impact and development of management options**

Pulles, Howard & de Lange Inc.  
(WRC Reference No 1150)

Small-scale mining already takes place widely in South Africa. The White Paper on Mineral Development in South Africa identifies small-scale mining as an important sector of the mining industry. The interests of the country and the community, however, require that all forms of mining, whether large-, small- or micro-scale, should be subject to the same requirements in respect of licensing, safety, health and the environment. It is also the view of Government that small-scale mining, like the rest of the mining industry, will be required to adopt measures that will promote environmental sustainability by means of the application of consistent standards and acceptance of the concept. This project will identify and characterise the critical water-related impacts of small-scale mining and is developing appropriate tools to assist their environmental management. The project will focus primarily on the water-related issues of peat extraction, clay-mining for brick making, alluvial diamond-mining and other small-scale mining activities associated with gravels, alluvial sands and sediments.

Estimated cost: R738 000  
Expected term: 2000 - 2002

#### Development of an estuarine water quality index for implementation in estuarine water quality management in Southern Africa

Department of Zoology, University of Zululand  
(WRC Reference No 1163)

Methodologies for the determination of water quality and quantity, as required by the NWA, are less well developed for estuaries than rivers. The aim of this project is to develop a water quality index based on rating curves for selected water quality determinants, to enable the interpretation of variable terms of ecological resource protection. It includes elements of similar indices developed elsewhere, but is applicable to South African estuaries, and will take the form of a decision support system. This links to the water quality component of the project titled **Information requirements for the implementation of resource-directed measures for estuaries**.

Estimated cost: R515 000  
Expected term: 2000 - 2003

#### Development of a user-friendly model for assessing the impact of waste discharge applications on downstream water quality

Stewart Scott Water Quality  
(WRC Reference No 1212)

Successful catchment management from a water quality perspective, requires *inter alia* an intelligent representation (modelling system) of the catchment which describes present water quality and which can be used to predict the effect that proposed new or modified impacts will have on water quality at specific points. Options that need to be incorporated in such a modelling system include applications for new discharge points, increased discharges or altered permit conditions. It is also necessary to assess the impact of current and projected water use and alternatives for managing water quality. This points to the need for a simple but robust technology that can be used to rapidly assess the impacts of applications to discharge waste and the effect of proposed management options. The purpose of this project is to develop such a tool that will not replace the more complex models, but could rather be used to sift options to determine if more complex models need to be applied. The proposed tool could also serve to standardise the approach taken by CMAs in evaluating the initial results obtained by a large variety of organisations. It will be developed in co-operation with DWAF's Directorate of Water Quality Management and its Gauteng Region.

Estimated cost: R449 900  
Expected term: 2001 - 2002

#### Survey of certain persistent organic pollutants in major South African waters

School of Environmental Sciences and Development,  
Potchefstroom University for CHE  
(WRC Reference No 1213)

Persistent organic pollutants (POPs) are organic compounds of natural or anthropogenic origin that resist photolytic, chemical and biological degradation, and also have toxic properties. They have low water solubility, but are readily soluble in lipids and can therefore accumulate in fatty tissue of biota. Because of their long persistence times and low volatility, they can be transported in the environment in low concentrations via water and air movements, as well as with migrating animals. This means that POPs can be transported to areas where they have never been used, and can therefore affect human and environmental health globally - consequently the need for international action. In 1997 the UN Environment Programme initiated a process to develop a global, legally binding instrument to reduce the risks these compounds pose to human health and the environment. South Africa signed an international convention in this regard on 24 May 2002. This still needs to be ratified. Much is known about POPs in northern countries. Far less is known about problems in developing countries. This situation may reduce the value of the POP convention for countries such as South Africa. South Africa might in fact be committed to a convention under which it will be obliged to act, while not knowing the full extent of its own contribution to global POPs (e.g. riverine transport to oceans). This study will establish the presence and levels of important POPs in major SA water bodies and thus help to identify the risks posed by these compounds in different geographical areas, and therefore also identify where management action should be focused. Alternative cheaper analytical methods will also be investigated.

Estimated cost: R410 000  
Expected term: 2001 - 2002

#### Assessment of current and future water pollution risks due to gold mining in dolomitic areas

Council for Geoscience  
(WRC Reference No 1214)

An earlier project entitled, **Tier 1 risk assessment of radionuclides in sediments of the Mooi River** (No 1095), has indicated that the release of radionuclides at levels of potential concern, cannot be ruled out. In a separate study, the Potchefstroom University found that

significant variations in the chemical conditions of the river water can occur over periods of hours or less, suggesting that existing data on samples collected at a much lower frequency, particularly those collected on a regular weekly schedule, may not adequately represent the short-term variations in chemistry. Other researchers have demonstrated that isotopic analyses can quantify the contributions of different water sources to polluted ground- and river-water. In this project this approach is being extended to include the material bound to the sediments. It will furthermore assess the current and future risk to local and downstream water users due to pollution, including heavy metals and radionuclides and establish a near real-time continuous monitoring capacity to determine the short-term variations in water chemistry as a guide to future monitoring needs.

Estimated cost: R300 000  
Expected term: 2001 - 2003

#### A case study for the practical assessment of the **Guide to Non-Point Source Assessment** in the A23 tertiary drainage region

Department of Chemical Engineering, Technikon  
Northern Gauteng  
(WRC Reference No 1279)

Because of the difficulties involved in quantifying non-point sources of pollution and the lack of guidance on suitable tools to use for this purpose, the WRC funded a project (No 696) to develop a guide to assess non-point source pollution of surface water resources in SA. The WRC recently published the *Guide to Non-Point Source Assessment*, which is the main product of this project. The present project aims to evaluate the suitability of this Guide for identifying the main non-point sources of pollution within the Soshanguwe and Mabopane areas. These areas are also the main source of students at Technikon Northern Gauteng. The staff of the Department of Chemical Engineering will be assisted with this project by the authors of the Guide and ERWAT Research and Development. It is foreseen that this project will not only yield valuable insight into the pollutants and pollution sources of the area and provide a first practical field test of the Guide, but will also contribute significantly to capacity building within the technikon and to raising awareness about water quality degradation and its causes, within the community.

Estimated cost: R540 000  
Expected term: 2001 - 2003

#### Programme 4: Human-induced impacts

##### Impact of urbanisation and industrialisation on the environment

Department of Chemistry (Mamelodi Campus), Vista  
University  
(WRC Reference No 717)

Increase in urbanisation results in a dramatic increase in industrial and domestic waste. Of major concern is the generation of toxic chemicals and heavy metals. This study aims to investigate the occurrence of polynuclear aromatic hydrocarbons (PAHs) as an indicator of pollution of urban water catchments. PAHs are potentially carcinogenic and the outputs will provide information on a subject area lacking knowledge.

Estimated cost: R380 000  
Expected term: 1995 - 2001

##### Aerosols, recirculation and rainfall experiment (ARREX)

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

Through a programme of airborne sampling various seasonal and atmospheric chemical and microphysical data have been collected which are now being analysed with a view to establishing whether transport and recirculation of long-lived, fine-fraction atmospheric aerosols, over South Africa and adjacent areas, may create conditions favouring a long-term diminution of rainfall over the region.

Estimated cost: R1 390 000  
Expected term: 1998 - 2002

##### Hydraulics of the impacts of dam development on river morphology

Department of Civil Engineering, University of  
Stellenbosch  
(WRC Reference No 1102)

Utilisation of a man-made structure, such as a dam, is very often unavoidable in water-source developments. The impact of the dam is that it alters the river flow regime and with it the sediment transport characteristics, thereby resulting in changes in the river morphology and the river's conveyance capacity.

Both of these factors affect the aquatic habitat of the river. Under regulated flow conditions as a result of a dam, removal of fine sediment through flushing flows does not occur - flows that are very important for the

maintenance of several characteristics of the river channel. Flushing flows, one of the facets on in-stream flow requirements (IFRs), has up to now not received adequate attention from a fundamental hydraulics point of view.

Flushing flows are important for a number of reasons. In addition to maintaining a suitable fishery habitat, maintenance of channel geometry and riparian vegetation, formation of pool areas and retention of adequate habitat heterogeneity, are all dependent on the occurrence of flushing flows of the required intensity and frequency. Current methodologies for the determination of the IFR of a river do not fully utilise acceptable hydrodynamic approaches based on sound theory of sediment transport.

The main objective of this project is thus to obtain a better understanding of the river sediment transport processes and the impacts of dam construction thereon. From this will emanate a methodology for determining flushing flow magnitudes, duration and frequency, thus ensuring maintenance or restoration of river morphology as close as possible to natural or desired conditions. In this regard fundamental hydraulic principles of sediment transport will play a very important role.

This project also emanates from the Workshop on Research Needs in the Field of Hydraulics which took place in March 1998. This workshop identified, *inter alia*, flushing flow IFR, river morphology, river restoration, sediment "management" and computational hydraulics as high priorities in hydraulics research.

Estimated cost: R660 000  
Expected term: 1999 - 2002

**Integrated approach to biomonitoring of wastewater for the presence of biologically active agents**  
*Highveld Biological Association*  
(WRC Reference No 1121)

Research undertaken in this project centres on the development of a rapid (<24h) and inexpensive biochemical water quality test using human cells. It is a colorimetric test and certain aspects can be automated to speed up the process. The method of the test ensures that the results are directly applicable to human health because the test is sufficiently sensitive to detect levels at which chronic responses will occur.

Estimated cost: R252 000  
Expected term: 2000 - 2001

## **Thrust 4:** **Policy Development and Institutional Arrangements for Water Resource Management**

### **Programme 1: Decision support for water policy formulation and implementation**

**Modelling benefits of integrated catchment management**  
*Department of Agricultural Engineering, University of Natal*  
(WRC Reference No 749)

In many water management areas we will find that present water resources have been over-allocated and some form of compulsory licensing and re-allocation of water use will have to be implemented. Based on 7 case studies, the trade-off between various water uses and associated socio-economic benefits is being investigated. This will make a science-based contribution to negotiating the best possible solution to problems of the allocation of a limiting water resource and optimisation of land use.

Estimated cost: R3 360 000  
Expected term: 1996 - 2001

**The value of water as an economic resource in the Great Letaba River catchment**  
*Economic Project Evaluation*  
(WRC Reference No 989)

Apart from separate sectoral analyses in defined subregions, no comprehensive comparison on the value of water for different uses has been undertaken in South Africa. The best option under these circumstances is to estimate water values through economic modelling. In view of the research backlog and the unacceptability of generalisations regarding water values, tenders were invited and approved according to specified guidelines. The outcomes of 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.

Estimated cost: R795 625  
Expected term: 1998 - 2002

**The value of water as an economic resource in the Vaal River system**  
*Greengrowth Strategies*  
(WRC Reference No 990)

Apart from separate sectoral analyses in defined subregions, no comprehensive comparison on the value of water for different uses has been undertaken in South Africa. The best option under these circumstances is to estimate water values through economic modelling. In view of the research backlog and the unacceptability of generalisations regarding water values, tenders were invited and approved according to specified guidelines. The outcomes of 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 organizations.

Estimated cost: R807 180  
Expected term: 1998 - 2002

**Water resource systems analysis: Training and transfer of the technology**  
*BKS (Pty) Ltd.*  
(WRC Reference No 1038)

DWAF uses several water resource systems models. Some of the research on evaporation losses will be incorporated in these models and this project contributes to preparing suitable training material which will also be exported to the SADC region. The emphasis in this project is therefore on technology transfer.

Estimated cost: R40 000  
Expected term: 1999 - 2001

**An analysis of the social, economic and environmental direct and indirect costs and benefits of water use in the irrigated agriculture and forestry sectors**  
*Division of Water, Environment and Forestry Technology, CSIR*  
(WRC Reference No 1048)

The concept of "best possible use" of water involves more than productive use of water since it explicitly provides for weighing up of social, economic, and environmental objectives to promote equity, efficiency and sustainability. It is important to quantify direct and indirect benefits and costs to allow a fair comparison of water use between water-use sectors. It is also necessary to determine backward and forward linkages in the economic activity of different water users within and outside the boundaries of catchment areas. The findings will therefore provide decision support for private and

public management of water allocation within river catchments.

Expected cost: R558 000  
Estimated term: 1999 - 2001

**Developing protocols for integrated catchment management (ICM) based on current initiatives and techniques**  
*Division of Water, Environment and Forestry Technology, CSIR*  
(WRC Reference No 1062)

This project, being undertaken in close cooperation with the DWAF Regional Director in Mpumalanga, seeks to develop protocols for defining the present state of the environment and the desired state of the environment. The required management actions will be formulated and monitoring procedures will be designed. The Sabie catchment is being used as a test case. Stakeholder participation is an important aspect of the protocol and the outcome of this project should be widely applicable in South Africa.

Estimated cost: R1 500 000  
Expected term: 1999 - 2001

### **Programme 2: Development and implementation of water policy instruments**

**Development of a framework for the introduction of waste discharge charge systems in South African catchments**  
*Stewart Scott*  
(WRC Reference No 949)

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. A WRC project laid the foundation for this provision by developing a philosophy and methodology for the implementation of the polluter pays principle. The current project was designed to build on the findings of the previous study by including a wider range of pollutants and by focusing on implementation issues. At an early stage of the project the WRC became aware the DWAF was about to start developing the protocol for implementing waste discharges. In order to prevent duplication, the WRC decided to integrate this project's activities with those of DWAF. Phase I of this initiative was completed with the publication of a *Framework Document* which describes the technical and legal frameworks for the waste discharge system, and the principles on which the development of the system is based. The WRC's contribution will end when the draft implementation strategies are completed under Phase II.

Estimated cost: R400 000  
Expected term: 1998 - 2002

### **Gender dimension of the water policy and its impact on water and sanitation provision and management**

Department of Development Studies, University of Fort Hare  
(WRC Reference No 1021)

Although government policy on water and sanitation services delivery recognises the important role that women have to play, there are currently no enabling policies for promoting the participation of women. This study is undertaking a critical analysis of the gender dimension in the development of the water policy. It is also investigating strategies and institutional arrangements for water services delivery in terms of decisions concerning the location of the water supply scheme, choice of technology, operation and maintenance, community involvement and how these affect women as managers of households.

Estimated cost: R303 000  
Expected term: 1999 - 2000

### **An evaluation of the role of water user associations in water management in South Africa**

Pula Strategic Resource Management  
(WRC Reference No 1140)

The institutional arrangements for water resource management adopted in the National Water Act delegate many water resource management functions (particularly resource protection and allocation) to organisations within a Water Management Area (WMA), namely catchment management agencies (CMAs) and water user associations (WUAs). WUAs are intended to operate at a restricted localised level, to facilitate co-operative associations of individual water users, who wish to undertake water-related activities for their mutual benefit. This study is aimed at clarifying the roles of WUAs, evaluating the functioning of a number of established WUAs against this framework and the particular needs of the local conditions, and formulating guidelines for the institutional and management arrangements.

Estimated cost: R380 000  
Expected term: 2000 - 2001

### **Programme 3: Institutional arrangements for IWRM**

#### **Human resource needs assessment - tertiary level: South African Water Sector up to 2015**

Department of Civil Engineering, University of the Witwatersrand  
(WRC Reference No 977)

Availability of human resources (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 this 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 research project will address the important issues at the national, provincial and community levels, with the necessary inter-linkages of the HR needs of industries, agriculture and other public or private (utility, consultancy, etc.) services.

Estimated cost: R259 000  
Expected term: 1998 - 2001

#### **Effective local management of water resources with reference to the Middle and Lower Orange River**

Department of Agricultural Economics, University of the Free State  
(WRC Reference No 1134)

A computer-based decision-support model based on the institutional arrangement of capacity-sharing, is

available for application in off-stream and instream water use management under conditions of uncertainty. This project evaluates the usefulness of this innovative approach under South African circumstances. This must be done within the context of the National Water Act, information requirements on the quantity and quality of water available, levying of water charges and tariffs in relation to water values for different uses and regulations for the performance of functions by the to-be-established WUAs. It is envisaged that the model will provide an appropriate tool for water management by irrigation farmers and other water users.

Estimated cost: R949 000  
Expected term: 2000 - 2002

#### **Towards integrated catchment management in the Mlazi River: A model for participation in the South African context**

Farmer Support Group, University of Natal  
(WRC Reference No 1157)

In a previous WRC-funded study a structure for community participation in integrated catchment management in the Mlazi catchment was explored. Considerable progress over a wide front of rural water-related activities was achieved. This project serves to develop a transfer policy to ensure that community participation brought about by external intervention is sustainable and that lessons learned can be translocated to other rural areas.

Estimated cost: R1 000 000  
Expected term: 2000 - 2001

#### **Decision support of stakeholder involvement in Reserve determination and other catchment management agency responsibilities**

Department of Statistical Sciences, University of Cape Town  
(WRC Reference No 1186)

There is a growing recognition that some form of multicriteria decision analysis (MCDA) can make a solid contribution to improving various water management decisions. This project builds upon previous experience and lessons learned in applying the MCDA methodology in the field of setting management classes for rivers (contributes also to **Water-Linked Ecosystems**).

Estimated cost: R578 000  
Expected term: 2000 - 2001

#### **Integrated socio-economic and cultural values as additional components of the criteria for estimating and managing the Reserve**

Institute for Natural Resources, University of Natal, Pietermaritzburg  
(WRC Reference No 1195)

The National Water Act of 1998 aims to achieve sustainable use of water for the benefit of all users. It also guarantees the protection of aquatic ecosystems. Historically, the evaluation of the importance of river systems has been largely based on ecological importance, while ignoring social and cultural aspects. This study is establishing the importance of integrating ecological, socio-economic and cultural values in the estimation and management of the Reserve. It is also providing information on the dependency of rural households on river system resources (contributes also to **Water-Linked Ecosystems**).

Estimated cost: R300 000  
Expected term: 2000 - 2001

#### **Developing and trialing guidelines for participatory water resource management at catchment and water management area scales**

Geography Department, Rhodes University  
(WRC Reference No 1233)

In a previous WRC-funded study the establishment of a WUA in the Kat River valley, Eastern Cape was used to formalise community participation. A considerable number of valuable lessons were learned in the process. In this project guidelines for participatory water resource management are being developed that can be used throughout South Africa. The project leader is working closely with Australian counterparts.

Estimated cost: R764 000  
Expected term: 2001 - 2002

#### **Programme 4: Transboundary water resource management**

##### **Security, ecology, community: Contesting the "water wars" hypothesis in Southern Africa**

Centre for Southern African Studies, University of the Western Cape  
(WRC Reference No 1106)

Decision-making processes concerning allocation and use of scarce water resources within certain SADC river basins are being investigated with a view to clarifying issues of potential conflict and common security relating to water scarcity. In the process, a number of graduate students are receiving appropriate training.

Estimated cost: R400 000  
Expected term: 2000 - 2002

### Hydropolitical history of South Africa's major international river basins

Centre for International Political Studies, University of Pretoria  
(WRC Reference No 1220)

Much has been written about the history of Middle Eastern river basins, but not much about South African rivers. Studies have been conducted on the hydropolitics of international river basins (Kunene and Orange Rivers). Although a historical element has been attached, the focus has been mainly on international relations between the actors involved. It is felt that the studies should be broadened to cover the hydropolitical history of the Orange, as well as of the Limpopo and Komati Rivers, to the present day.

An analysis of the hydropolitical history of these rivers is required to contextualise the current patterns of conflict and co-operation between the riparian states and users. Studying the hydropolitical history of the respective river basins can tell us how phenomena, operating in the past, may behave in the future, and how they impact on the hydropolitical dynamics of the rivers at present. This is particularly relevant in the light of the requirements of the SADC Protocol on Shared River Systems and elements of the National Water Act.

Filling of the knowledge gap in South African hydropolitical history will assist water resource planners, hydropolitical scientists, catchment management agencies and government officials to provide reasoned justification for their actions regarding the management of international rivers.

The proposed study has the following aims:

- To record the hydropolitical history of the major international river systems in South Africa in one coherent document
- To establish the past experience of water management in these river systems
- To draw up a framework/backdrop that project planner, water service utilities, government departments and CMAs can use for the effective management of these international river systems
- To contribute to a multidisciplinary understanding of the dynamics of South Africa's major international river basins
- To build capacity by incorporating research assistants from previously disadvantaged communities into the research team.

Estimated cost: R398 100  
Expected term: 2001 - 2003

## NEW

### Thrust 1: Water Resource Assessment

#### Programme 1: Groundwater occurrence in fractured-rock aquifers

**Technological transfer of all information necessary for the use, management and protection of Karoo aquifers**  
*Institute for Groundwater Studies, University of the Free State*  
(WRC Reference No 1321)

The semi-arid and arid central and western regions of South Africa, where there are no rivers or other surface water sources, cover approximately 66% of the country. The majority of the inhabitants in these areas depend on groundwater for their water supply. A large part of these regions, and approximately 50% of the country as a whole, is underlain by the so-called fractured-rock Karoo Sequence.

Over the last 20 years numerous research projects have been conducted on Karoo aquifers. An example of such a project is **Karoo aquifers: Their geology, geometry and physical properties**. The need to document the results of Karoo aquifer research projects was identified by the WRC's Fractured-Rock Aquifer Task Group. Experts from the geological (structural geology and sedimentology) and geohydrological fields were assembled to formulate the structure and content of the Handbook. The Handbook has been completed, and the time has come to distribute the information in a format understood by not only groundwater specialists but all parties responsible for supplying groundwater to the hundreds of villages dependent on groundwater from Karoo aquifers.

The proposed project aims to transfer knowledge generated through the research process to various stakeholders.

Estimated cost: R200 000  
Expected term: 2002 - 2003

**Recharge mechanisms in TMG aquifer systems**  
*Groundwater Group, Department of Earth Science,*

*University of the Western Cape*  
(WRC Reference No 1329)

Although groundwater recharge is widely recognised as the key factor in determining the sustainable management of groundwater resources, no comprehensive study of groundwater recharge of TMG aquifer systems has yet been undertaken. Particularly the lack of monitored data is presently seen as the key limiting factor in quantifying recharge of TMG aquifer systems. It is within this context that the WRC invited research proposals on "Recharge processes in the TMG aquifer systems". The aim of the WRC's request is to better understand recharge processes and to quantify recharge rates.

Critical issues around the sustainable development of the TMG aquifer systems are the understanding of recharge processes and factors influencing recharge, and ultimately quantification of recharge rates under various climatic, geomorphological and hydrogeological settings.

In order to estimate realistic recharge rates of TMG aquifers and to understand the climatic impacts on recharge and large-scale groundwater development, conceptual recharge models need to be developed. These models should account for a proper understanding of both physical and chemical characteristics of unsaturated and saturated zones at the various geomorphological settings and under changing climatic conditions.

The hydrogeological characteristics (groundwater flow regime, depth to water strike, recharge area, groundwater quality and quantity, the occurrence of springs and vegetation types, etc.) of the aquifers are highly variable. Recharge studies must therefore be guided from regional through intermediate to local scale. The focus of the studies will be on recharge mechanisms that are dominant in the TMG. In general, quantification of recharge rates may be concentrated at both scales of "type" areas and quaternary catchments, the latter being compatible with those of the resource-directed measures. Assessment of recharge will also be carried out where case studies of other TMG aquifer-related projects are located.

The aims of the project are:

- Quantification of realistic recharge rates and the processes of recharge in the TMG aquifer systems
- Evaluation of the sensitivity to rainfall patterns (spatial and temporal patterns) with a view to understanding the impacts of climate change on

water resources

- The use and development of innovative techniques to assist in recharge estimation in TMG aquifer systems.

Estimated cost: R800 000  
Expected term: 2002 - 2005

**Feasibility study on the use of chemical geothermometers for tracing deep groundwater flow**  
*Division of Water, Environment and Forestry Technology, CSIR (Stellenbosch)*  
(WRC Reference No 1331)

Chemical geothermometers were developed as a technique for measuring historical water temperatures in sedimentary basins and the method has been applied in the geothermal, natural gas and oil exploration industries. Using geothermometers to quantify the maximum depth of groundwater flow and thus quantify groundwater storage in fractured-rock aquifers could represent an innovative application of these techniques.

The specific objectives of this research proposal are:

- To establish the usefulness of chemical geothermometers for tracing deep groundwater flow systems
- To identify techniques in chemical geothermometry applicable to the major secondary aquifer environments in South Africa

Estimated cost: R99 600  
Expected term: 2002 - 2003

**Identification and prioritisation of type areas for detailed research in terms of regional variability of aquifer systems**  
*SRK (CE) Inc*  
(WRC Reference No 1332)

The TMG aquifer system extends from north of Vanrhynsdorp in the Northern Cape Province to Cape Agulhas in the south, and through to Port Elizabeth in the east.

Significant regional variations in the hydrogeological characteristics of these TMG aquifer systems were recognised. The TMG aquifer system was subdivided into a number of "type" areas based on significantly different folding and faulting styles, tectonic regimes during the development of the Cape Fold Belt (CFB) and its variable stratigraphic thickness, recharge, hydrochemistry, etc. The following "type" main areas were identified, from west to east:

- Western TMG area
- Central TMG area, Agter Witzenberg-Ceres-Hex-Koo-Villiersdorp valleys
- Coastal belt TMG area, i.e. from Kleinmond to Mossel Bay
- Klein Karoo TMG area
- Eastern Cape TMG area, Plettenberg Bay to Port Elizabeth, where quantitative hydrogeological information is scarce.

Similarly, this TMG outcrop area shows a great degree of variability in river flow (base flow) and floral-faunal habitats that are related to regional variations in the climate (rainfall, temperature), soils, altitude, etc.

The recent advances in GIS technology and spatial modelling techniques, as well as the availability of a large number of GIS datasets (recharge, vegetation, aquifer systems, groundwater abstraction, rainfall, digital terrain models, nature reserves, ecologically sensitive zones, etc.), makes it possible to cost-effectively develop a regional perspective of the variability of key issues discussed above and therefore to optimise the selection of type areas required to address this variability. The GIS database developed for this study will also provide valuable information for input into the more detailed local research projects.

The research project aims to identify suitable "type" areas for detailed research on groundwater abstraction from TMG aquifer systems, where the regional characteristics and variations in the TMG aquifer systems, climate and ecology are taken into account.

The specific objectives of this research project are:

- Collect and collate all the existing and relevant information into a GIS
- Identify gaps in the information system and where possible, capture such information
- Evaluate GIS datasets to ascertain key parameters required to characterise the geographical variability of the TMG aquifer systems and associated ecosystems
- Apply GIS-based spatial modelling techniques to identify "type" areas where research should be conducted in order to cover the variable conditions encountered in the TMG aquifer systems
- Describe the main characteristics used to define each type area, which will serve as key research needs for detailed study within a specific area.

Estimated cost: R244 000  
Expected term: 2002 - 2003

#### Geothermal studies of TMG aquifer systems

*Umvoto Africa cc*  
(WRC Reference No 1403)

The TMG is well known for the occurrence of hot springs, including the hottest and strongest in South Africa, namely Brandvlei near Worcester. These geothermal phenomena provide direct evidence for deep circulations of groundwater, but locally also exert a significant control on the ambient temperature of wetland soils and surface-water streams in the discharged areas.

In these areas the fluid-mechanical advection and concentration of geothermal energy supports distinctive microclimatic regimes that are largely buffered against extreme seasonal change, and which in turn allow characteristic micro-floral and micro-faunal populations to flourish. There is a dearth of hard information on what these hot-spring microbial ecologies are, and how higher floral and faunal elements in the wetland and riparian zone might depend on this geothermally-supported base for their nourishment. By analogy with conditions in other parts of the world, it might also be suspected that vertebrates, such as endemic fish or amphibians, are sensitive to the range of water temperatures at certain times of year.

Now that the groundwater resources of the TMG are receiving considerable attention as a potential long-term solution to increasing water scarcity in the Western Cape Province, there is new scope for the developing exploration and reservoir-characterisation methodologies, and the deep-drilling expertise required for this unique kind of fractured-rock aquifer. The circumstances also provide opportunity for broadening and deepening the knowledge of rock temperature gradient and heat flux in the area, but the generally "wet" and often flowing (artesian) nature of boreholes within the TMG terrain is not conducive to the classical modes of geothermal research, which assume that conduction is the principal mode of crustal heat transfer.

The research aims to:

- Determine whether, where, and how utilisation of aquifers is likely to affect the subsurface geothermal regime
- Determine the extent to which monitoring of borehole temperatures can be used to establish underground flow rates and affects on recharge/discharge areas

Estimated cost: R150 000  
Expected term: 2002 - 2003

#### Programme 2: Catchment hydrology

##### Formalisation of terms of reference for the update of the Surface Water Resources of South Africa.

*SRK Consulting (SA) (Pty) Ltd*  
(WRC Reference No 1315)

The WR90 study was an extremely successful one and its products have been and are presently widely used. An economic assessment recently carried out by a firm of independent economists has indicated that the WR90 study has paid for itself many times over. Since completion of this project, some of the most significant information has become outdated as it is based on data up to September 1990. This is due not only to the fact that the last 10 years (which contain significant droughts and flood events) have not been covered but also due to recent developments in the assessment of water usage by afforestation and alien vegetation and the introduction of the Reserve as a vital aspect of water resources appraisal.

If the database is allowed to remain unchanged its value to the community will diminish with time and a stage will eventually be reached when it becomes totally outdated. This is already the case with mean annual runoff (MAR) in catchments subject to afforestation, which has had to be modified to account for the phasing out of Van der Zel curves in favour of information derived by Forestek (CSIR) on afforestation usage.

The aims of the project are:

- To develop a terms of reference (TOR) for the updating and expansion of *Surface Water Resources of South Africa*
- To research PDI capacity and capability for playing key roles in the second phase where they would be "twinning" with recognised experts. These roles would be clarified and defined in the TOR
- To make provision for necessary amendments and address shortcomings/difficulties of the original WR90 data set.

Estimated cost: R351 000  
Expected term: 2002 - 2003

##### Development of a continuous simulation modelling system for design flood estimation in SA

*School of Bioresources Engineering and Environmental Hydrology, University of Natal, Pietermaritzburg*  
(WRC Reference No 1318)

The wide-scale destruction of hydraulic structures and loss of life caused by the February 2000 floods in the

north-eastern part of South Africa and other recent floods has raised the issue of the adequacy of procedures for design flood estimation in South Africa.

Regional approaches to the frequency analysis of observed floods, which supplement the time-limited sampling record by the incorporation of spatial randomness, are accepted as being more reliable and reduce uncertainties compared to estimates based on the analysis of data from a single site. In South Africa, record lengths of observed runoff data are relatively short (generally < 50 years), flow-gauging stations are relatively sparse and many DWAF gauging structures are frequently over-topped during significant floods. Further limitations of the observed runoff records are that the frequency of flood-producing rainfalls and catchment land-use characteristics may have changed during the period of historical measurement, resulting in non-stationary streamflow time series, which are not suitable for frequency analysis.

Easy-to-use methods which produce consistent results by different users are necessary for design flood estimation in South Africa. Event-based deterministic procedures such as the synthetic unit hydrograph and lag-route methods for design flood estimation were developed for South Africa in the late 1970s. With longer records from rain and flow-gauging stations now available for analysis, the development of climatic, elevation, land-use and soils databases available at a national scale, the increased computing power, the development of space-time stochastic rainfall models for South Africa, the availability of GIS and the development of new internationally accepted approaches to design flood estimation, it is imperative that a comprehensive updating of techniques for design flood estimation in South Africa is initiated as has been completed, for example, for Australia and the UK. A phased approach for South Africa is envisaged and this project, following on the pilot studies performed in the project **Rainfall statistics for design flood estimation** (WRC K5/1060), is viewed as the next logical step in this process.

The research aims to:

- Develop a methodology for the estimation of the frequency of floods in South Africa using a continuous simulation modelling approach. The computed exceedance probabilities of floods would not be inferred from rainfall, but would reflect the joint probabilities and complex interrelationships between rainfall, antecedent soil moisture conditions and runoff. The envisaged system would also have the ability to account for current or future land covers and management

practices and the generation of long time series of runoff, using either historical or stochastic rainfall series, will decrease the uncertainties in the estimated design floods. The proposed system is consistent with current international trends and could form the basis to update the deterministic event-based design flood estimation procedures developed for South Africa during the late 1970s.

Estimated cost: R1 460 000  
Expected term: 2002 - 2005

#### Definition and up-scaling of key hydrological processes affecting critical perturbations to water resources for application in models

School of Bioresources Engineering and Environmental Hydrology, University of Natal, Pietermaritzburg (WRC Reference No 1320)

There has been much research of hydrological processes at hill-slope and small catchment scales and an abundance of observations have been made in large-scale catchments. However, observations that could link appropriate process descriptions and parameter sets from the small to the larger scales are rare. In addition, the transfer of process descriptions derived from hill-slope and small catchment-scale observations to process descriptions at larger-scale catchments cannot be achieved easily, even when using distributed, physically-based models. Nevertheless, in order for the perturbations in streamflow caused by SFRAs to be identified, it is crucial that techniques be made available to model at the large-catchment scale, while retaining the ability to identify effects of small-scale processes.

There is a clear need for the simultaneous observation of processes over a range of scales. This is hypothesised as the only way to improve the process descriptions and parameter sets of distributed hydrological models employed at the medium-and large-catchment scale. These models will then also be better equipped to estimate the impact of the spatial distribution of land uses and SFRAs on discharge and low flows at points of interest.

This research effort addresses directly one of the key issues itemised in the WRC listing for SFRA's research needs.

The research aims to define key hydrological processes at a range of scales by observation and experimentation at these scales in order to:

Estimated cost: R2 100 000  
Expected term: 2002 - 2005

### Programme 3: Understanding and predicting rainfall variability

Research, development and verification of an operational and interactive system to forecast significant rainfall, 6 to 48 hours ahead, for the SA region using numerical weather prediction-, conventional- and remotely sensed weather data  
Meteorological Forecasting and Research & Training, University of Pretoria (WRC Reference No 1333)

Heavy rainfall causing severe floods occurs frequently over Southern Africa. These floods are often extensive and lead to large financial losses, severe damage to infrastructure and tragically to the loss of life. The loss of life as a result of the September 1987 floods (>300), damage to the infrastructure (> billion Rand) as well as the recent flood disaster, which occurred in the Northern Province and Mozambique, are examples. Water resource management becomes extremely difficult, if not impossible, without prior warning of widespread heavy rains. Better information on the spatial rainfall distribution and the identification of areas of heavy rainfall can be of vital importance to the survival of many communities who are living in informal settlements along the many flood plains of Southern Africa. Yet weather forecasters, at present, have insufficient tools to compile reliable prediction of the spatial and temporal distribution of heavy rainfall.

Research to predict the spatial, temporal and magnitude of heavy rainfall over South Africa had been neglected until recent research indicated that circulation parameters common to certain weather systems can be combined to predict areas of heavy rainfall. This research, supported in terms of WRC Project No K5/1011, suggested that the prediction of the spatial distribution of heavy rainfall could well have been improved if the influence of steep orographic gradients were incorporated. A prediction of the magnitude of the heavy rainfall during the floods over the Northern Province of South Africa during February 2000 could have contributed to lives saved and timeous implementation of relief programmes.

The main aim of this project is to develop an operational system, which will provide a predicted rainfall field over Southern Africa for 6 to 48 hours ahead. Special emphasis will be placed on heavy rainfall and the results can be incorporated into hydrological management systems. To achieve this aim the following steps are required.

- Development of methods to isolate heavy rainfall developing in weather systems classified as:

Tropical, anti-cyclonic disruption (cut-off low), tropical temperate trough and ridging anti-cyclones

- Develop means to model the enhancement of rainfall by steep topography
- Develop ensemble rainfall forecasts using model output from several models or model runs
- Development of an interactive rainfall prognosis by incorporating observed rainfall rates
- Run a training workshop for participants from Southern African countries in order to disseminate the knowledge gained and to empower delegates to run the system.

A second aim is to develop an operational rainfall verification system which will be used to validate the predicted rainfall field and to ascertain which rain-producing weather systems require further research.

Estimated cost: R578 000  
Expected term: 2002 - 2005

#### Skill comparison of dynamic and empirical down-scaling methods for Southern Africa from a seasonal climate modelling perspective

SA Weather Services, Pretoria Office (WRC Reference No 1334)

Droughts and floods have long been distinctive features of the climate of Southern Africa. Variability of the climate has been accentuated by the occurrence of the El Niño / Southern Oscillation (ENSO) phenomenon, but is by no means dominated by them. Climate variations have an important impact on agriculture, housing, water supply, industry and tourism. With an ever-increasing population that is putting an associated increase in demand on freshwater resources, effective water management has become essential. The need for providing improved seasonal rainfall forecasts, both temporally and spatially, is becoming more and more necessary in the region.

The main emphasis of the project is to assess the ability of an advanced state-of-the-art, albeit computationally expensive, method as a seasonal rainfall forecasting tool for Southern Africa in order to improve seasonal outlook information for hydrological purposes. Down-scaling the large scale to more localised seasonal rainfall over Southern Africa has been shown to be viable, but further research in down-scaling, with both improved spatial and temporal resolution, is required.

The main aims of the project are:

- Compile an appropriate GCM climatology of a

sufficiently large ensemble

- Nest dynamic regional climate models in the GCM simulated large-scale fields
- Compare the nested scheme's forecast skill with base-line skill levels
- Set base-line forecast skill levels, using statistical models.

Estimated cost: R450 000  
Expected term: 2002 - 2005

### Programme 4: Development of appropriate techniques for evaporation monitoring

#### The implementation of bichromatic scintillation as an operational tool for the measurement of spatially averaged evaporation

Department of Soil Sciences, University of Natal (Pietermaritzburg) (WRC Reference No 1335)

The need for increased food and timber production has led to dramatic increases in irrigated and forestry lands in South Africa. Agriculture and forestry face increased competition for water by industries, municipalities and other groups. This ever-growing demand for water makes it imperative that water resource management procedures and policies be wisely implemented and improved. The accurate assessment of evaporation is essential if this is to be done. Although the proposed investigation into bichromatic scintillometry to measure evaporation will focus on the more fundamental aspects of micrometeorological research, advances in this field will ultimately have direct benefits to water resource assessments and management processes.

The research aims to:

- Provide catchment researchers and consultants with a practical, accurate and operational tool to improve our understanding of comparative evaporative losses of water from land surfaces and water bodies associated with various forms of land use and a range of catchment conditions
- Make recommendations on the feasibility to provide guidelines for the use of, and to specify limitations of bichromatic scintillometry for the estimation of, a really averaged sensible heat flux over heterogeneous surfaces.

Estimated cost: R652 600  
Expected term: 2002 - 2004

**Programme 5: Water quality assessment studies and information systems**

**Development of technical guidelines for water quality use allocation procedures under the NWA through application of the Berg River water quality information system**

*Department of Civil Engineering, University of Stellenbosch  
(WRC Reference No 1301)*

The implementation of the National Water Act (NWA) (Act No. 36 of 1998) is gradually unfolding at both the national scale and at the catchment scale across South Africa. The NWA provides a statutory framework for integrated water resource management (IWRM) at the catchment scale through two tiers of interlinked water resource management (WRM) strategies:

- National Water Resource Strategy (NWRS), which provides a large-scale planning framework, procedures and guidelines to ensure that water deficits or poor water quality do not arise on a regional basis at the scale of declared water management areas (WMAs) and that international water-sharing obligations are met
- Catchment Management Strategies (CMSs) inside WMAs, which ensure sustainable, equitable and optimal water resource utilisation at the catchment scale with due ecological protection of the resource and with full participation by stakeholders and affected communities.

The NWA prescribes the minimum components of the CMS and prime amongst these are the formulation of water allocation principles and a Water Allocation Plan for each WMA (Section 9). However, for individual catchments in which water "stress" (water supply deficits or unacceptable water quality) exists or threatens, or where redress of past discrimination in terms of water use is urgently needed, the NWA requires the compulsory re-allocation of water, followed by compulsory licensing on the basis of elicited licence applications (Sections 43-47).

Because the NWA implementation is still in its initial stages, no compulsory re-allocations have hitherto been undertaken, even though the initial screening of catchments in preparation for the first edition of the NWRS has indicated a number of catchments which fall in that category. Consequently, no deep understanding currently exists of what would constitute best practice procedures in the water allocation process. From the DWAF Strategic Plan for the period 2001-2005 it is evident that the earliest compulsory licensing that is

foreseen would be during 2004. There is, therefore, time in hand to engage in a learning process so as to develop adequate understanding of what the compulsory re-allocation and licensing procedures need to entail both in a technical WRM context and in a participatory WRM context.

This project is proposed as such a learning process, but focuses on a very particular part of the allocation challenge, namely the allocation of "Water Quality Use". Intuitively, allocation may be associated with water quantity, but a significant innovation of the NWA is that it defines "water use" very broadly - amongst others to include the use of the resource to dispose of waste (Section 21). It can be expected that allocation procedures based on "water quantity use" of the resource will be developed by DWAF fairly readily during the next few years, but the same cannot be expected of allocation procedures of the "water quality use" of the resource. The complexity of point and non-point delivery and transport processes that determine the water quality constituent loads in a catchment, the relatively poor water quality databases and the role that statutory resource quality objectives are required to play in WRM (Section 13 of the NWA) all indicate that a focused research effort is required to unpack the conceptual and technical components of the water quality part of the allocation challenge.

The research aims to:

- Develop a conceptual framework for water quality use allocation procedures
- Develop and disseminate technical guidelines for water quality use allocation procedures.

*Estimated cost: R683 000  
Expected term: 2002 - 2004*

**Thrust 2:  
Integrated Water Resource Development**

**Programme 1: Integrated catchment management**

**The development of a computerised system for auditing real-time or historical water use from large reservoirs in order to promote the efficiency of water use from the reservoirs**

*CPH Water  
(WRC Reference No 1300)*

Irrigation water use exceeds 50% of South Africa's water resources. Much of this irrigation occurs from releases and/or direct abstraction from large Government owned or controlled dams. In the Water Conservation and Demand Management (WCDM) documents produced by DWAF it is acknowledged that there is scope to improve the efficiency of water use, especially by irrigation. A mere 10% saving in water use by irrigation has the potential to liberate more water than the water used by the entire afforested area in South Africa.

The research aims are to:

- Develop a well-researched generic computerised "water audit system"
- Increase the understanding and knowledge of the practicalities, strengths and weaknesses, and potential costs and benefits of developing and implementing a "water audit system" for use by CMAs
- Transfer knowledge/technology to decision makers and stakeholders
- Assess the feasibility of implementing the water audit system for the management of South Africa's water resources.

*Estimated cost: R902 000  
Expected term: 2002 - 2005*

**Development of guidelines for the design and operation of river diversion structures to deal with the problem of sedimentation**

*Ninham Shand (Pty) Ltd  
(WRC Reference No 1302)*

Many communities abstract water directly from rivers, usually by means of a pump. Due to the highly variable flow conditions and high sediment loads in our rivers, sediment deposition often occurs at the abstraction point. The same applies to larger water diversion & transfer schemes such as on the Olifants River, currently under construction, or the Thukela water diversion schemes which will be constructed in the near future.

There are, however, lessons to be learned from serious sedimentation problems experienced at a number of our major transfer schemes, such as the Tienfontein Pump Station on the Caledon River. Slow approach flow velocities at the pumps usually create an area of sediment deposition, which is detrimental to the sustainable use of the pumps, with resulting high pump replacement costs and inefficient operation.

The research aims to develop hydraulic guidelines for the layout, design and maintenance of river diversion

structures in South Africa to limit the influence of sedimentation. These structures include small pump stations to large hydraulic structures for major water transfer schemes. Specific techniques to be investigated to ensure sustainable operation include hydraulic flushing within the diversion structure (pump station).

*Estimated cost: R598 000  
Expected term: 2002 - 2004*

**Influence of spills and releases on the river geomorphology downstream of a selection of existing dam spillways**

*PD Naidoo Associates  
(WRC Reference No 1314)*

Hydrologists have long been challenged to document the degree to which human activities and uses of land and water have altered flood regimes and low-flow conditions. In recent decades, growing concern for the protection of biological diversity has led to increased scrutiny of the consequences of human-induced hydrological alteration to natural ecosystems.

Typical hydrological alteration takes place with the construction of a dam in a watercourse, usually eliminating or reducing a range of natural floods previously experienced in the river. This has a number of consequent effects on the river regime downstream of the dam wall. One consequence of such hydrological alteration is the changes in the channel geomorphology in the zone just downstream of a spillway. Since a dam acts predominantly as a silt trap, and spills and artificial releases from the dam are largely sediment free, the zone most susceptible to geomorphological change is the region just downstream of the dam spillway. Erodible material in this zone is the first that is vulnerable to attack and the material is selectively transported and deposited downstream. The extent to which this occurs is dependent on the quantity and energy of the release or spill from the dam. These changes have the effect of altering the habitat available for the sustainability of the river ecology, particularly in the zone within a few kilometres of the dam wall.

Environmental laws in South Africa now demand that artificial releases from dams meet the various instream flow requirements (IFRs) for environmental purposes. This implies that new dam outlets be designed to meet a range of planned environmental releases from low base flows and freshets to larger flushing type flows designed to achieve pre-determined environmental objectives. The larger flushing releases may typically be of the order of the average annual flood in size and can represent a significant part of the dam's volume.

The purpose of this study is to research the geomorphological changes that have occurred on a range of existing dams in South Africa with a view to expanding the knowledge available to teams involved in the IFR determination process. This will enable better assessments to be made of the magnitude of environmental releases that are required to achieve the objectives of flushing flows and to identify both the beneficial and negative environmental effects of such releases.

The main aim of the project is to develop an understanding of the degree of geomorphological changes on river reaches, that have occurred just downstream of the spillways of a selection of South African dams and to relate these changes to a defined range of influencing criteria.

*Estimated cost:* R500 000  
*Expected term:* 2002 - 2004

**Phase 2: Application on development of genetic algorithms for optimisation in the water industry**  
*Department of Civil Engineering, University of Pretoria (WRC Reference No 1388)*

This project will provide conceptual development procedures to implement genetic algorithms into the procedures used in South Africa for resource assessment. These are:

- Hydrology and water resource assessment
- Network optimisation
- Optimisation of rehabilitation, extension and upgrading of distribution networks during the planning and design phase
- Operation and maintenance scheduling

This phase of the research will extend the understanding and implement the value of this procedure in a number of priority water-related problems in South Africa. This will be achieved by the presentation of courses, development of utility software and the conceptualisation of procedures to use GAs in the assessment of the yield of surface water resources.

*Estimated cost:* R203 000  
*Expected term:* 2002 - 2004

**Thrust 3:  
Management of Natural and Human-Induced Impacts on Water Resources**

**Programme 1: Predicting the impact of global climate change**

**Analysis of groundwater level time series and the relation to long-term climatic conditions, climate change and recharge**  
*Division of Water, Environment and Forestry Technology, CSIR (WRC Reference No 1323)*

DWAF has for many years regularly monitored groundwater levels and water quality in some 400 boreholes country-wide. In most cases at least monthly records are available, although in several cases daily water level recordings are kept. These boreholes are mostly located in undisturbed hydrogeological environments, upstream of major catchment developments or groundwater abstraction schemes.

It is believed that an analysis of this information could give invaluable information pertaining to the cause for this trend, both on a local as well as a regional scale. In particular the possible link to long-term climatic changes is of interest. A possible explanation for this declining trend can be the role or effect of, or the link to longer term climatic changes over the last few decades, and even centuries. Closely linked to this is the concept of groundwater drought, which may have important management implications, but has not been properly explored. The groundwater drought concept is not new and has previously been addressed in an African context by the British Geological Survey. The decreasing trends that have been recorded in some boreholes may also be explored as part of the longer-term fluctuations established by paleo-geohydrological studies. Numerous studies have been documented over the last decade on paleo-climatic conditions (covering the last say 3000 years) in Southern Africa and Africa.

The research aims to:

- Determine whether the long-term declining trends observed in SA groundwater level data are indicative of a current and/or longer-term groundwater drought cycle(s) or whether other factors are contributing to this trend
- Collate and develop new methods if required, that

- can be used to correlate long-term water level fluctuations with rainfall and climatic cycles
- Document the analytical techniques available and used to analyse relevant geohydrological information to assist planners in the long-term planning of groundwater utilisation as part of integrated water resource management.

*Estimated cost:* R233 000  
*Expected term:* 2002 - 2003

**Programme 2: Groundwater protection**

**Quantification of the impact of irrigation on the groundwater resource underlying the Vaalharts irrigation area**  
*Institute for Groundwater Studies, University of the Free State (WRC Reference No 1322)*

Irrigated land in South Africa currently amounts to approximately 1.3 x 10<sup>6</sup> ha. Agricultural water use is estimated to be the largest water user in Southern Africa, with much of the region dependent on sufficient water of adequate quality for survival,

The Vaalharts is the largest irrigation scheme in the country. Approximately 30 000 ha of land is currently being irrigated. The salinity of the irrigated water has steadily increased over time. Several research projects have been undertaken to determine the fate of the added salts. The conclusion in these reports is that a very large proportion of the salts added to the subsurface due to irrigation are not returned to the surface water. A sink for these salts is therefore present. Research done on the salt balance of the area and the effect of the salts on soils and crops has suggested that the majority of this salt is being leached through the soils and into the groundwater resources underlying the irrigated area.

The underlying aquifer has a limited storage capacity. Once this capacity has been exceeded, a flow reversal is expected to occur. This process is likely to add a tremendous salt load (roughly estimated to be in the order of 100 000t/year to an already stressed river system. The adverse effects of such an addition would be catastrophic to the irrigation scheme and the receiving aquatic environment.

This project, therefore, aims to determine the processes leading to the scenario outlined above. The geology and field observation suggest that there is a perched aquifer overlying a deeper calcrete aquifer, believed to be the salt sink in the system.

The project will research the rate of leakage into the lower aquifer, the storage capacity of the lower aquifer and the salt load addition to the system. Based on these findings the questions surrounding time and salt load of the release should be more accurately quantified so that preventative and planning measures can be put in place.

Based on the findings from the Vaalharts pilot area, data will be collected from other heavily irrigated areas in South Africa, such as the Douglas area, the Modder/Riet catchment and others, and correlations identified. In this way future salinisation of water resources can be identified and managed.

The research aims are to:

- Construct feasible conceptual models for groundwater response to irrigation using the Vaalharts area as a case study
- Determine the storage in receiving aquifers and expected time before flow reversal occurs
- Quantify the groundwater component of the total flow currently and once the aquifer storage has been exceeded
- Determine the expected salt load addition from groundwater
- Use existing data to correlate to other irrigated areas, such as the Douglas area and Modder/Riet irrigation, and share the lessons learned.

*Estimated cost:* R510 000  
*Expected term:* 2002 - 2003

**Groundwater protection in urban catchments (a) identification (b) guidelines (c) determining standard of pollution in Southern Africa**  
*Institute for Groundwater Studies, University of the Free State (WRC Reference No 1326)*

Groundwater contamination can occur as a result of various activities of man. With increased human settlement and economic development, a range of undesirable waste products are produced which can end up in the environment. If these waste products are not well handled, they can cause contamination of groundwater. The threat caused by undesirable substances on groundwater is recognised in this country and measures have been put in place through legislation to protect groundwater from contamination (The National Water Act, Act 36 of 1998; The National Environmental Management Act No 107 of 1998). Although groundwater contamination incidences have been reported country-wide, we do not have an indication of the extent of the problem. A WRC project

identified several research priorities for understanding the extent of urban groundwater contamination. Groundwater contamination incidents have been widely reported in South Africa, but no clear picture of the extent or magnitude of the problem is available. The contaminant inventory through its identification and ranking of these constituents will go a long way towards addressing this gap in our knowledge base and should lead to better management of groundwater in terms of protection, regulation and measures to be put in place. Questions of interest include: What are the main (problematic) contaminants in urban catchments of South Africa? What are the main sources (activity-related) of these contaminants? Is it possible to prioritise such contaminants and sources? The contaminant inventory through its identification and prioritisation intends to address this gap in our knowledge base and should lead to better management of groundwater in terms of protection, regulation and measures to be put in place.

The aims are to:

- Identify and prioritise the type of contaminants and their associated sources which present a threat to groundwater, the environment and health in South Africa's urban catchments
- Formulate strategies for better understanding of the impacts of polluting activities on groundwater resources in urban catchments
- Establish a data information system on South Africa's contaminants.

Estimated cost: R1 000 000  
Expected term: 2002 - 2004

#### Ecological and environmental impacts of large-scale groundwater development in TMG aquifer systems CSIR / Umvoto (WRC Reference No 1327)

There is currently a debate concerning the extent to which groundwater abstraction from TMG aquifers will lead to environmental impacts. This debate will continue and inhibit better understanding of the water resources as well as inhibit development of the groundwater resources. Appropriate investigations are required to adequately inform key players and interested and affected parties, and to move the debate constructively forward.

This project aims to assess the dependency of aquatic and terrestrial TMG ecosystems on groundwater and predict impacts of groundwater abstraction. These ecosystems include wetlands, highland seeps, the riparian zone and spring discharge sites, amongst

others. Specific objectives are:

- The development of predictive tools to assess the impact (or risk) of groundwater abstraction on the environment
- To improve our understanding of groundwater-dependent ecosystems (GDEs) in the TMG and the sensitivity to groundwater level fluctuations
- The use of innovative techniques to determine the impact of groundwater abstraction on the environment
- The development of indicators to monitor the effect of abstraction on sensitive ecosystems
- Coupling time series and spatial databases in order to ascertain the impacts of low flows (groundwater and surface water interaction) on the environmental system
- Improved understanding of the impact of changing low flows on freshwater ecology
- Improved understanding of the relationship between surface flow, event discharge from high-lying TMG unconfined aquifers and deep confined-aquifer discharge in maintaining wetlands or seeps
- Improved understanding of subsurface TMG discharge in maintaining coastal plain wetlands and vleis.

Estimated cost: R2 201 327  
Expected term: 2002 - 2005

#### A multitracer study of the origins, systematics and hydrological linkages of high nitrate concentrations in Bochum District, Northern Province Schonland Research Centre, University of the Witwatersrand (WRC Reference No 1328)

In large tracts of the Northern Province with millions of inhabitants who rely almost exclusively on groundwater supplies, high nitrate values are reported. High nitrate concentrations in drinking water may lead to methemoglobinemia, impairment of the blood to transport oxygen in infants, whilst sustained exposure to high nitrate levels may cause intestinal cancer in adults.

The hydrogeochemistry of nitrate and isotope hydrology in the Taaibosch fault area indicated that the processes whereby unacceptable to very high nitrate concentrations develop, have only partially been addressed in earlier hydrochemical and isotope studies in other areas in South Africa. These earlier studies deal with nitrate build-up in the unsaturated zone whilst the present investigation suggests the importance of ongoing processes in the saturated zone as contributing

to high groundwater nitrate levels.

The results of this study are intended to produce strategies and guidelines for the mitigation of high nitrate concentrations which, it is expected, will find direct application in the current investigation which logically can be extended into a region in which an enhanced understanding of the systematics of excessive nitrate levels in groundwater is a high priority.

The aims are to:

- Use and elaborate the increasingly detailed knowledge of the geohydrology of the Taaibosch fault area developed during a current IAEA-sponsored project. This information is to be used as the framework of the detailed hydrochemical and nitrate study
- Develop up-to-date sample collection, preservation and analytical methods suitable for the routine determination of the isotopic composition of nitrate in the Southern African context. This is seen in terms of state-of-the-art analytical instrumentation not only as the basis for the present study but also to enhance the study of nitrates and other pollutants generally
- Determine the sources of and controls on the development of nitrate in groundwater of the project area. This is fundamental, as it is clear that anthropogenic influences are limited
- Establish the hydrogeological and hydrochemical framework for the development of high nitrate concentrations, in particular for denitrification processes. There are strong indications that saturated zone processes play an important role
- Devise development, exploitation and management strategies for the mitigation of the effect of high nitrate concentrations initially for the Taaibosch fault-zone groundwater supply scheme, to be followed by the wider area of investigation.
- Phase 2: Extend the experience and approach developed in Phase 1 to at least one other Northern Province area, possibly with a different hydrogeological setting in order to test the approaches developed in the study
- Adjust and elaborate the approach to integrate with a possible IAEA technical co-operation project which is being proposed and might be initiated in 2003.

Estimated cost: R300 000  
Expected term: 2002 - 2003

#### Programme 4: Human-induced impacts

##### Community-based research on the influence of rehabilitation techniques on the hydrology of degraded catchments

School of Applied Environmental Sciences, University of Natal (Pietermaritzburg)  
(WRC Reference No 1316)

Two neighbouring communities of Mnweni and Okhombe in the Amazizi and Amangwane Tribal Wards have both embarked upon intensive job creation programmes which have focused on the rehabilitation of degraded areas. Both areas are situated in the foothills of the Drakensberg which forms the main catchment area for KwaZulu-Natal. Loss of grass cover on these steep mountain slopes has resulted in poor water infiltration, increased runoff and severe soil erosion. Soil erosion is seen as a major threat to water resources and land productivity. The communities have been assisted in their erosion control efforts by various institutions including the University of Natal, Farmer Support Group, CSIR, Dept. of Agriculture and Natal Nature Conservation services.

One of the objectives of this project is to implement participatory monitoring whereby the rural participants record and analyse differences and change. This will provide an opportunity for learning where the people contribute to the monitoring process and are empowered to take subsequent decisions. In this way local capacity is enhanced and the communities become involved in technologies that fit local and environmental conditions.

The research aims to:

- Determine the effect of different rehabilitation techniques on runoff and soil loss
- Identify and prioritise rehabilitation interventions for establishing baseline conditions in the study areas
- Establish land users' perceptions of soil erosion and rehabilitation in conserving water
- Determine soil conservation measures that will be socially acceptable and physically effective in communal areas.

Estimated cost: R984 000  
Expected term: 2002 - 2006

**The relationship between soil water regime and soil profile morphology in the Weatherly catchment, an afforestation area in the North-Eastern Cape**  
*Institute for Groundwater Studies, University of the Free State*  
(WRC Reference No 1317)

There is a close relationship between the water regime of a soil profile and its morphology. This is because water plays a primary role in soil genesis. Because of this, the amount of water which has been available during the process is reflected in the morphology of the profile. The hydrological characteristics of soil can either be determined quantitatively by regular measurements, or qualitatively by inference from the soil colour, exchangeable bases, occurrence of mottles, concretions, etc. Soil colour is the most important morphological soil property used to predict the water regime of soil. The major soil classification systems of the world apply soil colours as distinguishing criteria.

Defining the relationship between soil profile morphology and soil water regime is generally difficult due to the lack of sufficient quantitative and qualitative soil water data. Improved understanding of the relationship between the water regimes of soil profiles and their morphology will lead to better classification of these soils. This will lead to improved definitions of hydrological response units and similarly ecotopes.

The aims of the project are to:

- Characterise and quantify the soil water regime and soil profile morphology, in the Weatherly catchment
- Determine the relationship between soil water regime and soil profile morphology, in the Weatherly catchment
- Develop a new model, using the above-mentioned data that will facilitate the assessment of the hydrological characteristics of catchments where soil water measurements are limited or absent
- Calibrate the above-mentioned model

Estimated cost: R924 000  
Expected term: 2002 - 2005

**Development of a system of simplified methods of vegetation water use based on the principle of limits to evapotranspiration**  
*Division of Water, Environment and Forestry Technology, CSIR, Stellenbosch*  
(WRC Reference No 1319)

Water resource managers will increasingly need to assess whether proposed changes in land use within catchments are likely to significantly reduce the quantity and temporal availability of water to downstream users. Such decisions need to be based on the relative annual (and perhaps seasonal) water use of the existing and proposed new crops or vegetation. The National Water Act makes provision for declaring certain land-covers (crops) as SFRAs (e.g commercial afforestation) but it is likely that other land-cover changes may also have a significant impact in some situations. The principle of limits to evapotranspiration will allow for the limiting factors to be identified in particular situations and thus for a screening of land-cover changes based on the likely impacts. It could also provide a useful framework for interpreting the impacts of regional climate change in South African situations

The aim of this project is to develop a framework of understanding about the major controls of evapotranspiration in different types of vegetation and crops in South Africa. This work will lead to:

- A better understanding of when a change in land-cover may have a significant impact on surface water yields from a land parcel
- Recommendations for simple models to use in assessing these impacts, easing the task of simulating water use in the wide variety of vegetation, both indigenous and alien, existing in South Africa.

Estimated cost: R1 013 000  
Expected term: 2002 - 2005

**An investigation into the impact of landfill leachate on the physical, chemical and microbiological quality of the Soutpan Stream and its immediate surroundings**  
*Department of Chemistry, Technikon Northern Gauteng*  
(WRC Reference No 1341)

The Soutpan Stream runs past a very poorly managed landfill site which serves the local Soshanguve community. The landfill is used for dumping of domestic and industrial wastes. Visible leachate is observed on a regular basis running into the Soutpan Stream. The Soutpan Stream serves a huge informal settlement as sole water source and thus presents a health hazard. The community uses the water for household practices, gardening and for animals to drink.

This project aims to improve the situation and make the water and the landfill practices acceptable according to set guidelines. This will serve as an upliftment project for the community as we will make use of their experience and knowledge.

The research aims to:

- Conduct an environmental inventory and audit of the study area
- Obtain information on how the landfill site is managed, the hydrogeological conditions, attenuating factors, weather patterns, volume and type of waste dumped, the volume and characteristics of leachate produced
- Investigate the direct and indirect physical, chemical and microbiological impacts and consequences over a defined range of temporal and spatial scales of the leachate generated at the poorly managed landfill site on the Soutpan Stream and its immediate surroundings.
- Suggest measures which will help to minimise any adverse impacts on the environment and human health.

Estimated cost: R386 000  
Expected term: 2002 - 2004

**A guide to conduct eutrophication assessments for rivers, lakes and wetlands**  
*Ninham Shand (Pty) Ltd*  
(WRC Reference No 1343)

Eutrophication is the enrichment of waters with plant nutrients which results in an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other undesirable changes that interfere with water uses. In South Africa, eutrophication has been recognised as a priority water quality problem for over 30 years. DWAF recently completed a study that assessed the eutrophication status of a number of South African water bodies. It was found that the extent of eutrophication of reservoirs and river systems has increased since the problem was first identified in the 1970s.

A recent study commissioned by the WRC found that South Africa's policy and approach to eutrophication control has been inadequate over the last 20 years. It also found that the lack of policy development, monitoring, research, reporting and capacity development has greatly diminished the country's ability to deal with the problem. A strong need was identified to remobilise and redevelop its capacity to manage eutrophication.

The publication of this report was followed by a workshop to discuss research and capacity building within the field of eutrophication. Assessment of the eutrophication problem was identified as the highest priority research area.

Three products are envisaged, a eutrophication assessment guide, an Internet-enabled version of the guide and the outline and course material for a short course on eutrophication assessment which uses the eutrophication assessment guide as primary text.

The research aims to:

- Provide professional guidance to practitioners in using assessment protocols that are aligned with national catchment water quality assessment studies to assess eutrophication-related catchment and receiving water body characteristics
- Provide a means by which local and international best eutrophication assessment practice (methodologies and protocols) can be captured and made available to a wide range of catchment assessment practitioners in Southern Africa
- Develop tools and course material that can be used to fast-track capacity building in eutrophication-related water quality assessment and management.

Estimated cost: R669 700  
Expected term: 2002 - 2004

## **Thrust 4: Policy Development and Institutional Arrangements for Water Resource Management**

### **Programme 1: Decision support for water policy formulation and implementation**

**Consolidation and transfer of knowledge and experience gained in the development and implementation of water and related policy in South Africa**  
*Division of Water, Environment and Forestry Technology, CSIR, Pretoria*  
(WRC Reference No 1295)

The political changes which have taken place in South Africa during the last decade have had profound

impacts on the development of new water policy, and have opened the way for significant shifts in policy and legislation generally, in relation to sustainable management of natural resources.

The South African water policy is considered to be very progressive and one of the best examples internationally for sustainable management of resources. It is relatively sophisticated, yet it must be implemented in a developing country context. The implementation context will strongly influence the future development and strategic direction of water policy in South Africa, but there is still limited understanding of the inter-relationships between policy development and implementation, with the added shaping forces of politics, economics and social factors.

This project aims to provide, through critical review and analysis, an understanding of where we have come from and where we are going to in terms of water policy, in order to support ongoing development and implementation throughout this and future policy cycles.

The project aims to:

- Capture and consolidate knowledge and experience gained in several recent policy development and R&D processes related to sustainable water resource management
- Provide guidance for future leaders in how to establish and manage policy development and implementation processes
- Provide guidelines for training and enhancing the capacity of people who are or will be responsible for policy development and implementation.

Estimated cost: R720 800  
Expected term: 2002 - 2004

**An investigation of the supportive role of the market mechanism in implementing the provision of the New Water Act (NWA) in order to achieve efficient and equitable water utilisation**

Conningarth Consultants  
(WRC Reference No 1297)

The NWA does not refer to any specific market-related mechanism as a tool to allocate water. In Section 26(n) of the Act reference is made that regulations may be made to allocate water by public tender. See also Section 45(2 F). The granting of water-use licenses will be the initial central allocation mechanism. This will be a crucial process because it is at this stage that the issue of equity and efficiency in water use will be addressed. The extent to which economic considerations will feature

in this process is not specified. The role of the proposed water tariffs (administered prices) in assisting efficient water use is not yet analysed.

Once the initial allocations have been made it cannot be assumed that the allocation should stay unaltered over time as the initial circumstances change. To some extent the five-year review process envisaged can address this issue. The way in which this five-yearly revision process will take place in practice has not yet been determined. The market mechanism can assist in providing a flexible mechanism for addressing this issue on an efficient basis.

It would therefore appear that the role of the market is not ruled out in the NWA. The issue is, however, to determine ways to strengthen its role. In this regard an incremental approach can be used by identifying areas where it will be relatively easy and gradually move towards the more complicated situations where the use of market forces might require (minor) adjustments in the Act.

The aims are to:

- Investigate the required institutional form and arrangements for water allocation based on international experience
- Determine the major concerns of DWAF in relation to the implementation of the efficient allocation of water use as envisaged by the NWA of 1998
- Investigate and propose adjustments to institutional arrangements in the NWA regarding water allocation to align them with the requirements to support the market to play a role in water allocation.

Estimated cost: R622 100  
Expected term: 2002 - 2004

**Multicriteria decision support for Reserve determination and other catchment management**

Department of Statistical Sciences, University of Cape Town  
(WRC Reference No 1298)

The primary purpose of the original project No K5/1186/0/1 (of which this is an extension) was to ensure that the MCDA methodology which has been developed is fully integrated into catchment management processes, to be applied by DWAF and their contracted consultants, and/or by catchment management agencies (CMAs). The original project plan called for identifying two or three CMAs or their

precursors and to work directly with them. After discussion with DWAF and the WRC, and at the advice of the steering committee, it was decided, however, that we should work together with consultancy groups which have been tasked with planning activities for selected catchment or water management areas. A number of discussions and workshops with such groups, together with some smaller-scale applications, revealed a wide recognition that the MCDA methodology did in fact provide the mechanism needed to ensure that the values and needs of stakeholders are taken into consideration according to the requirements of the new water act.

The process of identifying catchments for which the timing of the planning processes and the establishment of CMAs was matched to the project schedule took considerably longer than anticipated, especially in view of the change in focus suggested by DWAF, WRC and the steering committee (see above). Finally, two projects have been identified, namely:

- That of the CPH2O group in Pietermaritzburg, concerning SEA for streamflow-reducing activities in the Usutu/Mhlatuze catchment and decision support systems for ongoing management; and
- That of the Southern Waters Consultants in Cape Town on Reserve determination for the catchment. These two activities cover a wide range of catchment management issues, but the project team has also been invited to collaborate on the Inkomati catchment management strategy process which will shortly be undertaken, so that this may be included as a third case study.

The research aims to:

- Integrate multicriteria decision support methodology into current Reserve determination and strategic management processes in two or more catchments (in collaboration with consultants responsible for managing these processes)
- Extract practical experiences from these activities into a manual for the use of multicriteria decision support in achieving the objectives of the new water act at the catchment management level
- Establish the extent to which GIS and other existing modelling systems can be integrated with multicriteria decision support procedures
- Establish the effectiveness of Internet-based decision support for dispersed decision making in the above context.

Estimated cost: R262 000  
Expected term: 2002 - 2003

**Programme 3: Institutional arrangements for IWRM**

**Promoting democracy through the IWRM process: Developing a model for sustainable relationships for the management of a scarce natural resource**

Division of Water, Environment and Forestry Technology, CSIR, Pretoria  
(WRC Reference No 1294)

This project will be a role-model and success story for both government and research. It will provide a model for how human interactions in water resource management can be facilitated to promote behavioural changes that are in line with the principles and values of democracy. It will build capacity in the research team and wider target group and will demonstrate the role of capacity building in a society transforming around a scarce and critical natural resource. The project will also show what the role and opportunities are for research in this process and how collaborative research teams need to operate to fulfil those opportunities within the water resource management context.

The overall objectives of this project are to:

- Produce a model for co-operative water resource management that aligns human interactions with the principles, values and ethics that underpin democracy. The project aims to define the mechanisms (principles and processes) that will promote a change in behavioural patterns in people that will produce self-driven, co-operative, peaceful and equitable solutions to negotiations around the water resource management table.
- Communicate findings and thereby provide government and other key role players with a means of using the process of policy implementation as a vehicle for deepening democracy. Within this process, the project intends to develop a better understanding of the ways in which research can support policy implementation.
- Build a model for trans-disciplinary, learning-by-doing, "action research" for general use in IWRM. The project will build on and formalise existing positive team dynamics and provide an example of how team dynamics and collective learning can enhance collaborative research in support of democratic principles and practice.
- Build capacity in the research team, government and society. The project team will build further

understanding of the capacity building process and will demonstrate the contribution of capacity building, as part of research, to promoting democratic practice.

*Estimated cost:* R1 416 700  
*Expected term:* 2002 - 2005

#### **Institutional arrangements for groundwater management in dolomite terrains**

*SA Country Office, IUCN  
(WRC Reference No 1324)*

Water management areas (WMAs) have been demarcated largely according to surface water systems and seldom coincide with geohydrological boundaries. In the absence of an integrated approach that addresses complex transboundary issues, aquifer management is seldom optimised, leading to the unsustainable utilisation of groundwater.

Highlighting these challenges, the dolomitic groundwater in the Northwest Province is a valuable natural resource, which provides water supply to towns, rural settlements, industries, agriculture and other activities in an area where surface water resources are negligible. Groundwater also sustains the flow of several springs, wetlands, and river channels, and is the lifeline of the ecology of these freshwater systems. The dolomitic aquifer is divided between three WMAs, to be managed by three catchment management agencies (CMAs) and transcends the border between Botswana and South Africa.

Institutional arrangements are needed that take into consideration the characteristics and broad role of groundwater, while ensuring that groundwater is a beneficial component of integrated water resource management (IWRM). Further, groundwater protection needs to be balanced with addressing inequity in access to water resources and services, as provided for in the National Water Act (RSA, Act 36, 1998).

This project therefore seeks to develop institutional arrangements for the sustainable and equitable management of groundwater. Although based on a pilot study of groundwater in the dolomitic terrains of the Northwest Province, South Africa, institutional arrangements should be generic and adaptable to similar situations elsewhere.

The aims of the project are to:

- Develop a conceptual model of the dolomite aquifer as a technical/geohydrological basis for the development of institutional arrangements

- Identify potential conflicts among different water users and uses as well as potential trends in water demand that will affect the aquifer's capacity in the medium- to long-term
- Assess the existing institutional capacity required to fulfil geohydrological requirements (technical functions) for groundwater management
- Assess the existing institutional capacity required to fulfil the role and responsibilities of both strategic and operational management of groundwater
- Identify the financial and human resources required by newly established or establishing WUAs in relation to their involvement in groundwater management.

*Estimated cost:* R600 000  
*Expected term:* 2002 - 2004

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# KSA 2

## Water-Linked Ecosystems



Dr SA Mitchell  
Director:  
Water-Linked Ecosystems

### Scope

Water-linked ecosystems are defined as in-stream (fully aquatic), riparian (dependent on water stored in the river banks and linked to the river) and water-table dependent (dependent on a water table, but not on surface water). This KSA focuses on the protection and sustainable utilisation of the aquatic environment and biota (in-stream, riparian and groundwater). This includes the research needs around the international conventions on environmental management (e.g. biodiversity) as well as human needs from the aquatic environment (e.g. sustainable management for equitable ecosystem resource utilisation, recreation and ecotourism).

The above will be achieved by developing technologies and methodologies, adaptive management processes and capacity to protect the resource and to sustain the flow of goods and services in a time of both demographic and climatic change in the Southern African context. Technologies and methodologies will be developed within the KSA to support the implementation of the national water policy to ensure sustainable resource use.

### Objectives

The provision of knowledge to enable good environmental governance so as to ensure the utilisation and sustainable management of water-linked ecosystems in a water-scarce country during a time of demographic and climate change.

This will be achieved through the following:

- Develop an understanding of the ecological processes underlying the delivery of goods and services.
- Develop the knowledge to sustainably manage, protect and utilise the aquatic ecosystem.
- Transfer the knowledge to appropriate end-users.
- Build capacity in both research and management to sustainably manage aquatic ecosystems.

The research portfolio of current projects has been grouped into strategic thrusts and programmes which directly address the above-mentioned objectives and are summarised as follows:

### Thrusts and programmes

#### Thrust 1: Ecosystem Management and Utilisation

- Ecological Reserve
- Estuary management
- Ecosystem health
- Toxicology
- Amelioration of impacts
- Biological control

#### Thrust 2: Ecosystem Protection

- Rehabilitation
- Kruger National Park Rivers Research Programme
- Wetlands
- Groundwater-dependent ecosystems

### Budget for 2002/03 and 2003/04

Research portfolio	Approved 2002/03 R	Committed and requested 2003/04 R
Current projects	4 211 940	5 230 658
New projects	2 799 250	2 900 000
Total	7 011 190	8 130 658

### CORE STRATEGY

#### Strategic context

The KSA for **Water-Linked Ecosystems** may be defined both by the physical boundaries of the area addressed by the KSA, as well as by the strategic role occupied by the WRC in the field, with relevance to organisations active in ecosystem research and management. Physically, the field includes aquatic and riparian ecosystems as well as those dependent on groundwater.

#### History and position of the WRC in funding research into ecosystems

The WRC has played a role in the funding of research on ecosystems for approximately a decade and a half. Prior to this, research into aquatic ecosystem functioning and management in South Africa was the role of the national and provincial environmental affairs agencies. The NRF (National Research Foundation) funded into this with its programme on Inland Water Ecosystems. During the mid-80s, the Department of Water Affairs and Forestry (DWAFF) recognised the aquatic ecosystem (for the first time) as a water user competing with the other national users. During the mid-90s this viewpoint changed to the aquatic ecosystem being recognised as the resource, and as such needing particular attention. The process leading to the promulgation of the National Water Act

(NWA) in 1998 gave special emphasis to ecosystem protection in the form of the ecological Reserve. Currently DWAF is interested in the specific areas of aquatic ecosystem management which are required by the NWA. The national Department of Environmental Affairs and Tourism (DEAT) is responsible for overseeing the international conventions to which South Africa is signatory, and also runs the national parks. Each of these departments funds some research aimed specifically at addressing their (usually immediate) needs.

The provincial environmental affairs departments manage the environment outside the national parks system, previously largely through nature reserves, but now increasingly through conservancies in various forms established on private or communal land. The research capability of these agencies has been drastically scaled down over the last decade. In addition to the above, there are certain other organisations active in specific areas of environmental research and management. Some, such as the IUCN, are international and fund some initiatives themselves. Others, such as the Mondi (formerly Rennies) Wetland Project operate nationally on specific research and management projects. The Working for Water and Working for Wetlands Programmes (formed by a consortium of government departments), while primarily aimed at the removal of alien vegetation, are also doing some rehabilitation of degraded ecosystems as well.

The NRF (formerly FRD) has re-organised itself from time to time over the last decade. After its national programmes were closed down in the mid-80s no focused research on aquatic ecosystems was supported, although in the current structure there is a specific thrust funding of ecological research through tertiary institutions. The NRF also administers a research fund for DEAT (Marine and Coastal Management) for research into marine and coastal ecosystems. The emphasis of this research is to address the needs of the various bits of legislation on coastal and marine ecosystems. One of the thrusts under this fund addresses estuaries.

The WRC, with its mandate to improve the national capability to sustainably manage water in the country, has a specific role which differs from that of other research funders. Although in some cases there is an overlap, there is opportunity for synergy with other sources of funds, as the breadth of work funded by the WRC covers the short-term to longer-term strategic needs of the country, and ranges from fundamental to highly applied work within the area defined by the mandate.

## Needs analysis

There is currently an urgent need for the generation of the ability to implement the new legislation such as the NWA. However, the need also exists, possibly more than ever, for strategic research for innovation. The need to implement legislation tends to distract attention from this long-term need, although this will be handled proactively as far as possible within this KSA so that anticipated research products are available when needed. The capability to sustainably manage ecosystems is an overarching need which this KSA addresses, and the World Summit on Sustainable Development scheduled to take place later this year is an important event in this respect.

At the higher level, it is necessary to improve the interface between scientists on the one hand and managers and the public on the other. Without this the concept of sustainable management will remain in the realm of theory. An aspect of this will be a way to provide people, particularly rural communities, with a method of articulating their needs which will feed directly into the management of institutional arrangements. Another aspect is to generate the understanding that a healthy and sustainably managed environment is integral to a healthy and sustainable livelihood.

Fundamental research is needed to address the processes and function of various components of aquatic ecosystems so that policies developed and management decisions taken may be based on sound science.

At the operational level, in addition to the issues around the implementation of legislation, there is a need to provide knowledge on the mitigation of the effect of development (generally in the form of engineering interventions) on ecosystems.

## Overview of technological trends

Early research on environmental aspects was largely reactive to specific needs of the funders, usually government departments. An exception to this was the national programme for Inland Water Ecosystems co-ordinated by the NRF which ran during the 1980s. The focus of this programme was ecosystem functioning, and no specific steps were taken to ensure that the science was transferred to management. On the negative side, there was little progress toward integrating the bio-physical sciences with social or economic sciences, so the work tended to remain in the realms of academia. The positive side of this programme was that a great deal of capacity was built not only in the

understanding of ecosystem functioning and processes, but also in the recognition of the necessity for effective interaction with the management agencies as well as the social and economic aspects of the environment if the work was going to make a difference to environmental management in the long term.

New legislation has reflected the recognition of the need for a multidisciplinary approach to resource management. The National Environmental Management Act (NEMA) is the overarching act in environmental management, dealing with both the terrestrial and aquatic environments. But it is the innovative NWA in particular that has put substance to the concept of sustainable management of the water resource in the way that the resource is defined and in the requirements specified for resource protection. Current research trends are based to a large extent on these requirements, although the research goes beyond them.

Current national research drivers in ecosystem research are aligned with international trends, although the emphasis is on the local situation. They are as follows:

- **The ecological Reserve** provides knowledge to enable managers to balance resource use with sustainability
- **River health and toxicology** provides knowledge to balance the use of the resource and the discharge of effluents with the ecological health and sustainability of the resource
- **Co-operative environmental management** is being developed within the context of estuarine management, and is developing the capability to integrate ecosystem management with the social and economic requirements of the stakeholders
- **The amelioration of human impacts** addresses the problems caused by people altering environment to suit our requirements, perceived or real. This broad research area addresses such aspects as the management of the side effects of engineering structures, the introduction of alien biota and the rehabilitation of abused ecosystems
- **Wetlands and riparian zones** are complex systems and there is a need for increased understanding of their processes and functioning before the level of management required to ensure sustainability may be achieved.

Each of the above will continue into the future, some probably for a decade or more. In addition, there are some areas in which research is being pioneered, such as the dynamics of ecosystems dependent on shallow aquifers, a topic that has so far received little attention

internationally. The need to impound water in a semi-arid climate leads to secondary water quality problems such as cyanophyte blooms and the ensuing release of toxins. This is an area of concern world-wide, with South Africa having the dubious honour of the most severe incidence of poisoning world-wide (e.g. almost an entire dairy herd at Kareedouw).

## Key stakeholders (influencers)

The key stakeholders are the national government departments which have water under their jurisdiction (DWAF and DEAT), specifically at this time when they are implementing new legislation. Provincial and local government are also key stakeholders, and the anticipated needs of catchment management agencies are influencing research direction.

Donor funding is available in this field, usually for specific tasks which satisfy the donors' mandate. The largest funder is the Global Environment Facility (GEF), funded by the World Bank, which has been instrumental in establishing large biosphere reserves as well as the Cape Action Plan for the Environment (CAPE) in South Africa.

## Other players

Nationally, there are 2 main groups in this category, funders and end-users of research not mentioned above. The NRF has a thrust which overlaps to some extent with the field covered by this KSA, although this has not been running for long and the NRF is in the process of restructuring again so this may be changed. DWAF and DEAT give some funds for research, although this is largely for the purpose of consultancies aimed to address specific short-term needs. Some organisations, such as the science councils, fund research internally to increase their competitiveness in areas of opportunity. All of these offer the opportunity for leverage and synergy with WRC funds where the integration can be managed.

There are a number of end-users of research such as SA National Parks and various consultants who have specific requirements and who also play, directly or indirectly, an important role in managing the aquatic environment. The needs of these groups are important as well.

## Providers

The providers of new knowledge in the field covered by this KSA are widely distributed. Researchers are located

at the Universities of Venda, The North, Witwatersrand, RAU, Potchefstroom, Free State, Zululand, Natal (both Pietermaritzburg and Durban), Transkei, Rhodes, Port Elizabeth, Stellenbosch, Western Cape and Cape Town. Within these universities the researchers are often housed within specific institutes or other units focused on specific aspects of research. In addition to this, some consultant firms work in the field of ecological management and sometimes do research. This is normally focused on highly applied aspects for rapid implementation, and is a good way of rapidly implementing research results.

## Links to Vision and Mission of the WRC

Knowledge generated through the research done within this KSA will be innovative and focused on the needs of the country, but contributes to global needs and so to the position of the WRC as a global leader in this field. The research done within this KSA has contributed to making the WRC a hub for knowledge in this field, both nationally and internationally. The quality of the work done has, in the past, been of high standard and this will continue to be a focus of the KSA. Central to the *modus operandi* is the empowerment of stakeholders to manage the goods and services delivered by ecosystems equitably and to provide the knowledge which will enable sustainable ecosystem management.

## RESEARCH PORTFOLIO FOR 2002/03

### General aims and expected outcomes

The stated aims and objectives will be addressed from research done within the following thrusts and programmes within each thrust.

Each programme within each thrust is designed to deliver products which are needed by specific end-users in the short- medium-and long-term. In the case of the thrust on ecosystem management and utilisation the end-users will be managers and policy makers, while in the case of that on ecosystem protection the results may be the same as above, but will also provide the basis on which the more applied research would be based. Each programme is designed with the input of the relevant stakeholders, taking global trends into account, and so

is able specifically to address the needs expressed, and so benefit the country.

Products are planned, as far as possible, to be ready before they are needed by the end-users, in this way effecting innovation.

Capacity-building and competence development are central to the work funded in this KSA as, apart from normal attrition, the implementation of the National Water Act (NWA) and all the changes that that implies to the management structures, requires that water management will be devolved to lower levels, requiring greater numbers of people able to fulfil the function.

An overview of KSA 2 research thrusts and programmes for 2002/03 is presented in Table 1.

## Research projects

The findings of projects completed during the year under review are given, as well as a summary of current projects and the motivation and objectives for new projects which commenced between 01 April 2002 and 31 March 2003

## COMPLETED

### Thrust 1: Ecosystem Management and Utilisation

#### Programme 1: Ecological Reserve

**The importance and role of water resources in the environment - a training course for social facilitators**  
IWR, Rhodes University  
(WRC Reference No 1180)

Social facilitators are used extensively in rural upliftment programmes, but they usually have limited understanding of the environment. This means that they are unable to adequately educate rural communities about limited water resources. The aim of this project was to develop material for use in courses to train people in this position to be able to carry the correct message to communities. This in turn would enable the communities to participate in processes required by catchment management agencies in the management of the resource.

Table 1: Overview and description of KSA2 thrusts and programmes for 2002/03.

Thrust 1: Ecosystem Management and Utilisation	
<b>Scope:</b> Within this thrust research will be conducted to specifically address the management of ecosystems for sustainable utilisation. Central to this is the need to manage the social and economic requirements of society from ecosystems and the implementation of policy and legislation. It also covers the amelioration of the impacts of human activities.	
Programme	Scope
1. <i>Ecological Reserve</i>	Within this programme research will be conducted to develop and refine methods for determining and operationalising the ecological Reserve as required by the National Water Act. The programme will address the more strategic issues such as the development of new and improved methods as well as the shorter term issues such as implementation of the Reserve. This programme is managed in close association with DWAF.
2. <i>Estuary management</i>	Within this programme research will be conducted to develop an understanding of the ecological processes within estuaries, and the effect of anthropogenic disturbance on these. This understanding is then conveyed to stakeholders (tiers of government, communities) as management guidelines to inform them on how to manage estuaries sustainably. This programme is managed in close association with Marine and Coastal Management, DEAT.
3. <i>Ecosystem health</i>	The River Health Programme (RHP: custodians are DWAF, WRC and DEAT) aims to implement nationally (at the level of provincial government and industry) a coherent biomonitoring programme with well-defined indices. Much of the R&D will be done within this programme. Additional issues on the management of river health, although they may not directly be part of the RHP, link closely with it and so are kept in the same programme.
4. <i>Toxicology</i>	Within this programme research will be conducted to develop bio-assays (both in the laboratory and the field) which will be employed to protect people and the environment from the effects of poor water quality. It will develop methods and competence to enable the use of toxicology in effluent discharge licences as well as its use in environmental water quality as required in the ecological Reserve. This programme addresses the longer-term development and refinement of methods and the competence to use them, as well as the shorter term competence required to implement policy in terms of the NWA. This programme links to the endocrine disrupter programme.
5. <i>Amelioration of impacts</i>	Within this programme research will be conducted to develop methods to ameliorate the effects of human impacts such as flow regulation and infrastructure development.
6. <i>Biological control</i>	Within this programme research will be conducted to develop environmentally friendly and sustainable control methods for invasive biota.
Thrust 2: Ecosystem Protection	
<b>Scope:</b> This thrust includes research addressing the processes and functioning of ecosystems, dealing more specifically with the biophysical processes and form of ecosystems as well as the rehabilitation of these in ecosystems. Knowledge generated by research within this thrust will be used to increase the national capability to sustainably manage ecosystems and the impact of people on it.	
Programme	Scope
1. <i>Rehabilitation</i>	Within this programme research will be conducted to develop methods to rehabilitate rivers (including wetlands) which will address both abiotic and biotic components, and seek to rehabilitate ecological processes and restore biodiversity as far as possible in degraded rivers and wetlands. This will be done in terms of both the international conventions to which South Africa is signatory as well as recent legislation from both DEAT and DWAF. The programme will also develop the competence to implement rehabilitation. Projects in this programme all link closely with each other, and are managed as a unit.
2. <i>Kruger National Park Rivers Research Programme</i>	This programme has been finalised, but there are some projects finalising certain aspects. It will be closed once these projects have been completed. The scope was to develop multidisciplinary understanding of the ecosystem functions and their response to disturbance, and to develop management capability based on this knowledge to enable the Kruger National Park to manage its resources optimally.
3. <i>Wetlands</i>	Within this programme research will be conducted to develop understanding of the ecological processes and functioning of wetlands, and assessing their value to both the catchment and the people living adjacent to them.
4. <i>Groundwater-dependent ecosystems</i>	Within this programme the dynamics of groundwater-dependent ecosystems will be investigated in relation to the aquifers on which they depend. This will be related to exploitation of the groundwater. Special attention will be given to the vulnerability of these systems.

The booklet produced, which was distributed at the DWAF-run workshops on National Water Resource Strategy, addresses the interface between people and the various aspects of water resource management in a simple way which has been shown to be effective. It begins with a short section on the water law, and then addresses the goods and services provided by rivers to people. Further chapters deal with river health and water in the environment, and the final section exhorts people to become involved in water resource management at their own levels, especially locally.

Cost: R68 000  
Term: 2000 - 2001

#### **Spatial and temporal heterogeneity in lotic systems: Implications for defining reference conditions for macroinvertebrates**

*Freshwater Research Unit, University of Cape Town  
(WRC Reference No K8/404 (Report No KV138/02))*

Ecological reference conditions are essential for the widespread application of a biomonitoring programme because these allow certain fundamental assumptions to be made on the state of a water resource even if it has not been monitored on a regular basis. This project built on a protocol developed from work done in Mpumalanga, and confirmed that this protocol was robust enough to work under different conditions in different regions. The protocol developed was not based on absolute values, but on biological bands derived from the relationship of ASPT (average score per taxon) to SASS4 (South African Scoring System Version 4) scores.

Spatial variability could be accommodated provided that the same SASS biotope is compared and recognising the intrinsic heterogeneity found in these latitudes. It proved possible to define reference conditions based on several sites in a way that enabled the detection of anthropogenic disturbance at sites within the same region but remote from the reference sites. However, temporal variability was less well defined than spatial variability. It could be detected between seasons, so it does need to be considered when determining reference conditions. The importance of seasonal differences was shown to vary between geographic regions. Temporal variability did not, however, curtail the detection of disturbance at monitoring sites.

Cost: R83 200  
Term: 2001

#### **Programme 2: Estuary management**

##### **Decision support for the management and conservation of estuarine systems: Phase 2**

*Institute of Natural Resources, University of Natal  
(WRC Reference No 756)*

The output of this project has been published in three documents. The Fish Importance Rating (FIR) (TT/03) is designed to assess the importance of estuaries from the fish point of view when implementing the ecological Reserve under the National Water Act, specifically to identify estuaries with high conservation status from the fish point of view. The index is based on seven criteria considered to reflect the importance of estuaries and their associated fish fauna.

The river-estuary interface study (756/1/03) was a multidisciplinary study relating estuarine hydrology to biotic dynamics at various trophic levels. Estuarine hydrodynamics was modelled using Mike-11 to predict salinity distributions for pre- and post- the 1996 flood. These differed substantially due to the scouring effect of the flood. It was also used to calculate the volumes of water in the estuary of each salinity range (0 to 35 ppt in increments of 5ppt) for different river flows pre- and post- flood. In this way the volume available for the habitat (based on salinity) for aquatic organisms could be calculated.

There was no apparent correlation between river flow and nutrients in the water body of the Gamtoos Estuary. There was, however, a gradient of decrease in all major nutrients from the river to the sea. In addition, the concentrations of major nutrients in the interstitial pore-water of the bottom sediments was 5 to 10 times higher than in the water column, indicating that groundwater inflow contributed nutrients to the system. Total phosphorus concentrations were low, indicating a P-limited system. While the nitrate level in the estuary was positively correlated with the river flow, the highest algal concentration in the estuary occurred at a base flow of ca.  $1\text{m}^3\cdot\text{s}^{-1}$ . This flow gave an estuarine hydraulic residence time (HRT) of about 42 days (or 3 spring-tide cycles). Diatoms dominated the estuarine micro-algae at an HRT of 42 days and shorter, but longer HRT caused dinoflagellates to dominate increasingly. Highest algal biomass was recorded at a vertically averaged salinity of ca. 10%. The algal assemblage in the REI does not differ from that of other zones of the estuary. However, the species assemblages of aquatic invertebrates within the REI are quite different from

those lower down the estuary in higher salinities. Benthic assemblages within the REI display different trophic organisation to those from more saline waters, being dominated by filter-feeders. In addition, food-web components within the REI have a distinct carbon isotope signature, indicating that the transmission of energy through the food web within a salinity zone may lead to only minimal mixing of organic matter between salinity zones. Invertebrates form the intermediate step between micro-algae and fish. Since freshwater promotes productivity in estuarine micro-algae and so through the food-web to fish, it is clearly an important factor in maintaining the productivity of fisheries where the fish depend on these for part of their life cycle.

Significant numbers of important commercial line-fish and recreational species of fish occur in the REI zone. High flows reduced both the contribution of marine species to the total species assemblage in the REI zone (from 60% to <30%) as well as the total number of fish in the estuary. Floods have the potential to cause fish mortalities.

The significant contribution of estuarine fish to the economy is derived from both commercial and recreational fisheries (756/02/03). Commercial catches both in estuaries and the near-shore are substantial, but there are 22 times more recreational than commercial fishermen, and the recreational fishery realises over 100 times the value per kilogram of fish caught. A balanced conservation strategy for estuarine fisheries is recommended to reserve this valuable resource.

Cost: R979 004  
Term: 1996 - 2000

##### **Removal of marine sediment in South African estuaries with specific application to Eastern Cape estuaries**

*SAB Institute for Coastal Resource Management,  
University of Port Elizabeth  
(WRC Reference No 1109)*

Land surrounding estuaries is in high demand for development, with the result that structures are placed in and along estuaries. This together with the abstraction of water in the catchments means that the character of estuaries will change. One of the negative changes is the deposition of sediment where there was no sediment previously, and this causes people to expect remedial action to restore the perceived original state of the estuary. This problem is currently particularly acute in the Eastern Cape where water is being abstracted from the rivers resulting in a net ingress of marine sediment. This project analysed the sedimentation characteristics

of South African estuaries reviewed and evaluated the methods available for managing marine sediment accumulation in estuaries. In addition, aspects such as the permitting requirements for interventions are covered.

Cost: R266 000  
Term: 2000 - 2001

#### **Programme 3: Ecosystem health**

##### **The invertebrates of South Africa - identification keys Umgeni Water**

*(WRC Reference No 916)*

Six of the 10 volumes have been published thus far. Three more volumes of this series were completed during the year, bringing the total number of volumes published to 6 of the 10. **Volumes 2, 3 and 4** cover the Crustacea and were published by the end of 2001. The three volumes published during 2002 are as follows:

- **Volume 5:** Non-Arthropods. This volume covers the Protozoa, Porifera, Cnidaria, Platyhelminthes, Nemertea, Rotifera, Nematoda, Nematomorpha, Gastrotrichia, Bryozoa, Tardigrada, Plocheata, Oligochaeta and Hirudinea.
- **Volume 6:** Arachnida and Mollusca. This volume covers the Araneae, water mites and the Mollusca.
- **Volume 9:** Diptera.

The final 4 volumes in the series are scheduled for completion during 2003.

Cost: R348 000  
Term: 1998 - 2001

##### **Assessment of the implications of interbasin water transfers for the genetic integrity of donor and recipient river basins using selected taxa**

*Department of Zoology, University Cape Town  
(WRC Reference No 975)*

There are a number of interbasin transfers in South Africa, and previous research by the authors of this report has shown that there is a transfer of biota with these interbasin transfer (IBT) schemes. This project examined the integrity of catchments within the framework of evolutionarily significant units to assess the implications of IBT for conservation for river ecosystem functioning and riverine biodiversity. This knowledge will form part of the management protocol for the assessment of effects of IBTs on both the donor and recipient basins.

Four organisms, with differing capabilities for dispersal, were selected for the study. The Cape Galaxias, a small fish confined to freshwater and the Net-Winged Midge (*Elporia barnardi*) have no to very limited capacity for migration over watersheds. The South African Stream Hawker Dragonfly (*Aeshna subpupillata*) is a robust animal with potential for wide dispersal, and the Stonefly *Aphanicercapensis* has a dispersal potential intermediate to the above organisms.

The results showed that there was little genetic variability within populations, implying stable populations. Poor dispersers displayed relatively high degrees of genetic differentiation between catchments, while the robust disperser displayed little genetic differentiation. In addition, the genetic differentiation of the Cape Galaxias and the Net-Winged Midge between catchments is such that it is apparent that each is comprised of several species each endemic to a catchment. This has serious implications for biotic integrity in catchments subject to IBTs.

It is recommended that the impact on biodiversity be a consideration in the feasibility assessment of all future IBTs.

Cost: R115 000  
Term: 1998 - 2001

#### River system research in South Africa: A strategic analysis

*Institute of Natural Resources, University of Natal*  
(WRC Reference No 1198)

This project had its origins in the growing appreciation of the need for research on river systems to contribute more immediately and directly to improved river system management. Research is perceived as a service that leverages change in the way in which river systems are managed and so should improve our capacity to act in ways that direct behaviour towards sustainable use. This required the simultaneous addressing of 4 issues: **Perceptions of the state of the resource, the behaviour that determines the state, and the regulatory environment.** Research should present seamless interpretations, as this is how society experiences the real world.

If research is to improve leverage of change then it must address 'outcomes' (as well as outputs) more explicitly than has been the case. In addition, the language in which research outputs are expressed is not supportive of the leveraging of change. This is because society, by and large, perceives rivers as a resource providing goods and services (not all of which need be monetised) and through the use of these the individual experiences

benefits and costs. Scientists, on the other hand, usually refer to the ecological state. The proposal is made that rivers are viewed as production systems, and the environmental Reserve as the allocation to sustain this production so that society can, in perpetuity, draw on this production. In this way, it may be easier to convey the concept of the Reserve to others.

This shift of emphasis draws attention to the rights of use. Rights of use and the authority regimes underpinning these rights need to be clear if sustainable use is to become reality. Rights of water use are clear, but rights of use of the goods and services are less clear, especially where common property regimes prevail. Two strategic research needs underpinning this are discussed in the report. One is that we need to understand how to design and implement public-private compacts to promote sustainable use of river systems. The second is that we need to understand how to use the rights of access to goods and services and distribution of costs and benefits to deepen democracy. This process would promote efforts to achieve dynamic equity in resource use.

The key strategic research issues identified are:

- Establishment of an inter-organisational entity (Centre of Competence in River Management) that maintains our fitness to respond to issues pertinent to river system management.
- Strengthen our ability to leverage change based on research findings by shifting emphasis of research to outcomes and by connecting researchers and managers effectively.
- Strengthening of democracy in support of dynamic equity in apportioning costs and benefits deriving from the use of river systems and the adjacent land.
- Effective public-private compacts that empower civil society to promote sustainable use of rivers.
- A system for analysing and assessing the propagation of impacts and their consequences across scales (local to regional) whereby scenarios can be generated for decision making.

A range of interlinked products (including Report 955/1/03) were produced during the project which addressed the *Resource-Directed Methods and the Source-Directed Controls* of DWAF, a protocol for toxicity testing in flowing water and instream toxicity monitoring.

Cost: R187 000  
Term: 2000 - 2001

#### Programme 4: Toxicology

##### The use of indigenous riverine organisms in applied toxicology and water resource-quality management

*The Institute for Water Research /Rhodes University*  
(WRC Reference No 955)

The stimulus for research into the tolerances of riverine organisms to water quality variables is provided by the recognition that:

- Quantitative resource quality objectives could not be set for the rivers of the Kruger National Park with any confidence
- The South African water quality guidelines for aquatic ecosystems were based entirely on values from international toxicological databases
- There were minimal experimental data for the responses of indigenous riverine invertebrates to water quality stressors.

This project was co-funded by the WRC and DWAF and aimed to extend the range of variables and whole effluents used in toxicity testing on indigenous riverine organisms, to apply the current toxicological database to the setting of general and site-specific guidelines and to synthesise and assess results to evaluate their usefulness for resource quality management and to contribute to the further development and application of the national water resource policy.

Cost: R963 600  
Term: 1998 - 2002

#### Thrust 2: Ecosystem Protection

##### Programme 2: Kruger National Park Rivers Research Programme

##### Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park rivers

*Department of Botany, University of the Witwatersrand + CWE*  
(WRC Reference No 1063)

Rivers flowing through the Kruger National Park are expected to change in response to development outside the KNP with consequences in the KNP. This project aimed to address two important questions, firstly, whether the riparian zone would become invaded by terrestrial species, and secondly the transfer of

ecological knowledge into the strategic adaptive management (SAM) system through rule-based models (RBM). The two RBMs transferring knowledge into SAM were the Breonadia model (to address the threshold of probable concern - TPC - of increased sediment deposition in the river channels) and the terrestrialisation RBM (to address the invasion of the riparian zone by terrestrial species in response to reduced flow in rivers). The Breonadia model measures the extent of the negative J-curve of plants recruited to the population, with recruitment only occurring on clean rocky substrate, not on sediment. The Breonadia model was tested in the KNP together with the staff of Scientific Services, but the very severe floods of 2000 (predicted by the model to exceed the TPC for four years) put an end to meaningful field testing during the life of this project. However, the response monitored was within the prediction of the RBM for a flood of this magnitude.

The terrestrialisation RBM is based on the proportion of the riparian and terrestrial species at any point in the catena, with colonisation at any point on the catena dependent on the degree of inundation or lack thereof. Four key species were selected, all of which have established seed banks and occur across the macro-channel floor. The two selected to represent the riparian (R) flora are able to survive inundation, and the two selected to represent the terrestrial (T) flora are very sensitive to flooding, so will not establish in areas which have flooded recently. The degree of terrestrialisation is gauged by the T:R ratio

Cost: R710 500  
Term: 1999 - 2002

##### Multi-party strategic adaptive management (SAM) of the Sabie River

*Centre for Water in the Environment, University of the Witwatersrand*  
(WRC Reference No 1097)

Arising from the Kruger National Park (KNP) Rivers Research Programme was the realisation that the KNP could not achieve its management goals without the co-operation of the users of water upstream of the Park. This was the first attempt at co-ordinating water management around 'environmental flows' (the Reserve) for a particular river, and required the co-operation of all managers in the Sabie River.

It was clear that without a 'crisis' to manage it would be difficult to initiate procedures for strategic adaptive management (SAM) at catchment scale. Predictions made by Birkhead indicated that the environmental flow set for the Sabie River was unlikely to meet KNP

objectives and this served as the basis for engagement between scientists and resource managers. The resource managers were initially difficult to engage partly because the floods of February 2000 introduced urgent and new priorities, but this was achieved.

The objectives hierarchy developed for the rivers of the KNP provides the vision for management. Within this system, the goals provide managers on the ground with specific ecological end-points which are measured by thresholds of probable concern (TPCs) which are statements or hypotheses of limits of acceptable change. SAM hinges on the axiom that ecosystems are complex dynamic systems, and the three components to ensure that science is used in management are research, interfacing, and an institutional system. The report outlines a number of lessons learnt for improving both the operations within the KNP and management of technology development and transfer.

This project has made important contributions to the KNP management system and conservation managers are now better able to respond to river management problems, and it has provided a background process which will benefit CMAs once they are established.

Cost: R98 600  
Term: 1999 - 2001

### Programme 3: Wetlands

#### Cultivation of high-value aquatic plants in restored urban wetlands for income generation in local communities

Abbott Grobicki (Pty) Ltd  
(WRC Reference No 1054)

Wetlands are very valuable areas because of the biodiversity of bird life, insects, and wetland plants that they contain. They also offer benefits to our precious water because they act as filters and are capable of purifying water that flows through them. Yet wetlands in urban areas are under great pressure due to competition for land resulting from poverty and inadequate infrastructure and services, particularly housing. Wetlands are routinely filled in, and as a result South Africa has lost some 50% of all its wetlands including the majority of its wetlands in urban areas. As a way to remedy this situation it has been suggested that wetland conservation and rehabilitation would be encouraged if urban wetlands could be turned into economic assets.

This project achieved this through researching the types of indigenous plants which could grow in wetlands and had an economic value, whether they be used for crafts,

traditional medicines, cut flowers or pot plants. A privately funded project was set up in Khayelitsha, near Cape Town, growing arum lilies for export in the Khayelitsha Wetland, and compared this project to other wetland projects elsewhere in South Africa.

**Ecological effects:** The immediate ecological benefits of wetland cultivation consisted of cleaning the area of litter, human waste, and alien invasive plants. Cultivation and management of the area prevents new dumping, alien plant growth, and grazing and trampling by domestic stock, which Reserves the wetland area from further degradation.

**Economic effects:** Although the Inyibiba Pilot Project did not become economically sustainable in its 12 months of operation, in that time it provided employment and wages to members of a community with high levels of unemployment. It also established an area of 1ha containing over 36 000 arum lily plants which can be harvested for flowers in future seasons.

**Social effects:** Staff were employed from the local community and trained in all aspects of planting, growing and harvesting arum lilies. Setting up the Inyibiba Pilot Project contributed to the capacity of the local authorities, particularly the Tygerberg Administration and Cape Metropolitan Council, to set up and administer projects such as this.

It was concluded that:

- It is possible to cultivate economically valuable plants at high density in an altered urban wetland, and if growing conditions are optimised then it should be possible for such a project to become a sustainable source of employment and wetland protection.
- Wetland cultivation projects can provide at the very least the ecological benefit of preserving the wetland from further degradation or from settlement, and create an opportunity to rehabilitate the wetland in the future.
- Cultivation of economically valuable plants creates a source of employment and skills development for communities near the wetland. Wetland cultivation projects have the potential to become a focus for other business and entrepreneurial activities in the surrounding communities.
- Thus cultivation of economically valuable plants in wetlands can provide the economic incentives needed to ensure the continued preservation and rehabilitation of wetlands.
- In addition, the database of wetland plants is now available to anyone who is interested in starting up

a similar project in a wetland. The database is organised by the different climatic regions of South Africa, and contains 68 wetland plants that can be considered for cultivation, together with their uses, and other information. It is available from the WRC website at [www.wrc.org](http://www.wrc.org)

- The guidelines for setting up a cultivation project in a wetland are also available in a straightforward step-by-step format. They include the necessary authorisations that may be required, and how to assess and evaluate a site. These guidelines have been tested in a real-life situation; however, every situation is different, and every wetland site is unique.

Cost: R550 000  
Term: 1999 - 2001

#### Ecological and economic evaluation of wetlands in the upper Olifants River catchment, with reference to their functions in the catchment and their management

Wetland Consulting Services (Pty) Ltd.  
(WRC Reference No 1162)

The need to assess the value of the wetlands in the Upper Olifants River Catchment (UORC) arose because many wetlands in the area face irreversible degradation due to developments in the catchment, and because wetlands are increasingly recognised as areas of economic and ecological importance. Whether degradation of wetlands in the UORC is reason for concern was uncertain, as neither the ecological nor the economic value of these wetlands was known. If decisions regarding the conservation vs. development of wetlands in the area are to be optimal for society, then it is necessary to develop an understanding of the sorts of costs and benefits that need to be traded off. This study aimed to classify and inventurise the wetlands in the UORC and to assess the net economic value of these wetlands.

The study relied mainly on existing information supplemented by limited fieldwork and limited liaison with stakeholders. It was recognised that a desktop study would provide ball-park estimates and guidance for future research.

Wetlands of the study area were mapped, and found to cover 64 813 ha (9.9% of the UORC). A total of 17 hydrogeomorphic wetland types were recognised which fall into 6 main categories: Floodplain or non-floodplain riparian, hill slope seepage, pans, other non-riparian and artificial wetlands. The highest concentration of wetlands is associated with dolerite intrusions.

A number of ecosystem services were valued, and the values compared with coal mining and agriculture, the two main land uses in the area. Wetlands cover about 10% of the entire study area, although individually they are small and disjunct. This is probably the single biggest contributor to their degradation.

Different types of wetlands are estimated to have a value (based on direct and indirect services) of between R1 000 and R32 000-ha<sup>-1</sup>. A rough estimate of the value of drained wetlands to agriculture is R725-ha<sup>-1</sup> for grazing land and R1 500-ha<sup>-1</sup> for cultivated land. The value for coal mining, however, is much higher. The price of coal varies, depending on quality, from R0.30 to R4.t<sup>-1</sup> (R1.t<sup>-1</sup> was agreed as a realistic average), giving the average opportunity cost of a wetland underlain by coal as R45 000-ha<sup>-1</sup>.

The proposal made is that the trade-off between conversion of a wetland or its conservation be made on the estimated values of the opportunity cost vs. the biodiversity costs. The assumptions in this equation are that it is very difficult to monetise all values of an ecosystem, particularly where there is also a scarcity value of a wetland (as more are converted, those remaining increase in value), and that the precautionary principle should apply.

Mined wetlands can be rehabilitated, but the extra cost of rehabilitating a wetland is likely to be more than the monetised value of the wetland.

Cost: R585 000  
Term: 2000 - 2001

## CURRENT

### Thrust 1: Ecosystem Management and Utilisation

#### Programme 1: Ecological Reserve

##### Development of a classification system for rivers of the KNP, and a model for analysing trends in the condition of these rivers

IWR, Rhodes University  
(WRC Reference No 881)

In spite of the wealth of information on the rivers in the Kruger National Park (KNP), particularly the Sabie, it is not clear how this information can be extrapolated to other rivers in the area. During Phase 3 of the KNPRRP comparable data have been collected from all the rivers in the KNP, and a classification system is required to enable comparisons and predictions to be made. While a proposed national classification system lacks sufficient definition, it provides guidelines for the development of a more specific system which should be based on physical structure, ecological integrity and desired future state. The classification system being developed through this project is based on a geomorphological template with habitat overlay.

Estimated cost: R113 000  
Expected term: 1997 - 2001

##### Incorporation of economic considerations into quantification, allocation and management of the environmental water Reserve

Institute for Natural Resources, University of Natal  
(WRC Reference No 978)

Instream flow requirement assessment provides a process whereby the environmental Reserve from an ecological perspective is quantified and characterised. This project is aimed at introducing economic criteria into this process. Policy measures are being implemented to promote efficient use of water. To achieve this, there is a movement towards a water allocation system in which the value of water is acknowledged and taken into account. 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.

Estimated cost: R488 000  
Expected term: 1998 - 2001

##### Development of numerical methods for assessing water quality in rivers, with particular reference to the "instream flow requirements" process

Department of Zoology, University of Cape Town  
(WRC Reference No 956)

The management of water quality in the environmental Reserve is more complex than that of water quantity. The principal aim of this project is to examine the relationship between water quality and water quantity with particular reference to instream flow requirement assessments, and to produce a framework for the assessment of water quality in IFR studies. Secondary aims are to investigate how the Biobase database may be used in the assessment of water quality guidelines.

Estimated cost: R800 000  
Expected term: 1998 - 2001

##### Integration of water quality tools for the ecological Reserve into a risk-based DSS

Institute for Water Research, Rhodes University  
(WRC Reference No 1108)

The relative complexity of water quality has meant that it has received less attention than water quantity in the Reserve methodology. This project seeks to link water quality firmly into the DSS being developed (Development of a computer based decision support system for quantifying the components of the ecological Reserve) to express flow in terms of invertebrate stress, using a risk-based framework.

Estimated cost: R278 000  
Expected term: 2000 - 2001

##### Impact of groundwater abstraction on ecosystems in the Kammanassie Nature Reserve and environs

Department of Applied Natural Sciences, Technikon of South Africa  
(WRC Reference No 1115)

The Vermaak River well-field established in the Kammanassie Mountain Range to the east of Oudtshoorn supplies water to the Klein Karoo rural water supply scheme. This project addresses concerns about the effects that high abstraction rates may have on the ecology of the area and is advancing our current understanding of the interaction between groundwater and the environment through an appropriate case study.

Estimated cost: R200 000  
Expected term: 2000 - 2001

#### Programme 2: Estuary management

##### Evaluating the environmental use of water-selected case studies in the Eastern and Southern Cape

Department of Economics, University of Port Elizabeth  
(WRC Reference No 1045)

In the Working for Water Programme, considerable capital and operating expenditure have already been incurred on the project to eradicate alien vegetation. The potential saving of water and appeal of reintroducing indigenous vegetation are generally accepted. However, a comprehensive identification, quantification and valuation of benefits and costs have so far not been undertaken. This information is essential to retrospectively justify expenditure for public funds and to ensure the economic and ecological sustainability of alien plant removal in different catchments.

Estimated cost: R143 000  
Expected term: 1999 - 2002

##### Directed estuary research programme to facilitate and enhance management for the sustainable use of Eastern Cape estuaries (Phase III)

Institute of Natural Resources, University of Natal  
(WRC Reference No 1246)

Approximately 50% of the country's estuaries are in the Eastern Cape, but very little is known about these compared to those on other coastlines of South Africa. Many are thought to be in near pristine condition, relatively free from the catchment disturbances which have resulted in degradation of many of the nation's estuaries in other areas. Estuaries are important resources for adjacent communities, but form the focus of coastal development and ecotourism opportunities as well. They are also very sensitive to disturbance, and so can easily be degraded. The Eastern Cape has a high unemployment rate, and it is likely that the natural resources in the region will be exploited to provide for the regional population. If these resources are managed sustainably, then they will continue to provide wealth generation and employment opportunities. If the management is not sustainable, however, the pressure on the resources is likely to damage them to the point where they have little value, even to the rural poor living beside the estuaries themselves.

Considerable progress has been made during the previous phase (Phase II) of this programme in terms of its articulated goals and this has generated a good deal

of momentum in the region. In addition to ongoing capacity-building in estuary management, co-operative governance was identified as a specific problem which will be addressed, with the aim to create the capacity and protocols to enable sustainable estuary management.

Estimated cost: R1 920 000  
Expected term: 2001 - 2003

##### Phytoplankton primary production and community structure in two temporarily closed estuaries

Department of Zoology and Botany, University of Port Elizabeth  
(WRC Reference No 1255)

Estuaries are fragile systems which are important to both those living adjacent to the estuaries (for the goods and services they provide) as well as others (for the recreation opportunities provided). Their fragility results in part from their geographical position as final integrator of activities in the catchment and the sea. Increasing water abstraction inland means that more of the nation's estuaries will be closed for longer periods than previously.

The major energy pathways of open-mouthed estuaries have been worked on, but those of estuaries that are closed for varying periods are less well known. In addition, these periods of closure result in a build-up of pollutants which would otherwise be washed out to sea.

Through addressing the following aims this project will contribute to the national ability to manage these estuaries in terms of the requirements of the National Water Act.

Through this project understanding will be generated on the major energy pathways that are driven by phytoplankton production of various size fractions during periods of month breaching and closure, shifts in phytoplankton community structure following nutrient enrichment, the spatio-temporal distribution and influence of fluctuating water levels on phytoplankton, and to use this knowledge in the estuarine Reserve determination process.

Estimated cost: R597 000  
Expected term: 2001 - 2004

**Dealing with estuarine sedimentation-assessment of the hydraulics of estuarine sediment transport processes and the development of water Reserve management guidelines**

Department of Civil Engineering, University of Stellenbosch

(WRC Reference No 1257)

River flow reduction resulting from increasing abstraction combined with the increased erosion caused by unsustainable veld management, has negatively impacted on the sediment transport dynamics in estuaries. This results in both an increase in the accumulation of fine sand derived sediments, which are often cohesive, as well as an ingress of marine sediments which may or may not result in mouth closure. The accumulation of sediments in estuaries has negative economic impacts for the region (commercial fishing and recreation), as well as negative impacts for ecosystem stability (reduction of habitat by sediment accumulation and reduced tidal prism). The cohesiveness of the fine sediments makes this trend effectively irreversible, as they do not erode at all easily.

This project aims to generate knowledge on the sediment transport and flushing processes of estuaries, and then to develop guidelines on how to manage the ecological Reserve of the estuaries to ensure the maintenance of a long term equilibrium.

Estimated cost: R950 000  
Expected term: 2001 - 2003

**Programme 3: Ecosystem health**

**Benthic diatoms in the rivers and estuaries of South Africa**

Dept of Botany and Institute for Coastal Resource Management, University of Port Elizabeth  
(WRC Reference No 1107)

This follow-on project (from the project entitled **Identification of diatoms and their use in the assessment of water quality**) will address 3 aspects of the use of diatoms in monitoring for water quality. The determination of the relationship between dominant diatom assemblages and freshwater quality will continue. The same will be done for estuarine diatoms, where the relationship between water quality and dominant assemblages will be defined. Thirdly, a manual of South African diatoms will be produced. The product of this project will enable the use of diatoms, long recognised as being sensitive indicators, in water quality management at the technician level, not achieved elsewhere before.

Estimated cost: R415 000  
Expected term: 2000 - 2002

**Suspended sediment concentration and its implications on macro-invertebrates in the Umzimvubu River, Eastern Cape**

Department of Zoology, University of Transkei  
(WRC Reference No 1182)

The project on which this one follows (**Water quality and aquatic faunal studies in the Umzimvubu catchment, Eastern Cape, with particular emphasis on species as indicators of environmental change**) indicated that the Umzimvubu River transports an enormous sediment load, but only preliminary investigations were undertaken on the effect of this on instream biota. This project seeks to quantify this effect as well as to attempt to measure the sediment load actually carried (above the bed) by floods

Estimated cost: R90 000  
Expected term: 2000 - 2002

**Managing rivers in rural regions through community involvement and community awareness programmes. Phase One: Determining the influences and interactions of the factors affecting biotic integrity through an investigation of habitat requirements**

Department of Zoology, University of Venda  
(WRC Reference No 1197)

Rural communities with low per capita income, such as those on the Luvuvhu and its tributaries, depend heavily on the natural resources provided by a river and its catchment. The aims of this project are to firstly identify the factors leading to the loss of biodiversity. Secondly, a draft management plan will be prepared based on the principle of strategic adaptive management as developed for the Kruger National Park.

Estimated cost: R100 000  
Expected term: 2000 - 2001

**Evaluation of the fish assemblage integrity index to assess river health, and its refinement to ensure high levels of accuracy**

Contractor: Ecosun  
(WRC Reference No 1256)

World-wide there is a trend towards biomonitoring for the initial monitoring of water quality. Some of the reasons for this are that it would be virtually impossible to monitor chemically for all the substances released into the environment, and biomonitoring offers a cost-effective way of ascertaining the water quality and

alerting authorities to the existence of problems. The South African River Health Programme, a biomonitoring programme using a suite of methods, has been piloted in Mpumalanga and is in the process of becoming institutionalised in several provinces in the country.

The prototype Fish Assemblage Integrity Index (FAII), one of the indices used in this programme, has been developed over a number of years in Mpumalanga and the Northern Province, and has been used elsewhere in the country. It has proved its value within the River Health Programme, but its application has identified additional work that needs to be done to make it the robust and universally applicable tool that is required by the Programme. With this in mind, the aims of the project are to relate fish distribution to the eco-regions, evaluate the suitability of the FAII in assessing levels of site specific impairment for rivers, to amend and standardise techniques used as part of the FAII to ensure acceptable levels of accuracy, precision and representativeness and to develop guidelines for the use of the FAII to enable the evaluation of the levels of site-specific impairment.

Estimated cost: R93 000  
Expected term: 2001 - 2003

**Geomorphological research for the conservation and management of Southern African rivers**

Department of Geography, Rhodes University  
(WRC Reference No 849)

Fluvial geomorphology is an essential discipline in the determination of environmental flow requirements. Geomorphologists are able to make an input both in the form of long-term predictions of the effect of altered flow patterns and defining the habitats available to stream-dwelling organisms. The broad aim of this project is to integrate geomorphology into the conservation of Southern African river systems. Specifically, it will refine the geomorphological input into the determination of instream flows, develop indices and monitoring procedures for the assessment of channel condition and refine the hydraulic biotope concept.

Estimated cost: R738 000  
Expected term: 1997 - 2001

**Development of monitoring methods for the ecological Reserve (quantity) for rivers**

IWR, Rhodes University  
(WRC Reference No 1101)

The National Water Act requires that the Minister ensure that monitoring is performed. However, although a

number of Reserve determinations have been done, very few have been implemented and there is no monitoring protocol to ensure that:

- the required flow is being delivered
- it is achieving what it was intended to achieve.

This project has developed a protocol to address these two aims and discussions are underway with DWAF officials to implement this as a monitoring programme.

Estimated cost: R538 000  
Expected term: 1999 - 2001

**Development of DRIFT, a second generation methodology for instream flow assessment**

Southern Water Research and Ecological Consulting cc  
(WRC Reference No 1159)

DRIFT, first tested in the World Bank-funded study in the Lesotho Highlands, addresses the shortcomings identified in the building block methodology by adopting an approach to the process of flow determination which allows the assessment of the importance of individual components to the ecological integrity of the river. This project seeks to develop this methodology to ensure that it addresses the needs of managers, compile guidelines for its use and transfer the methodology to the management milieu.

Estimated cost: R 848 000  
Expected term: 2000 - 2002

**Development of a computer-based decision-support system for quantifying the components of the ecological Reserve**

Institute for Water Research, Rhodes University  
(WRC Reference No 1160)

The objective of this project is to develop a consistent protocol for the quantification of the ecological Reserve within a risk-based framework. This will be incorporated within a DSS which will accommodate all the steps and procedures required to quantify the Reserve. It will also develop a risk-based process for the biotic flow requirements by combining their stress/response relationships with flow time series.

Estimated cost: R1 089 000  
Expected term: 2000 - 2002

### Hydraulic analyses for the determination of the ecological Reserve for rivers

Department of Civil Engineering, University of Witwatersrand  
(WRC Reference No 1174)

Implementation of the ecological Reserve requires the integration of the hydrology and the biotic requirements. This project aims to provide this integration in a way that may be used by experts and managers for both the intermediate and comprehensive Reserve, and also to define the hydraulic characteristics of instream habitats

Estimated cost: R1 050 000  
Expected term: 2000 - 2003

### Information requirements for the implementation of resource-directed measures for estuaries

Dept Zoology and Botany/University of Port Elizabeth  
(WRC Reference No 1247)

The National Water Act requires that aquatic ecosystems be protected (the Reserve) to ensure sustainable development. The implementation of the Ecological Reserve through the *Resource-Directed Measures Strategy* of the Department of Water Affairs and Forestry is well advanced in rivers, but currently behind in estuaries. Where estuaries are involved, though, their needs are likely to influence the decision on the Reserve, as the estuarine environment is fragile and easily disturbed. The process currently being followed to develop policies for the sustainable management of estuarine ecosystems within this context has indicated that there are gaps in knowledge that need to be addressed.

Through the overall aim of providing data and understanding to support the estuarine component of the *Resource-Directed Measures Programme* of the Department of Water Affairs and Forestry, the following specific aspects will be investigated: The response to flow variation in temporarily open / closed estuaries, the response of biota to water quality and to devise an overall index of importance rating for South African estuaries.

Estimated cost: R1 125 000  
Expected term: 2001 - 2003

### Programme 4: Toxicology

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

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

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 this 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

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

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

The project aims to investigate the scope and degree of toxicity of cyanophytes:

- Methods for growth and cultivation of toxic and non-toxic cyanophytes on a laboratory-scale are being developed to provide a constant supply of these bacteria to research laboratories to be used as standards.
- The project also addresses the control of pesticide synthesis as a prelude to determine genetic control of the algae.
- Gather information on the occurrence, treatment and management options to address algal blooms from all the water suppliers, agricultural sectors and DWAF for the development of a management manual that could be of benefit to both smaller rural drinking water treatment plants and the larger water suppliers.

- Investigate if microcystins modulate the immune system of mammals and whether this modulation of the immune system can be used for diagnostic and analytical purposes.

Estimated cost: R372 000  
Expected term: 1999 - 2001

#### Applied aquatic ecotoxicology: Sub-lethal methods: Whole effluent toxicity (WET) testing, course development and communication

Institute for Water Research, Rhodes University  
(WRC Reference No 1245)

The release of harmful and potentially harmful substances into the environment has caused water quality problems world-wide. Toxicology offers a cost-effective way of measuring the likely impact of an effluent on the environment, in that it will identify whether the effluent is toxic, including any synergistic and antagonistic effects. This will allow for both the determination of the suitability of the effluent for discharge to be determined for licensing purposes, and for specific industries to monitor their compliance with licence conditions.

Most toxicity tests measure acute effects and the chronic values are calculated empirically. The measurement of sub-lethal methods will, thus, provide accurate values on which to base decisions, so enhancing the capacity of managers to protect the water resource.

During this project new methods will be developed for quantifying the chronic effects of toxic effluents at sub-lethal concentrations.

Estimated cost: R1 397 000  
Expected term: 2001 - 2004

#### Application of biosensors for ecotoxicity testing of water resources

Department of Microbiology, University of Durban Westville  
(WRC Reference No 1286)

Microbial biosensors offer advantages over other methods of ecotoxicity testing by the rapid and sensitive response they provide, ease of culturing and maintenance, and the possibility of selecting for an environmentally relevant micro-organism. The use of bioluminescence-based biosensors is gaining support as a sensitive method in microbial ecotoxicity assessment. The Microtox assay, which uses a naturally bioluminescent marine bacterium, has become widely adopted as a microbial biosensor. This assay is expensive

and not appropriate for all environmental applications. The use of a marine micro-organism for the assessment of soil and freshwater samples presents a number of disadvantages because it requires pH and salinity conditions normally associated with the marine environment. The cloning of lux genes from marine vibrios into terrestrial bacteria offers the opportunity for bioluminescence-based toxicity testing using biosensors relevant to the environment being tested. The focus is to develop the tests and the capacity to use them in the country.

Estimated cost: R650 000  
Expected term: 2001-2003

## Thrust 2: Ecosystem Protection

### Programme 1: Rehabilitation

#### Decision-support system for rehabilitation and management of riparian systems

Institute for Natural Resources, University of Natal  
(WRC Reference No 1064)

Only recently have efforts been made to prevent the degradation of riparian areas. There are a number of techniques available for use for the purpose of prevention of degradation, but there is a lack of experience and guidelines for integrating the concepts of biodiversity conservation and habitat rehabilitation in a way that can be implemented. This project is providing a vehicle to develop both guidelines and experienced people in a field by piloting a rehabilitation exercise in the Mhlatuze catchment using students from designated groups.

Estimated cost: R 600 000  
Expected term: 1999 - 2001

#### Ecological and geomorphological principles for river rehabilitation

Department of Zoology, University of Cape Town  
(WRC Reference No 1161)

Decades of poor catchment management, over-abstraction of water, use of rivers as waste disposal systems, destruction of riparian buffer strips and river beds have contributed to the toll of badly degraded rivers. The costs of poorly functioning rivers are largely externalised in any development activities, and so unknown. At present, there is not a developed science to deal with this in South Africa. There are no guidelines

for, or even general principles, guiding such rehabilitation. The aim of this project is to pilot river rehabilitation in the Western Cape and to develop generic guidelines for rehabilitation, while at the same time building capacity for the science in 2 students

Estimated cost: R1 190 000  
Expected term: 2000 - 2002

#### **Development of an estuarine water quality index for implementation in estuarine water quality management in Southern Africa**

Department of Zoology, University of Zululand  
(WRC Reference No 1163)

Methodologies for the determination of water quality and quantity, as required by the NWA, are less well developed for estuaries than rivers. The aim of this project is to develop a water quality index based on rating curves for selected water quality determinants, to enable the interpretation of variables in terms of ecological resource protection. It includes elements of similar indices developed elsewhere, but is applicable to South African estuaries, and will take the form of a decision support system. This links to the water quality component of the project titled **Information requirements for the implementation of resource-directed measures for estuaries** (No. 1247).

Estimated cost: R515 000  
Expected term: 2000 - 2001

#### **Refinement of geomorphological tools for sustainable management of the river environment**

Department of Geography, Rhodes University  
(WRC Reference No 1181)

Existing riparian habitat assessment protocols do not directly address the relationship between habitat and the adjacent landscape. Given the values of riparian areas in the landscape, the objectives of habitat rehabilitation should include the reinstatement of such values and functions. This project will develop appropriate protocols.

Estimated cost: R99 000  
Expected term: 2000

#### **Programme 2: Kruger National Park Rivers Research Programme**

##### **Rule-based modelling of fish: Facilitating strategic adaptive management of the Kruger National Park rivers through model development and technology transfer**

Institute for Water Research, Rhodes University  
(WRC Reference No 1065)

A management model based on fish was developed for the country's east-flowing rivers early in the 1990s, but not along the lines of strategic adaptive management (SAM), the highly effective and currently accepted method. This project specifically aims to express the problems surrounding fish biodiversity within the context of SAM, and develop appropriate thresholds of probable concern to inform the process. This project is developing a technology transfer product.

Estimated cost: R552 000  
Expected term: 1999 - 2001

#### **Programme 3: Wetlands**

##### **A biophysical framework for the sustainable management of wetlands in the Northern Province with Nylsvlei as a reference model**

University of the North in conjunction with Rand Afrikaans University  
(WRC Reference No 1258)

Wetlands are internationally poorly understood and large areas are drained annually for development of one form or another. South Africa is no different, in that we do not understand or appreciate the role that wetlands play in river ecosystems. In spite of South Africa being signatory to the Ramsar Convention, it has been estimated that by 1998 over half of the country's wetlands had been destroyed. Wetlands deliver a number of goods and services such as flood attenuation, raised dry season baseflow, improvement of water quality and increase in biodiversity. Although the value of these has not been fully quantified, there is a growing awareness in certain quarters that this value justifies maintaining the wetlands intact as may be seen from the funds committed to wetland rehabilitation nationally by Working for Wetlands and in Seekoeivlei by Rand Water.

There are a number of wetlands in the Waterberg area of the Northern Province; Nylsvlei is not only the largest but is also a proclaimed Ramsar site. The wetlands of this area are subject to the same destructive influences as elsewhere, and as is the case elsewhere, the

knowledge and understanding of the systems are not available to allow us to manage and restore them optimally. This project aims to lay the foundation for this by compiling a draft sustainable management programme for Nylsvlei which would include guidelines for water quality and biomonitoring, and to propose a strategic management plan for the sustainable use of wetlands in the Waterberg region of the Northern Province.

Estimated cost: R745 000  
Expected term: 2001 - 2003

## **NEW**

### **Thrust 1: Ecosystem Management and Utilisation**

#### **Programme 1: Ecological Reserve**

**Refinement of aspects of the Reserve determination methodology for water quality, including the assessment of potential impacts on aquatic biota**  
Freshwater Research Unit, University of Cape Town  
(WRC Reference No 1311)

This follow-up project will develop certain tools that are still outstanding and are needed for determination of the water quality in the ecological Reserve in rivers and wetlands. These include refinement of the work done on nutrients, particularly identifying which nutrient criteria should be used to assess the nutrient status of a river or wetland and providing, where necessary, protocols for evaluating the nutrient status of rivers and wetlands for Reserve determinations. The capability to protection of aquatic biota will be enhanced by continuing the thrust started during the previous project (Report No 956, Vols 1 and 2) and expanding its use in the Reserve determination process. Thirdly, the methodology for the assessment of water quality in wetlands for Reserve determinations will be assessed and where possible tools / methods will be developed where needed.

Estimated cost: R300 000  
Expected term: 2002 - 2004

**Assessment of the geomorphological reference condition: Application to resource-directed measures and the river health programme**

Department of Geography, Rhodes University  
(WRC Reference No 1306)

Fluvial geomorphology provides the template on which the ecological processes occur within a river. The aims of this project are to refine the geomorphological index for biomonitoring for use by scientists and managers to assess the condition of the river. Methods developed for classifying the present geomorphological state and the geomorphological reference condition are aimed largely at the resource-directed measures procedure of DWAF, partly as a basis for assessing the category of the river and partly as a basis against which to implement rehabilitation where deemed necessary.

Estimated cost: R429 000  
Expected term: 2002 - 2004

#### **Further development of methods to quantify water quality aspects of an ecological Reserve assessment and dissemination of information via a decision support system and associated manuals**

Institute for Water Research, Rhodes University  
(WRC Reference No 1312)

Water quality is currently trailing water quantity in the ecological Reserve methodology. Further development of the methods used is necessary to enable the water quality component to be considered adequately. The aims of this project are to develop acceptable time-series data for selected water quality variables, encapsulate the expert water quality knowledge in an organised way and encode these for inclusion into the DSS currently being developed as part of a parallel project, and co-ordinate this with other water quality projects working on the Reserve. This will ensure that decisions taken on water quality in the Reserve determination process are done in a standard way and in parallel with those on water quantity.

Estimated cost: R800 000  
Expected term: 2002 - 2004

#### **Development of resource monitoring procedures (step 7) for estuaries to establish resource status and to monitor the response to resource-directed measures (RDM) implementation**

Environmentek, CSIR  
(WRC Reference No 1308)

Monitoring of water resources is required under the NWA, but some methods still need to be developed. Monitoring of the ecological Reserve in estuaries is a case in point, and the aim of this project is to develop resource monitoring procedures to establish the status of the estuaries and to monitor the response to the RDM once implemented. Monitoring is necessary to provide

feedback to the ongoing management of individual estuaries, but more importantly to refine and increase confidence in Reserve determinations. Personnel will also be trained to do the work. This project links to the estuary management programme

Estimated cost: R195 000  
Expected term: 2002 - 2003

#### Groundwater-dependent ecosystems CSIR (WRC Reference No 1330)

During this project a national scale summary of known and probable groundwater dependent ecosystems in South Africa will be produced based on geohydrological-type settings. This overview is necessary to enable scientists and managers to begin to understand this new field of research, and particularly relevant in terms of the resource-directed measures as required in the National Water Act. Guidelines will also be drawn up to enable CMAs and DWAF to assess the importance and vulnerability of groundwater-dependent ecosystems and to test the application of the tools developed for measuring groundwater use and dependency. Significant gaps in existing knowledge will be identified for future research.

Estimated cost: R600 000  
Expected term: 2002 - 2004

#### Programme 2: Estuary management

**Valuation of changes to estuary services in South Africa as a result of reductions in freshwater inflows**  
Department of Economics, UPE  
(WRC Reference No 1304)

The renewable natural resource, river water, has been subject to persistent open access exploitation in South Africa. Inevitably, problems have arisen that are typically associated with poorly defined property rights and externalities. Inter alia, traditional water pricing policy in South Africa has been found to be inefficient.

The primary focus of attention of ongoing economic research is on identifying the benefits and beneficiaries of functional estuaries and the value of these benefits. In essence this work follows a two stage approach to valuing the benefits per estuary. Stage 1 is to value each estuary service individually and Stage 2 is to add these values together.

Estimated cost: R336 000  
Expected term: 2002 - 2004

#### Appropriate, cost-effective and environmentally friendly technology and management systems for the removal of marine sediments in SA estuaries Institute for Natural Resources (WRC Reference No 1305)

Ingress of marine sediments into estuaries was the single most important issue in estuary management identified in the western part of the Eastern Cape during the early stages of the EC Management Programme. The local authority for the Port Alfred / Boesmans River area has committed funds to develop the predictions of the effect of interventions on the problem. If the predictions indicate that an intervention may be successful, then the EIA around the planned intervention will be undertaken within this project. Thereafter, the implementation of any technology will be for the expense of the local authority.  
Estimated cost: R160 000  
Expected term: 2002 - 2003

#### Programme 3: Ecosystem health

**The nature of catchment and river signatures, the affect on these of different disturbances, and the management implications**  
Freshwater Research Unit, University of Cape Town  
(WRC Reference No 1303)

Previous research (Report 754) identified the fact that rivers tend to exhibit a 'signature' through their length, rather than, for instance, headwater regions between adjacent rivers being comparable. This has not been recognised before, and so management has taken the latter view. The main aim of this project is to study the extensive dataset developed during the previous project in order to identify the causes of this and consider the implication to river management. Secondary aims of this project are to assess the influence of these signatures on SASS scores of the sampling site within a river reach and to refine the database developed during the previous project.

Estimated cost: R478 000  
Expected term: 2002 - 2004

**Ecological impacts of reverse hydrograph water releases from Albert Falls Dam on in-stream processes**  
Umgeni Water  
WRC Reference No 1307)

Impounded water is usually released at times of natural low flow. Most South African rivers are affected in this way, but there is little data on the impacts (positive or negative) of this. The aim of this project is to examine the impact of this "reverse hydrograph" on the river. This will enable guidelines to be developed on optimising

environmental releases from impoundments within the management requirements of the system. This information will contribute to the development of operational rules for impoundments from which releases are required in order to supply flow in terms of the ecological Reserve.

Estimated cost: R363 000  
Expected term: 2002 - 2005

**Development of criteria for the design of fish ladders for South African rivers and estuaries**  
Pulles, Howard and de Lange Inc.  
(WRC Reference No 1310)

Many fish-ladder designs exist, some of which are more effective in certain situations than others. The Department of Water Affairs and Forestry plan to incorporate fish ladders into future weir designs and need to know which design(s) will be effective. The project leader seeks to provide this information through a combination of information reported in the literature and observations of an adjustable fish ladder installed on the Nhlabane Weir by Richards Bay Minerals. This project links to the project No. 1270, **Flow measurement at natural controls and the provision of fish-ways** in the thrust **Water Resource Assessment (KSA 1)**.

Estimated cost: R553 000  
Expected term: 2002 - 2005

**WRC Programme for Endocrine Disrupting Contaminants (EDC)**  
Consortium Members: US; UFH; MEDUNSA; Technikon Free State; Technikon Pretoria; SABS; CSIR Environmentek; ARC-PPRI; Consultant manager  
(WRC Reference No 1402)

This Programme, which is the result of several preliminary studies, is intended to determine the present status of EDC pollution in South African waters. A wide variety of chemicals will be identified and techniques for their detection will be developed, where necessary, and tested. A battery of bio-assays and chemical analyses will be identified in order to monitor EDC pollution. Thereafter, training workshops involving local and international expertise are planned in order to transfer specific skills and build capacity at laboratories on a country-wide basis. This is a follow-up of the preliminary studies of the EDC programme. The Programme will focus on the present status of EDC pollution in the aquatic systems of the country. The programme will address the wide variety of chemicals involved to determine those crucial for the SA environment and the special techniques and skills needed for the detection thereof. It will be a combined effort between laboratories

country-wide with specific capabilities and skilled researchers to develop a battery of bio-assays and chemical analyses that could be used to determine the extent of the EDC pollutions in SA. Each laboratory will be expanding on their special capabilities and building capacity to form a centre of expertise, but not working in isolation, to the benefit of this research in SA.

Estimated cost: R3 000 000  
Expected term: 2002 - 2005

#### Programme 4: Toxicology

**A programme for research into the application of aquatic toxicology to water resource management**  
Institute for Water Research, Rhodes University and Ecosun  
(WRC Reference No 1313)

Toxicology Programme. The programme will investigate the application of aquatic toxicology to water resource management. The specific aims will be determined at a workshop to be held early in 2002 together with DWAF.

Estimated cost: R1 900 000  
Expected term: 2002 - 2005

### Thrust 2: Ecosystem Protection

#### Programme 1: Rehabilitation

**Consultative project to situate, contextualise and plan for a river rehabilitation program in SA; to link this to relevant water-related initiatives; and to trial the Australian procedure for river rehabilitation on a small degraded urban stream**  
Laughing Waters  
(WRC Reference No 1309)

Australian procedures for river rehabilitation are ahead of those in South Africa. The project leader has spent time in Australia working with the Australians, and the aim of this project is to introduce, as applicable, their concepts to our situation. This will enable us to develop more rapidly than would otherwise have been the case. In addition to the widespread consultation process, a pilot rehabilitation exercise will be commissioned on a small urban river.

Estimated cost: R372 650  
Expected term: 2002 - 2004

### Thrust 3 (XD D): Water Quality Risk Assessment and Management

#### Programme 1: Development and application of techniques for the detection of Cryptosporidium and Giardia

##### Monitoring environmental water on the East Rand for the presence of toxic agents: A pilot study

Highveld Biological  
(WRC Reference No 1397)

Environmental monitoring is normally only carried out by institutions with substantial resources, which in South Africa has tended to create a top-down approach to water quality problems. Decisions are taken and priorities assigned by people who are not themselves affected by the problems they are investigating. Small disadvantaged communities have become passive participants in a process that impacts directly upon their constitutional right to safe water.

In a previous WRC project the project leader has developed a rapid low-cost method of monitoring the toxicity of water prior to and after human use. This project is a pilot study intended to demonstrate the effectiveness of the method with the co-operation of disadvantaged communities.

Estimated cost: R250 000  
Expected term: 2002 - 2003

##### Origin and fate and clinical relevance of water-borne pathogens in South Africa

Collaborators: University of Pretoria, University of Venda,  
Rand Water  
(WRC Reference No 1398)

The introduction of water-borne pathogens through faecal pollution of surface water has serious health and economic consequences for communities who rely on such water sources for drinking water, irrigation or recreation. This project will investigate potential sources, build-up and transport, and fate of three pathogens, viz. *Salmonella* spp; *Vibrio cholerae* and *Cryptosporidium*. The association between environmental factors and social determinants and water-borne diseases will also be investigated.

Estimated cost: R620 000  
Expected term: 2002 -2004

An investigation into cadmium levels in the Umtata River, and its associated health impact on rural communities who are primary users of water from the river  
University of Fort Hare  
(WRC Reference No 1399)

An initial study of the water quality of the Umtata River (WRC Ref No 1067) has indicated that high levels of cadmium are present in the Umtata River. This is a cause for concern because of its toxicity and endocrine disruptive effects on humans and animals. This project is intended to identify the point and diffuse sources of the cadmium and to investigate the health impact of chronic cadmium poisoning on the primary users of the river water. An epidemiological survey of cadmium-related diseases will be conducted.

Estimated cost: R250 000  
Expected term: 2002 - 2003

### Thrust 4 (XD D): Eutrophication and Algal Blooms

#### Programme 1: Detection and management of cyanobacteria

##### Cyanobacteria Programme: Investigation into toxin blooms and toxin promotion

Consortium members: PU for CHE; University of Port  
Elizabeth; Technikon Pretori  
(WRC Reference No 1401)

The first part of this programme will investigate, in vitro, algal physiological aspects concerning phosphorus and nitrogen nutrition as part of an ongoing study as to why problem algae form harmful blooms.

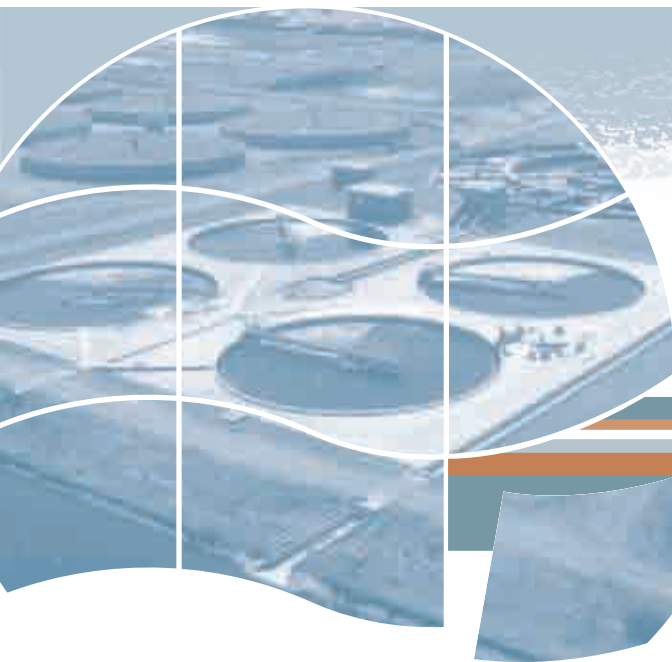
A model for the prediction of toxic bloom events based on the cellular mechanisms of modulation of toxin production by nutritional environmental parameters will also be developed.

The third part will be an investigation of algal blooms and release of decomposition products and cellular material with consequent effect on water quality during lysis of the bloom in the Hartbeespoort Dam.

Estimated cost: R630 000  
Expected term: 2002 - 2005

#### Contact Person:

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# KSA 3

## Water Use and Waste Management



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### Scope

The provision and supply of water of adequate quality and quantity for economic and public health purposes remain continuous challenges. Water is a finite resource and specifically in the context of South Africa, becoming incrementally scarce. Managing water use and the waste released to the water environment is thus of paramount importance to ensure the sustainability of the resource and the activities relying on it.

Water use and waste management in South Africa is consequently a key factor for social and economic growth, as well as our environment. The entire way we think about and use water is thus an important factor in determining our future.

Water use by the sectors differs from each other. The domestic sector generally requires high-quality potable water for drinking and commercial purposes whereas the industrial and mining sectors require highly reliable and affordable water of adequate quality for their internal processes. Collectively the water usage activities of these sectors generate a large quantity of wastes and wastewater that is detrimental to the receiving environment, and thus needs to be managed. The supply of the water and the management of the wastes and wastewater are highly synergistic and the technologies and processes are applicable across the sectors.

### Objectives

**Water Use and Waste Management (KSA3)** focuses mainly on the domestic, industrial and mining water sectors. The objectives of this KSA are (through research) to support the strengthening of institutional processes, the development of appropriate and innovative technologies and processes, capacity-building and the co-ordination of information.

- KSA3 aims to proactively and effectively advance technology, science, management and policies relevant to water supply, waste and effluent management, to the municipal, commercial, industrial and mining sectors.
- The emphasis of this KSA is on providing knowledge that ensures reliable, affordable and

efficient services to enhance quality of life, and contributes to economic growth and improved public health.

The research portfolio of current projects has been grouped into strategic thrusts and programmes which directly address the above-mentioned objectives and are summarised as follows:

### Thrust and programmes

#### Thrust 1: Water Services: Institutional and Management Issues

- Cost-recovery in water services
- Institutional and management issues - Water services
- Innovative management arrangements - Rural water supply
- Rural sanitation and hygiene education
- Peri-urban sanitation research

#### Thrust 2: Water Supply and Treatment Technology

- Drinking water treatment technology
- Water treatment for rural communities
- Drinking water quality
- Water distribution and distribution systems

#### Thrust 3: Wastewater and Effluent Treatment and Reuse Technology

- Biological sewage treatment processes
- Sludge characterisation, treatment, utilisation and disposal
- Treatment and recovery of organics from agro-industrial processing
- Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents
- Training in wastewater treatment plant operation

#### Thrust 4: Industrial and Mine-Water Management

- Quantification of water use and waste production
- Regulatory mechanisms to improve industrial and mine-water management
- Minimising the impact of waste on the water environment
- Minimising waste production
- Improved ability to predict and quantify effects

### Budget for 2002/03 and 2003/04

The approved funding of the research portfolio for 2002/2003 provides the basis for the funding of new projects for 2003/04. The consolidated budget is presented below:

Research portfolio	Approved 2002/03 R	Committed and requested 2003/04 R
Current projects	17 202 282	13 018 485
New projects	10 987 997	14 149 900
Total	28 190 279	27 168 385

## CORE STRATEGY

### Strategic context

The provision and supply of water of adequate quality and quantity for economic and public health purposes remain continuous challenges. Water is a finite resource and, specifically in the context of South Africa, is becoming incrementally scarce. Managing water use and the waste released to the water environment is thus of paramount importance to ensure the sustainability of the resource and the activities relying on it.

Water use and waste management in South Africa is consequently a key factor for social and economic growth, as well as our environment. The entire way we think about and use water is thus an important factor in determining our future.

Although the water requirements for domestic and urban (11%), industrial and mining (6%) use are a fraction compared to total water availability and water consumed, it is the assurance and continuation of the supply that dictates the high capital and infrastructure costs. Industrial and mining processes, though a small user of water, together contribute to the bulk of the pollution affecting our water environment.

It is clear that the costs of providing clean water and sanitation to a fast-expanding and growing economy will continue to escalate. In an environment of increasing resource and financial constraints, coupled with the vision of some for all and the need to redress past imbalances, efficient use of water for domestic, industrial and mining purposes, as well as improved sanitation, would be critical for improving public health, eradicating poverty and contributing to global competitiveness.

To achieve the above, more innovative policies and improved implementation strategies for water use and waste management, will be required, supported by a good basis for appropriate technologies, changes in

infrastructure approaches and broader water management policies. It is inherent that institutional processes and capacity be in place, supported by sound technologies and methodologies.

Over the past 30 years, the science of water supply and collecting, treating and beneficially using wastewater and stormwater has grown significantly. As a nation we have gone from rudimentary treatment to complex systems involving multiple phases and types of treatment. We have also expanded considerably the infrastructure of collection systems feeding increasingly sophisticated treatment plants. But much still needs to be done. As water and wastewater flows continue to increase, supply and treatment systems must be optimised for better management and efficiencies. This can be achieved not only by increasing infrastructure but by finding new and innovative technologies and processes that will enhance the performance of systems. An example is treatment processes that can target development of new media and increasing treatment flow-through. New innovative and appropriate technology will play a key role in the improved management and extension of our water resources.

During the early years of the WRC's existence, much of the effort to improve industrial water management was devoted to quantify and reduce the water use by large industrial water consumers. These efforts met with much success. The NATSURV investigation quantified the water use and pollution emanating from factories representative of the industrial sectors operating in South Africa. This survey and its results are fairly unique from an international perspective and still serve as benchmark against which industrial water use and water quality management is measured. Efforts to reduce water use by large industrial water consumers led to the situation where the South African electricity generation, paper and pulp and textile industries today are world leaders with respect to low water consumption per unit production.

More recently, as a result of adopting a more holistic approach towards managing the effects of industrial and mining pollution, the research focus concerning these sectors has shifted. In the case of especially mining and domestic wastewater, it is now recognised that their pollution is often of a non-point source nature that needs to be managed differently from point sources. Significant progress has been made in quantifying pollution from non-point sources, developing predictive abilities, prevention strategies and treatment of acid mine drainage (AMD). AMD has primarily been targeted after being identified as the most prominent water quality problem emanating from mines. With industrial pollution

it was recognised that water pollution is an integral part of our greater environmental problem, which, if treated and managed in isolation, could easily lead to shifting the pollution burden to other components or the environment, such as soil or air or to increasing energy demands (which has a ripple effect of environmental consequences). Research on water pollution and water quality management is thus increasingly emphasising the role to be played by cleaner production methods and waste minimisation by using tools such as life-cycle analysis and pinch technology. The WRC is taking a leading role in this regard and plays a prominent role in raising awareness and adopting these approaches in the SADC region.

The development of improved and innovative technologies for the treatment of water and wastewater has always been a strong point of the WRC-funded research. Much of the early wastewater research conducted by the WRC was aimed at refining treatment processes to purify wastewater for potable reuse. South Africa is still recognised as a leader in this field. WRC-funded research was primarily responsible for developing the biological phosphate removal technology that enabled wastewater treatment works to minimise the effect they have on the eutrophication of water resources. Research funded by the WRC on membrane technology led to the establishment of South Africa's own membrane manufacturing capabilities in 1979. A significant number of further innovations in membrane technologies for water and effluent treatment set South Africa as one of the leaders in this technology. Potable water treatment technology development funded by the WRC resulted in improved dissolved air flotation (DAF) technology (incorporating sand filtration and grid-based float removal). A design guideline for DAF was published and received international acclaim. A number of other guidelines were also produced. More recently the WRC played a key role in satisfying the research needs that emanated from the government's drive to supply the whole population with clean water and sanitation. One of the key contributions in this regard was the identification of institutional problems as the main stumbling block in achieving national goals on a sustainable basis.

With all these achievements and developments, it is clear that South Africa has a good knowledge base and the competencies required to face the future challenges. There is a need to develop greater environmentally sound technologies and processes that command greater integration in the solutions they provide. A more holistic and integrated approach is required towards providing sustainable solutions focusing on aspects related to the participation of society, impact on the

environment and resource base, institutional and management issues, minimisation of wastes and other emerging issues.

### Needs analysis

The key challenges facing the water sector in South Africa are:

- It is clearly evident that new issues in water supply (water treatment, distribution, etc.) will continue to emerge as new contaminants are introduced into the water sources. Technical solutions are needed to provide solutions. Great challenges also exist in providing sustainable and affordable technical solutions for the poor and indigent sections of the population.

In water supply and treatment technology the needs over the next few years revolve around the supply of more affordable water of improved quality, especially to those people who do not yet have a reliable drinking water supply. Specific issues and research needs include the reduction in cost of water treatment and supply; the removal of organic contaminants; the removal of *Cryptosporidium* and *Giardia*; safe and efficient water fluoridation; improvement in the efficiency of small- to medium-sized water treatment plants; dependable and efficient distribution systems; cost-effective distribution systems for rural water supply and sustainable and low-cost small water treatment systems.

- Most of the country's industrial and mining activities are concentrated in areas where there is a lack of the water resource. These sectors generate large amounts of wastes (toxic and non-toxic), which have a profound impact on the ecology of the receiving water environments. It is therefore imperative that solutions are generated to manage these negative impacts. As urbanisation and industrialisation increase, more and more complex wastewater streams are introduced. The ultimate solution for treating wastes remains a challenge and there is a great deal of research yet required in reaching this goal. It is also important to accelerate the process whereby cleaner production and waste minimisation technology is being introduced by South African industry and mining. Further there is growing recognition for more innovative approaches such as cleaner production and waste minimisation. This new area requires greater

research support for knowledge generation and application.

- The mining industry presents additional needs that emanate from its legacy of water quality-degrading waste that has been accumulating for more than a century, and which could potentially affect water quality for future generations. In the case of gold-mines these needs have to be addressed with urgency, as many mines are about to close down, which may represent lost opportunities to introduce pollution prevention measures.

Key challenges are to:

- Accelerate the process whereby cleaner production and waste minimisation technology is being introduced by South African industry and mining.
- Develop innovative solutions to deal with the legacy of waste and acid-mine drainage potential that has accumulated as a result of mining activities.
- There is a need for improving institutional capacity in the management of water and wastewater problems, as it has become increasingly clear that these problems cannot (in the South African context) be solved by technical solutions alone. Institutional reform and strategic management issues (such as regulation, capacity, competencies, partnerships, tariffs, community participation, etc.) all play an equivalent role in meeting an integrated solution. Great strides in information and knowledge are required in this area over a short period of time.

## Technological trends

In water supply and treatment technology the current international trends are toward the increased removal of more and more specific contaminants in the water. In addition, it is aimed at adding fewer and fewer chemicals to the treated water product. The removal of pesticides, heavy metals, endocrine disruptors, disinfection by-products and other harmful organics is receiving attention. The filtration of *Cryptosporidium* and *Giardia* and the use of membrane filtration in this regard are receiving much attention, especially in the USA. The characterisation and removal of emerging micro-organisms are also being researched.

In both the municipal and industrial sectors, the most significant trend internationally, nationally and at local authority level has been the growing realisation, actively encouraged by the WRC as a leading player in this area, that treatment of wastewaters and wastes which have been generated without application of cleaner production and waste minimisation principles, is a losing game ultimately costing all the parties material and energy resources, i.e. money. The consequences are profound: Co-regulation becomes a meaningful negotiation; value as co-product is extracted from "wastes" before discharge, thereby further reducing the waste load requiring treatment; technologies for treatment aim at being "cleaner", are more focused towards specific waste fractions or even constituents and include recovery and reuse where technically and economically justifiable; resource-efficient technologies are not only favoured but even their optimum deployment ("where" in the process stream) is critically examined; etc. These trends are predicted to not only continue but in fact to accelerate in the future. The mining industry has to date not embraced these new realities, and wastewater and waste treatment in this sector presently continues to be material- (e.g. chemicals) and energy-intensive, although more environmentally-friendly solutions are increasingly favoured, for example biotechnological treatment of acid-mine drainage associated with potential recovery and reuse of the renovated water for a variety of purposes. The cost-effectiveness of clean production technology is increasingly recognised and will in itself be a strong driving force for the accelerated introduction of the technology. Another driving force is the international trade sanctions that are increasingly being applied against manufacturers that do not apply responsible environmental practices. In South Africa it is foreseen that the introduction of waste discharge charges will be a further powerful driver towards internalising pollution costs and implementation of cleaner technology.

The contribution that mining-related non-point sources makes to water quality degradation is increasingly appreciated and has given rise to a need for improved techniques with which to quantify their contribution and improved technologies to minimise their effect.

## Key stakeholders

The following stakeholders are important to the WRC in general, and to KSA 3 in particular. They are divided into internal and external stakeholders.

The internal stakeholders are the WRC personnel, Executive Management and Board, as well as research

steering committees. The external stakeholders are divided into shareholders (i.e. central government departments and the ministers representing them) and clients, customers and beneficiaries (i.e. the users or potential users of research, development and knowledge products produced through WRC funding). The external stakeholders consist of central government departments and the ministers representing them (DWA, DEAT, DPLG, DoH, Mineral and Energy, etc.), local governments, Development Bank of Southern Africa, water boards, catchment management agencies, water-user associations, industrial sectors, industry representative bodies (mining, forestry, etc.), NGOs, consultants, tertiary institutions, primary and secondary education institutions, science councils, professional bodies (WISA, SAICE, etc.) and water service providers.

## Providers

Providers are solicited or unsolicited individuals and organisations who generate research, development and knowledge products with WRC funding and/or under WRC leadership. The key providers are tertiary institutions, science councils, consultants, NGOs, water boards, research units within government departments and local government, private companies and individuals.

## Links to Vision and Mission of the WRC

The strategic focus of this KSA is on the efficient use of water and the minimisation and management of wastes generated through water-use activities. This is also important for improving public health, environment health and economic growth. To achieve these new and innovative technologies, processes and management are required which are the fundamental scope of this KSA. Providing environmentally sustainable solutions that are relevant, address problem areas and are of such scientific excellence that their application is successful and implementable, are of paramount importance to this KSA.

The research work is needs-driven and fills gaps in knowledge in the supply and efficient use of water and waste management that sustains the water resource and the environment. Through these activities this KSA makes a strong and direct contribution to achieving the mission and vision of the WRC.

# RESEARCH PORTFOLIO FOR 2002/2003

## General aims

This KSA focuses on water use and waste management in three sectors, these being:

- Domestic
- Industrial
- Mining

Water use by the sectors differs from each other. The domestic sector generally requires high-quality potable water for drinking and commercial purposes whereas the industrial and mining sectors require highly reliable and affordable water of adequate quality for their internal processes. Collectively the water usage activities of these sectors generate a large quantity of wastes and wastewater that is detrimental to the receiving environment, and this needs to be managed. The supply of the water and the management of the wastes and wastewater are highly synergistic and the technologies and processes are applicable across the sectors.

Activities of at least 9 of the past WRC research fields directly impact on KSA3 and address a diversity of areas. Collectively the fields represent a research area that has had a long period of research support, allowing for growth in competencies and excellence. It is one of the areas that has contributed to the international recognition of the competency of the SA water sector.

KSA3 aims to proactively and effectively focus on advancing the technology, science, management, and policies relevant to water supply, waste and effluent management to the municipal, commercial, industrial and mining sectors. The emphasis of this KSA is on providing knowledge that ensures reliable, affordable and efficient services that enhance quality of life, and contributes to economic growth and improved public health.

The KSA will focus on four thrust areas that have been identified through a strategic process. The rationale for the selection of the thrusts mentioned below is based on a combination of the following: Strength and excellence of research capacity, past trends, future needs, priority needs and technology trends.

An overview of KSA3 research thrusts and programmes is presented in **Table 1**.

Table 1: Overview and description of KSA3 thrusts and programmes for 2002/03.

Thrust 1: Water Services - Institutional and Management Issues	
<p><b>Scope:</b> The efficient functioning of water services institutions and their viability is key to sustaining water services in rural and urban areas. The focus of this thrust is to address strategic research aspects related to policy issues, institutional reform, regulation, infrastructure management, operations and maintenance, sanitation (stormwater, sewerage and on-site sanitation), water-related competencies and capacity required to the strengthening of water institutions (water services providers, water services authorities, water boards, national departments) in providing sustainable water services.</p>	
Programme	Scope
1. Cost-recovery in water services	The issue of cost-recovery has been identified as a critical aspect affecting sustainable services. In an environment where genuine poverty affects cost-recovery, this program intends to develop innovative strategies and processes to tackle the problem. The focus will be on generating in-depth knowledge of the problem and testing of new approaches.
2. Cost-recovery in water services	Relationships and partnerships between service providers, both external and internal, are a key to sustainable water service delivery. This program aims to generate knowledge and processes that would support this new form of service delivery. Innovative management techniques are a necessity for viable and sustainable water service provision. This programme intends to find innovative solutions to critical problems with the financing and management of essential services such as water supply and sanitation
3. Innovative management arrangements - Rural water supply	The focus of research within this programme is to provide support to water service institutions with special reference to sustainable cost-recovery and implementation of the free basic water policy; key performance indicators for monitoring and evaluation of service delivery; guidelines for sound management of water service institutions and development of effective strategies for promoting an integrated approach to rural development.
4. Rural sanitation and hygiene education	South Africa is faced with a challenge of finding options for accelerating the delivery of adequate sanitation services to millions of households who currently lack access to these services. The focus of research within this programme is on approaches to motivate households to take an active role in improving their sanitation facilities and adopting hygienic practices. Development and evaluation of key performance indicators for successful sanitation and hygiene promotion programmes will also be addressed. Sustainable solutions to sanitation provision for rural areas will also be investigated.
5. Peri-urban sanitation research	The aim of this programme is to provide research support to sanitation in informal and developing urban areas. Until recently the focus of sanitation has been on rural areas, but the situation in urban areas is much more critical and volatile in terms of public health. Urban sanitation differs from rural sanitation issues related to institutional arrangements, community dynamics and management of interventions. Due to the high densities, technical choices are more complex where an affordable and sustainable service is to be provided. Outcomes from this programme will support local authorities in implementing sustainable solutions, which cater for both the user and institutions needs.
Thrust 2: Water Supply and Treatment Technology	
<p><b>Scope:</b> The provision and supply of affordable and reliable water of quality and quantity for drinking (domestic) and economic (industrial/commercial and mining) activities, remain continuous challenges. Research support for these activities is the focus of this thrust. Linked to water supply and use is the provision of sanitation to achieve maximum public and environmental health benefits. The objective of this thrust is to develop innovative technologies and processes that address aspects related to bulk water supply, water treatment technology, distribution and water quality.</p>	
1. Drinking water treatment technology	This programme aims to acquire adequate understanding of potable water treatment processes and related activities and to be able to assist in treating our scarce water resources in the most efficient and cost-effective way to an acceptable quality for potable and industrial use. Expected outcomes include improved and more cost-efficient process technologies, increased operational efficiency of treatment plants and an improved manpower training level and knowledge base.
2. Water treatment for rural communities	This programme aims to provide, through research products, adequate quantity and quality water to rural communities on a sustainable basis. Expected outcomes required to achieve sustainable water services include community involvement, cost-recovery, effective operation and maintenance, affordability and willingness to pay for water services.
3. Drinking water quality	The programme aims to protect human health by ensuring that water supplies and sanitation are of acceptable quality and standards. Outcomes include improved analytical methodologies, treatment technologies and hygiene practices.
4. Water distribution and distribution systems	The programme aims to optimise the quality, quantity and reliability of the distribution and supply of treated, potable water to the end users thereof. The programme has the following expected outcomes: To develop reliable processes in predicting and improving the operational efficiencies in distribution systems, with the purpose of reducing both capital and operational costs. To ensure that the quality and quantity of water are maintained in the distribution system - from the water treatment plant to the furthest end-user. To develop innovative methods, tools and processes that will improve system integrity and reliability.

Thrust 3: Wastewater and Effluent Treatment and Reuse Technology	
<p><b>Scope:</b> With the continuous increase in wastewater and effluent flows, the challenge arises to better manage treatment, so that the effluent produced meets requirements and can be considered as a resource. Research in this thrust aims to develop innovative treatment technologies and systems that would optimise treatment processes and infrastructure in the municipal, mining and industrial sectors.</p>	
Programme	Scope
1. Biological sewage treatment processes	Further development, process modification and optimisation of activated sludge and other biological systems for sewage treatment, towards greater cost-efficiency, affordability, enhanced performance security and wider application.
2. Sludge characterisation treatment, utilisation, and disposal	Systematic characterisation (organic and inorganic), quantification and categorisation of sludges from domestic and industrial sources in the RSA and the development of technically secure, cost-effective, environmentally acceptable and sustainable treatment process technologies, utilisation strategies and disposal practices.
3. Treatment and recovery of organics from agro-industrial processing	Development and piloting through to full-scale implementation of treatment technologies for problematic organic effluents from agro-industry processing, including forestry (pulp and paper) and livestock products, in particular where the effluents generated contain organic components which are too concentrated, refractory, inhibitory or even toxic in terms of the normal biological treatment processes available at municipal sewage works. The programme aims to develop treatment processes for such problem effluents, including options where appropriate for conversion of such components to more degradable or commercially useful products.
4. Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents	Heavy metals and inorganic salts such as sulphates in industrial and mining effluents have deleterious bio-inhibitory or bio-toxic effects on the performance of sewage works, the fitness of treated wastewaters for reuse, the sludge quality produced and the aquatic environment in general. This programme aims to develop a range of processes for effective treatment and disposal of such components/effluents, including the potential recovery of materials and water for beneficial reuse and suitable for both high-concentration-low-volume industrial wastewaters (e.g. tannery effluent) and high-volume-low-concentration sources (e.g. acid mine drainage). Fundamental scientific/engineering support is also provided for such process development.
5. Training in wastewater treatment plant operation	Development and delivery of appropriate course material, management systems and training for wastewater treatment operators, to provide tools for strengthening and enhancing the skills base necessary for effective control and management of the diverse needs of the water industry in the RSA.
Thrust 4: Industrial and Mine-Water Management	
<p><b>Scope:</b> The usage of water in the mining and industrial sectors produces high concentrations of wastes and effluents. Some mining activities produce wastes that act as non-point sources of water quality degradation and acid mine drainage. This thrust aims to provide appropriate, innovative and integrated solutions to water use and waste management in the industrial and mining sectors.</p>	
1. Quantification of water use and waste production	In order to prioritise those facets of industrial and mine water management that needs most urgent attention, it is important to quantify the water used and waste produced by different sectors. The NATSURV investigation conducted by the WRC provides the benchmark for water use and waste that are produced by the major South African industries. While the WRC reported on water use by coal-mines and COMRO on water use by gold-mines, no overall assessment of the effect of mining or industrial waste on water quality is available. The available information thus needs to be updated and refined. Furthermore, new information needs to be gathered for those sectors that may present important emerging issues.
2. Regulatory mechanisms to improve industrial and mine-water management	The regulatory authorities are responsible for managing the impact that industrial and mining waste have on the quality and quantity of our water resources. Traditionally the resource-intensive command-and-control approach was used almost exclusively to manage water quality. Internationally use is increasingly made of indirect economic or other instruments to supplement or even replace the command-and-control approach to water quality management. These new approaches are believed to be more cost effective and to improve equity. Both the established and new approaches are being investigated and refined in order to support improvements to the regulatory mechanisms that are used to control and reduce the negative environmental effects associated with industrial and mining waste.
3. Minimising the impact of waste on the water environment	South Africa has a large legacy of mining and industrial waste products that impact negatively on the water environment. In spite of efforts to the contrary, the quantity and range of waste products are expected to increase in the foreseeable future. It is thus necessary to develop cost-effective techniques and approaches to minimise or reduce the impact that historical and new waste products have on the water environment. Approaches such as pollution prevention, rehabilitation, waste beneficiation and reuse, are investigated to assess their application potential and suitability to reduce and minimise the negative impact of industrial and mining waste on water quality.
4. Minimising waste production	There exists a direct link between the quantity of waste produced and its impact on the water environment. The type of waste that is produced may, however, often be of even greater importance than quantity. In order to reduce the negative impact of waste production, it is thus important to reduce both the quantity and toxicity of waste. The international trend towards waste management is therefore to minimise the production of waste by adopting cleaner production processes. Approaches such as life-cycle analysis are employed to ensure that the net effect is positive and does not merely represent the transfer of negative effects from one sector or environmental medium to another. This programme investigates and promotes the implementation of approaches that minimise waste production.
5. Improved ability to predict and quantify effects	The environmental consequences of waste products are almost always long-term in nature, with impacts that may potentially last for hundreds of years. These long-lasting effects were often not fully appreciated in the past, and consequently not properly considered when waste was disposed of. In the present regulatory environment it is increasingly expected of waste producers to quantify the present and future environmental impact of their operations and to indicate how these will be remedied. This programme is primarily aimed at establishing and improving pollution prediction capabilities appropriate to the South African situation.

## COMPLETED

### Thrust 1: Water Services - Institutional and Management Issues

#### Programme 1: Cost-recovery in water services

Researching, developing and testing of payment strategies for the lower income groups at four selected communities in order to manage charges for water use  
*Marketing Surveys and Statistical Analysis*  
(WRC Reference No 1202)

Previous research has found that poverty played a major role in non-payment. However, it is also stated that the "culture of non-payment" was a minority phenomenon and rather a "climate of non-payment" because "everybody does it". Studies have also identified a lack of knowledge about water cost and the way revenues were utilised. Most studies undertaken regarding non-payment lack an in-depth attempt to uncover "causal relationships in the data".

The aim of this study was, amongst others, to explore this lack of attempt to uncover relationships in the data.

The most significant finding regarding possible solutions for the problem of the non-payment for water was the availability of more payment options to water consumers. Consumers frequently expressed the need for more options, which would make it easier for them to choose an option for paying.

The majority of water consumers in the study were quite satisfied with the quality and provision of water in their residential areas. An alarming finding, however, was that consumers highly under-estimated their water consumption. These estimations varied between three to seven times less than their actual water consumption. If the situation is allowed to continue, it may result in the further escalation of debts, and subsequently increasing pressure on water providers.

Consumers frequently expressed the need for continuous information from the Councils. Signs were observed that traditional measures against defaulters, such as the prompt cutting off of the water supply, were not perceived as an ideal solution for the problem. Consumers expressed the need for personal communication with a friendly official at their homes.

Water consumers displayed a lack of knowledge of the units in which water consumption is expressed. The bigger the units (kilo and mega litres), the less the respondents knew about them. These aspects could be addressed in information campaigns.

In conclusion, it could be said that the financial, social and psychological dynamics of non-payment for water is a complex and multivariate problem. Poverty, negative attitudes to payment for water, excessive water usage, and the lack of interest in water saving measures, were identified as major causes for payment default. Signs of solutions for the problem were, however, observed. Multiple payment options, combined with a personal approach of visiting consumers who are in areas with the payment for water, provide some optimism for alleviation of the problem of non-payment for water in the study areas.

Although the findings of this study cannot be generalised to other areas (due to the method of selection of the respondents), it is significant to note that the groups in arrears consistently exhibited similar negative attitudes and payment behaviour, lack of interest in water saving measures and excessive water consumption.

Cost: R271 580  
Term: 2001

#### Programme 2: Institutional and management issues - Water services

The option of corporatisation of municipal water services providers

*Palmer Development Group*  
(WRC Reference No 1141)

The restructuring of municipal water departments into stand-alone companies has been a long-standing subject of debate within the industry. This study aimed to further explore the concepts of corporatisation and its relevance to the South African water sector by, combining an international literature review with local case studies and policy reviews.

#### International case studies:

Findings from case studies drawn from low-, middle- and high-income countries, led to the conclusions that:

- Corporatised water service utilities exist world-wide. In fact the use of separate legal entities is a fairly common approach across low-, medium- and high-income countries
- The corporatisation of water services does not, however, guarantee success in its own right

- Utilities succeed or fail for a wide variety of reasons. Success requires a combination of factors, especially good governance, managerial independence - and a measure of luck
- The regulatory framework is important, but will not in itself ensure a positive outcome. For instance Botswana has a very weak regulatory environment while Melbourne has a very strong regulator, yet both have successful utilities. Both attribute their success, in part, to sound management practices
- A trend amongst corporatised utilities is to improve service delivery through increasing involvement of the private sector. These partnerships are more likely to entail service outsourcing and organisational development through the adoption of advanced management techniques than long-term leases or outright asset transfers.

#### The local environment for corporatisation indicated that:

- The current environment for corporatisation in South African is not particularly favourable and transaction costs can be very significant. Despite advances in national government policy a considerable amount of uncertainty remains. Further legal reforms are still necessary
- Existing corporatisation initiatives have led to a high level of politicisation, with stand-offs between government and labour, and even between different spheres of government.

The research concludes that corporatisation in itself does not guarantee performance. Whilst a shift in legal form from a municipal department to a stand-alone legal entity can make a difference, this is not the only or major determinant of performance. Various objective factors and broader governance factors are likely to have a greater impact than simply the legal form of the utility. Further corporatisation may be a suitable option for some municipalities. For capacity reasons corporatisation is only likely to be feasible within the large metropolises at this stage. As the experience base grows within South Africa, and transaction costs diminish, corporatisation may become feasible for smaller local authorities. A possible exception to this conclusion may be the cases of multiple local authorities merging as a result of the demarcation process, or where the Structures Amendment Act has resulted in water functions being shifted from local authorities to district councils who have previously not held water-related responsibilities. These radical, policy-induced organisational changes may create a one-off

opportunity to consider corporatisation options which might not otherwise have arisen. Another possible exception may be the case where a local authority requires a partner to invest in a defined component of the water services system (such as wastewater treatment plants) and establishes a corporatised utility as a vehicle for the partnership. In a case such as this the issues of ownership and control would be particularly important.

This study highlights that before embarking on a corporatisation process municipalities should assess whether they have sufficient financial, managerial and political capacity to see the process through.

Cost: R170 000  
Term: 2000 - 2001

#### National benchmarking project for the South African Association of Water Boards

*The Association of Water Boards and Rand Water*  
(WRC Reference No 1201)

The aim of this project was to set up a benchmarking system for SAAWU. The study emanated in the development and commissioning of an Internet-based benchmarking system fully capable of:

- User controlled login/logout facilities
- Options to capture month, year-to-date or annual data
- Options to report on any category of captured data
- Present information in a bar or line format
- Ability to analyse monthly or annual data based on the number of times the indicator was selected for viewing by users
- Monthly/year-to-date data are retained in detail for the previous and current-year periods
- Annual data provide for three years of historical values, current-year budget and target to be achieved (best of class/world standard)

Cost: R350 000  
Term: 2001

#### Programme 3: Innovative management arrangements - Rural water supply

Fog-water collection: Implementation of an operational prototype system

*Department of Geography, University of the North*  
(WRC Reference No 902)

This project was a sequel to a project (No 671) conducted from 1995 to 1998, which was aimed at determining the feasibility of using fog to supplement

existing water supplies to communities. As part of the earlier project, a number of small fog collectors were erected in fog-prone parts of South Africa and the yields monitored over a two- to three- year period. The results indicated that fog harvesting is indeed a viable option along the west coast and the mountainous areas in the east of the country. The aims of the present project were to design, erect and operate a fog-water collection system to provide water to a small rural community, and to research the factors associated with water collection at the site. The site selected for the project was the Tshanoa Junior Primary School, situated at an elevation of 1 004 m in the Soutpansberg Mountains of Limpopo Province. The closest water source was a non-perennial spring 2 km from the school and a dam in a valley more than 5 km away. The fog-water collection system intercepted both fog and rain, giving an average daily yield of 2.85ℓm<sup>-2</sup> over the long term. Maximum daily yields in excess of 3 000ℓ were recorded on a number of occasions. Collected water was of a high quality, with a very low dissolved solids content, no disease-causing organisms and heterotrophic bacteria reflecting those present in the air.

The project showed that harvesting fog and rain water provides a relatively inexpensive source of good quality water in suitable areas where conventional sources are not an option. Communities located in the Soutpansberg, along the eastern escarpment and in the Cape mountains could derive benefit from a fog-water collection system, which could also supplement water for small-scale agriculture, domestic animals and tourism.

Cost: R500 000  
Term: 1998 - 2001

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

Environmentek, CSIR  
(WRC Reference No 962)

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 objectives of the research were:

- To collate existing expertise and information on cost-effective water treatment and supply for small communities.
- To collate existing expertise and information on practical measures to protect local water supplies from pollution, applicable to small communities.
- To establish decision-support guidelines and methodologies in the form of personal-computer based expert-systems applications as well as a guidelines handbook, to facilitate select water treatment and supply, as well as practical measures to protect local water supplies from pollution applicable to small communities. The output WATTREAT expert systems decision support software was developed, capable of the following programs:
  - Water supply microbial sampling/monitoring and chlorine disinfection advisors
  - Laboratory determinand test selection aid
  - Laboratory determinand test interpreter aid
  - Water treatment option suitability ranking tool
  - Water hardness and corrosion potential advisor
  - Drinking water contaminant limits exceedance tool
  - Water source protection advisor

Cost: R499 985  
Term: 1998 - 2001

**Capacity-building and training needs of district councils and transitional rural councils in the management of community water supply and sanitation in the Easter Cape**

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

This study was initiated to address the capacity-building challenge faced by the new local government structures that were established in 1995. In terms of the constitution, local government has a responsibility to make sure that all South Africans have access to basic water and sanitation services. The main objective of this research was to identify the capacity-building needs of rural district and local municipalities in order to make recommendations for a strategy to build their capacity. The study focused on two district municipalities, namely, Amatola District Council and Stormberg District Council in the Eastern Cape. The following four local municipalities located within these two district councils were used as case studies: Peddie, Fort Beaufort, Queenstown and Whittlesea. Semi-structured interviews

and workshops involving key stakeholders were used to assess the quality of the training received by Councillors and capacity-building needs for rural councils (municipalities). The study also evaluated the training material used to train the local government officials and Councillors.

This evaluation showed that the training materials were in line with the DWAF guidelines on capacity-building and training. Evaluation of the impact of training indicated that the training was not effective because the duration of the training course was too short, consequently, the trainees were not able to assimilate the new information and apply it to their work environment. Lack of mentoring was also identified as a major problem because most of the training consultants were external agents who were not accessible to the learners after the completion of the training course. The medium of instruction was English; this created a problem for trainees with low literacy levels. The content of the training material was too generic and did not take the local context into consideration; consequently, it did not help the municipal officials in improving their capacity to deliver water and sanitation services. There was also no monitoring and evaluation system to assess the quality and the impact of the training provided.

Cost: R209 000  
Term: 1998 - 2000

**The development of generic and sectoral competencies in the water supply and sanitation training section**

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

DWAF expressed a need for better co-ordination of training activities for the water and sanitation sector. The development of generic and sectoral competencies would provide a formal method for assessing the quality of training programmes offered. The aims of the project were to develop generic, sectoral and target modular-based competencies and to develop a model which would facilitate co-ordination and standardisation of training. The research developed a set of competencies that reflect the following characteristics:

- Ensuring that the learning processes are focused on helping people learn skills relevant to the water and sanitation sector
- Promote flexibility that is nationally consistent with the requirements of the water and sanitation sector.

The study developed a database (CD) containing approximately 3 625 competencies and 77 occupational functions relevant to the water and sanitation sector. This database can be applied in the water and sanitation sector in the following ways:

- Learnership and unit standard setting process
- Training
- Skills development
- Development of qualification packages
- Quality control of training in the water and sanitation sector

This research has made a valuable contribution to the establishment of Standard Generating Bodies and the Water Chamber of the Local Government Water and Related Services Education and Training Authority (LGWSETA).

Cost: R295 000  
Term: 1999 - 2000

**An investigation into implementation of operation and maintenance of rural water supply programmes**

In-Touch Community Development and Project Managers cc  
(WRC Reference No 1099)

For water systems to function there are a number of key elements that are required. Operation and maintenance (O&M) are part of these key and important items which contribute to the successful functioning of schemes. The aim of the study was to contribute to the improved understanding and knowledge of O&M within water systems covering two broad items: Institutional development and capacity-building.

O&M is not just 'spanner technology' that repairs burst pipes, but has a much wider context:

- Community needs are addressed
- Customer satisfaction
- Cost-recovery
- Efficient operations and maintenance
- Improved health
- Economic spin-offs.

The findings of the study emanate from the surveys carried out in 5 villages. This information may be specific to other village water schemes in the country. The study concluded that:

- The literature review indicated that internationally, the trend was that services were being privatised to dedicated water management agents with mixed results

- Nationally there is a lack of data on O&M aspects of village water schemes. Accessing the CWSS village database only indicates the village, scheme number, population served and does not indicate the operational status of the village scheme
- Training was viewed as the most important need for water committees and the following essential skills were identified: General management, financial skills, technical skills, communication and administration.

Cost: R200 000  
Term: 1991 - 2001

#### Creating a monitoring and evaluation system for water and sanitation delivery in small Northern Cape municipalities

McIntosh Xaba & Associates  
(WRC Reference No 1287)

Monitoring and evaluation (M&E) are essential for effective management of projects and programmes. Monitoring is an integral part of the day-to-day management of projects and programmes through the collection and analysis of data to equip managers in government departments, stakeholders and the general public with accurate data about progress and performance.

This project was designed to assist municipalities to create an M&E system that will enable them to undertake periodic assessment of issues such as the efficiency, effectiveness, impact, relevance and sustainability of programmes in relation to the stated objectives. The main objective of this project was to design appropriate monitoring and evaluation procedures for water and sanitation services provided by local authorities. The researchers conducted interviews with the decision-makers from the Karoo-Hoogland Municipality; Emthanyeni Municipality (De Aar) and Kamiesberg. The data collected from the interviews together with secondary data were used to prepare an M&E manual and associated workbooks, entitled: *A Monitoring and Evaluation Manual for Municipal Water and Sanitation Management*.

This manual gives an outline of the steps required to introduce an M&E system and is supported by two workbooks, **Appendix A** and **Appendix B**, respectively. **Appendix A** focuses on monitoring operation and maintenance of water service infrastructure; **Appendix B** focuses on monitoring water conservation and demand management. The target audiences for the manual and workbooks are small municipalities and national government departments that have a responsibility for

water services delivery. This research will be of great value to the municipalities in the Northern Cape, because the manual has been developed using the municipalities from this province as case studies.

Cost: R100 000  
Term: 2001 - 2002

#### Programme 4: Rural sanitation and hygiene education

**An investigation of water supply issues in typical rural communities: Case studies from Northern Province**  
Ninham Shand (Pty) Ltd  
(WRC Reference No 1271)

Evaluation of water supply schemes implemented by the DWAF and Mvula Trust showed that most of schemes were unsustainable due to many factors such as poor operation and maintenance and lack of cost-recovery. The primary objective of this study was to develop an understanding of sustainability issues in community water supply. The study is based on case studies from the Limpopo Province and a few cases from KwaZulu-Natal, focusing on existing rural water supply schemes.

The study has identified the following key factors that are crucial to sustainable water service delivery:

- Communication:** In most villages where water supply schemes were functioning intermittently or had collapsed, poor communication among the various stakeholders was identified as the major problem.
- Locally-based institutional arrangement:** It was found that water supply schemes that were managed by DWAF regional offices experienced long delays in response to breakdowns (3 to 6 months).
- Cost-recovery:** Most villages lack a clear cost-recovery plan; unwillingness to pay was identified as crucial factor in intermittent and collapsed schemes.
- Appropriate technology choice:** This led to poor affordability and lack of access to spare parts thus leading to the collapse of some schemes.

Based on the findings of this study, guidelines for appropriate operation and maintenance of water supply schemes have been developed. These guidelines will assist DWAF and municipalities to achieve rural water supply scheme sustainability. If these guidelines are adopted by municipalities, they will help them in achieving the government's goal of providing water to all South Africans by 2008.

Cost: R170 000  
Term: 2001 - 2002

#### Programme 5: Peri-urban sanitation research

**Monitoring of leachate and biogas emissions from existing experimental field cells**  
Department of Civil Engineering, University of the Witwatersrand  
(WRC Reference No 995)

The work described is a follow-up to an earlier WRC-funded project. This earlier project dealt with the construction and commissioning of 4 field test cells at the Weltevreden Landfill. One cell (Cell 1) was filled with refuse from a typical middle-class suburb and contained a large proportion of paper and putrescibles. Another cell (Cell 4) was filled with refuse from an informal settlement and consisted primarily of ash and dust, while the remaining two cells (Cells 2 and 3) were filled with blends of these two waste streams. The aim of the study was to continue to monitor the quantity and quality of both leachate and biogas emissions.

By the end of the study the quality of the leachate being generated by all cells still showed no sign of reaching an acceptable quality. The concentration of chloride in the leachate from all cells showed a gradual decline in concentration with increasing proportions of pore volumes flushed, but still appeared to be a long way from reaching acceptable concentrations.

The primary, and most useful outcome of the work performed in this study is thus to raise concerns about the long-term viability of our current approach to landfilling in semi-arid parts of the country. By encapsulating the waste and maintaining it at a relatively low moisture content, the effect is to retard biological degradation processes and thus effectively retain the polluting potential of the stored waste. However, the waste cannot be isolated from the ingress of moisture in perpetuity and once moisture begins infiltrating into the stored waste (e.g. through a damaged or poorly maintained cover system), the process of biological degradation, with associated generation of highly contaminated leachate, will begin again. Current legislation in South Africa requires that a landfill and its surrounding environment (e.g. adjacent groundwater) be monitored for a period of 30 years after closure, to ensure the environmental and health risks posed by the landfill are not unacceptable. The problem with this approach in a semi-arid climate appears to be that even after this period of aftercare the landfill may in fact be many years from achieving a stable and acceptable state. In short, it may still have a very large proportion of its initial contaminating potential.

The major conclusion to be drawn from this ongoing study is that an urgent re-think is required on current provisions for post-closure monitoring of municipal solid waste landfills in South Africa. In addition, we should be investigating techniques of accelerating the decomposition of refuse within the landfill in order that the contaminating potential of the stored refuse can be reduced to acceptable values within the operational and reasonable post-closure period. If this issue is not addressed now, it is suggested that we will inevitably be forced to revisit it sometime in the future when today's landfills become tomorrow's sources of environmental contamination.

Cost: R118 000  
Term: 1999 - 2001

### Thrust 2: Water Supply and Treatment Technology

#### Programme 1: Drinking water treatment technology

**Evaluation and development of physical water treatment processes for the reduction of CaCO<sub>3</sub> scale**  
Department of Chemistry and Biochemistry, Rand Afrikaans University  
(WRC Reference No 836)

The build-up of scale is an expensive problem for many industries and domestic users of heating and cooling installations involving water. Heat transfer efficiency is reduced with a concomitant rise in energy costs, systems block, cycles of concentration in cooling systems have to be reduced, which leads to large volumes of blowdown water. Traditional chemical-scale control methods are expensive, require sophisticated dosing equipment, and are unfriendly to the environment because of the increased amount of polluting chemicals in the water.

In physical water treatment (PWT), water with scale-forming potential is exposed to an electromagnetic field in a simple flow-through system. It is claimed that this treatment will reduce or prevent scale, remove existing scale, and produce a softer scale which can be removed easily without the use of chemicals. Although PWT therefore presents a promising alternative, it was up to now only substantiated mainly by anecdotal evidence. The uncertainty surrounding its mode of action and the absence of credible scientific models to explain the mechanism involved in PWT seriously inhibits its general acceptance by the technical community. An additional

problem is that PWT devices do not always have the same degree of success in all installations, and in some cases do not succeed at all. These problems stem from the lack of understanding of the scale-preventing mechanism.

The aim of this project was to translate previous findings into practical products which can be used by industry to prevent scaling in pipes, heat transfer equipment and membranes.

The study showed that at least two completely different mechanisms involved in explaining the effect of PWT on scale reduction. The first involves the effect of metal ions released by PWT devices and the second has to do with the effect of electromagnetic fields produced by some PWT devices on the solid-liquid interface during the crystallisation process.

An important conclusion reached in this study was that AFM can be used to study electric double-layer characteristics by acquiring force-distance data in different electrolyte media using modified AFM tips. It was proven that the double-layer contraction as a function of increasing electrolyte concentration could experimentally be measured at the nanometer level. AFM results obtained during preliminary experiments at Nottingham University and RAU indicated that double-layer contraction was triggered by exposure of electrolyte to electromagnetic fields. This is a far-reaching result which would enable the study of electromagnetic fields on solutions and colloids at the molecular level.

Cost: R399 000  
Term: 1997 - 2001

**Water desalination and clarification by electronically enhanced membrane technology**

*Department of Polymer Science, University of Stellenbosch*  
(WRC Reference No 930)

Approximately 10 years ago the use of electrically enhanced defouling of membranes for waters being concentrated by RO was mooted by a WRC research manager. Subsequently, a local membrane company has produced electrically enhanced spiral wrap desalination elements that have a proven use history. However, the exact mechanism and effects of the electrically enhanced de-fouling phenomenon was not understood properly, leading to problems in controlling the defouling under varying process conditions. It was, therefore, necessary to obtain a fundamental understanding of what takes place on the membrane surface itself and to monitor the fouling in real time. In

this project an ultrasonic time-domain reflectometry (UTDR) technique was developed as a non-invasive technique to investigate fouling layer formation and growth on membrane surfaces. The ultrasonic testing technique provides a method for the early detection and monitoring of fouling in progress, without opening the membrane in any way.

Results showed that the UTDR technique could effectively detect fouling-layer initiation and growth on, and its removal from, the membrane in real-time. The acoustic signal response had a good correspondence with flux-decline behaviour during fouling. The UTDR technique was also capable of detecting subtle changes, such as the presence and/or absence of a cake layer on the membrane surface. More specifically, it was demonstrated that the technique could even be used to quantify the thickness of a fouling layer on a membrane surface. A patent was registered since considerable potential exists to commercialise this technology in various forms and applications.

Cost: R549 000  
Term: 1998 - 2002

**Development of a "defouling on demand" strategy for operation of bioactive membranes**

*Department of Biochemistry and Microbiology, Rhodes University*  
(WRC Reference No 932)

This project proposed to utilise enzymes for the development of a "defouling on demand strategy", an operational strategy that may revolutionise ultrafiltration and other pressure-driven membrane processes, e.g. ultrafiltration, microfiltration, nanofiltration and reverse osmosis. This "defouling on demand strategy" involves immobilisation of a combination of activatable enzymes onto the membrane surface. As soon as fouling becomes too high, the enzymes are activated (i.e., on demand) by supply of a chemical activator solution to alleviate fouling and restore flux to such systems. The project succeeded in achieving this aim, thereby providing a significant advance over current enzyme and other cleaning systems. An enzyme, laccase, activated once a day by simple oxygen injection, was found to be an effective, "activatable" defouling agent for the defouling of membranes used in the treatment of potable water from coloured surface water sources. The defouling restored flux through the membrane to near initial values. The enzyme was stable enough to withstand repeated oxygenation for several days in a row, potentially making this system a viable way of cleaning membranes on demand of the operator.

Given the simplicity and non-toxic nature of the process, it is considered enabling technology which will allow the use of membrane water purification units for application in potable water use.

Cost: R389 000  
Term: 1999 - 2000

**Capillary ultrafiltration membrane process and systems R & D**

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

There are many examples in South Africa of water supplied for use or distributed to small towns, communities, schools and clinics not meeting the SABS standards set for potable water. In these small-to-medium scale applications ultrafiltration could offer a technology for the small-to-medium scale point-source treatment of water. However, capital and operating costs and sophistication of a process can be a deterrent in applying any new process technology, especially where small systems are required for the production of potable water in the rural environment, and where skilled manpower may be limited. It was the core aim of this programme that these issues should receive attention; that the specific energy requirements (kW/m<sup>3</sup>) of the ultrafiltration process be minimised, and that the decision-making part of plant operation be reduced.

During the study a number of improvements were made to the previous systems during experimentation in the laboratory and in limited field trials. An operating and cleaning protocol for the cost-effective operation of capillary ultrafiltration processes was established. A simple flow destabilisation device with strategy was developed to improve mass transfer at low energy inputs. A protocol by which adsorptive foulants can be identified and removed with environmentally friendly and biodegradable agents, was devised. At the end of the project period a functional, economic and marketable system was designed and produced, having excellent potential to provide drinking water to small communities in South Africa.

Cost: R1 245 000  
Term: 1998 - 2002

**Inhibition of biofilm regrowth in potable water systems**

*Department of Biochemistry and Microbiology, University of Fort Hare*  
(WRC Reference No 1023)

The need to provide adequate water supplies to communities is a major objective of the South Africa Government's Reconstruction and Development Programme. To ensure bacteriologically safe drinking water, drinking water producers try to avoid bacterial growth in a drinking water distribution system. This could be possible by identifying appropriate disinfection processes and pipe materials used for the distribution of potable water.

The research programme aimed at investigating the inhibition of bacterial and biofilm regrowth in a chlorinated water distribution system. To have a comparative study, groundwater and surface water were used as test water sources while stainless steel and galvanised mild steel were used as pipe materials for the study of biofilms. The effect of PVC, uPVC, MDPE, asbestos cement, and cement on biofilm formation was identified and a comparative study was performed using statistical analysis.

The present study confirms the instability of chlorine, leading to bacterial regrowth in chlorinated surface and groundwater systems. A combined chlorine-monochloramine process resulted in a longer residual monochloramine that could be detected up to 168 and 678h in groundwater and surface water systems respectively. Less than 1 bacterial count (viable or total cells) was detected in both combined water systems and on surfaces of both types of piping material exposed to the combined chlorine-monochloramine. It was shown that a combined system provides an effective treatment for the inhibition of bacterial and biofilm regrowth in drinking water as long as the residual monochloramine concentration persists above ca 0.35 mg·l<sup>-1</sup> for surface water and ca 0.2 mg·l<sup>-1</sup> for groundwater.

Cost: R193 500  
Term: 1999 - 2001

**Assessment of the limestone mediated sidestream stabilisation process, with emphasis on use thereof by Rand Water for stabilisation of the Lesotho Highlands Scheme Water**

*Environmentek, CSIR*  
(WRC Reference No 1027)

Water conditioning to prevent aggression and/or corrosion (termed stabilisation) is conventionally achieved by the addition of lime (Ca(OH)<sub>2</sub>) and carbon

dioxide (CO<sub>2</sub>). This process has a number of drawbacks which include the use of notoriously troublesome lime-dosing equipment, high chemical operating costs, and the need for high-quality white lime, currently in short supply in South Africa. An alternative stabilisation process is stabilisation via contact with limestone (solid calcium carbonate (CaCO<sub>3</sub>)), which has been shown to have many advantages over lime-mediated stabilisation. The use of limestone for large water treatment works is made viable by the development by the CSIR of the limestone-mediated sidestream stabilisation process (SSP). The SSP consists of taking a sidestream of the unstabilised water, dosing high levels of gaseous carbon dioxide (CO<sub>2</sub>), and then contacting the CO<sub>2</sub>-acidified stream with limestone. The acidified sidestream takes up considerable amounts of calcium carbonate (CaCO<sub>3</sub>), increasing the alkalinity and the calcium concentration. Thereafter CO<sub>2</sub> is stripped, recovered and reused in the process. After CO<sub>2</sub> stripping, the sidestream is blended with the main stream in the correct proportions to allow for a fully stabilised main-stream. Preliminary pilot-plant trials have shown that the SSP process potentially provides significant cost savings and other advantages over conventional stabilisation. SSP technology and its derivations are patented internationally.

The aims of the project were to develop a model describing the process, which could be used to:

- identify the operational limitations of SSP
- identify means to improve the performance and optimise the operation of the process.

It was further aimed to determine the suitability of the SSP for the Lesotho Highlands scheme, and assess the motivation for industrialisation and full-scale implementation of the process.

The modified SSP was shown to be a viable alternative for the full stabilisation of soft, acidic waters. The simplified SSP provides significant financial savings over conventional lime and carbon dioxide stabilisation. Conservative financial assessment of SSP for use at Clarens (Lesotho Highlands Scheme), in which CO<sub>2</sub> recovery and reuse assumptions were well within pilot-plant performance and indicates that SSP provides significant financial savings over conventional lime and CO<sub>2</sub> stabilisation, with a project payback period of 4.3 years and an internal rate of return of 52%.

The damage to pipes and reservoirs due to aggressive acidic waters is currently a major problem. Water leakage results in great financial loss. Where this technology has been implemented, over 70% reduction of water leakage due to pipe failure has been recorded.

Wide usage of this technology will be of great benefit, especially in reducing water leakage losses, resulting in millions of Rands saved.

Cost: R300 000  
Term: 1999 - 2000

**Electrochemical generation of high-concentration ozone in compact integrated membrane systems**  
*DINAX Technologies cc*  
(WRC Reference No 1071)

The role of ozone in the treatment of potable water supplies and wastewater is well known as a disinfectant and a powerful oxidant.

The general aim of the project was to develop a South African-made cost-effective unit capable of producing ozone with concentrations six-fold higher than currently available units. Another objective was to identify the best niches for the application of the novel technology in various water and effluents treatment processes

An electrochemical ozone generator comprising glassy carbon electrodes and a water-soluble electrolyte was built and tested. Ozone concentrations of up to 20% were achieved. However, in theory the electrochemical processes, which are used for ozone generation are capable of producing ozone very power-efficiently. In practice, the theoretical efficiency cannot easily be achieved, and the electric current consumption in the generators is higher than that in large corona-discharge units. That is why it is expected that such a system would only be applicable to small-scale applications.

Based on the results of the current project it is clear that the electrolytic high-concentration ozone technology could successfully compete with the traditional ozone generation technology for small-scale applications, such as mobile medical sterilisation units, colour removal systems, odour removal systems, mobile rescue disinfecting units and mobile systems for destruction of chemical weapons. The technology could therefore be cost-effective in cases when the cost of ozone generation is of less concern than achieving high efficiencies of oxidation.

Cost: R809 000  
Term: 1999 - 2001

## Programme 2: Water treatment for rural communities

**Evaluation and optimisation of a crossflow microfilter for the production of potable water in rural and peri-urban areas**

*Department of Chemical Engineering, University of Natal*  
(WRC Reference No 662)

Crossflow microfiltration is rapidly gaining recognition as a technology that can produce high-quality water at an economically viable production rate. Results from a previous WRC project (No 386: **The development of a crossflow microfilter for rural water supply**) have been extremely positive. High-quality water is produced with a low turbidity, and over 99% of bacteria are removed.

Experience, however, highlighted the necessity for fundamental changes in the mechanical design, if the unit is to be regarded as a robust, reliable, cost-effective unit for the production of potable water. The unit employs a high-pressure spray-cleaning system, which has a high potential for regular failure. Mechanical failures needed to be addressed and an improved feeding manifold arrangement was required. The project therefore aimed to rectify these mechanical and cleaning problems and evaluated the modified plant as a potential, commercially viable, filtration unit for water and effluent treatment. A comprehensive evaluation of the unit and an assessment of its performance and requirements were made in various operating modes. Six operating modes were investigated.

It was found that the dead-end mode of operation could be particularly attractive, yielding a similar permeate production rate to high-velocity crossflow microfiltration but at a significantly reduced energy consumption. If so, this mode of operation could be ideal for rural areas, and would significantly increase the economic viability of the process. Unfortunately it was also found that a much poorer quality of water was produced in dead-end mode than in crossflow mode. The best quality of water was produced in crossflow mode using a pre-coat as well. Accordingly, the crossflow mode with pre-coat would be the most appropriate in applications where a high quality permeate is required, whereas the dead-end mode would probably be the most suitable for pretreatment applications where energy is a major consideration, or where the system was used as pretreatment.

In solving some of the historic problems associated with woven fibre crossflow filtration, a significant step was taken toward the successful commercialisation of this technology.

Cost: R383 000  
Term: 1995 - 2000

**Economically viable solar still units for use in remote, rural areas of South Africa**

*McCracken Solar Stills (Pty) Ltd*  
(WRC Reference No 1032)

A need exists to provide a simple and inexpensive technology to supply potable water to small communities dependent upon salt and brackish groundwater sources. Many of these small communities live in the more arid areas of the country - such as the Karoo and Northern Cape areas. Therefore a research project was launched to develop affordable and durable solar desalination plants for the provision of sufficient freshwater to such small and remote communities. A further objective was to demonstrate the viability of using this technology to provide a reliable source of good quality water in small, remote and previously disadvantaged communities.

Imported solar still designs were optimised for local conditions and various construction materials were tested. Field tests were carried out over a period of one year in each of the target areas. Solar distillation can be considered as an alternative to existing drinking and cooking water supply options for small communities and single households. It can easily be utilised in dual (integrated) water supply systems, e.g. complementing rainwater or groundwater. The project succeeded in its main aim of lowering the cost of solar stills to a fraction of the cost of the original imported units.

As the demonstration part of the project, a solar still unit supplying a small community of 30 people at Kerkplaas in the Karoo was built and evaluated. It proved to be very successful in supplying this community with their potable water requirements on a permanent basis. The success of the project prompted DWAF to fund another unit at Algeyrskraal, also in the Karoo.

Cost: R338 000  
Term: 1999 - 2001

**Development of a simple chemical dosing system (CDS) for small and rural water treatment plants, and evaluating its performance in roughing filtration (RF) and slow sand filtration (SSF)**

*Department of Civil Engineering, Peninsula Technikon*  
(WRC Reference No 1281)

Recent studies done to determine the upgrading needs of small and rural water treatment plants in South Africa (Swartz CD (1999) *Guidelines for the Upgrading of Existing Small Water Treatment Plants*, WRC, South

Africa) identified some important research needs for small systems water treatment. One of these research needs is the development of simple, effective and reliable chemical dosing systems and cost-efficient instrumentation for controlling chemical dosages under varying water quality conditions.

This project was aimed at overcoming unaffordable over-designs by evaluating and introducing simpler technologies to ensure sustainable water treatment and encourage more community involvement. To this end the combination of a novel, hydraulic, flocculant dosing system and various configurations of upflow and slow sand filtration were evaluated. A simple chemical dosing system (SCDS) was developed and successfully evaluated over time. It was found that the combination of dosing system and filtration provided a good quality of potable water from typical (turbidity-spiked) surface waters. The system seemed easy to operate and robust, thereby making it potentially suitable for application in areas that cannot afford to operate and manage sophisticated mechanical systems. Areas in which the SCDS can be applied include small urban towns and rural communities where skilled personnel are not readily attracted and do not have adequate finance. However, areas that can afford more complex facilities can also utilise this system as a standby unit. Field studies are being undertaken to test the system under real operating conditions, under a follow-up project (Project No 1396, accepted by the WRC for funding at the same institution).

Cost: R202 000  
Term: 2001

### Programme 3: Drinking water quality

#### Measurement of COD (organics) in drinking waters and tertiary effluents

Department of Civil Engineering, University of Cape Town (WRC Reference No 833)

Dissolved and suspended organics invariably are present at low but variable concentrations in tertiary effluents and natural terrestrial waters. Quantifying the concentrations of these is often important: for tertiary effluents, to assess treatment efficiency and aid in process control, and also to effect impact analyses on receiving impoundments; for terrestrial waters, in the control of unit processes in drinking water treatment works effecting removal of organics in order to minimise both trihalomethane (THM) formation and biogrowth in drinking water distribution systems.

The project aimed to develop, apply and disseminate methodology for measuring chemical oxygen demand (COD) in waters containing low concentrations of dissolved organics (i.e. treated and pretreated drinking waters).

An alternative procedure is proposed for assessing dissolved organic carbon (DOC) in water down to concentrations of about 1 mg C/l (i.e. COD of about 3 mg/l). The method involves a novel modification to the conventional COD test. It hinges around effecting a potentiometric titration on the digested sample in place of the conventional colorimetric end-point titration. The potentiometric titration data are then analysed using a novel modified Gran function (developed within this project) to yield the COD of the sample. A user-friendly computer program GRANCOD is presented to ease analysis. Evaluation of the method showed that it is precise and accurate to within 0.3 ml of titrant. Furthermore, a closely constant ratio between COD and DOC was found for natural terrestrial waters (but not those after treatment for humic removal); in the Western and Eastern Cape DOC (mg/l) = 0.35\*COD and for the inland waters of the Gauteng region DOC (mg/l) = 0.46\*COD.

This technique overcomes the limitations of having to use the current expensive and intricate apparatus and hence makes it possible in the near future for small municipalities to carry out such measurements.

Cost: R163 000  
Term: 1997 - 1999

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

Environmentek, CSIR (WRC Reference No 1026)

Soft, acidic waters attack distribution systems through being aggressive (to cement concrete) and corrosive (to metals). Such attacks can have significant implications relating to lost water, distribution network rehabilitation requirements and undesirable change in water quality; accordingly, in larger, formal water supply systems, water conditioning processes are used to stabilise the water, thereby ameliorating aggressive and corrosive attack. Conventionally, stabilisation of soft, acidic waters is achieved via the addition of lime and carbon dioxide. However, for smallholdings, farms, country hotels and smaller municipalities, stabilisation via lime dosing (with or without carbon dioxide), is problematic, requiring skilled, well-trained staff and expensive equipment. Furthermore, stabilisation with lime is expensive, often

comprising about half of the overall chemical cost of treating brown waters. For small-volume water users, stabilisation is not readily implementable and the costs of corrosion can be significant. However, an alternative means of stabilising soft, acidic waters by contact with limestone (CaCO<sub>3</sub>) is considered in this report.

The aims of the project were to perform research, development and implementation of lime contactors for groundwater stabilisation/iron removal in small systems; and water stabilisation in medium-scale (2 to 40 Ml/d) systems.

A number of operational limestone contactor units that treat surface waters of varied quality have been investigated. In all cases the limestone contactors improved the aggressive/corrosive qualities of their feed waters, and in most cases, significantly so. Results from this investigation will be captured in a guidelines document for the design and operation of these units.

Cost: R313 000  
Term: 1999 - 2000

### Programme 4: Water distribution and distribution systems

#### Development of a model to estimate hour-day factors in potable water distribution systems in South Africa

WRP Consulting Engineers (Pty) Ltd (WRC Reference No 1205)

The minimum night-flow (MNF) occurs in most water supply systems between the hours of 02:00 and 04:00 when demand for water is at its lowest. It is normal practice to evaluate the performance of some water demand management measure by monitoring the change in MNF and extrapolating the reduction (or increase) over the full 24-hour period. Unfortunately such a simple extrapolation can sometimes be misleading since the savings achieved during the hour of MNF may not be achieved over the full day. To overcome this problem, the concept of the hour-day factor (HDF) was established.

The HDF is simply a factor applied to a reduction (or increase) in the pressure-dependent flow occurring at the hour of MNF to provide an indication of the total daily saving (or increase) in pressure-dependent flow that can be expected over the whole 24-hour period. If the same savings can be achieved over the whole day, then the HDF for the area in question will be 24, i.e. simply the number of hours in a day. In most normal systems, however, a value of between 18 and 22 can be expected while in areas which are already operating

under some form of pressure control, values in excess of 24 can be expected. In some extreme cases where leakage levels are very high, the savings achieved from pressure management can be significant even during the daily peak demand periods. In such cases, the HDF can be significantly higher than 24 when some form of pressure management is implemented

The HDF Model allows water suppliers to make better estimates of the savings that can be expected from some form of WDM measure that has the effect of reducing pressure-dependent leakage. Simply multiplying the reduction in MNF by 24 will often yield over-optimistic expectations and is a common error made in many WDM investigations. The HDF Model also provides a very simple and useful procedure for estimating the pressure exponent (often referred to as the N1 value) for a particular water supply system. The correct selection of N1 for a system is important and the HDF Model therefore provides water suppliers with a very simple and easy-to-use approach to this issue.

The models are supplied through the WRC for use within South Africa and further details can be obtained from the WRC website on <http://www.wrc.org.za>.

Cost: R150 000  
Term: 2001

#### The development of a methodology to determine the effectiveness of water conservation (WC) and water demand management (WDM) measures

Stewart Scott (Pty) Ltd (WRC Reference No 1273)

The development of a methodology to determine the effectiveness of WC and WDM measures was undertaken taking into account the particular conditions pertinent to South Africa, existing related methodologies as well as local and international case studies.

In formulating the overall objective for the methodology, cognizance is taken that when measures are implemented they should facilitate the achievement of equitable access to, and sustainable use of, water resources by all stakeholders within the geographical area of application, while maintaining the characteristics and integrity of the overall water resources within agreed limits.

Specific related objectives included:

- Reasonable water use through reduced unaccounted-for water and encouragement of the efficient use of water

- Appropriate allocation of water through its optimal beneficial use, equitable access as well as economic efficiencies
- Implementation of integrated demand and supply approaches taking cognizance of the need to minimise the cost of supply and to increase community water supply coverage
- Achievement of a more sustainable use of water through the limitation of negative environmental impacts and achievement of an acceptable water quality
- Consensus-based decisions that reflect local needs.

Therefore the emphasis is on the development of a practical methodology to determine the effectiveness of WC and WDM measures that are consistent with the principles of integrated resource planning (IRP) as well as being applicable to developing countries.

Cost: R190 000  
Term: 2001 - 2002

**Development of a framework for the economic evaluation of water conservation/water demand management measures with specific application to decision-making in Cape Town**  
*Independent Economic Researchers cc*  
(WRC Reference No 1275)

For many years the primary focus of water resource planning in South Africa was the expansion of supply. Only fairly recently with the promulgation of the Water Act (Act 108 of 1998) has the importance of water conservation / water demand management (WC/WDM) been recognised. In consequence, techniques for the evaluation of WC/WDM measures are less sophisticated than those for the evaluation of new sources of supply. This study develops a framework for the financial and economic evaluation of WC/WDM measures.

An investigation of the available literature indicates that cost-benefit analysis (CBA) remains the technique favoured for the analysis of the bulk of public sector investment decisions. It was also the method most commonly appearing in the literature on guidelines for the financial and economic evaluation of WC/WDM measures. Linking this to the Cape Town Integrated Water Resources Planning, the process and results show that study participants indicated satisfaction with the MCDA (multicriteria decision analysis) process used as it encouraged a holistic approach in which participants were prompted to appreciate each other's points of view and build consensus. The parts of the process dealing with financial and economic evaluation relied heavily on CBA principles.

At a local policy level, CBA remains the preferred technique for financial and economic evaluation of water projects. The framework for the evaluation of WC/WDM measures presented by this study needs to be consistent with CBA principles given the likelihood that revised CBA guidelines would be accepted by DWAF and possibly more widely. Through these procedures the study has developed a framework for economic evaluation of WC/WDM measures.

Cost: R111 200  
Term: 2001 - 2002

### Thrust 3: Wastewater and Effluent Treatment and Reuse Technology

#### Programme 1: Biological sewage treatment processes

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

Based on work in the field of algal biotechnology undertaken at Rhodes University, the objectives of this project commissioned in 1991 were to undertake a feasibility study on the development of an integrated system for treatment, effective utilisation as a resource and ultimate disposal of saline effluent wastes, which were identified as one of the critical problems facing the country and impacting directly on the availability of freshwater. The study consisted of definitive literature reviews and laboratory investigations covering a low-technology system comprising algal ponding and anaerobic digestion for the economic treatment and disposal of saline effluents, possible recovery of algal products of value by the use of membranes, and the removal of nutrients and heavy metals from brine effluents enabling their disposal by dilution where appropriate.

Major conclusions of the study, which later gave far-reaching direction to research in this area, were that saline (and specifically sulphate-saline) wastewaters could be viably treated in algal ponding systems, that integrated algal ponding systems (IAPS) provided a core technology for linked saline-sanitation treatment, that nutrient values could be recovered as algal products, and that, in addition to a range of other possible by-products, treated water of suitable quality for return to the national water resource could be produced.

The seminal results obtained in Project No 410 have been combined for publication with more detailed results obtained in subsequent follow-on projects, and have now been published as the introductory **Volume 1** to the ISBN series No. 1 86845 853 9 entitled: **Salinity, Sanitation and Sustainability: A Study in Environmental Biotechnology and Integrated Wastewater Beneficiation in South Africa**. Final reports on the various follow-on projects (Project Nos 495, 651, 656, 658, 799, 869, 972, 1073, 1078, 1169 and 1336) are being published as various parts of **Volumes 2 to 4** of the series.

Cost: R76 500  
Term: 1991

**A monitoring and optimisation study on high-rate biofiltration, aerobic biological treatment processes for tannery and fellmongery wastewaters**  
*Leather Industries Research Institute (LIRI)*  
(WRC Reference No 457)

The overall project aim was to develop and assess the use of biological processes (in particular biofiltration) rather than physico-chemical processes for the treatment of tannery wastewaters. Specific objectives were to study an existing full-scale plant at a Port Elizabeth tannery in order to improve and optimise biofilter design and operation, produce a treated effluent quality suitable for membrane polishing, and improve the dewaterability of the sludges produced. The scope and budget were substantially expanded (in 1993) when it was decided to purpose-build a dedicated wastewater research facility at LIRI, Grahamstown. The plant was designed, constructed and commissioned during 1994 to 1996, operated and monitored from 1996 to 1998 under Project No 457 and a follow-on WRC Project No 826, and upgraded and further monitored in 1999 under a second follow-on WRC Project No 1085. During its operational life the plant was also used for training wastewater treatment personnel from industry, under WRC Project Nos 657 and 941.

The work carried out showed biofiltration to be a viable option for treating tannery wastewaters, with nutrient (phosphate) addition and regular high-rate flushing contributing to improved performance and process stability. The humus sludge produced could be dewatered fairly rapidly on drying beds, and the overall process was relatively odour-free in contrast with many other facilities treating tannery effluents.

At its final meeting in 1997 the steering committee reviewed the draft final report for the project and recommended its acceptance by the WRC subject to a

number of recommended revisions being carried out by the project team. Due, however, to the subsequent liquidation of LIRI, commencing 31/12/99, a revised final report was not obtained and it was agreed in 2002 to close the project without publication of the final report.

Cost: R1 466 560  
Term: 1992 - 1993 (Ext 1996)

**Appropriate low-cost treatment of sewage reticulated in saline water using the algal high-rate oxidation ponding (HROP) system**  
*Department of Biochemistry and Microbiology, Rhodes University*  
(WRC Reference No 656)

The overall project aim was to evaluate the potential of algal ponding systems treating sewage in saline waters. As an urgently-required response to the growing threat of acid mine drainage (AMD) in the RSA, the initial focus was towards AMD aspects. In comparative studies using tannery wastes, sewage solids and algal biomass as carbon substrates, each was found to provide an effective electron donor source for the biological reduction of sulphate, with sulphate-to-sulphide conversion rates in the range 200 to 300 mg·L<sup>-1</sup>·d<sup>-1</sup>. The algal strains investigated were reasonably tolerant to high sulphide concentrations, and the bio-availability of algal biomass for this purpose has practical significance for biodesalination of acid mine drainage in remote locations.

Heavy metals were shown to be removed both by biochemical precipitation (as sulphides, carbonates and hydroxides) and microbiological adsorption (directly on the algal biomass and/or by binding to extracellular polysaccharides), with both playing significant metal-removing roles. The overall degree of metal removal could include final polishing to very low residual levels.

The third area investigated was the use of algae to raise the pH of acidic AMD effluents. *Spirulina* spp. effected this neutralisation while maintaining active cell growth, but the growth of *Dunaliella salina* declined rapidly under low-pH conditions. An important general result is that bicarbonate (seldom present in AMD, but required in the bio-alkalising process) can be provided by utilising the bicarbonate biologically released during sulphate reduction.

The final report on Project No 656 has been published as Report 6 in the ISBN series No. 1 86845 853 9 titled: **Salinity, Sanitation and Sustainability: A Study in Environmental Biotechnology and Integrated Wastewater**

*Beneficiation in South Africa. Volume 3: Integrated Algal Ponding Systems and the Treatment of Domestic and Industrial Wastewater. Part 3: Mine Drainage Wastewaters - The ASPAM Model.*

Cost: R160 000  
Term: 1997

**The ratio between chemical oxygen demand (COD) and dissolved organic carbon (DOC) and its use for wastewater plant operations**

*East Rand Water Care Co (ERWAT)  
(WRC Reference No 668)*

As alternatives to biological oxygen demand (BOD) and chemical oxygen demand (COD) tests for measuring the organic strength of wastewaters, total organic carbon (TOC) and dissolved organic carbon (DOC) tests are rapid procedures in which organic material is combusted in oxygen and the carbon dioxide produced is measured as an indirect quantitative measure of the concentration of organic matter in the sample. In this project the TOC and DOC parameters were investigated to determine whether their ratios to COD measurements were consistent enough to offer an alternative on-line determination for plant control purposes.

The results obtained show that the ratios of TOC:COD and DOC:COD vary widely from 1:1 to 1:32, depending *inter alia* on the source of the sample. In particular, TOC/COD and DOC/COD ratios in sewage influent samples varied widely, presumably due to differences in composition caused for example by differing industrial effluent contributions. The observed ratios at different stages of treatment through to the final treated effluent also did not correlate well. The conclusion reached by the researchers is that the variation observed does not allow the use of TOC or DOC in-line measurements as a consistent stand-alone substitution for COD determinations for sewage treatment plant control.

Cost: R100 000  
Term: 1995 - 1996

**Full-scale demonstration of filamentous bulking control in a biological nutrient removal activated sludge plant at Mitchells Plain Wastewater Treatment plant**

*Department of Civil Engineering, University of Cape Town  
(WRC Reference No 823)*

Sludge bulking reduces the effective operating efficiency of biological nutrient (both N and P) removal, which has led to plants being over-designed to cope with the poorly-settling sludge. The WRC has supported a series of projects since 1981 with this UCT research group,

during which time they have tested conventional thinking on the problem (typically the use of specific process control methods for non-filamentous bio-selection) and have developed a new hypothesis - basically that in biological N-removal systems, incomplete denitrification at the anoxic/aerobic switchover point promotes the growth of low F/M filaments, termed anoxic-anaerobic (AA) bulking.

The objectives of the research programme were to:

- Demonstrate and evaluate, at full scale, specific bulking control measures in N & P removal systems
- Transfer research and development in bulking control undertaken at laboratory scale to full scale
- Verify at full scale the specific bulking control hypothesis developed from laboratory research.

The Cape Metropolitan Council was fortuitously able to offer replicate pilot-scale plants to the project team for testing their hypothesis at large pilot-scale (3M<sup>3</sup>d<sup>-1</sup>). It was planned to manage these plants to promote either bulking or non-bulking conditions, providing a unique opportunity both for testing the AA filament bulking hypothesis and also for running replicated experiments and/or controls. However, despite significant expenditure and effort in modifying, refurbishing, operating, monitoring and analysing the pilot plants, persistent problems with aeration, back-mixing across the anoxic-aerobic baffle and sludge back-flows did not allow the AA filament bulking hypothesis to be definitively proved or disproved - AA filamentous bulking did not occur as expected in the pilot plants, but did occur in a parallel UCT-system unit. The researchers concluded that "finding a cure for AA bulking in BNR systems remains elusive despite the considerable attention it has received over the past 20 years in the RSA and internationally".

Cost: R454 000  
Term: 1997 - 1999

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

*Wates, Meiring and Barnard (now Golder Associates Africa (Pty) Ltd)  
(WRC Reference No 929)*

Approximately 23% of South African domestic wastewater treatment plants still have trickling filters as reflected by the results of a recent national survey of approximately 1 100 plants. Process developments related to trickling filters continue and trickling filters are utilised in new and innovative ways. The integration of trickling filters with other treatment processes such as

oxidation ponds and activated sludge also opens up new opportunities for application. Many existing installations can be optimised by the implementation of recent developments related to trickling filters.

The project aimed to provide guidelines for the design and application of more refined and optimised high-rate trickling filter technology, mostly based on stone packing. A guideline document was compiled, which is aimed at technical practitioners in the wastewater treatment field, as well as managers, operators, designers and researchers. These guidelines were largely based on research executed on high-rate trickling filter research undertaken at the Baviaanspoort Pilot Test Facility. However, full-scale plant case studies were also conducted at the Riverview (Witbank) plant, Oberholzer (Carletonville) plant, Gammams (Windhoek) plant and Velddrift plant. The guidelines are therefore based on experience and practices in Southern Africa, but will apply to any trickling filter facility operated under similar flow, load and climatic conditions. The document provides guidelines for the effective design and operation of trickling filters in both existing and new installations. These guidelines will impact positively on both the ability of the consulting engineering fraternity to produce improved designs of trickling filters, as well as on the more cost-effective upgrading of overloaded plants and the design of more effective new trickling filter plants.

Cost: R233 000  
Term: 1998 - 2000

**External nitrification (EN) with the aid of fixed media trickling filters (TF) to increase the capacity of biological nutrient removal (BNR) suspended medium activated sludge (AS) systems**

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

Many trickling filter (TF) wastewater treatment plants in South Africa have been extended by adding biological nutrient removal activated sludge (BNRAS) systems, particularly in inland areas to meet the 1.0 mg P/l standard. Retro-fitting approaches include either directing a proportion of the influent to the TF and discharging the TF effluent to the BNRAS system, or chemically treating the TF effluent for P removal. For different reasons neither approach is ideal; this project accordingly investigated a system in which the nitrification process is removed from the BNRAS and effected externally in a fixed-media system. Such external nitrification (EN) allows the sludge age in the BNRAS reactor to be reduced, with a consequent potential increase in the system capacity for removing both organics (COD) and nutrients (N&P).

Experimental investigations on three laboratory-scale ENBNRAS systems showed that COD removal was good (>90%); the oxygen demand/aeration requirement was substantially (60%) lower than in conventional BNRAS systems; high(>80/90%) removal of N-species was obtained, with consequently low (<10 mg N/l) concentrations in the treated effluent; P-removal was lower (30% less) than expected; and the settleability of the sludges produced was good (90 to 100 ml/g) in the process configuration used. The work carried out also extended the kinetic simulation model for all BNRAS (including ENBNRAS) systems to include anoxic P uptake and denitrification. Experimental data correlated well with predicted values and this augurs well for the use of the model for practical design and implementation of ENBNRAS systems.

From this study, ENBNRAS systems offer apparent performance advantages (P-removal being the exception) over conventional BNRAS systems. Economic analysis showed a 30% capital cost saving but only a 5 to 10% total saving when the (normal) high proportion of operating versus capital cost is factored in. In practice, the performance benefits offered (better effluent quality) could influence design decisions more than the modest cost saving indicated.

Cost: R665 000  
Term: 1998 - 2000

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

*Department of Food Science, University of Stellenbosch  
(WRC Reference No 1022)*

A previous WRC study showed that when sudden stress conditions were applied to UASB systems under controlled environmental conditions, the granulation process was enhanced. The aims of this project were to mass-culture granules for use in UASB digesters, to analyse the microbial consortium within granules, to include selected microbes into granules in order to enhance degradation of specific wastewaters, to evaluate the economic benefits of using different media and to evaluate storage potential and stability of mass cultured granules. Small (250 ml) to larger (5l) batch systems were evaluated to assess the influence of reactor volume on the granulation process. Different carbon and nitrogen sources were tested for their impact on granule production. The impact of sludge sources, substrates and cultivation techniques on granule activity and extracellular polymer composition was also evaluated.

Factors found to influence the granulation process included the presence of divalent cations ( $\text{Fe}^{2+}$ ), inert matter, the accumulation of extra-cellular polymers (ECP) and the presence of essential microbial populations. Nitrogen sources were less critical for the enhancement of granulation, while glucose was found to give the best granule enhancement (followed by lactate). Fruit canning effluent, as the cheapest carbon source, gave the highest increase in granule enhancement when combined with glucose. Of the different preservation techniques evaluated, freeze-drying showed the highest granule activity. In granules cultured under different conditions, the ECP composition depended on the nature of wastewater fed to the UASB. Granules with higher ECP yields exhibited greater biogas and methane activities. Granule numbers were also affected by the batch cultivation technique, e.g. roller-table cultivation gave a higher yield than shaker/water-bath methods. The study successfully demonstrated the cultivation of granules in a larger scale reactor, with important economic implications in terms of a faster start-up process, independence from importation of granules, better biomass retention and higher permissible loading rates.

Cost: R231 000  
Term: 1999 - 2001

**Microbial characterisation of activated sludge mixed liquor suspended solids**  
*Department of Microbiology & Plant Pathology, University of Pretoria*  
(WRC Reference No 1191)

This project was one of three commissioned in Y2000 as a collaborative programme to combine engineering (mathematical modelling) and scientific (microbiological) expertise towards deriving a more fundamental description of the 'active mass fractions' extensively used in kinetic models of biological treatment processes and in particular the activated sludge process with biological nutrient removal. The scope of this project was limited to a focused investigation to compare adenosine-triphosphate (ATP) determinations with other analytical parameters such as mixed liquor suspended solids (MLSS), mixed liquor volatile suspended solids (MLVSS), oxygen utilisation rate (OUR) and total plate count (TPC) as a measure of the active fraction in activated sludge.

From samples of activated sludge taken from the aerobic zones of five sewage treatment plants in the Greater Tshwane area, MLSS and MLVSS values were much higher than population estimates from ATP and TPC determinations. ATP was preferred to TPC as a biomass estimator due to higher counts (more than one log unit

difference) and smaller standard deviations. ATP determination by means of a bio-probe is moreover cheap, simple and rapid and can be used on site for on-the-spot results. Profiles of batch reactors showed that OUR followed the same trends as ATP, demonstrating a correlation with metabolic activity.

The main conclusion reached is that ATP is a "better" measure of biomass activity than MLSS or MLVSS, with TPC and OUR broadly following the same trends as reflected by ATP measurements. A fundamental quantitative correlation between ATP concentration and the active biomass fraction in biological sludge has, however, not been demonstrated. The results and conclusions of this low-budget study should be viewed in conjunction with the outcomes of the related WRC Project Nos 1178 (Durban Institute of Technology) and 1179 (University of Cape Town).

Cost: R88 000  
Term: 2000 - 2001

### **Programme 3: Treatment and recovery of organics from agro-industrial processing**

**Evaluation of immobilised semi-conductor particles for photo-catalytic oxidation of organic pollutants in industrial and domestic waters**  
*Department of Chemistry, University of Stellenbosch*  
(WRC Reference No 552)

The aim of this project was to assess titanium oxide ( $\text{TiO}_2$ ) photo-catalysis for the oxidative removal from raw waters of complex organic compounds which arise naturally (humic acids, etc.) or from agro-industrial sources and which are not efficiently removed by traditional flocculation/coagulation processes. A major technical advantage offered by photo-catalytic destruction of trace organics in raw waters and industrial effluents is that the treatment process is not concentration-dependent, as in conventional flocculation/coagulation. This is particularly relevant when concentrations of the contaminant organics vary rapidly, as is often the case. The studies were carried out initially on laboratory scale, and subsequently in a larger photo-catalytic reactor.

Reasonable success was obtained in laboratory-scale photo-catalytic treatment of organic flotation agents found in mineral beneficiation effluents (including xantates, thiocarbonyl and dithiophosphate). The acid hydrolysis products of some of these flotation agents were also destroyed. This application was further investigated in a follow-up WRC project in which a larger falling-film type photo-catalytic reactor was designed,

constructed and optimised for the destruction of para-chlorophenol as found in some industrial wastewaters (results given in WRC Report No 834/1/00).

Photo-catalytic treatment of raw water containing humic acids was reasonably successful at elevated pH levels (pH 10) but less so at the natural pH (around pH 7 and lower), due to the formation of an intermediate product that absorbed onto and deactivated the surface of the  $\text{TiO}_2$  photo-catalyst particles. The deactivation was effectively irreversible as the absorbed compounds could not be easily separated from the catalyst. The alternative proposed, i.e. chemical pre-flocculation/coagulation to remove the bulk of the humic acid content before photo-catalysis, does not appear to offer any real advantage over conventional chemical treatment, other than as a polishing step of unproven cost/benefit effectiveness.

Cost: R95 400  
Term: 1996 - 1997

### **The complete treatment of dairy factory effluents by means of primary anaerobic digestion and secondary algal production**

*Agricultural Research Council / Irene Animal Production Institute*  
(WRC Reference No 673)

After various delays and extensions over the period 1995 to 1999, it was agreed between the WRC and the ARC in 2000 to 2001 that this project had effectively never commenced and that the contract would be terminated by mutual agreement and without prejudice, with the ARC repaying the unaudited project funds received (R119 700). No final report will be published.

Cost: R120 000  
Term: 1995 (Ext 1999)

### **Further development of a biotechnological approach to the management of wastewaters from the pulp-and-paper industry**

*Department of Microbiology and Biochemistry, University of the Free State and Sappi Biotechnology Laboratory*  
(WRC Reference No 1082)

Biotechnology can offer some apparent benefits to the pulp-and-paper industry. These include potential increase in pulp yield, higher brightness ceiling, reduced chemical loads, improved effluent quality, establishing environmentally friendly bleaching sequences, and increased pulp efficiency and capacity. However, information available on some of these biotechnical approaches is limited and further investigations were required to gain a better insight into the mechanisms

involved in biobleaching and bioremediation of effluents which in turn would allow the optimisation of these bioprocesses for practical realisation.

The research programme set itself the following objectives:

- Development of a modern biobleaching technology to improve the existing chemical bleaching processes of pulp-and-paper production in an environmentally-friendly and cost-effective way
- Reduction of the environmental impact of wastewaters from the pulp-and-paper industry by employing micro-organisms with special emphasis of wastewater biodecolorisation, biodegradation and bioremediation
- Utilisation of wastewaters from the pulp-and-paper industry to obtain valuable products such as enzymes (xylanases), single-cell protein (SCP) and/or high-value fatty acids (gamma-linolenic acid)

Biobleaching-based wastewater bioremediation research showed that implementation of the enzyme bleaching technology in the pulp-and-paper industry could improve the existing technology of pulp-and-paper manufacture in a cost-effective and environmentally friendly way. Chemical savings of up to 2.5 kg of  $\text{ClO}_2 \cdot \text{t}^{-1}$  of pulp could be achieved when dissolving pulp was bleached with xylanase whereas biobleaching of soda-aq pulp effected a 30% reduction (4.5 kg  $\text{ClO}_2 \cdot \text{t}^{-1}$  of pulp) of the total amount of chlorine dioxide used.

In terms of bioremediation of wastewaters, good results were obtained in COD and colour reduction using biological treatment systems (especially with rotating biological contactors) and two strains of white-rot fungi. Wastewater was further utilised successfully for xylanase production using *Aspergillus* species. The application of the crude xylanase preparations in the pretreatment of the post-oxygen soda-aq pulp at relatively low enzyme doses resulted in a significant brightness increase. Alternatively, biobleaching could reduce the  $\text{ClO}_2$  consumption by up to 30% while retaining brightness at the control level. It was also found that tall oil, which is a by-product derived from kraft mill spent liquor, could be utilised by selected fungi for the production of high-value fatty acids such as gamma-linolenic acid.

Cost: R400 000  
Term: 1999 - 2000

#### A survey and preliminary investigation into biodegradation of pesticide wastes

Pollution Research Group, University of Natal  
(WRC Reference No 1128)

This desk study reviewed pesticide use and waste generation in Southern Africa, and existing technologies for their disposal, from local and international information and consultation with interested and affected parties including suppliers, users, regulators and environmental lobbies. The report includes a general overview of pesticides; a brief review of their toxicological and hazard classification; a survey of local pesticide producers, distributors and users; pesticide use by category in the RSA; a status review of obsolete pesticide stocks in Southern Africa (1997 to 2000); some options for reducing pesticide use or minimising the dangers posed; a schedule of local suppliers; and a world-wide survey of technologies available for disposing of pesticide residues and remediating contaminated soil and groundwater sites.

Pesticide sales figures (1994 to 1998) indicate that *per capita* use in Africa is predictably lower than in Europe and the USA but that South Africa is a leading user in Africa. The agricultural and forestry sectors are major users in pesticide categories covering insecticides, herbicides, fungicides, nematocides, ascaricides, and plant growth regulants. Little or no information could be obtained regarding use by the government sector. Existing technologies for treatment and disposal include thermal, chemical, physical and biological methods, but all are expensive and require expert management. Remediation of pesticide-contaminated soil or groundwater is particularly slow and costly.

An integrated hazardous waste disposal approach covering policy and practice is therefore strongly indicated. The report details recommendations encompassing legislation (adequate, but requires more capability for controlled enforcement without placing undue costs on the manufacturer/supplier and/or the user and thereby potentially threatening food security), cleaner production preventative techniques (e.g. education, training, regulation and monitoring; promotion of integrated pest management; incentive schemes for reducing pesticide use; stringent monitoring programmes; etc.), the provision of appropriate treatment and disposal facilities for existing and residual pesticide wastes (e.g. 'best available technology' facilities on a user-pays basis, responsibly controlled by the manufacturer, end-user and/or government, and clean-up technology (e.g. bioremediation expertise being made accessible for decontaminating soil and groundwater sites).

Cost: R114 000  
Term: 2000

#### Treatment of landfill leachate from hazardous and municipal solid waste

Environmentek, CSIR  
(WRC Reference No 1167)

Municipal leachates are regarded as one of the most pressing pollution problems in South Africa, and one of the most difficult problems to solve. Current oxidation technologies, such as ozone, ultraviolet light and hydrogen peroxide are not adequately effective for the detoxification of leachates, or for the removal of high concentrations of salts which are integral to most leachates. Therefore membrane processes have been suggested internationally as a possible and feasible solution to the leachate problem. In membrane treatment both the organic and inorganic pollutants can be removed. The small volumes of concentrates are then dried and pelletised, or immobilised in power station ash or in cement. Although some initial work overseas has shown success, the South African leachates are much more concentrated as well as unique to the country.

The main aim of this project was to develop a combined electro dialysis and reverse-osmosis process technology for the treatment of hazardous municipal leachates with high total dissolved solids (TDS) and high organic concentrations. The secondary aim of the project was to develop reverse-osmosis process technology for the treatment of hazardous municipal leachates with low TDS and low organic concentrations. A novel South African non-fouling membrane system was also compared to current technology during the project. The research took place at two waste fill sites, i.e., Holfontein, Springs (concentrated leachates) and at Bisasar Road, Durban (normal leachates) and entailed pilot-plant evaluations of the various membrane and pretreatment processes. It was demonstrated that electro dialysis (ED) was a suitable process for the desalination of highly concentrated leachates and reverse osmosis was a suitable process for the treatment of the average leachates from municipal waste dumps. Costs were determined for both these alternative processes and their applications. This is the first comprehensive study on the treatment of leachates with membranes undertaken in South Africa. Guidelines provided in the report regarding the potential application of these technologies will assist local authorities in improved management of these problem leachates. In this regard the project will make a great impact on the waste dump leachate treatment and management options available to local authorities.

Cost: R630 000  
Term: 2000 - 2001

#### Programme 4: Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents

##### Development of bioreactor systems for the treatment of heavy metal containing effluents

Department of Biochemistry and Microbiology, Rhodes University  
(WRC Reference No 845)

This study evaluated the effectiveness and cost of biotechnology-based processes for removing heavy metals from wastewaters in comparison with more established methods such as ion-exchange and chemical precipitation. Specific aims were to evaluate the potential of algae, water fern (*Azolla*) and algal exopolysaccharides for heavy-metal accumulation, and to optimise bioreactor design for on-site application of the technology.

The primary focus was on mining industry effluents, which are generally complex with numerous chemical species influencing the metals: biomass binding/adsorption. *Azolla filiculoides* effectively accumulated gold(III), lead(II), iron(III), copper(II) and platinum(IV) from synthetic solutions. In batch studies, gold(III) adsorption was principally pH-dependent with optimal removal (95 to 100%) at pH 2. Lead(II), iron(III) and copper(II) did not compete with gold(III) adsorption under equimolar and simulated effluent conditions. Halides affected gold uptake, with increasing affinity for gold progressing chloride < bromide < iodide. Column studies, better suited to high-volume treatment, also showed little or no competitive interference between lead, iron, copper and gold uptake, with halides affecting gold(III) uptake similarly to the batch studies (0 to 25% inhibition). Lead, copper and iron could readily be recovered from the biomass; gold and platinum recovery was more complex but achievable. The best bioreactor design found for continuous application was an up-flow column, relatively loosely packed with biomass. *Azolla* biomass could be easily cultivated in simple shallow baths supplied with nutrients, and then inexpensively air- or sun-dried for use. Preliminary studies on algal exo-polysaccharides showed these polymers to be efficient metal accumulators, but with difficulties and high costs involved in their production and extraction.

The study concluded that biosorption could be viable as a pre- or polishing step in integrated systems for metal removal and desalination. Good conditions for metal

removal have been established but further investigation is needed to establish similar efficiencies for metal desorption, recovery and concentration.

Cost: R598 000  
Term: 1997 - 1999

##### Biological sulphate desalination and heavy metal precipitation in industrial and mining effluents using the algal integrated ponding system (AIPS)

Department of Biochemistry and Microbiology, Rhodes University  
(WRC Reference No 869)

Developing out of a number of closely related studies on linking saline and sewage wastewater treatment through integrated algal ponding systems, this project aimed at investigating the use of waste organic (carbon) sources instead of high-cost substrates for treatment of sulphate-saline wastewater. Initial studies focused on increasing the understanding of the hydrolysis of complex carbon substrates in biosulphidogenic treatment of acid mine drainage (AMD), and reactor design options were then evaluated.

The Rhodes BioSURE® Process, utilising primary sewage sludge as the carbon source for bacterial sulphate reduction, was conceptualised and developed during the study as a two-stage process in which substrate hydrolysis and sulphate reduction could be optimised in separate unit operations. On-site piloting of the process was undertaken in collaboration with ERWAT in a DWAF-mandated evaluation of desalination technology during 1997/1998 at Grootvlei Mine. Calculated conversions of organic carbon to acetate equivalents showed that primary hydrolysis of the complex substrate occurred in the recycling sludge bed reactor (RSBR), while volatile fatty acid consumption and associated sulphate reduction occurred mainly in the second stage of the process. At hydraulic retention times around 96 hours, > 80% sulphate removal was achieved with an efficiency of >30% conversion of sludge to acetate equivalents. In the process heavy metals are precipitated, the AMD stream is neutralised, and high-rate algal ponding could further polish the treated stream to remove residuals of metals, sulphides, organics and possible microbial contaminants.

The insights gained into the biosulphidogenic hydrolysis of complex organic carbon substrates led to a number of follow-up studies, including further development (Project Nos 972 and 1169), bio-sulphur recovery and metal removal (Project No 1078), scaled-up evaluation (Project No 1336), and collaborative studies on enzymatic mechanisms (Project No. 1170) and

modelling (Project No. 1251). The linked sewage-sludge-disposal-with-acid-mine-drainage-treatment process offers environmental sustainability advantages, significant on the Witwatersrand where sewage and mine water are both present in large volumes and where the treatment of decanting AMD waters may be necessary for long periods of time.

The report has been published as Report 9 in the ISBN series No. 1 86845 853 9 entitled *Salinity, Sanitation and Sustainability: A Study in Environmental Biotechnology and Integrated Wastewater Beneficiation in South Africa: Volume 4*. The Rhodes BioSURE® Process. **Part 1: Bidesalination of Mine Drainage Wastewaters.**

Cost: R673 000  
Term: 1997 - 1999

#### **Electro-membrane reactors for desalination and disinfection of aqueous solutions**

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

The use of desalination and disinfection processes is of vital importance for the adequate protection of South Africa's water resources. Amongst the most widely used desalination methods are those based on adsorption technologies used for removal of both ionic and non-ionic substances from aqueous media. There are a great variety of adsorbents produced by the industry, which allow for a choice in each case of wastewater, of the optimal material and operating conditions. However, the application of adsorbent processes for water purification has some limitations which impact negatively on their efficiency.

The project aimed at the development of a generic electro-membrane reactor system for the desalination and disinfection that will find application at virtually all water related areas of the South African economy through the production of new types of electro-conductive membranes with optimal electrochemical properties. The overall idea was to develop a desalination unit that would work under low pressure without the need for additional chemicals for regeneration and which would at the same time have micro-filtration properties.

The main result of the project was that a novel type of purification unit was developed which is capable of removing both ionic species and micro-particles from aqueous solutions.

Due to problems experienced with the clogging of membrane pores during long-term experiments further

work will have to be done on the flow-through technology. The non-flow-through ceramic electro-sorption system is already being commercialised. At this point in time, there is no other known technology that is capable of doing all these in one step. There are, however, technical barriers to be overcome before ceramic membranes will be able to compete with polymeric membranes.

Cost: R874 000  
Term: 1998 - 2000

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

*Department of Biochemistry, Microbiology and Biotechnology, Rhodes University (WRC Reference No 972)*

The specific aims in this project were to elucidate the reaction mechanism involved in the biosulphidogenically-enhanced hydrolysis of complex substrates, to evaluate reactor design options for applying the enhanced hydrolysis reaction to the treatment of AMD, and to scale up the bidesalination process for technical-scale on-site evaluation at a mine.

Results from laboratory-scale recycling sludge bed reactors (RSBRs) confirmed that a complex carbon source such as primary sewage sludge (PSS) could be used as the electron donor to drive biological sulphate reduction and that the biosulphidogenic environment enhanced the rate of sludge hydrolysis, with smaller flocs than found in methanogenic reactors. A descriptive model of the enhanced sludge hydrolysis was developed and molecular biology techniques confirmed that the lignocellulosic component of PSS was being broken down. The study was progressively scaled up from 2l bioreactors to 10l and then to a technical-scale (23 m<sup>3</sup> reactor) pilot plant, installed at Grootvlei Mine and operated for over 12 months. Sulphate balances in the pilot-plant investigation showed that a minimum of 52% of the particulate carbon entering the reactor was solubilised to readily-available forms. This exceeds previously published values by over 60% and confirms the effectiveness of the RSBR design. Periodic sludge depth profiles showed that sludge accumulation within the RSBR was minimal.

Following on the insights from Project No 869, this study has increased the understanding of the mechanisms of the biosulphidogenic hydrolysis of complex organic carbon structures, and an effective reactor design has been developed and proven on a technical-scale pilot

plant. The results obtained demonstrate the feasibility of linking sewage sludge disposal to the treatment of acid mine drainage, and point to a range of potential applications which are being followed up on an ongoing basis.

Cost: R922 000  
Term: 1998 - 2001

#### **Applicability of waste minimisation clubs in South Africa: Pilot studies**

*Pollution Research Group, University of Natal (WRC Reference No 973)*

Within overall objectives of preserving and improving water quality by implementing cleaner production principles to prevent industrial water pollution and reduce industrial water demand at source, the main aim of this project was to contribute to the competitiveness of industrial small-, medium- and micro-enterprises (SMMEs) by developing the concept and establishment of waste minimisation clubs in the RSA for this vital economic sector. Linked aims were to promote waste minimisation, cleaner production, industrial energy efficiency and sustainable development among SMMEs, tertiary educational institutions, local authorities, government agencies and professional consultants.

The approach adopted was to establish, monitor and support two pilot waste minimisation clubs, one sectoral (metal finishing) and one regional (Hammarisdale). The results obtained show that both pilot clubs were very successful, in terms of the environmental improvements that members were able to make through participation in the project, the positive model that this provided for other resultant initiatives, and the lessons learned for further applications including success factors, barriers, the importance of training, data needs, and the achievable return on investment by the implementation of waste minimisation and cleaner production. These successes have led to more than 20 waste minimisation clubs subsequently being formed in the RSA by various industrial groupings.

The conclusion reached is that organisation of SMMEs into waste minimisation clubs has been shown to be a very successful mechanism for achieving improved environmental performance in this industrial sector, members of which do not have the financial or technical information, knowledge or resources to adequately address such issues. The project has had far-reaching impacts, including the stimulation of national policy to the extent that the formation of waste minimisation clubs has been adopted as part of the DWAF/ DEAT National Waste Management Strategy.

Cost: R1 062 000  
Term: 1998 - 2001

#### **Assessment and application of the latest technology available for the bioremediation of heavy metals**

*Centre for Wastewater Research, Technikon Natal (now merged with ML Sultan Technikon to form Durban Institute of Technology) (WRC Reference No 1083)*

In a previous WRC project (No. 688) carried out by the same research group, waste biomass materials were assessed for their potential for biosorbing heavy metals from wastewaters but it was concluded that the rates and capacities were too low for practical application. The aims of the current project were to evaluate commercially-available biosorbents to identify and select superior candidates for testing, including evaluation of suppliers' product claims by laboratory- and pilot-plant trials and analysis of economic viability for industrial application.

From comprehensive literature and patent searches, three biosorbents were selected and imported for test purposes. The biosorptive capacities of each for adsorbing metal ions from synthetic single metal and mixed metal solutions were assessed in batch experiments, from which affinity series of metals:biomass were quantified. The Langmuir equation was found to be the simplest monolayer adsorption model describing the type of bonding, but it was noted that other mechanisms of metal incorporation into the biomass, e.g. internalisation, could also be present.

Following on the laboratory-scale experiments, one potential application was tested in trials treating drag-out bath effluents from the metal finishing industry with varying nickel, chromium, copper and silver concentrations. *B. subtilis* and *Citrobacter* both showed 5 reproducible cycles for nickel removal before a decrease in uptake capacity was observed. *B. subtilis* did not remove chromium, copper and silver. *Citrobacter* spp. were able to remove chromium with markedly decreasing uptake in repeated cycles, and were unable to remove copper and silver.

To determine their economic feasibility, the cost of current treatment for the electroplating effluents tested was compared to that of the imported biotechnologies. Both start-up and operation of the imported technologies were found to be prohibitively expensive compared to current conventional treatment.

Cost: R350 000  
Term: 1999 - 2000 (Ext. 2001)

Development of integrated biosorption systems for the removal and/or recovery of heavy metals from mining and other industrial wastewaters, and determination of the toxicity of heavy metals to bioremediation processes

Department of Biochemistry, Microbiology and Biotechnology, Rhodes University  
(WRC Reference No 1243)

The objectives of this study were to:

- provide a cost-effective biotechnology for treating effluents containing heavy metals
- evaluate the potential toxicity of heavy metals to micro-organisms in bioremediation processes
- develop local expertise in this biotechnology
- transfer technology to collaborating industries.

Initial laboratory studies with the alga *Spirulina* spp. showed rapid metal binding, an affinity series of  $Pb > Cu > Zn > Fe$ , but a relatively low binding capacity compared to a range of other biosorbents. Treatment of an effluent from a base metal mine by direct contact with *Spirulina* cultures was effective for a period of time, but most of the metal removal could be attributed to alkaline precipitation resulting from the high carbonate content of the growth medium. Toxicity studies showed copper and zinc to be acutely toxic to *Spirulina*, with threshold toxicity levels of  $< 10 \mu\text{moles metal}\cdot\text{g}^{-1}$  of biomass. Lead was less toxic but induced considerable changes in cell morphology. Overall, *Spirulina* was concluded to be unsuitable for application in a treatment system involving direct contact with toxic metals.

Pilot-plant studies were subsequently undertaken to investigate the potential of an integrated biological system for treating acid mine drainage. A system using *Oscillatoria* was operated for 90 days without a loss of efficiency. The anaerobic digester component was able to consistently generate bicarbonate at a rate of  $4\ 200 \mu\text{moles}\cdot\text{L}^{-1}\cdot\text{d}^{-1}$ . Over 99% of copper and lead was consistently precipitated using hydrogen sulphide gas. By blending the hydrogen-sulphide-treated acid mine drainage with the algal overflow at an acidity:alkalinity ratio of 1:2 all the heavy metals (except Mn) were precipitated to concentrations below acceptable environmental risk levels. The biosorption system effectively removed heavy metals from an effluent similar to that being discharged from the East Rand Basin, at an estimated cost considerably lower than that of a physico-chemical system.

Cost: R97 000  
Term: 2001

### Programme 5: Training in wastewater treatment plant operation

Course development for the education and training of industrial wastewater treatment plant operators and managers

Department of Biochemistry, Microbiology and Biotechnology, Rhodes University  
(WRC Reference No 657)

Some 4 000 employees in the water and wastewater industry have little formal education and training and need competency-building in order to properly manage some 2 600 works in South Africa (WRC Report No. KV 35/92). The aim of this project was to develop structured courses for the education and vocational training of industrial wastewater treatment plant operators and managers. Operators' courses would focus on hands-on aspects of plant operation and would include adult literacy (ABET) as required, while the managers' courses would include both theoretical and practical aspects at a more advanced level requiring matriculation-level mathematics and science and resulting in a National Certificate Qualification.

In progress reports in 1995 and 1996, first drafts of 6 course modules were presented covering the Introduction; the Hydrological Cycle in the Environment; Water Chemistry and Biology; Industrial Water Auditing; Environmental Standards and Regulations; and Treatment Options. A draft final report presented in 1997 included two further modules: *Wastewater Treatment: Understanding Biofiltration* and *ABET Level 3: Numeracy, Integrated Science, Water for Life*. Testing of these modules on learners and interested parties revealed that a suitable interactive electronic distance-learning delivery mechanism was required to cater for a lack of infrastructure in many industries (private and public). A follow-on WRC project (No 941) addressed this aspect as well as generating further course material to provide a complete, combined package of coursework plus delivery mechanism.

LIRI was unfortunately liquidated commencing 31/12/99 and the (unrevised) draft final report for Project No 657, along with the course modules developed (electronic and hard copies), have been accepted for closure of Project No 657, without publication of a final report but leaving open the possibility of using the course material on another basis.

Cost: R140 000  
Term: 1995 - 1996

Operation and monitoring of the WRC/LIRI wastewater treatment pilot plant for industrial effluent research and the training of wastewater treatment personnel

LIRI Technologies  
(WRC Reference No 826)

This follow-on to Project No 457 aimed at continued monitoring of the tannery wastewater treatment pilot plant at LIRI, evaluating high-rate algal ponding (HRAP) as a tertiary treatment option, and extending the use of the plant for training wastewater treatment personnel from industry.

Pretreatment of the wastewater consisted of segregating alkaline sulphidic unhairing and acidic chrome liquors in the tannery, precipitating chrome with magnesium oxide to  $< 10 \text{ mg/L}$ , air-oxidising sulphide to  $< 10 \text{ mg/L}$  and maintaining aerobic conditions after the mixing of the pretreated sulphide and chrome streams to reduce odour to below olfactory nuisance levels. The combined pretreated effluent passed to an oxidation ditch and then to biofiltration. Overall reductions of  $> 90\%$  COD and SS were obtained. Nitrogen removal was less satisfactory (53% TKN reduction), thought to be due to slow nitrification and denitrification kinetics aggravated by low operating temperatures (10 to  $12^\circ\text{C}$ ) in winter. In 1997 the pilot plant was extended by adding a double-deck algal reactor with an anaerobic lower section and an aerobic algal upper section. The unit was fed initially with oxidation ditch effluent and then with pretreated tannery effluent in parallel with the oxidation ditch. Preliminary results obtained were promising, with large quantities of algal biomass being produced.

The pilot plant was used as a demonstration and training facility in a number of courses conducted by LIRI in 1997 to 1998 for industry management personnel (legislation, discharge standards, odour control, water use, sludge management), operating personnel (primary and secondary treatment processes), leather technicians (effect of processing changes on effluent quality) and post-graduate students (process principles).

Subsequently, LIRI was liquidated in 1999, and it was concluded from discussions that there was no cost-effective way of producing an acceptable final report (the project funds were fully disbursed between 1997 and 1998) and that the project should be terminated without such publication.

Cost: R350 300  
Term: 1997 - 1998

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

LIRI Technologies  
(WRC Reference No 941)

The project objective was to structure an education- and training-based career path for the development of human resources in the wastewater treatment industry, from operational through to managerial levels of qualification. The core delivery mechanism to be developed was an electronic distance-learning technology (CYBERTUT) meeting the education and training needs of the widely-spread wastewater treatment industry. Following on WRC Project No 657, further course material would be developed for this purpose and the performance of learners would be evaluated as feedback to both the course content and the electronic delivery process.

Good progress was reported in 1998 and 1999 in respect of the electronic delivery system (early bandwidth limitations in the RSA were overcome using pre-recorded electronic slide shows for tuition sessions), development of course material (by 1999 seven modules were in trial use, covering the water environment, pretreatment technology, the activated sludge process, biofiltration, anaerobic digestion, tannery wastewater treatment and wastewater analysis) and student participation (8 learners in 1998 and 14 in 1999, ranging from N1 to N3). Planned developments for 1999 to 2000 in the work programme were improvements to the electronic delivery system, course modules on environmental management and small-scale domestic sewage plants, exporting to other African countries as Internet networks improved (UNIDO had already commissioned one course for Zimbabwe), and accreditation for certification of the course through SETA.

The project was abruptly cut short in December 1999 with the liquidation of LIRI. It was unfortunately discovered thereafter that both the course material and the distance-learning CYBERTUT delivery system which had been electronically stored at LIRI had been irretrievably lost during the course of this liquidation. It was reluctantly accepted that the project be terminated without publication of a final report as there was no realistic cost-effective prospect of regaining the anticipated project outputs.

Cost: R432 000  
(less unspent balance of R142 000)  
Term: 1998 - 2000

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

Leather Industries Research Institute (LIRI)  
(WRC Reference No 1085)

This follow-on to WRC Project Nos 457 and 826 aimed to continue the operation and monitoring of the WRC/LIRI pilot plant, specifically to further research and develop the anaerobic/algal double-deck reactor (AIPS-COMBI) both as a stand-alone process and in combination with other unit processes; to assess the effect of various tanning chemicals on the performance of the wastewater treatment plant; and to continue training of students, wastewater treatment plant operators and management personnel.

At the inaugural steering committee meeting held on 29/06/99 a comprehensive set of pilot-plant analytical and operating data for the period January-June 1999 were presented and the project was on target to meet the project objectives as set out in the project proposal. Commencing 31/12/99, however, LIRI was liquidated and there was no prospect of continuing the project as the supply of tannery effluent had ceased. The project has therefore been terminated without publication of a final report.

Cost: R420 000  
(less unspent balance of R265 450)  
Term: 1999 - 2001

### Thrust 4: Industrial and Mine-Water Management

#### Programme 2: Regulatory mechanisms to improve industrial and mine-water management

The review of industrial effluent tariff structures in South Africa and guidelines on the formulation of an equitable effluent tariff structure

Des Kerdachi Consultancy  
(WRC Reference No 854)

Industrial effluent tariffs in South Africa are characterised by a wide variety of formulae that have been illogically designed, and have no sound financial and technical basis. A correct formulation will allow for an equitable proportion of finance to be derived from industry for the services provided. These services are the acceptance, conveyance and treatment of industrial

effluent. Such a formulation must lend itself to application in any size town or metropolitan area so that transparency, equity, and sustainability are prevalent.

The main objectives of the project were as follows:

- Produce guidelines on the formulation of an equitable industrial effluent tariff structure applicable on a national scale
- Provide a sound, rational basis for the essential elements that contribute to or influence the compilation of an industrial effluent formula
- Simplify current systems in use in order that they are easily understood and can be administered without much difficulty.

Ten local authorities were chosen throughout South Africa on the basis of their variation in size, industrial activities, known availability of reliable analytical, operational, and industrial effluent data and records. Some of the ten local authorities (e.g. Durban Metropolitan Council, Greater Johannesburg Metro Council, Cape Town Metropolitan Council) consisted of large operational areas with many wastewater treatment facilities included within their boundaries. Within these integrated schemes, there were areas of overloaded treatment facilities with substantial industrial effluent contributions while within the same areas of jurisdiction there were areas of "low key" industrial activity.

The methodology used to obtain data that would allow for an appraisal and evaluation of industrial effluent tariff structures in South Africa, was to provide a checklist of information required, viz. operational, financial, industrial and legislative. This was combined with a personal site visit to enable explanatory discussions and verbal interaction with senior personnel involved in the subject matter. Additional meetings were also held with senior staff from the service providers Umgeni Water, East Rand Water Care Company (ERWAT), and East Gauteng Services Council (EGSC).

The findings of the report are presented in three parts: The overview sketches the background to industrial effluent tariffs in South Africa. An outline is provided on the relevant principles, impacting legislation, water quality standards and formulae fundamentals that form the basis for the Guidelines presented in Part III. This section also introduces the reader to GAMAP (generally accepted municipal accounting practices) and the application of depreciation in the calculation of effluent tariff charges. Its use to establish a cash reserve fund and to obtain a return on assets is unique in a municipal context. The review presents the results and interpretations of the processed data extracted from the

checklist. The information has been presented in a manner that allows for meaningful comparisons to be made between local authorities of different size.

The guidelines take cognizance of all the principles outlined in Part 1. This information is used to present a systematic methodology to derive an equitable effluent tariff structure that can be applied anywhere.

Basic principles and potential benefits of an equitable industrial effluent tariff formula are detailed, as well as a brief reference to the legislative basis for effluent treatment cost-recovery. Definitions of the terms used are carefully delineated to ensure that there is clarity in understanding all of the components involved. It is recommended that only effluents of significant volume and load should be sampled. However, a minimum charge based on the fixed costs as defined is applicable to everyone that discharges to the sewer provided that the effluent is classified as an industrial effluent by definition.

The unique features of the recommended tariff structure are the emphasis on full cost-recovery, combined with a reasonable return on assets; the utilisation of depreciation to achieve these benefits; the use of variable and fixed-cost apportioning of the O&M expenditure and the combination of the liquid and solid phase operating expenditure into one treatment component

The project has indicated that there is a definite need for more internal communication and liaison between the different departments within a local authority involved in such a multidisciplinary subject as industrial effluent tariffs. The abundance of accumulated data, and the observed wealth of specific expertise within different departments/sections of the organisations concerned could be more effectively utilised if a co-ordinated approach was used.

Cost: R175 000  
Term: 1997 - 2000

#### Programme 3: Minimising the impact of waste on the water environment

A guideline for the development of rehabilitation management strategies for reclaimed gold-mine dump sites in South Africa

Pulles, Howard and de Lange Inc.  
(WRC Reference No 1001)

An earlier preliminary assessment of pollution contained in the unsaturated and saturated zones beneath

reclaimed gold-mine dumps, indicated that this pollution can have a significant negative environmental impact on the underlying vadose zone and subsequently the groundwater system. This study identified five alternative rehabilitation strategies to deal with this pollution and modelled their expected impact at three study sites. The strategies were found to represent mainly two opposing alternatives, i.e. those that result in the pollutant remaining within the confines of the residue deposit area, and those in which the pollutants are transported to the deeper aquifer, away from the source. The preferred management option would thus depend on whether containment or dilution and migration of pollutants would be the desired option. The problems associated with reclaimed mine-residue deposits were also assessed by evaluating the various risks that are associated with the source of contamination, the pathway it would follow and the receptor that would be adversely affected by the contaminated substance. Site-specific variation in physical characteristics was found to have a marked influence on the resultant risk assigned to individual aspects. The introduction of a risk assessment approach, a phased and chemically orientated approach to site investigation, and the selection of remediating strategies from a number of technologies, were identified as intrinsic components of the rehabilitation process. This would require that rehabilitation be conducted on a site-specific basis. The basic methodology for this approach is outlined in a companion document to the project report.

Cost: R595 000  
Term: 1999 - 2001

#### Programme 5: Improved ability to predict and quantify effects

On-site and laboratory investigations of spoil in open-cast collieries and the development of acid-base accounting procedures

Institute for Groundwater Studies, University of the Free State  
(WRC Reference No 1055)

Current predictions suggest that most South African collieries will at some stage in future decant acid water. This will have a serious impact on aquatic life in streams and other water users. Results from the many methods that are used internationally to predict the production of acid mine drainage, do not agree. This project expanded on its aim to investigate the various acid-base accounting (ABA) procedures (which are used as a first-order classification procedure for predicting whether mine decant water will turn acidic) to include a range of complementary predictive techniques and evaluate them

under field conditions. The result was the description of a suite of acid-drainage prediction tools, applicable to South African open-cast coal-mine conditions and the coining of a new acronym, ABATE (derived from Acid-Base Accounting, Techniques and Evaluation), to describe this approach, that in addition to static ABA techniques, include long-term kinetic testing and geochemical modelling. Through a workshop held to involve the leading consultants and regulating authorities, consensus was obtained concerning the tests to include in the ABATE system and their standardisation.

Cost: R866 000  
Term: 1999 - 2000

## CURRENT

### Thrust 1: Water Services - Institutional and Management Issues

#### Programme 1: Cost-recovery in water services

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

Mvula Trust  
(WRC Reference No 886)

The operation and maintenance requirements for rural community water supply schemes 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. This project is to determine the factors which constitute the monthly running costs of rural water supply schemes that are necessary to ensure sustainable operation and maintenance.

This study is also developing a financial framework that will provide planners and water service institutions with guidelines on basic monthly running costs for these schemes.

Estimated cost: R378 000  
Expected term: 1998 - 2001

**Identifying examples of successful cost-recovery approaches in low income, urban and peri-urban areas**  
*Sigodi Marah Martin Development Consultants*  
(WRC Reference No 1131)

In spite of a high level of publicity and political attention, the Masakhane campaign is perceived to have met with very limited success. Opinions vary on the cause of this, and although some work has been done in the field, the problem has not received the consistent, detailed study, that a matter of this importance deserves. In particular insufficient attention has been paid to the factors which generate success. This research is providing an opportunity to study these issues in depth. In particular, by concentrating on the successful models it will enable stakeholders to understand the role that the factors of political pressure, of administrative methods, of billing and collection systems, sanctions and community values will play in these issues. This study is expected to result in important gains in respect of understanding this problem, which can be translated into higher levels of payment and an increase in the level of development for the disadvantaged members of society. The outputs of this study are of relevance to the concept of customer management and complement the WRC study on customer management.

Estimated cost: R438 000  
Expected term: 2000 - 2001

**Institutional and social economic review of the use/application of electronic prepaid meter technology in the provision of water supply services to urban and peri-urban areas**

*Sigodi Marah Martin Development Consultants*  
(WRC Reference No 1206)

The use of prepaid meter technology in water supply management is beginning to gain greater emphasis after its initial application achieved limited success. This could be attributed to the quick-fix approach adopted for the sole purpose of cost-recovery during a period when the technology was not properly tested and experienced many technical teething problems. The problems were compounded by lack of community education and understanding and more important, the high cost of the technology.

This situation created a great deal of uncertainty in many water suppliers regarding the use of the technology, stating the lack of knowledge around the institutional requirements and other support mechanisms required to sustainably support the technology as the main reasons. The objective of this study is not specifically to look at technical issues, but to

look at the important services issues that make water services provision sustainable. Of importance is that the outputs will contribute towards development of policy and guidelines in the use of prepaid systems for provision of water supply services.

Estimated cost: R375 500  
Expected term: 2001 - 2002

**A cost-recovery analysis of the trickle feed rural community water supply system**

*Lenehan Engineers and Environmental Consulting*  
(WRC Reference No 1272)

This research will investigate the cost-recovery efficiency of the trickle feed system. In this system a known quantity of water is delivered each day to a storage tank at each customer's house. This allows the implementation of a monthly prepaid cost-recovery system with relatively low administration. The Mvula Trust has identified the potential benefits of implementing the trickle feed system in rural areas. It is currently implementing trickle feed systems in pilot projects in Northern KwaZulu-Natal. Analysis of the cost-recovery efficiency of these projects will enable adequate assessment of this technology for future application. The main objectives of this research are to assess cost-recovery efficiency of trickle feed systems and to identify variables that affect cost-recovery in these systems.

Estimated cost: R176 500  
Expected term: 2001

#### Programme 2: Institutional and management issues - Water services

**Innovative partnership to improve water and sanitation services in deprived urban and peri-urban areas: KwaZulu-Natal pilot project, Inanda-Ntuzuma, Durban, Edendale, Pietermaritzburg**

*Durban Metro Water Services, Mvula Trust, Pietermaritzburg TLC, Compagnie Generale des Eaux, Umgeni Water*  
(WRC Reference No 1139)

The Business Partners for Development (BDP) project is an innovative approach and attempt to address water and sanitation issues in urban and peri-urban areas in developing countries. It is about bringing together private sector, public sector, non-governmental sector and civil society, towards addressing water and sanitation needs. The rationale is that sharing of experience and lessons between the Durban and Pietermaritzburg pilot projects will contribute towards

improved services delivery in the future. An important aspect is the capturing of lessons and experience on the partnership. The key aspect is supplemented by aspects that transform services delivery from a beneficiary/recipient approach to a customer approach, where the customer is part of the development process. The project is a learning and exploratory exercise and findings will provide answers to local, as well as global questions on how to provide services to poor urban areas and informal communities.

Estimated cost: R880 000  
Expected term: 2000 - 2001

**The preparation of a guideline for water services providers dealing with customer services issues**

*Umgeni Water*  
(WRC Reference No 1207)

Recent experiences internationally and locally emphasise the need for a customer focus in the provision of services. Moreover, related to water services provision, literature indicates the importance of this customer orientation is contributing to the sustainability of services. This recognition has also influenced much of the new water legislation and will become a requirement with the enactment of the Municipal Services Bill, whereby all municipalities will have to develop and demonstrate a customer management plan.

The fact that the concept of customer service has received little attention in South Africa is perhaps related to the historic situation where water supply and sanitation services were provided on a monopolistic take it or leave it basis, particularly in the case of poorer customers. It is now recognized increasingly that successful water services provision is strongly associated with the application of good business principles. This implies a service orientation, with a primary focus on the customer. It also implies a mutually beneficial relationship between customer and service provider where the customers must fulfil their responsibility to pay for the service. The aims of the project are:

- To assess international best practice with regard to customer service by water services providers.
- To undertake two case studies of water services providers in South Africa who are currently providing successful customer services locally.
- Based on local and international findings, to communicate the findings relating to customer services through a guideline and workshops for water services providers in South Africa.

Estimated cost: R370 000  
Expected term: 2001 - 2002

**Use of selected key performance indicators in the benchmarking of rural water supply schemes: An aid to development of meaningful local government capacity**  
*Partners in Development*  
(WRC Reference No 1222)

Since 1994, DWAF has spent large sums of money on training water committees to manage the new water supply schemes. As projects have moved into the operational phase, it has become apparent that training alone is not adequate to ensure proper management of water supply schemes. The new local authorities have limited knowledge on the nature of inspection needed to promote good management at community level. Therefore, the challenge is to develop simple and effective systems that are easily understood by water committees. These can be used to report to the community as well as to their local authority. This project will test a set of key performance indicators (KPIs) that have already been developed. These will be tested on a number of RDP projects that are presently being transferred from Umgeni Water to relevant district councils in KwaZulu-Natal.

*Estimated cost:* R271 000  
*Expected term:* 2001 - 2002

**Least-cost planning for the water services section in South Africa**

*Semanya Furumele Consulting*  
(WRC Reference No 1274)

As water shortages and needs increase, competition for water amongst all sectors (urban, rural, industrial and agricultural) will also become more intense. Increasing population and improving living standards have led to growing water demand and unfortunately to more pollution which effectively reduces availability of water. The environmental implications are also becoming more extreme owing to greater land-use changes and more extreme hydrological changes, possibly due to extreme climatic changes. Water conservation (WC), and water demand management (WDM) are no longer only options, but must be implemented immediately, especially in South Africa where the resource is not only scarce, but also limited.

In a scenario of rising cost, demand growth, resource constraints, financial constraints, environmental concerns, political and legal constraints, public scrutiny and accountability and advances in analytical capability, least-cost planning (LCP) is emerging as an indispensable tool to meet the prevailing challenges.

This study aims to:

- Explore the subject of LCP in general
- Review local and international LCP initiatives (methodology and processes)
- Identify constraints and opportunities of LCP in the water services sector
- Identify potential interaction of LCP with other planning practices and protocols
- Overview the water services and institutions in South Africa
- Develop framework for implementing LCP in South Africa
- Illustrate the potential of LCP through a case study in Gauteng
- Explore a computer model for LCP in the water services sector.

*Estimated cost:* R200 000  
*Expected term:* 2001 - 2002

**Programme 3: Innovative management arrangements - Rural water supply**

**Assessing the impact of gender in water and sanitation provision and maintenance**  
*Networks for Development*  
(WRC Reference No 1087)

Water supply and sanitation projects are implemented as community projects; therefore, for the projects to be successful, both men and women should participate at all stages of the project planning and implementation process. This study assesses the impact of gender in water and sanitation services provision and maintenance. The findings of this assessment are being used to develop gender-sensitive approaches that would ensure effective participation of both men and women in water supply and sanitation projects. This study together with a project focusing on policy dimension of gender participation in water supply and sanitation projects are contributing to the achievement of a gender-balanced approach within the water sector.

*Estimated cost:* R150 000  
*Expected term:* 1999 - 2001

**Development of a methodology and guidelines for the design of community-based O&M systems based on local capacity and practice**  
*Mvula Trust*  
(WRC Reference No 1130)

Evaluation studies of new water projects show that poor operation and maintenance (O&M) of water supply schemes is responsible for the high failure rate of water projects. These studies have also shown that the O&M

systems that were implemented were generally unresponsive to user needs. This highlights the importance of basing the development of O&M guidelines on local knowledge. This study explores different methods that communities have used to manage their water supply schemes prior to the implementation of new water projects. This study is also documenting local knowledge and experience that would form a basis for the development of O&M guidelines.

*Estimated cost:* R546 000  
*Expected term:* 2000 - 2001

**Programme 5: Peri-urban sanitation research**

**Pilot initiative to implement shallow sewerage technology in Durban**  
*Durban Metro Services*  
(WRC Ref No 1146)

Sanitation, because of the major impact it has on health and quality of life, is a service with a high priority. The level at which such sanitation services are provided, and the arrangements for implementing the associated projects, are possibly the most debated and contentious issues in the field of urban service provision. Findings from a previous WRC study indicated that shallow sewer systems provide a viable intermediate sanitation alternative, with a total cost between Ventilated Improved Pitlatrines (VIPs) and conventional sewerage. With this as a stimulus, the Durban Metro Water was the first local authority to indicate interest in taking the recommendations further. This study is a partnership between the WRC, Durban Metro Water Services and Water Supply and Sanitation Services (WSSA) in an initiative to pilot and test the technology local.

*Estimated cost:* R600 000  
*Expected term:* 2000 - 2001

**Towards policy, strategy and detailed procedures for the provision of sanitation to low income settlements in Johannesburg**  
*Johannesburg Water (Pty) Ltd*  
(WRC Reference No 1192)

A Sanitation Policy and detailed procedures in the form of a Sanitation Protocol for the provision of sanitation to low-income settlements were developed for Greater Johannesburg Metropolitan Council (GJMC) - now City of Johannesburg (CoJ) - under an earlier research project (GJMC, 2000a; Pegram et al., 2000) by Pula Strategic Resource Management (Pty) Ltd, with funding from the Eastern Metropolitan Local Council (EMLC)

and the British Department for International Development Southern Africa (DFIDSA). The project was completed in early 2000, but due to political factors within GJMC during local government elections in December 2000, the process of establishing the Sanitation Policy and Protocol was temporarily suspended, and the Policy and Protocol were never formally accepted by GJMC. Subsequent to these events, the institutional environment has changed very substantially, and a very different institutional arrangement is now in place.

The aim of this research project has been to review the Sanitation Policy and Protocol for appropriateness for use in CoJ as well as for more generic use in the urban and peri-urban areas of South Africa, in the light of developments in the intervening period since they were developed. The review has in fact been extended to take in a range of other policy and protocol documents that have been developed in this period. The intention is that this review should provide a basis for discussion of Johannesburg's policy, strategy and detailed procedures, as well as those of other local authorities.

*Estimated cost:* R150 000  
*Expected term:* 2000 - 2002

**Sanitation demand and delivery in informal settlements**  
*Peninsula Technikon*  
(WRC Reference No 1280)

This research project aims to broaden the benefits that may be derived from a particular project that is currently being implemented in informal settlements in Khayelitsha. The purpose is to derive added value from the project experience by means of rigorous research for evaluative purposes. The research approach and methodology are to develop a substantial research product from in-depth examination of each key component of sanitation delivery, so that the lessons may be applied by local authorities, both locally and more widely.

The research methodology is based on action research, as appropriate for the adopted project-based learning approach. Qualitative research is appropriate to the scope of the initiative, which spans across the perspectives of sanitation role-players, and is based on their active participation in investigation and reflection. Quantitative data will be utilised to complement the investigation and its outcomes.

Aims:

- Community demand: Draw lessons from the collaborative and participatory approach and the

creation of community demand for sanitation and hygiene awareness.

- Service provider protocol: Investigate the institutional, technical, social and financial aspects of developing a sanitation protocol guiding sanitation options for local authorities in peri-urban areas, based on evaluation of the current approach in relation to broader experience;
- Community response to delivery: Evaluate the factors influencing sustainability of sanitation services, in terms of approach to delivery and options, by taking community responses and roles into account.

Estimated cost: R250 000  
Expected term: 2002

## Thrust 2: Water Supply and Treatment Technology

### Programme 1: Drinking water treatment technology

#### Designed functionalised polymers by anionic macromolecular engineering for membrane development

Department of Chemistry, Vista University (Port Elizabeth Campus)  
(WRC Reference No 723)

Fouling of membranes remains the biggest obstacle to the widespread use of membranes for water and wastewater purification. Fouling is to a large extent caused by the hydrophobic nature of the membrane materials, leading to the attraction of fouling components in the water with concomitant fouling of the membrane surface and lowering of permeate production. In order to render the locally developed ultrafiltration membranes less fouling, the surface of the membrane has to be made more hydrophilic.

The project aims are the following:

- The synthesis of novel functionalised polymers and graft copolymers based on commercially available polysulphone.
- Evaluation of these functionalised polysulphone derivatives and graft copolymers in terms of their non-fouling properties as separation membranes.

Hydrophilic surface active groups have been grafted onto the membrane surface in a patented process and initial studies show that a significant improvement in hydrophilicity could be achieved.

Estimated cost: R476 335  
Expected term: 1995 - 2001

#### Development and implementation of gas and liquid chromatographic organic water profiles as a management tool

Scientific Services, Rand Water  
(WRC Reference No 831)

Tastes and odours and organic micropollutants are major concerns in organic drinking water quality. The analysis of individual organic compounds is time-consuming, labour-intensive and generally very expensive - there are too many compounds. Numerous separation, concentration and extraction techniques have been developed and the resin-based techniques seem to have the largest and the most flexible bandwidth. To identify the components of a complex mixture, the GC and HPLC are the most versatile and general. Current methods such as those by Van Rensburg, who developed an Organic Pollution Index, have certain drawbacks such as lengthy extraction procedures that are prone to errors. Development of this technique will therefore involve improvements in three areas:

- Preconcentration technique
- Chromatography to encompass a GC analysis phase and an HPLC analysis phase
- Analysis to use neural networks to establish the definition of the profiles.

Hence the research aims are to:

- Enlarge and develop GC and HPLC methods to determine the organic profiles and fingerprints of the volatile fractions in both source and drinking water
- Monitor differences in the sample profiles and group major troublesome compounds
- Formulate guidelines, removal efficiencies and cost of the different treatment processes.

On distribution of the technology of the completed project, other water suppliers can obtain profiles of their particular water supply that can, in time, be networked / analysed to give an overall picture.

Estimated cost: R551 000  
Expected term: 1997 - 1999

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

Department of Civil Engineering, University of Natal and Scientific Services, Umgeni Water  
(WRC Reference No 919)

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 backwashing 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; and
- 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

Scientific Services, Rand Water  
(WRC Reference No 920)

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

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

Chris Swartz Engineering  
(WRC Reference No 924)

The Cape coloured waters are known to have considerably high colour levels, and this is due to high natural organic matter. This project aims to characterise the natural organic matter in South Africa and to develop operational coagulation diagrams for the removal of the organic matter in order to improve the effectiveness and cost-efficiency of treatment of these coloured waters. Finally it will draft guidelines on the treatment of South African coloured surface waters.

Estimated cost: R317 000  
Expected term: 1998 - 2001

#### Modelling of flocculation, thickening and sedimentation in water treatment

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

South Africa is a semi-arid country running out of water for all its needs. The problem of decreasing availability and increasing cost of water can be addressed in a number of ways. The first order of priority should be to make the best possible use of what is available, i.e. to effect a significant saving in water consumption. One method to attain this is to optimise water treatment processes. A significant loss of water occurs during treatment due to inefficiencies in the sedimentation/clarification and filtration processes. The reason

for the losses in the sedimentation process is the lack of a comprehensive understanding and model of the process itself that can be used to optimise design and operation. Availability of such a tool will improve the technique considerably.

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

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

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

Estimated cost: R269 000  
Expected term: 1999 - 2001

#### Microbiological assessment of membrane technology in water treatment

Biological Sciences, ML Sultan Technikon  
(WRC Reference No 1034)

Membrane technology potentially offers the water industry a barrier to secure compliance with standards that are being recommended world-wide. The Institute for Polymer Science, University of Stellenbosch, has developed low-cost capillary membranes which show great potential for the treatment of potable water. This technology has a tremendous potential for small-scale

potable water production, particularly in developing countries. To complement this technology, simple, reliable methods to test and set microbiological performance criteria of these membranes are needed. In this project the integrity of locally manufactured membranes is being evaluated for the rejection of micro-organisms in potable water production for small communities. A protocol for the correct operation to safeguard end water supply in terms of microbiological quality is also being compiled.

Estimated cost: R683 000  
Expected term: 1999 - 2001

#### Support, maintenance and debugging of WATREX - Expert system for water treatment plant design

Sutherland Associates  
(WRC Reference No 1041)

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

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

Estimated cost: R84 000  
Expected term: 1999

#### Development and evaluation of new South African ozoniser technology for removal of pathogenic organisms, possible enteric viruses indicated by bacteriophages, and tastes and odours present in Hartbeespoort Dam water

PARC Scientific  
(WRC Reference No 1127)

Ozone is recognised as very effective in the removal of pathogenic organisms, enteric bacteriophages, tastes and odours from eutrophic waters. This project is aimed at developing an optimised, energy-efficient, modular power supply compatible with a recently developed ozone generator. It will further establish the operational parameters and design a full-scale ozonation system. This will result in a cheaper, but more efficient ozonation system.

Expected cost: R 398 000  
Estimated term: 2000 - 2001

#### Development of guidelines for the disposal of water treatment sludges to land

School of Applied Environmental Sciences, University of Natal  
(WRC Reference No 1148)

South Africa's turbid waters give rise to the production of huge quantities of sludge during the water treatment process. Chemical precipitants are added to the turbid waters to promote flocculation. Once flocculated, the solid fraction that settles under gravity is transferred to drying beds, while the supernatant is filtered and clarified for domestic consumption. The dewatered solids (sludges) are regarded as industrial wastes and must be disposed of accordingly. The traditional method of sludge disposal has been by landfilling, but given the economic constraints associated with landfill maintenance, alternative methods of sludge disposal have to be considered. A disposal option that is gaining increased acceptance internationally is the application of sludge directly onto land.

Land disposal is based upon the fundamental tenet that the physical, chemical and biological properties of the soil can be used to digest the applied waste without inducing negative effects on soil quality, groundwater or plant growth. Sludge could have two opposing physical effects on soils, viz. the polyelectrolyte could improve soil structure, or the fine silt and clay could lead to structural degradation. Chemically, the behaviour of heavy metals and the high phosphorus-fixing ability of the sludge also give rise for concern. These concerns will be evaluated as part of this project.

Estimated cost: R650 000  
Expected term: 2000 - 2002

#### Alternative approaches for sustainable water supply schemes

Options to Solutions  
(WRC Reference No 1223)

There is a need to be more creative in approaching the delivery of water services so that delivery encompasses the holistic objectives of ensuring sustainability. There are various options that could be explored, and this project is doing that. It reviews the different approaches that have the potential to render water supply schemes sustainable.

Further, it carries out specific technical and economic analyses on identified projects representing an individual approach and will finally develop and disseminate the demand-led planning tool (guideline) that will promote and support a technically viable approach, integrating rural water supply with community activities.

Estimated cost: R496 100  
Expected term: 2001 - 2003

#### Ultraviolet light in combination with cavitation flow

Rand Water  
(WRC Reference No 1224)

Infections by protozoa, specifically *Giardia lamblia* and *Cryptosporidium parvum*, are now accepted as common world-wide causes of acute, self-limiting diarrhoeal disease in the human host. This project is looking at the use of UV light alone or in combination with either/or low cavitation and ultrasonic treatment to destroy protozoan cysts or oocysts in water. It is seeking to establish minimum energy input required and to design the ultraviolet light treatment system.

Estimated cost: R300 000  
Expected term: 2001

#### Coagulation and cationic polymers

Umgeni Water  
(WRC Reference No 1225)

Coagulation is an essential part of water treatment, playing a role in the overall separation of solids and liquids and providing a primary barrier against water-borne diseases. Despite the advantages of using polyelectrolytes as coagulants, no method exists on which to base selection, and many of the chemical reactions which take place when polyelectrolytes are added to water, are not well elucidated. This project will

characterise these reactions and aims to determine the effect of natural organic matter. It will further develop procedures and tests to enable accurate and easy selection of polyelectrolyte coagulant type and dose for a particular type of water.

Estimated cost: R 204 000  
Expected term: 2001 - 2002

## **Programme 2: Water treatment for rural communities**

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

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

A commercialisable small membrane treatment unit is being designed and evaluated for cost-effective treatment of contaminated surface waters for the supply of potable water to small communities. Since membranes present a positive barrier to micro-organisms, require no or little chemical addition and need very little maintenance, such plants are attractive for the supply of point-of-use potable water to small communities.

Estimated cost: R630 000  
Expected term: 1999 - 2001

### **Small water treatment systems: A case for development of an approval/certification system**

Options to Solutions  
(WRC Reference No 1125)

The supply of clean, safe drinking water in rural South Africa has been largely hampered by failures of small treatment systems. This project is aimed at building a case for an appropriate pre-approval/ certification/ evaluation system which when adopted will drastically increase the treatment system's predictable mean time before failure.

Estimated cost: R 290 000  
Expected term: 2000 - 2001

### **Design manual for small water treatment plants for rural communities with specific emphasis on community involvement and the use of indigenous treatment technologies**

Chris Swartz Engineering  
(WRC Reference No 1185)

A large number of small water treatment systems installed in South Africa are subject to failure during their lifetime. According to feedback at a recent conference held in East London (Appropriate Practice Conference, March 1999), of a number of more than 50 small treatment systems that were installed in Southern Africa, only a small percentage are performing according to the requirements and can be considered to be successful water supply projects. This implies that a failure to gain the support and participation of the communities during the initial stages of successful water supply projects may result in failure of the system. It is of utmost importance that the communities accept the technology and that the technology should work for the community. A number of guideline documents have been drawn up about various aspects of rural water supply, and on the different technologies used in rural water treatment plants (WRC Report Nos. 231/1/93, KV 58/94, TT 68/95, 449/1/95, 450/1/97, and 354/1/97; various Technical Guides by the CSIR Division of Water Technology). However, none of these guides specifically address the pitfalls that should be guarded against when designing small treatment systems, and which often lead to failure. There is, therefore, a need for a comprehensive design manual for small rural water treatment plants, which specifically identifies pitfalls to be avoided in the design of these plants, and which contains the very important guidelines on how to obtain community support and participation in the project. Because many of the treatment systems designed by engineers for rural applications are over-designed or inappropriate (too sophisticated; community does not accept the technology), the aim is also to provide guidelines on how the "simpler" and indigenous technologies can be used to ensure community participation, cost reduction and sustainability of the systems.

Estimated cost: R95 000  
Expected term: 2000

### **Technical and social acceptance evaluation of a novel microfiltration and ultrafiltration membrane system for potable water supply to rural and remote communities**

Chris Swartz Water Utilization Engineers  
(WRC Reference No 1227)

The project entails the evaluation of locally developed membrane systems for the production of potable water for small communities from a variety of surface water qualities found in South Africa. The evaluation will be performed using both ultrafiltration and microfiltration mobile treatment systems. Guidelines for the application of these membrane systems to specific surface water qualities will be drafted. The project scope includes operational guidelines for potential users as well as the establishment of social acceptance factors of the technology with rural communities.

Estimated cost: R556 000  
Expected term: 2001 - 2004

### **Guidebook for alternative small-scale desalination technologies for potable household water augmentation in South Africa**

Institute for Polymer Science, University of Stellenbosch  
(WRC Reference No 1228)

This project aims to evaluate small-scale water purification technologies for potable water supply to farms, schools, clinics and small communities from brackish surface water sources. The report will be produced in the form of a guide to assist decision makers in the selection of these technologies. Both membrane-and distillation-based technologies are being assessed, mostly in terms of a desk study. Recently developed local innovations will be included into this guide.

Estimated cost: R215 000  
Expected term: 2001 - 2003

### **Treatment of rural groundwater for potable use**

Department of Chemistry, Potchefstroom University for CHE  
(WRC Reference No 1230)

High nitrate concentrations are prevalent in groundwater from various parts of the country. High nitrate-containing groundwater which is consumed by babies can lead to a blood illness methemoglobinaemia, or so-called "blue baby" syndrome. This project aims to evaluate various nanofiltration membranes for the removal of nitrates (and other unwanted salts, such as sulphates and bromides) from groundwater used for community water supplies in the North West Province.

Estimated cost: R178 000  
Expected term: 2001 - 2002

### **Removal of fluoride from drinking water**

Department of Civil Engineering, Rand Afrikaans University  
(WRC Reference No 1289)

The deleterious health effects of excessive fluoride are well known. However, fluoride removal methods are difficult to implement due to cost and complexity. Currently, the most promising development is a simple domestic unit containing brick fragments as adsorption medium. This project is currently seeking to understand the fundamental mechanisms whereby fluoride is adsorbed onto baked clay and how it is affected by the firing temperature. It will also demonstrate the feasibility of a clay-based domestic fluoride removal unit in a rural village currently plagued by excessively high levels of fluoride in its drinking water.

Estimated cost: R 495 000  
Expected term: 2001 - 2003

## **Programme 3 : Drinking water quality**

### **Systems for the abstraction of surface water through river sand-beds**

Chunnett, Fourie and Partners (CE)  
(WRC Reference No 829)

A number of areas in South Africa have river waters with high sediment load or turbidity. Numerous problems are associated with the storage, abstraction and treatment of such waters, including:

- Accumulation of sediments in instream reservoirs, off-take structures and raw water pump sumps
- Rapid wear of raw water pumps and higher cost of chemicals for flocculation
- Lower capacity of water treatment plants due to more time required for flocculation, sedimentation and filtration
- More regular cleaning of sedimentation tanks, filters and higher water loss.

If water is abstracted through a river sand-bed as opposed to being abstracted directly from the river, the sand can act as a natural filter and raw water with low turbidity can be supplied to water treatment plants. Many of the above-mentioned problems associated with high sediment-load waters could be drastically reduced. An earlier study demonstrated that the use of such alternative systems could result in savings of up to R8.5 m. over a period of 20 years. The aims of this new project are to:

- Establish a directory of systems in South Africa that were designed and constructed for the purpose of abstracting surface water from sand-beds
- Determine whether there is a correlation between low yield of abstraction system and factors such as design, method of construction, geology, surface water quality and total bacterial count
- Establish guidelines for the design, construction and operation of river sand-bed abstraction systems, based on information obtained from the survey of the abstraction systems and from an in-depth case study.

*Estimated cost:* R449 000  
*Expected term:* 1997 - 1999

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

*Scientific Services, Rand Water  
(WRC Reference No 1028)*

When cases of diarrhoea occur in the community the public is often very quick to blame the water. Confidence in the quality of the water can then only be restored if this accusation has been investigated to the satisfaction of the public. This project is developing a handbook that provides practical guidelines on how to conduct such an investigation. This book will pull together the relevant methodology (from traditionally remote disciplines) required to find out whether cases of diarrhoea could be due to water consumption. The target audience for this manual includes both the water supplier and the health sector.

*Estimated cost:* R225 000  
*Expected term:* 1999 - 2001

**Caustic management and reuse in the beverage bottling industry**

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

Sodium hydroxide solution (caustic) is widely employed as a cleaning agent in the food industry, with a high proportion of the water that enters bottling plants being discharged as a caustic effluent. The industry is now giving serious consideration to caustic management and reuse/recycling. The aims of the project are to develop a viable membrane-based process for the reuse and/or recovery of sodium hydroxide; demonstrate the process to potential users; develop a commercialisation strategy for the proposed process; and develop a human

resource skills base that is capable of implementing such processes in industry.

*Estimated cost:* R370 000  
*Expected term:* 1999 - 2001

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

*Scientific Services, Rand Water  
(WRC Reference No 1069)*

The current SABS standard plate count (SPC) or heterotrophic plate-count (HPC) guidelines for treated drinking water in South Africa are often exceeded by water suppliers and when this happens water suppliers add more chlorine to comply. The association between HPC bacteria in drinking water and gastroenteritis could not be proved so far. This study aims to assess the health risk posed by virulent heterotrophic bacteria with cytotoxic and invasive properties using various methods. Current microbiological water quality guidelines for South African conditions will probably need to be re-evaluated pending the findings of the study.

*Estimated cost:* R500 000  
*Expected term:* 1999 - 2001

**Evaluation of powdered activated carbon (PAC) for the removal of taste-and odour-causing compounds from water and the relationship between this phenomenon and the physico-chemical properties of the PAC and the role of water quality**

*Process Development, Rand Water  
(WRC Reference No 1124)*

The presence of nuisance compounds like geosmin and 2-Methylisoborneol (MIB) in drinking water often leads to consumer complaints. Unfortunately, toxic compounds like microcystin may go by unnoticed. Very few water treatment plants in South Africa are equipped to remove such troublesome compounds as unit treatment processes for the removal of taste and odour compounds and other metabolites are usually not installed. This is because the problems normally occur sporadically or seasonally. There is seldom any associated health risk and treatment costs are high. Since PAC is required intermittently, the selection of the correct type of material could present a problem as water quality may change, and may have an influence on the adsorption of the nuisance compounds. In the absence of available information, it is important to establish the possible relationship between the physico-chemical properties of PAC and the removal of taste-and odour-causing compounds from water and to also

investigate whether water quality could influence the efficiency of removal. The aims of this project include setting guidelines for the evaluation of PAC for the removal of taste- and odour-causing compounds like geosmin and 2-MIB from water. It will also look at the relationship between the physico-chemical properties of PAC and the removal efficiency of taste- and odour-causing compounds from water. Finally, it will try to establish whether compounds exist which mimic geosmin/2-MIB with regard to the removal by PAC and which are cheaper and easier to evaluate. The whole process will be evaluated nationwide.

*Estimated cost:* R400 000  
*Expected term:* 2000 - 2001

**Assessment of the risk of infection associated with viruses in South African drinking water supplies**

*University of Pretoria, Potchefstroom University for CHE, University of Fort Hare, University of Venda, Technikon Free State, Technikon Soshanguwe, Technikon ML Sultan, Rand Water and Umgeni Water  
(WRC Reference No 1164)*

The aims are to:

- Develop simpler, more sensitive, more economical techniques for the detection of small numbers of viruses in large volumes of drinking water
- Determine indicators of virological quality of drinking water supplies
- Examine the incidence of a spectrum of enteric viruses in selected representative drinking water supplies
- Obtain new data for guidelines on drinking water quality and monitoring programmes
- Transfer techniques to previously disadvantaged educational institutions.

*Estimated cost:* R1 000 000  
*Expected term:* 2000 - 2002

**Prevalence, survival and growth of bacterial pathogens in biofilms in drinking water distribution systems**

*University of Pretoria, University of the Western Cape, CSIR, Umgeni Water and Free State Technikon  
(WRC Reference No 1276)*

In summary the project aims to determine the occurrence, survival and growth of bacterial pathogens in drinking water biofilms. Specific aims are to:

- Determine the prevalence of pathogenic bacteria in biofilms both in drinking water distribution systems and in containers used for distribution and storage of water in informal settlements;

- Study the growth of biofilms on PVC surfaces of water storage containers
- Assess the survival of general water quality indicator bacteria in biofilms within water distribution systems
- Determine the fate, survival and possible growth of specific pathogenic bacteria in:
  - Drinking water distribution systems
  - Containers used for distribution and storage of water in informal settlements.

*Estimated cost:* R721 800  
*Expected term:* 2001 - 2003

**Programme 4: Water distribution and distribution systems**

**Quantifying the influence of air on the capacity of large-diameter water pipelines and developing guidelines for effective de-aeration**

*Ninham Shand (Pty) Ltd.  
(WRC Reference No 1177)*

In any major water supply development, the utilisation of large-diameter pipelines is unavoidable. Even though de-aeration has always been a problem, it would still appear that current practices in this regard do not always meet the objectives. These problems result in decreased capacities, which, in turn, result in increased operational costs and even augmentation schemes. In addition, areas of accumulated air are subject to increased corrosion with the accompanying negative effects.

The need for research on acceptable and reliable practices with regard to de-aeration in large-diameter pipelines was also identified during a workshop on research needs in the field of hydraulics in March 1998. The project addressed a need, the importance of which can only increase in future water transfer schemes in South Africa. In order to achieve the objective of guidelines for effective de-aeration of pipelines, the project will attend to, inter alia, the following:

- Field determination of the current hydraulic capacity of large-diameter pipelines and comparing it to design capacities;
- Laboratory investigations into the effect of localised air bubbles on the magnitude of the transient waves and stresses in the pipeline, hydraulic transportability of free air in pipelines and the dynamics of air bubbles at apex points; and
- Establishing the requirements for effective air release from pipelines, the dimensions of

accumulators in terms of the pipeline characteristics and the air valve operational features.

It is worth mentioning that significant contributions were made by three parties: Rand Water, Umgeni Water and Vent-O-Mat (Pty) Ltd. These contributions, together with the availability of Rand Water's B8 pipeline, are providing a unique opportunity to address this problem without disrupting normal activities.

*Estimated cost:* R750 000  
*Expected term:* 2000 - 2002

#### **Investigation of the performance of domestic copper pipe in coastal areas**

*Pipeline Performance Technologies*  
(WRC Reference No 1208)

Basic copper corrosion is well researched and documented; however, the exact cause of leaking domestic and industrial copper pipes is not well understood at present. A developing phenomenon in coastal areas is the reporting of cases of pin-hole ruptures. This situation is not normal, especially where copper is the recommended material for use with softer waters and in coastal areas. In the Blaauwberg Municipal Area a number of these incidents have occurred in the recent past, resulting in unsatisfied customers and an impact on the insurance industry. This situation has left the municipality in some difficulty, as they do not have any solutions to the problem.

Aims are to:

- Fully investigate the cause of the corrosion (pin-hole ruptures) in domestic copper pipes in the Blaauwberg Municipal Area and other municipal areas.
- Research, understand and document the mechanism of this type of corrosion.
- Provide technical cost-effective solutions to municipal authorities to eradicate the problem.

*Estimated cost:* R192 000  
*Expected term:* 2001

#### **Factors influencing the friction loss in pipelines and the relationship between water quality, operating conditions and the performance of different liner systems and pipe material**

*Department of Civil Engineering, University of Pretoria*  
(WRC Reference No 1269)

This research will quantify the contributing factors altering the hydraulic capacity of pipelines and will reflect the most appropriate pipe material selection and lining systems for different operating characteristics and water quality. An increasing water demand and the objective to provide water to unserved communities require the optimal utilisation of the existing water infrastructure. The lack of sufficient development capital necessitates the need to prioritise the upgrading and extension to the infrastructure. The effect of ageing, deterioration and failing of the liner systems in conjunction with the operating characteristics and water quality contribute to the change in hydraulic capacity.

*Estimated cost:* R746 000  
*Expected term:* 2001 - 2003

### **Thrust 3: Wastewater and Effluent Treatment and Reuse Technology**

#### **Programme 1: Biological sewage treatment processes**

##### **Development and monitoring of integrated algal high-rate oxidation pond (AHRP) technology for low-cost treatment of sewage and industrial effluent**

*Department of Biochemistry, Microbiology and Biotechnology, Rhodes University*  
(WRC Reference No 799)

This project is undertaking comprehensive monitoring of integrated algal high-rate oxidation pond (AHRP) plants previously constructed for the treatment of tannery, sewage and abattoir effluents, in order to evaluate parameters for optimised operation, quantify the value-adding potential of algal biomass produced, and determine constraints and further research needs for wide-scale application of the process.

*Estimated cost:* R510 000  
*Expected term:* 1997 - 2001

#### **PETRO® process to provide for biological nutrient removal**

*PGJ Meiring Konsult*  
(WRC Reference No 971)

The aim of this research is to develop a link-up between the PETRO® process for algae removal and the biological nutrient removal 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 meeting stringent nutrient and other quality requirements for discharge.

*Estimated cost:* R889 000  
*Expected term:* 1998 - 1999

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

*Department of Biochemistry, Microbiology and Biotechnology, Rhodes University*  
(WRC Reference No 1073)

The algal integrated ponding system (AIPS) offers a low-cost alternative wastewater treatment technology eminently suitable for South African conditions. The scope of this project is to scale up and evaluate laboratory findings relating to the improved performance of the AIPS anaerobic pit digester utilising UASB-type configurations, and to develop the application of the AIPS high-rate algal pond as a free-standing tertiary treatment unit operation for the removal of nitrates and phosphates from conventionally treated sewage effluents.

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

#### **Computational fluid dynamic support to water research projects**

*Pollution Research Group, University of Natal*  
(WRC Reference No 1075)

Computational fluid dynamics (CFD) is being used in this project as a numerical procedure for calculating the properties of moving fluids, as occurs in most water treatment processes, to provide process insights which otherwise would not have been possible. This project extends and builds on the lessons and skills obtained in a previous WRC project, with the overall aims of providing a CFD modelling and training service to water researchers, thereby promoting the use of CFD in practical applications.

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

#### **Determination of heterotrophic active bacteria in activated sludge using novel molecular techniques**

*Centre for Water and Wastewater Research, Durban Institute of Technology*  
(WRC Reference No 1178)

This is one of three projects (WRC Project Nos 1178, 1179 and 1191) in which scientific (Durban Institute of Technology and University of Pretoria) and engineering (University of Cape Town) disciplines are combining kinetic modelling and microbiological techniques in a collaborative sub-programme aimed at identifying and defining the active fractions in the heterotrophic and autotrophic biomass populations involved in biological nutrient removal (BNR) activated sludge systems. Major potential benefits are security of design and operation, reduced costs and improved (more reliable) effluent discharge quality. This project focuses on applying molecular biology techniques for characterising constituent fractions in the biomass.

*Estimated cost:* R875 000  
*Expected term:* 2000 - 2001

#### **Measurement of heterotrophic and autotrophic organism active biomass in biological nutrient removal activated sludge systems**

*Department of Engineering and Built Environment, University of Cape Town*  
(WRC Reference No 1179)

This is one of three projects (WRC Project Nos 1178, 1179 and 1191) in which scientific (Durban Institute of Technology and University of Pretoria) and engineering (University of Cape Town) disciplines are combining kinetic modelling and microbiological techniques in a collaborative sub-programme aimed at identifying and defining the active fractions in the heterotrophic and autotrophic biomass populations involved in biological nutrient removal (BNR) activated sludge systems. Major potential benefits are security of design and operation, reduced costs and improved (more reliable) effluent discharge quality. This project is applying wastewater engineering expertise to operate and model BNRAS systems.

*Estimated cost:* R322 600  
*Expected term:* 2000 - 2001

### Evaluation of the anaerobic baffled reactor for sanitation in dense peri-urban settlements

Pollution Research Group, University of Natal  
(WRC Reference No 1248)

Wastewaters from dense peri-urban settlements are low-volume high-strength (because of low domestic water use) and intermittent in terms of both organic and hydraulic load (because of diurnal population activities). The anaerobic baffled reactor (ABR) system is potentially a good treatment choice for this application because it effectively retains bio-solids, provides good sludge-liquid contact, and is cheap, easy and low-maintenance in operation. In this project the ABR process is being evaluated on pilot scale for this purpose, in collaboration with a number of other parties representing technical, funding and community inputs.

Estimated cost: R1 500 000  
Expected term: 2001 - 2003

### Practical implementation of external nitrification in biological nutrient removal activated sludge systems

Division of Water Quality Engineering, University of Cape Town  
(WRC Reference No 1262)

In this project, full-scale trials are being run on external nitrification in biological nutrient removal activated sludge (BNRAS) systems to test the fundamental, laboratory-scale and economic studies done to date by this research group, which have shown that external nitrification in BNRAS systems can be a more efficient and cheaper (20 to 25% lower) alternative compared to other BNRAS systems covering both green-fields and retro-fitting situations. In this collaborative exercise between UCT, the Cape Metropolitan Council, and Water & Sanitation Services SA (Pty) Ltd (the local agent for CIRSEE/Suez Lyonnaise-des-Eaux), the cash contributions by others (excluding contributions in kind) amount to about 40% of the total budget.

Estimated cost: R1 280 000  
Expected term: 2001 - 2005

### Investigation into the minimum flush volumes required for settlement of faecal solids in domestic septic tanks using controlled experiments

Du Pisani & Associates  
(WRC Reference No 1285)

The WRC has funded two projects to investigate the biological processes taking place in on-site low-flush sanitation systems and the rates of sludge build-up in these systems. The results from this research were

inconclusive because conditions under which the domestic on-site systems were used, were different. Therefore, it is necessary to determine the minimum flush volumes required for the settlement of faecal solids in domestic septic tanks under controlled conditions. The study will also establish a link between water use and sludge build-up rates; this information will assist manufacturers in improving the design of on-site sanitation tanks. The main objective of this research is to establish the minimum flush volumes required for settlement of faecal solids in septic tanks. Systems that receive sullage and systems where only toilet wastes enter the tank will be studied. This research is applicable to solids-free sewer systems and on-site disposal systems.

Estimated cost: R266 000  
Expected term: 2001 - 2002

### Programme 2: Sludge characterisation, treatment, utilisation and disposal

#### Intermediate scale-up evaluation of the Rhodes BioSURE® process for hydrolysis and solubilisation of sewage sludges in a sulphate-reducing bacterial system

Department of Biochemistry, Microbiology and Biotechnology, Rhodes University and ERWAT  
(WRC Reference No 1169)

The accelerated hydrolysis/solubilisation of complex carbon sources (e.g. sewage sludge) under bio-sulphidogenic conditions is potentially of major interest to sewage treatment plant operators. In this project, ERWAT, in collaboration with Rhodes University, is carrying out a pilot-scale evaluation of the process for accelerated hydrolysis/solubilisation of primary sewage solids and their subsequent treatment in conventional aerobic treatment processes. Specific objectives are to quantify the role of sulphur compounds as inventory reagents in the process, to derive design criteria and to evaluate application opportunities.

Estimated cost: R700 000  
Expected term: 2000 - 2001

#### Enzymology of accelerated primary sewage sludge solubilisation and digestion in sulphate-reducing systems

Department of Biochemistry, Microbiology and Biotechnology, Rhodes University  
(WRC Reference No 1170)

A spin-off from WRC-funded research into the biological reduction of sulphate in high-volume sources such as acid mine drainage is the accelerated hydrolysis

observed of complex carbon sources in the presence of sulphate-reducing bacterial systems. Enzymological studies are being carried out in this project to identify the bio-catalysed reactions occurring, to characterise the physico-chemical factors involved (e.g. time, temperature, pH, redox potential, sulphur-species concentrations, etc.) as a step towards maximising the overall reaction efficiency.

Estimated cost: R707 000  
Expected term: 2000 - 2002

#### An evaluation of dedicated land disposal practices for sewage sludge

Institute for Soil, Climate and Water, ARC  
(WRC Reference No 1209)

Most sewage sludge produced in the RSA is presently disposed of on dedicated (i.e. sacrificial) land. It is the least expensive of the available alternatives, but has several undesirable environmental consequences and is, furthermore, not viewed as sustainable. The objectives of this project are to:

- Evaluate the extent of the current practice;
- Evaluate the potential risk the practice poses to the water environment at selected sites covering the range of climatic and other conditions; and
- Estimate the potential future impact of dedicated land disposal of sewage sludge on the water environment.

Estimated cost: R595 000  
Expected term: 2001 - 2003

#### Effects of sulphate and pH on hydrolysis of sewage sludge for use in the treatment of acid mine drainage waters

Dept of Civil Engineering, University of Cape Town  
(WRC Reference No 1216)

The Rhodes BioSURE® process utilises complex substrates (sewage sludge) as the carbon source for sulphate-reducing bacteria in the treatment of low-pH, high-sulphate, high-volume wastewaters from acid mine drainage (AMD). An essential rate-defining step is the bio-hydrolysis of the complex carbon sources to render them available for subsequent bio-reactions. Sulphate, sulphide and pH conditions significantly affect the solids hydrolysis rates obtained. In this project, a systematic experimental protocol is being carried out to quantify and simulate these effects in terms of a calibrated mathematical model.

Estimated cost: R250 000  
Expected term: 2001 - 2002

### Technical and financial review of sludge treatment technologies

Africon  
(WRC Reference No 1240)

In the development of appropriate and practicable guidelines for the management and disposal of sewage sludges in the RSA, the wide disparity in resources available in different localities must be taken into account, with the overarching requirement of providing environmentally sustainable practice for the country. This project aims at developing an authoritative reference document, in which locally and internationally available sludge management technologies (handling, treatment and disposal), their applicability in the RSA, and their cost implications estimated for local conditions, are reviewed and evaluated.

Estimated cost: R275 000  
Expected term: 2001

#### A detailed metal content survey of South African sewage sludges and an evaluation of analytical methods for metal determination

Research and Development, ERWAT  
(WRC Reference No 1283)

Current sludge disposal guidelines indicate that even sludges from predominantly domestic wastewater catchments do not meet the heavy metals criteria proposed for unrestricted beneficial reuse (Class D). It is, however, difficult to be categorical about this, firstly because analytical techniques for determining metal concentrations in sludges and soils are not standardised and are expensive, and secondly because the mobilities of metals as they affect groundwater quality and absorption into the food chain are not well understood. This project addresses the first concern, by evaluating different analytical methods for metals in sludges and receiving soils, and by sampling and analysing sludges from 50 wastewater plants in 5 categories (industrial, domestic, waste activated, digested and Class D sludges).

Estimated cost: R524 000  
Expected term: 2001 - 2002

### **Programme 3: Treatment and recovery of organics from agro-industrial processing**

#### **Purification of abattoir effluents by means of the protein reclamation process**

Abakor Ltd.

(WRC Reference No 652)

One of the major problems confronting abattoirs is managing the effluent. Physical-chemical techniques, as well as biological processes, are normally employed to treat the effluent. Both types of processes, however, suffer from the drawback of being either relatively expensive or of still discharging a pollution load to the environment. An alternative treatment process is the culture of single-cell protein in the effluent. This process has the advantage of being environment-friendly, of relieving the pollution load to existing municipal sewage treatment plants and of being an additional source of protein. The aim of this project is to transfer single-cell protein technology to a full-scale plant at the Johannesburg Abattoir.

Estimated cost: R300 000  
Expected term: 1994

#### **Assessment of a baffled (compartmentalised) anaerobic digester for the treatment of high-strength and toxic organic industrial effluents**

Pollution Research Group, University of Natal

(WRC Reference No 853)

Organic effluents from the agro-industrial sector are generally problematic in terms of their concentrated, variable, intermittent and sometimes toxic nature. Many streams would be amenable to treatment by anaerobic digestion if the toxicities of particular components are identified at an early stage so that the microbial populations in a suitable reactor can be acclimated to the constituents concerned. The anaerobic baffled reactor (ABR) offers good separation between hydraulic and solids retention times, good solids retention, and the potential for selecting acclimated microbial biomass fractions in a series configuration. This project aims to develop and apply an ABR for treating dyeing effluents from the textile industry.

Estimated cost: R1 218 000  
Expected term: 1998 - 2001

#### **Co-digestion of high strength / toxic organic effluents in anaerobic digesters at a wastewater treatment works**

Department of Chemical Engineering, University of Natal  
(WRC Reference No 1074)

A previous WRC project (No 762) indicated that while there is potentially spare anaerobic digestion capacity in KZN, landfill sites in the region have failed due to the excessive application of liquid effluents. The aim of this project is to provide an alternative, environmentally-acceptable treatment and disposal option for high-strength liquid organic effluents that are currently being disposed of to landfill, by demonstrating that such effluents can be effectively treated in conventional sewage works at the anaerobic digestion stage, and providing a protocol for the evaluation of liquid effluents for such treatment and disposal.

Estimated cost: R1 260 000  
Expected term: 2000 - 2002

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

DB Thermal (Pty) Ltd.

(WRC Reference No 1081)

In previous work funded by the WRC, replacement of the conventional settling tank in an activated sludge system with a fine screen resulted in the possibility of growing filamentous organisms (mainly fungi) as a near-monoculture in an open reactor, without any sterilisation, while simultaneously purifying the water. In order to finalise the work, in this project animal feeding trials are being carried out on the biomass to assess its applicability as animal protein and its commercial value.

Estimated cost: R196 000  
Expected term: 1999 - 2001

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

Centre for Water and Wastewater Research, Durban  
Institute of Technology

(WRC Reference No 1084)

Effluents from the South African vegetable oil industry generally have a high pollutant profile based on their pH and high concentrations of COD, greases and phosphates. The aim of the project is to develop multi-stage processes to remove COD anaerobically (i.e. with minimum biomass production) and to remove phosphates aerobically (to produce a treated effluent of acceptable quality).

Estimated cost: R350 000  
Expected term: 1999 - 2001

#### **Development of a membrane bioreactor system using the white-rot fungus *Trametes versicolor* for bioremediation of industrial wastewater**

Department of Biochemistry and Microbiology, Rhodes University

(WRC Reference No 1129)

The use of a white-rot fungus in combination with a membrane is being investigated for the breakdown of phenolic organics in petroleum and pulp-and-paper effluents. These effluents are difficult to treat with conventional methods. The scale-up of a laboratory unit and technology transfer to the relevant industries are included in the scope of the project.

Estimated cost: R533 000  
Expected term: 2000 - 2002

#### **Effluent harvesting and detection of steroidogenic agents by affinity separation**

Institute for Polymer Science, University of Stellenbosch

(WRC Reference No 1165)

Chemical groups are being grafted (reversibly) onto existing locally manufactured membranes. These chemical groups ("ligands") are chosen such that various wanted or unwanted components could be removed from the water or effluent selectively. A part of the project is aimed at producing an analytic tool for the analysis of oestrogenic compounds in water making use of this principle.

Estimated cost: R1 560 000  
Expected term: 2000 - 2002

#### **Design, investigation and evaluation of electrochemical combustion plant for rural water disinfection and industrial effluent organic removal**

Department of Chemical Engineering, University of Stellenbosch

(WRC Reference No 1196)

In a present research programme at the Institute for Polymer Science, i.e. electro-assisted membrane processes for contaminant removal in water and effluent treatment, major success has been achieved in a catalytic material for the complete combustion of organics in water. This research was material oriented and not engineering oriented, but did provide a preliminary indication of good potential for both the disinfection of potable water and the combustion of organics in the treatment of industrial water. An initial

feasibility and cost estimate requested from the proposer (attached to the proposal, Appendix 1) confirmed this potential and pointed toward the niche application areas to be researched.

The system consists of a membrane impregnated with a novel, conducting, catalytic material. A low-voltage current is sent through this catalytic membrane, thus effecting the oxidation or even complete combustion of micro-organisms and organic compounds in the water. Because only low voltages are required, solar cells may also be used to power the system. From single household to large industrial units may potentially be constructed.

The aims of the project include the following:

- Design and evaluate electrochemical combustion plants for rural water disinfection and industrial organics removal.
- Design a fixed-bed electrochemical cell suitable for multi-family usage, and also big enough to be useful for industrial effluent.
- Investigate newer cell designs, fluidised bed, spouting electrode, etc. as alternatives to a fixed bed design.

Estimated cost: R455 000  
Expected term: 2001 - 2002

#### **On-line removal of organic foulants from membranes by use of ultrasonication**

Department of Chemical Engineering, University of Stellenbosch

(WRC Reference No 1229)

The fouling of membranes treating water which contains organic pollutants remains a serious problem limiting the free use of membranes in these applications. The aim of the project is to study the feasibility of the use of ultrasonic waves for the on-line prevention and/or removal of organic foulants from membranes used in various potable water and industrial effluent treatment applications. The study will mostly deal with fundamental aspects on a laboratory scale, but configurations for the best use of ultrasound energy in membrane defouling and the use of novel, simple and effective ultrasound generators will also be investigated.

Estimated cost: R286 500  
Expected term: 2001 - 2003

**Membrane reactor for the electrocatalytic minimisation of organic matter in water and effluents**  
*Department of Chemistry, University of the Western Cape*  
(WRC Reference No 1231)

Novel proton-conducting ceramic membranes for the oxidation of recalcitrant organic material in water have been developed at the University of the Western Cape. Initial laboratory studies show good promise. The aim of this project is the further development and improvement of these membranes. Prototype membranes will be evaluated on organics removal from a selection of possible effluents, such as Cape surface water, textile, power station and petroleum effluents. The scope includes the construction of a small pilot plant from which large plants could be upscaled.

*Estimated cost: R422 000*  
*Expected term: 2001 - 2003*

**Development of a reverse-flow microfilter**  
*Department of Chemical Engineering, ML Sultan Technikon*  
(WRC Reference No 1232)

A novel idea is being evaluated whereby the woven fibre "fire hose" microfilter, previously developed by the University of Natal, is being modified to allow sucking water and effluents from the outside inward in the purification process. This simple microfiltration system could be much more cost-effective than similar current systems. Studies up to bench-scale level on high-turbidity water, low-turbidity water and a gelatinous effluent are being performed. Preliminary costs are to be estimated.

*Estimated cost: R194 000*  
*Expected term: 2001 - 2003*

**Process development and mechanical design to construct and commission a 100 to 1 000 kg industrial bioreactor for mass culturing of UASB**  
*Department of Chemical Engineering, University of Stellenbosch*  
(WRC Reference No 1239)

Biogranulation (pelletisation) is an important feature of upflow anaerobic sludge blanket (UASB) bioreactors. The physical properties of the biogranules allow a greater upflow velocity, more even substrate distribution, more stable bio-reaction behaviour, and the potential for tailoring bio-processes to produce value-added products. In this project the biogranulation enhancement system established in previous WRC projects is being developed to a larger industrial scale. A potential national economic benefit is the reduction or

elimination of expensive importing of biogranules, with possibilities of establishing an export market.

*Estimated cost: R 235 000*  
*Expected term: 2001 - 2002*

**Hydrophilisation of hydrophobic ultrafiltration membranes**  
*Institute for Polymer Science, University of Stellenbosch*  
(WRC Reference No 1268)

The locally manufactured polysulphone capillary membranes are normally hydrophobic in nature. Although these membranes are very inert, they are also prone to fouling. The aim of this project is to improve these membranes with regard to their fouling propensity. Various techniques are being followed to modify the membrane surface characteristics in order to make this membrane less fouling and more competitive internationally in both water and effluent purification applications.

*Estimated cost: R650 000*  
*Expected term: 2001 - 2004*

**Programme 4: Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents**

**Solid stabilisation of soluble wastes generated in the South African ferrochrome industry**  
*Council for Mineral Technology (Mintek), Mineralogy & Process Chemistry Division*  
(WRC Reference No 942)

The RSA ferrochrome industry is a major foreign exchange earner and employer, but also generates solid wastes such as ferrochrome slag and bag filter dust (BFD, up to 100 000 t/a) containing toxic (carcinogenic) and mobile Cr(VI) which poses a risk to health and the environment. The aim of the project is to solid-stabilise (immobilise) soluble wastes from ferrochrome production, by incorporating them into building materials (bricks and cement blocks) using wastes available on site (recycle water, slag and BFD). The leachability of soluble salts and toxic components (Cr(VI)) from the manufactured bricks/blocks will be evaluated by internationally accepted test procedures, to assess their potential as building construction materials with an economic value and as input materials for utilisation in the national Reconstruction and Development Programme (RDP).

*Estimated cost: R205 000*  
*Expected term: 1998 - 2000*

**Neutralisation of acid mine water and sludge disposal**  
*Environmentek, CSIR*  
(WRC Reference No 1057)

Since their low pH and high metal content make acid mine drainage waters unacceptable to the aquatic environment, they have (as a minimum requirement) to be neutralised and steps taken to ensure the safe disposal of the metal-rich sludge which is formed during neutralisation. In Gauteng alone, 240 M<sup>3</sup>/d of acid water from gold mines is being produced. The calculated cost of the lime required as neutralising agent amounts to about R57m./yr. Several alternative and supplementary processes to increase the efficiency and/or reduce the cost associated with the active treatment of acid mine water, have been identified and tested over the years. In an earlier investigation, researchers on this project were able to reduce the cost of chemicals by a factor of three through substituting lime with limestone in the neutralisation process. This project aims to take this process further by conducting laboratory- and full-scale pilot studies, supplemented with further laboratory studies, which will address several of the urgent needs associated with active neutralisation of acid mine water.

*Estimated cost: R700 000*  
*Expected term: 1999 - 2000*

**Development of environmentally friendly bio-polymeric heavy metal adsorbing membrane materials for industrial wastewater treatment**  
*Department of Chemical and Mineral Engineering, Potchefstroom University for CHE*  
(WRC Reference No 1072)

The removal of heavy metals from water and effluents remain a world-wide problem. This project aims to develop environmentally friendly bio-polymeric materials, both in pellet and membrane configuration, for the absorbance of heavy metals. To this end chitosan, derived from chitin (e.g. from crayfish shells) is being formed into pellets or membranes for the adsorption and removal of a few model heavy metals from effluents. Sourcing of local shells and the local manufacturing of chitosan is part of the scope of the project.

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

**Development and piloting of the integrated biodesalination process for sulphate and heavy metal removal from mine drainage water incorporating co-disposal of industrial and domestic effluents**  
*Department of Biochemistry & Microbiology, Rhodes University*  
(WRC Reference No 1078)

Recent WRC projects have researched algal ponding technologies and applied these low-cost processes to the treatment of mining and tannery wastewaters containing sulphate and heavy metals. The Rhodes BioSURE® process has been developed as a sulphate-reducing biodesalination process using sewage solids as the carbon source for the treatment (neutralisation and removal of heavy metals and sulphates) of such wastewaters. This project aims to complete the pilot plant being constructed at Grootvlei Mine as a collaborative research venture between WRC, ERWAT and the mine owners, and to complete pilot-scale evaluation of sewage as a complex carbon source/electron donor in the integrated BioSURE® process.

*Estimated cost: R1 700 000*  
*Expected term: 1999 - 2002*

**Investigation into sulphur chemistry with specific application to biological sulphate removal processes**  
*Department of Civil Engineering, University of Cape Town*  
(WRC Reference No 1079)

This project complements current WRC research efforts into biological processes for treating acid mine drainage and other metaliferous sulphate-containing effluents. The aims are to apply fundamental aqueous chemistry to model metal precipitation and recovery, simulate the effects of pH and temperature on sulphur speciation and solubility along with active stripping of hydrogen sulphide (H<sub>2</sub>S), and explore the extent of conversion, reaction kinetics and control of a process to recover elemental sulphur by chemical oxidation of soluble sulphides.

*Estimated cost: R280 000*  
*Expected term: 1999 - 2000*

**Mechanism and kinetics of biological treatment of metal sulphate containing effluent**  
*Department of Chemical Engineering, University of Cape Town*  
(WRC Reference No 1080)

Active bioprocesses show promise for the treatment of acid mine drainage and other such acidic high-sulphate wastewaters in the RSA, particularly if a cheap carbon

source can be utilised for bacterial sulphate reduction such as in the WRC/Rhodes BioSURE® process in which sewage sludge is used as the electron donor. This project provides complementary engineering input into the optimisation of this process. Specific aims are to establish the kinetics of critical sub-processes, to develop simulation models for process optimisation and to optimise the recovery of elemental sulphur as an end-product.

*Estimated cost:* R574 000  
*Expected term:* 1999 - 2000

#### **Development of a novel membrane photobioreactor for the production of algal toxins**

*Department of Biochemistry and Microbiology, Rhodes University  
(WRC Reference No 1103)*

A locally developed capillary membrane system is employed to cultivate algal toxins using a patented "gradostat" technique. In the membrane reactor, algae are put under varying degrees of stress to ensure the production of algal toxins. Algal toxins are required world-wide for water treatment and health-related experimentation purposes but are not freely available because of inadequacies of current production methods and concomitant high price.

*Estimated cost:* R81 000  
*Expected term:* 2000

#### **Visualising the effects of electro-magnetic and turbulence defouling techniques in membrane modules**

*Institute for Polymer Science, University of Stellenbosch  
(WRC Reference No 1166)*

Mathematically-manipulated ultrasonic wave deflection is being utilised to "visualise" the fouling layer thickness and character on the surface of a membrane. Simultaneously, membrane cleaning effects of ultrasonication are being investigated. This technology is showing significant potential and will be the subject of international co-operative research under the Pentaparty agreement with America, Germany, the Netherlands and Australia.

*Estimated cost:* R992 000  
*Expected term:* 2000 - 2002

#### **Effective design of woven fabric microfiltration and tubular filter press technologies for different process applications in South Africa**

*Umgeni Water  
(WRC Reference No 1172)*

In this project long-term performance and operating/maintenance considerations of woven fibre-crossflow microfiltration technology are being evaluated in critical comparative assessment studies being carried out by Umgeni Water and ML Sultan Technikon according to agreed task activities. The programme aims to optimise the tubular filter press (TFP) process and provide least-cost data from pilot-scale studies for dewatering of waterworks sludges on an existing TFP plant, and to compare the results to other full-scale dewatering technologies.

*Estimated cost:* R587 000  
*Expected term:* 2000 - 2002

#### **Purification of wastewater with crown ethers and other macrocycles bound to water-soluble and/or elastomeric polymers**

*Department of Chemistry, University of the Free State  
(WRC Reference No 1173)*

The technology being investigated involves the development of a ligand system which can be tailored to selectively trap and then release the contaminant ions in high-concentration/low-volume and low-concentration high-volume industrial effluents. The ligand system, consisting of macrocyclic crown ethers, is anchored on a mobile polymer support. Specific technical aims are to modify crown ethers and other macrocycles to permit polymer anchoring; develop a suitable polymeric anchoring carrier; evaluate the polymer-bound macrocycles as cation and anion scavengers of wastewater contaminants; and develop techniques for regeneration of the ligand/polymer matrix.

*Estimated cost:* R702 000  
*Expected term:* 2000 - 2002

#### **Simultaneous water recovery and utilisation of two harmful effluents, fly-ash leachate and acid mine drainage, for production of high-capacity inorganic ion-exchange material useful for water beneficiation**

*Department of Chemistry, University of the Western Cape  
(WRC Reference No 1242)*

The huge quantities of fly-ash that are produced when low-grade coal is burned in coal-powered utilities, presents a serious disposal problem because the fly-ash itself contains high level of metals and other

contaminants and its caustic leachate contains high concentrations of hydroxides, carbonates, sulphates and metals. At the other end of the pH scale, acid mine drainage (AMD) with its high concentrations of dissolved salts and metals, presents probably the most serious threat to water quality associated with gold- and coal-mining activities. Previous research at UWC has indicated that co-disposal of AMD with fly-ash leachate simultaneously neutralised two highly corrosive waste streams. The resultant effluent was approximately neutral and could be further treated by ion exchange and electro dialysis reversal. Metal precipitates formed at the co-precipitation stage have properties which are suitable for application as high-value adsorbates and which can be further beneficiated to increase their ion exchange adsorbate capacity. This project will further investigate these reactions with the aim to utilise two harmful effluents, fly-ash leachate and acid mine drainage (AMD), to yield useable water while at the same time producing high-capacity inorganic ion-exchange adsorbate materials.

*Estimated cost:* R 580 000  
*Expected term:* 2001 - 2003

#### **Novel method for removal of metal ions from acid mine drainage waters and development of a passive aeration system for sulphide and ferrous bio-oxidation**

*Department of Civil Engineering, University of Cape Town  
(WRC Reference No 1244)*

This project aims to remove heavy metals from acid mine drainage by precipitation of ferrous and ferric ions as a stable fast-settling complex under controlled pH conditions, followed by the addition of small amounts of sulphide to form stable metal colloids which can be removed by further precipitation as a well-settling floc which can be easily separated and concentrated (dewatered). A second aspect is to investigate the bio-oxidation of ferrous and sulphate ions using a novel passive aeration / oxidation system to recover sulphur and ferric ions where the latter is employed in sulphur recovery.

*Estimated cost:* R 520 000  
*Expected term:* 2001 - 2002

#### **An investigation of the mechanism and kinetics of bacterial sulphate reduction**

*Department of Chemical Engineering, University of Cape Town  
(WRC Reference No 1251)*

A previous WRC project (No 1080) aimed at developing basic kinetic models for the breakdown of complex

(sewage sludge) organics in biological sulphate-reducing processes for treating acid mine drainage wastes, and metal precipitation by the pH-raising properties of algae in high-rate ponding systems in an integrated process scheme. The present project aims at completing the anaerobic dynamic simulation model to incorporate sulphate / sulphide inhibition and sulphate reduction, and at developing a model for metal precipitation (as sulphides, carbonates and hydroxides) resulting from sulphide and carbonate production in the biological sulphate-reducing process.

*Estimated cost:* R 1 146 000  
*Expected term:* 2001 - 2003

#### **Removal of heavy metals from water by use of biomaterials**

*Department of Chemical Engineering, Cape Technikon  
(WRC Reference No 1259)*

This project investigates a technology that seeks to take advantage of the natural ability of certain biological materials (algae, yeast, fungi, etc.) to absorb or otherwise temporarily take up heavy metals at levels much greater than their metabolic requirements for trace elements. The biotechnology "trick" is that the toxic heavy metals can thus be concentrated into a relatively small biomass which can be much more effectively managed in terms of ultimate disposal or even recovery of the heavy metal component(s), thereby reducing the toxic potential threat to receiving water bodies.

*Estimated cost:* R105 000  
*Expected term:* 2001

## **Thrust 4: Industrial and Mine-Water Management**

### **Programme 1: Quantification of water use and waste production**

#### **Electrochemical treatment removal of phosphates and sulphates from sewage and acid mine drainage respectively**

*Anglo Coal, Anglo Operations Ltd.  
(WRC Reference No 940)*

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. Such benefits have previously been negated by the high cost of EC processes. The project is revisiting EC treatment of wastewater, using modern electric, electronic and control technology. The approach adopted is to employ sacrificial scrap electrodes, which could make the process cost-competitive. Further cost advantages could be derived by developing a generic EC-reactor using scrap metal.

*Estimated cost:* R670 000  
*Expected term:* 1999 - 2001

#### **An investigation of water usage at gold- and platinum-mine flotation plants**

*Department of Environmental Engineering, Technikon Pretoria  
(WRC Reference No 1003)*

The flotation process forms an integral part of the gold- and platinum-mining industry and is mainly used for the recovery of gold, platinum and pyrite. The density of the pulp is controlled by water addition to attain the necessary densities for optimum recoveries. In this process, control of water consumption is essential but the conservation of water is at this stage not the predominant feature in the control process. It is believed that flotation plants use large amounts of water, and that the effluent carries a high pollution load due to the chemicals used in the flotation process. This project will investigate these issues and identify the effects that the released chemicals have on the water environment. Possible water wastage and means to address the pollution load of the effluent will also be identified as part of this investigation of several flotation plants.

*Estimated cost:* R224 000  
*Expected term:* 1999 - 2000

#### **Programme 2: Regulatory mechanisms to improve industrial and mine-water management**

##### **Development of an appropriate procedure for the closure of deep underground gold-mines**

*Pulles, Howard & de Lange  
(WRC Reference No 1215)*

There are a number of regions within South Africa where large-scale cessation of mining activities at deep underground gold-mines has occurred and can be expected to continue to occur in future. Although these mines pose long-term threats to the surrounding ground and surface water environment, there is currently no clear procedure that can be applied to successfully close

these mines. Contributing reasons for this are that adjacent mines are mostly hydraulically interconnected, making it difficult to apportion responsibility for water volumes and contaminant loads. Mines are, furthermore, often partially flooded, making it difficult to collect certain data and to apply certain pollution prevention measures. There is also uncertainty regarding assessment procedures that should or could be applied to assess the long-term problems and to evaluate alternative management strategies. The premise of this project is, therefore, that the closure of gold mines should be planned and evaluated on a regional and not on a mine-by-mine basis, unless a mine can clearly and unequivocally prove that it is hydrologically and geohydrologically isolated from all other surrounding mines. This necessitates the development of strategies that encompass and enforce the principle of regional co-operation between mines - a concept that has implications for mine environmental planning and management (EMPRs) and closure. The project therefore aims to develop an appropriate and agreed procedure that will enable mines to plan and implement closure in a responsible manner and in a way agreed to by all stakeholders.

*Estimated cost:* R503 800  
*Expected term:* 2001 - 2002

#### **Programme 3: Minimising the impact of waste on the water environment**

##### **Practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor Cape Metropolitan Council (WRC Reference No 606)**

Following on previous work in which a basic landfill was developed and constructed, in this project the co-disposal of non-toxic waste along with municipal refuse is being extended to full scale. The design developed for the landfill modules (or cells) gives good mechanical compaction properties and minimal leachate, with evaporation of the liquid fraction.

*Estimated cost:* R544 000  
*Expected term:* 1994 - 2001

##### **A quantitative evaluation of water utilisation in different rehabilitation methods for slimes dams**

*Envirogreen and Freegold  
(WRC Reference No 899)*

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:* R135 190  
*Expected term:* 1998 - 2002

#### **Understanding and modelling of water flow through soil covers used for rehabilitating coal discard dumps and open-cast mines**

*Wates, Meiring and Barnard  
(WRC Reference No 1002)*

Since 1993 the contractors have, with the collaboration of DWAF and with funding from the WRC, been running an experiment to determine the recharge through ten different natural soil covers. Part of this project was aimed at calibrating existing computer models for use as a tool to predict recharge through natural soil covers. The available models, however, did not adequately predict the relationship between rainfall events and recharge, especially for the typical short-duration thunderstorms of high intensity observed in South Africa. The predicted quantity available for recharge was found to be significantly lower than under low-intensity rainfall conditions. This follow-on project aims to develop a clear understanding of the flow mechanism in the top unsaturated soil layers of a natural soil cover on a microscale, in order to accurately model recharge. Existing mathematical models will be used as a basis for the study. Evapotranspiration will be derived with the help of a continuous logging weather station while the soil-water profile will also be monitored regularly.

*Estimated cost:* R247 000  
*Expected term:* 1999 - 2000

#### **Reduction of urban litter in drainage systems through integrated catchment management**

*Department of Civil Engineering, University of Cape Town  
(WRC Reference No 1051)*

In **Volume 1** of the final report (Report No 691/1/98) on the project entitled **The removal of urban litter from stormwater conduits and streams**, reference is made to the dearth of information on litter wash-off rates in urban areas, and the need to reduce the quantity of litter that finds its way into stormwater drainage systems. In addition to amounts, more detailed information is required, not only on the source and types of litter encountered in urban catchments, but also on the efficiency of various catchment management techniques to ensure a reduction in urban litter reaching drainage systems. Further research in the above regard was strongly supported at a workshop in March 1998. In 1991 it was estimated that 780 000t of litter annually enter drainage systems in South Africa, and at a current removal cost of approximately R1 000/m<sup>3</sup>, it amounts to a total annual cost of R780m. Ways to reduce litter loadings through better management are, therefore, urgently required not only from a cost point of view, but also as far as its negative impact on the environment is concerned.

This project will be focusing on the abovementioned needs, and has the potential to drastically reduce urban litter pollution in streams, resulting in considerable cost savings to local authorities. Against this background the project addresses the following aims:

- To improve the knowledge of the source type and amount of urban litter coming from different types of urban catchments; and
- To provide scientific data on the efficacy of various management techniques in reducing the amount of urban litter reaching drainage systems. This information, together with that of the first aim, would enable the development of Litter Management Plans (LMPs) resulting in reduced litter loadings and realising considerable cost savings. The project will be executed in partnership with the Cape Metropolitan Council which will be contributing to installation costs of the various litter-removal structures.

*Estimated cost:* R690 000  
*Expected term:* 1999 - 2002

#### Assessment of procedures used in Southern Africa to evaluate chemicals used in water and wastewater treatment

Department of Process Services, Umgeni Water  
(WRC Reference No 1184)

A large number of chemicals are used in the production of potable water and in the treatment of wastewater effluents. In potable water treatment, chemicals such as inorganic salts and polymeric organic coagulants are used for primary coagulation, as coagulant aids and for sludge dewatering; lime and soda ash allow for pH correction and water stabilisation; caustic soda is used for pH adjustment; powdered activated carbon (PAC) can remove taste and odour compounds and micropollutants such as atrazine; bentonite aids coagulation; and ammonium hydroxide is used in chloramination.

At present there are some recommended tests available for the assessment of some of these chemicals such as the *SABS 459 1955 Standard Specification for Lime* which is used for chemical and metallurgical purposes. However, the tests described in this specification are, for the most part, outdated gravimetric procedures which are particularly time-consuming. In the case of polyelectrolytes used for primary coagulation during potable water treatment, there is currently no legislation or regulation system available in this country to control the use of these chemicals and no standard tests are available to measure the effectiveness of these chemicals for coagulation. This lack of standard tests in the water and wastewater chemical industry makes it difficult to assess or compare these products and this can have negative health and environmental implications. A handbook containing standard tests, which have been properly evaluated and which, for the most part, can be performed using relatively simple equipment, would be of great benefit to the entire water industry. The main aims of this project are to:

- Assess the various procedures used in Southern Africa to evaluate the different chemicals used in water and wastewater treatment
- Identify the critical determinants for the evaluation of these chemicals and to recommend standard procedures
- Produce a handbook for all Southern African water and wastewater authorities which can be used for the evaluation of the chemicals used in water and wastewater treatment. This handbook would set out standard procedures for the assessment.

Estimated cost: R89 000  
Expected term: 2000 - 2001

#### Programme 4: Minimising waste production

##### Application of pinch technology as a strategic tool in the rational management of water and effluent in an industrial complex

Pollution Research Group, University of Natal  
(WRC Reference No 851)

Pinch technology was first used for assessing and integrating the overall interrelated energy needs of a complex series of industrial processes. The project objectives here are to apply and assess pinch technology as an approach for minimising water use and effluent generation in large industrial complexes; develop procedures for integrating water quantity and quality requirements of individual unit operations; establish guidelines for the use of pinch technology as a planning tool for water management; and transfer the technology for application in water conservation.

Estimated cost: R907 000  
Expected term: 1998 - 2001

##### Further application and development of pinch analysis for water and effluent management

School of Chemical Engineering, Pollution Research Group, University of Natal  
(WRC Reference No 1158)

The City of Durban has proposed a scheme to provide reclaimed wastewater to industrial areas. However, pollutants from certain factories in the area may prejudice the reuse of water by other participating factories. Pinch analysis of the water use of the entire industrial community could make such a scheme workable and beneficial to the whole community by identifying the optimal technical decisions and targets. The expertise developed in this project will be transferred to the wider South African water industry, as a neutral tool that can be used by industry to set targets and to indicate their environmental performance to the public and the authorities.

Estimated cost: R1 603 000  
Expected term: 2000 - 2002

##### Establishment of a methodology for initiating and managing waste minimisation clubs

School of Chemical Engineering, Pollution Research Group, University of Natal  
(WRC Reference No 1171)

Waste minimisation (wastemin) clubs are very successful as a model for achieving significant improvements in local environmental performance by industry. In this

multi-stakeholder approach, the interests of industry, regulatory authorities and affected communities are constructively combined. The main aim of this follow-up project is to develop a sustainable method of promoting and managing wastemin clubs, by producing, *inter alia*, a guide for effectively establishing and managing wastemin clubs, specific sectoral self-assessment guides, and training for wastemin consultants in a quality-controlled operation.

Estimated cost: R882 000  
Expected term: 2000 - 2002

##### Application of pinch technology in water resource management to reduce water use and wastewater generation for an area

Process Technology Division, CSIR  
(WRC Reference No 1241)

The objective of this project is to use pinch technology for identifying and optimising external (inter-operator) water use and reuse possibilities in a multi-operator study area. Previous studies have shown that the systematic pinch methodology for optimising the quality-quantity requirements and outputs from a series of water-using processes on a single site can achieve very meaningful water-saving and economic benefits. This project extends this to a regional scenario incorporating power stations, a petrochemical complex, mining operations, local towns and farms.

Estimated cost: R 281 800  
Expected term: 2001 - 2002

##### A life-cycle assessment of a secondary water supply

Department of Chemical Engineering, University of Natal  
(WRC Reference No 1252)

Life-cycle assessment (LCA) methodology provides a holistic basis for policy-making and decision-taking. In this project, previous work carried out into developing a customised RSA database for various industrial processing activities is being applied to investigate a rational (LCA) approach to options for water supply and wastewater disposal in a coastal RSA city, using Durban as the case study. LCA comparisons are being made of the environmental trade-offs involved in providing secondary (reclaimed) wastewater rather than potable water to industry for processing purposes, and the treatment of wastewater at conventional land-based sewage treatment works as opposed to direct marine disposal.

Estimated cost: R 1 239 000  
Expected term: 2001 - 2003

#### Programme 5: Improved ability to predict and quantify effects

##### Investigation into the long-term impact of inter-mine flow in the Mpumalanga Collieries

Institute for Groundwater Studies, University of the Free State  
(WRC Reference No 1056)

The mining industry in 1996 conducted an investigation into inter-mine flow. This investigation dealt with a trial area of 30 x 30 km, south of Witbank, which constitutes about 30% of the Mpumalanga coalfield. From this investigation it was concluded that mining activities have extensively disrupted natural groundwater flow paths and that it is the pathways within mines which will in future dictate flow of under-groundwater and where water will decant onto the surface. The combined potential impact of inter-mine flow and water to be decanted onto the surface is of a magnitude not previously anticipated in modelling exercises. The flow of polluted mine water between collieries in Mpumalanga is an issue that needs to be resolved before a holistic mine-water management scheme can be implemented. This investigation will, *inter alia*, establish a geographic information system for all the collieries in the Mpumalanga coalfield, showing mined out areas, future areas to be mined and mining methods, identify seepage and decant positions where water from mines will impact on groundwater and surface water, and quantify contributions through field investigation and modelling.

Estimated cost: R897 000  
Expected term: 1999 - 2000

##### Evaluation and validation of geochemical prediction techniques for underground coal-mines in the Witbank / Highveld region

Pulles, Howard & de Lange  
(WRC Reference No 1249)

The Witbank/Highveld coalfield in Mpumalanga is the most important coal-mining area in South Africa. While this coalfield makes a significant contribution to the economic development of the country it is also the source of potentially the most serious water quality problem facing the region over the longer term. There is thus an urgent need to develop and test tools with which to predict the progression of acid mine drainage (AMD) over time, and to develop, test and apply management options that will alleviate the situation. This project, together with Project Nos 1263 and 1264 will investigate the management of under-groundwater flow in collieries at various stages of closure with an aim to minimise the

salt load emanating from them, evaluate alternative geochemical prediction techniques to use in the longer term, comparison of alternative management options, and the mapping of modal proportions of primary and secondary minerals. The contribution of this project will be to evaluate alternative geochemical prediction techniques for the prediction of water quality at underground coal-mines, based on on-site investigations and predictions, and to develop the ability to provide a long-term prediction of water quality and the effect of alternative management strategies on this water quality.

Estimated cost: R1 416 100  
Expected term: 2001 - 2003

**Investigation of water decant from underground collieries in Mpumalanga and Free State, with special emphasis on predictive tools and long-term water quality management**

*Institute for Groundwater Studies, University of the Free State*  
(WRC Reference No 1263)

The Witbank/Highveld coalfield in Mpumalanga is the most important coal-mining area in South Africa. While this coal field makes a significant contribution to the economic development of the country it is also the source of potentially the most serious water quality problem facing the region over the longer term. There is thus an urgent need to develop and test tools with which to predict the progression of acid mine drainage (AMD) over time, and to develop, test and apply management options that will alleviate the situation. This project, together with Project Nos 1249 and 1264 will investigate the management of undergroundwater flow in collieries at various stages of closure with an aim to minimise the salt load emanating from them, evaluate alternative geochemical prediction techniques to use in the longer term, comparison of alternative management options, and the mapping of modal proportions of primary and secondary minerals. The contribution of this project will be to investigate and describe the *status quo* in terms of mining methods, scheduling, geology, geohydrology, hydrochemistry, water and salt balances at six underground collieries that are in the process of decanting or where decanting is imminent, investigate management options whereby the quality of mine water can be influenced in operating underground collieries and identify those management options that should be applied to achieve the long-term goal of minimising the salt load to the environment.

Estimated cost: R843 000  
Expected term: 2001 - 2002

**The quantitative evaluation of the modal distribution of minerals in coal deposits in the Highveld area and the associated impact on the generation of acid and neutral mine drainage**

*Department of Geology, University of the Free State*  
(WRC Reference No 1264)

The Witbank/Highveld coalfield in Mpumalanga is the most important coal-mining area in South Africa. While this coalfield makes a significant contribution to the economic development of the country it is also the source of potentially the most serious water quality problem facing the region over the longer term. There is thus an urgent need to develop and test tools with which to predict the progression of acid mine drainage (AMD) over time, and to develop, test and apply management options that will alleviate the situation. This project, together with Project Nos 1249 and 1263 will investigate the management of under-groundwater flow in collieries at various stages of closure with an aim to minimise the salt load emanating from them, evaluate alternative geochemical prediction techniques to use in the longer term, comparison of alternative management options, and the mapping of modal proportions of primary and secondary minerals. This proposal deals with the mapping of modal proportions of primary and secondary minerals and will perform a survey of the coal-mines and coal residue deposits that would contribute to the evaluation of the environmental impact associated with AMD generation. Through on-site investigations and laboratory-based studies, it will evaluate the modal proportions of primary and secondary minerals *in situ* in coal seams and residue deposits. It will furthermore prepare a guideline on the significance of the modal distribution of primary and secondary mineral phases in terms of their potential impact on the generation of AMD.

Estimated cost: R580 000  
Expected term: 2001 - 2003

**NEW**

**Thrust 1:  
Water Services - Institutional and Management Issues**

**Programme 1: Cost-recovery in water services**

**Payment strategies and price elasticity of demand for water in different income groups at three selected areas**

*Marketing Surveys and Statistical Analysis*  
(WRC Reference No 1296)

Water pricing and payment strategies are currently receiving a very high profile in South Africa. Water Affairs Minister, Ronnie Kasrils, announced on 14 February 2001 that free water (the first 6kl) be supplied to households from 1 July 2001. Price elasticity of demand for water is an essential input into water price setting and management policy formulation. It is therefore considered essential that further investigation of the price elasticity of demand for water and insight into the impact of different applied payment strategies, should be gained without delay.

To this end it is proposed that both a participate payment strategy testing methodology (PPSTM) approach as well as a contingent valuation methodology (CVM) approach be used in this study. The PPSTM approach, as developed by MSSA, together with the CVM approach as used by EPE, would be the vehicle to provide both a short-term price elasticity of demand and a long-term payment strategy for lower income residential water users in the major metropolitan areas of South Africa. It is recommended that both these approaches are undertaken, firstly for comparative purposes, and secondly so that decision-making, with respect to short-term and long-term water management policy, may be undertaken.

Estimated cost: R700 000  
Expected term: 2002 - 2004

**Effective cost-recovery in a changing institutional and policy environment: Municipal demarcation, the "Free Basic Water Policy" and financially sustainable service delivery**

*Sigodi Marah Martin*  
(WRC Reference No 1384)

Effective cost-recovery is crucial to the financially

sustainable provision of water services to all South Africans. Recent institutional and policy changes have profoundly altered the environment in which cost-recovery must take place - with municipal demarcation redefining the local and metropolitan units directly responsible for service delivery, and the adoption of a "free basic water" policy nationally substantially modifying the prevailing paradigm of cost-recovery. Because of these changes, very few municipalities enjoy the luxury of a viable *status quo*, and a thoroughgoing review of national and municipal cost-recovery is inevitable. The project will highlight and clarify the links between municipal restructuring, the "free basic water" policy, and the challenge of financially sustainable service provision. It will yield information and insights to assist and track the development of cost-recovery strategies during a period of major institutional and policy change. It will build upon existing research - in particular, WRC Project No K5/1131 - in using systematic data collection and analysis to estimate determinants of cost-recovery in a dynamic environment. Although sophisticated statistical modelling techniques will be applied, practical implications for national and municipal decision-makers will be presented in an accessible and non-technical way.

Estimated cost: R400 000  
Expected term: 2002 - 2004

**Programme 2: Institutional and management issues - Water services**

**Economic regulation of water services models for South African municipalities**

*Palmer Development Group*  
(WRC Reference No 1383)

DWAF is currently engaged in a process of developing a water services regulatory framework for South Africa. The Department has set up an initial project which aims to:

- Establish an overall regulatory framework, addressing the functions of the various organisations which need to participate in regulation
- Integrate the regulation of water boards into the framework
- Integrate regulation of water resource institutions, such as catchment management agencies into the framework
- Review requirements for legislation (including regulations) to implement the regulatory framework.

For the regulation of water services to become effective in South Africa, considerable additional work needs to be undertaken. In particular the methodology to be used in undertaking economic regulation needs to be addressed. This will define the manner in which water services authorities regulate water services providers, within the framework established by the above project. Of primary importance in this regard is the methodology for economic regulation and in particular regulating tariffs and associated financial parameters.

It is intended that the research will complement the work on regulation being undertaken by DWAF. The research will focus on appropriate mechanisms for economic regulation, an area which is not covered by the current DWAF investigation.

Estimated cost: R379 500  
Expected term: 2002 - 2003

### Programme 3: Innovative management arrangements - Rural water supply

#### Development of models to facilitate the provision of free basic water in rural areas

Mvula Trust  
(WRC Reference No 1379)

Most rural municipalities are faced with a big challenge of implementing the free basic water policy. Unlike their urban counterparts they lack the wealthy customer base that generates financial resources to cross-subsidise the poor households. Most rural households obtain their potable water from standpipes, therefore, their water consumption level falls within the 6 kL limit prescribed by the free basic water policy. This research project will investigate the actual costs of providing free basic water. The expected research output will be cost-effective institutional and subsidy models that will ensure financial sustainability of rural water supply schemes. This research will contribute towards the building of the capacity of rural municipalities to implement the free basic water policy.

Estimated cost: R500 000  
Expected term: 2002 - 2003

#### Development of a strategy for effective public participation in rural water supply projects

Nemai Consulting  
(WRC Reference No 1381)

When undertaking projects in rural areas very little consideration is given to the view and concerns of the affected community. A strategy for public participation

and involvement in rural water supply and sanitation projects will ensure the thorough understanding of the project by the local community, a user-friendly design of the infrastructure due to input from the end-users, i.e. the community itself, provide a platform for community consensus and give the social development consultant a better understanding of the community skills levels and hence the production of a better training document for the operation and maintenance phase resulting in a sustainable project.

This study also aims to analyse the various scientific techniques used in public participation, analyse the impact of each technique and develop a strategy to enhance public participation and public involvement in rural water supply and sanitation projects.

Estimated cost: R77 000  
Expected term: 2002

#### Programme for the development of health-related guidelines

Lenahan Engineering and Environmental Consulting;  
Pulles, Howard & de Lange Inc.  
Consultancy members: Umgeni Water; CSIR; BKS; ARC; DWAF  
(WRC Reference No 1400)

This programme focuses on the development of a series of guidelines and protocols to promote and advocate the safe use of water with the aim to build awareness and to transfer technology to the public to minimise water-related health risks. This programme is intended to meet the needs of practitioners and will consider aspects of water use and health, hygiene, hazards and risks as well as epidemiological studies, communication protocols and education guidelines. These projects are concerned with translating scientific data into accessible formats.

The following products will be developed:

- Management of *Legionella* and health-risk assessment guidelines (TT 174/02)
- Guides on the management of water-related microbial diseases (TT/175/02)
- Risk communication guidelines (1400A)
- Linking human health and ecosystem health risks (1400B)
- Child-centred course for teachers to promote basic health in rural communities (1400C)
- Guidelines for health impact assessments before and after water-related interventions

Estimated cost: R1 167 000  
Expected term: 2002 - 2004

#### Sub-project: The development of risk communication guidelines

Environmentek, CSIR  
(WRC Reference No 1400 A)

#### Sub-project: Protocol manual for the transfer of methodology required to link ecosystem and human health

Pulles, Howard & de Lange Inc.  
(WRC Reference No 1400 B)

#### Sub-project: The development of a child-centred course for teachers to promote basic health and hygiene awareness in rural communities

Lenahan Engineering and Environmental Consulting  
(WRC Reference No 1400C)

#### Programme 4: Rural sanitation and hygiene education

##### Developing indicators and measuring the impact of water provision on the livelihoods of rural households in South Africa -

Mvula Trust  
(WRC Reference No 1375)

This research will assess the impact of the different levels of water service provision on the individual household livelihood. This is an attempt to provide policy makers and planners with feedback on the impact of investment in water supply infrastructure. The study will also develop a set of indicators to assess whether the provision of potable water at different levels of services is linked to increased household productivity. These indicators will provide government with a tool for measuring the improvement in the quality of life for rural communities.

Estimated cost: R300 000  
Expected term: 2002 - 2004

##### Review, consolidation and evaluation of key performance indicators for successful sanitation, health and hygiene promotion programmes

Rural Support Services  
(WRC Reference No 1378)

International experience shows that the success of sanitation improvement depends on an effective health and hygiene awareness/education campaign. In this study, rural communities will be involved in the development and consolidation of key performance indicators for successful sanitation programmes, this will empower them to evaluate the quality of services they receive from implementing agents. The main objective

of this study is to establish a framework within which to evaluate the sustainability of sanitation promotion programmes.

Estimated cost: R250 000  
Expected term: 2002 -2003

##### Increasing the pace of sanitation delivery by methodologically integrating health, sanitation and income generation

Mvula Trust  
(WRC Reference No 1380)

This research seeks to support the acceleration of sanitation service delivery without improving developmental principles such as demonstration of ownership and community-based participation. The study will investigate methods of improving communities so that they can earn an income which will enable them to make a partial contribution to the costs of building toilets. The study will be undertaken in selected villages in the Eastern Cape.

Estimated cost: R204 694  
Expected term: 2002 - 2003

##### Development of a marketing plan for sanitation promotion: A participatory approach

Limakhozu Development Agency  
(WRC Reference No 1382)

This study will use participatory approaches to identify factors that motivate people to adopt safe hygiene practices. The identified factors will be used to develop a social marketing plan for sanitation and hygiene promotion in rural areas. The research output will be used to encourage households to invest their own financial resources in the improvement of their sanitation facilities.

Estimated cost: R300 000  
Expected term: 2002

##### Strategies to ensure sustainable effective disinfection in small municipal water distribution systems

Department of Biochemistry and Microbiology, University of Fort Hare  
(WRC Reference No 1391)

In South Africa, the emphasis of the effective Safe Drinking Water Act and its amendments is the attainment of standards at the point of consumption. However, previous studies on the microbiological quality of water had indicated that this water was of poor quality. The regrowth of indicator bacteria in chlorinated water had been recorded at the treatment point. The

counts of these indicator micro-organisms exceeded by far the limits allowed by the *South African Water Quality Guidelines for Domestic Use* (DWAf, 1996). Considering the overall bacteriological quality of drinking water, it can be concluded that this water constitutes a serious threat to public health. Moreover, it has been reported that in many of the water treatment plants and small water supply schemes, existing disinfection practices are unreliable and often not monitored. The reasons for the failure and unreliability of disinfection include the following: Lack of chlorine chemicals, lack of operator attention, no provision made for chlorine addition and no monitoring of chlorine residuals. The need, therefore, exists to develop strategies which will ensure sustainable effective disinfection in small municipal water distribution systems.

The aims for the project are as follows:

- Access the operational constraints of the existing disinfection system in water treatment plants
- Establish guidelines to ensure a sustainable effective disinfection in South African small municipal water treatment plants.

Estimated cost: R355 000  
Expected term: 2002 - 2004

#### Programme 5: Peri-urban sanitation research

##### Impacts of stormwater and groundwater ingress on municipal sanitation services

*Water Systems Research Group, University of the Witwatersrand*  
(WRC Reference No 1386)

Recent significant changes in land use, particularly in urban areas, have highlighted an awareness of issues present in numerous municipal areas such as, for example, the fluctuation in local groundwater tables and increased flood-lines of urban regulated streams.

The changes in water legislation and environmental protection law, the concerns over increasing pollution of groundwater resources, and particularly the need for water services authorities and providers to optimise the allocation of capital between new developments and upgrading of existing infrastructure and processes, are all leading to the need for detailed investigations on the impacts of stormwater and groundwater ingress.

The effects of urban developments on stormwater quality and quantity as well as groundwater infiltration into the sewer facilities cannot be left anymore to *ad hoc* solutions and there is an urgency for a strategic

approach to these problems. This research project will provide the necessary strategy and answers to these problems.

Estimated cost: R340 000  
Expected term: 2002 - 2004

## Thrust 2: Water Supply and Treatment Technology

### Programme 1: Drinking water treatment technology

#### Nanoporous polymers for the removal of organic contaminants in water

*Envi Sabi Scientific*  
(WRC Reference No 1393)

Present removal of organic contaminants in water relies primarily on activated carbon, which is largely successful, even in the Stander sewerage reclamation process, but organics are becoming more persistent and difficult to remove. Newer technologies are becoming available that improve on activated carbon, especially in the area of persistent organic pollutants. This project is aimed at synthesising and analysing polymer materials by means of a variety of mechanical and chemical techniques and establishing their efficacy in removing a range of organic contaminants from water.

Estimated cost: R450 000  
Expected term: 2002 - 2005

#### Evaluating the potential for upgrading existing SA filtration plants to high-rate filters

*Umgeni Water*  
(WRC Reference No 1395)

International experience indicates that gravity sand filters can be operated at filtration rates of up to 30 m/h. Standard practice in South Africa has been to design and operate filters at filtration rates of between 7 and 10 m/h. These are conservative filtration rates and are based on historical English and French design criteria.

The maximum filtration rate achievable in a filter is determined by its hydraulic design. However, the maximum rate which can be achieved before deterioration of filtrate quality or unacceptably short run times occur depends on the floc strength and filter media design (size and depth). High-rate filtration typically requires deeper beds and coarser media sizes

than conventional rapid filtration and filter aid is often required to meet filtrate turbidity standards. However, in some cases it is found that existing filters operating at conventional rates can tolerate higher rates without any upgrades or changes in chemical pretreatment.

Sand filters contribute a substantial part of the total capital costs of water treatment plants. Upgrading existing filters to high-rate filtration as opposed to building new filters could potentially minimise or totally eliminate the need for capital expenditure on upgrading existing plant capacity. This in turn would have a direct impact on the water tariff being paid by the consumer. Once the maximum feasible filtration rate for various filters designs is determined, the potential for and costs of upgrading existing conventional filters to high-rate filters can be assessed.

Estimated cost: R208 000  
Expected term: 2002 - 2004

### Programme 2: Water treatment for rural communities

#### Research on the application of *in situ* groundwater treatment as robust low-cost rural water supply treatment option

*Environmentek, CSIR*  
(WRC Reference No 1325)

High nitrate concentrations are a widespread phenomenon impairing groundwater quality. Water Services Planning, DWAf, has found that high nitrate content in groundwater is the single most important reason for groundwater not to comply with the RDP standards and in a large number of communities, mainly in the three northern provinces, groundwater with more than 20mg/l of nitrate-N is being used as drinking water.

The HIV AIDS pandemic has introduced a further urgency into the matter as infants that would have been breastfed now run the risk of being exposed to having their formulas prepared with nitrate-contaminated water. Higher concentrations of nitrate cause abortion and stillbirths that are generally not recorded as nitrate-related. At very high concentrations nitrate poisoning causes stock losses. The Department of Arts, Culture, Science and Technology (DACST) considered the matter as serious enough for funding a collaborative research project into the occurrence of nitrate in the three countries. The present WRC project allows for the preliminary mapping of the occurrence of nitrate in groundwater and the risk to the population while the DACST project extends it to the neighbouring countries. In this way the areas most seriously affected are being

identified. Through the DACST project complementary research with the exchange of information is encouraged and the Department of Geological Sciences in Botswana has already started a German BGR-funded research project investigating the accumulation of nitrate in groundwater in the Serowe-Orapa area.

*In situ* groundwater treatment, i.e. treating the water in the aquifer before pumping it to the surface, provides an elegant and robust solution to groundwater treatment, and has been proposed, investigated and patented in Germany at the beginning of the century.

The aims of the project are to:

- Identify from the literature and scientific contracts abroad, groundwater treatment processes that are (hydro)chemically suitable for *in situ* application
- Obtain an overview of the mechanics of *in situ* treatment, the relationship to aquifer properties, and the intricacies of chemical injection for subsurface dosing, gas and treatment product control
- Identify the factors controlling the economic feasibility of *in situ* groundwater treatment
- Indicate potentially viable *in situ* treatment options for other troublesome groundwater constituents (e.g. iron, manganese and fluoride).

Estimated cost: R250 000  
Expected term: 2002 - 2003

#### Durability and performance testing of operational basin solar stills, including microbiological water quality characterisation

*McCracken Solar Stills (Pty) Ltd*  
(WRC Reference No 1392)

The effective use of solar still plants for the production of potable water for small rural communities in arid regions has been demonstrated as part of a previous WRC project. Local water provision authorities in the Western Cape and Northern Cape as well as the development bank of Southern Africa are now seriously considering investing in the implementation of solar still technology. Further issues that need to be investigated have been identified.

These are:

- Expected life cycle of the equipment
- Bacteriological water quality
- Improvement of winter productivity in order to increase water supply without increasing water production costs

Estimated cost: R252 000  
Expected term: 2002 - 2004

#### **A sustainable colloidal silver-impregnated ceramic water filter for household potable water treatment**

*Envi-Sabi Scientific  
(WRC Reference No 1394)*

A simple, yet reliable technology for treatment of water in a rural setting, including emerging situations is quite valuable. A colloidal silver-impregnated ceramic water filter is capable of providing a solution that uses minimal chemicals, low residual waste, ease of operation and low operational costs.

The aims of the project are to:

- Develop a low-cost, artisan-made colloidal silver-impregnated ceramic water filter from first principles
- Optimise the performance of the filter for acceptable microbiological quality of output water
- Develop training material to address the multi-faceted challenge of introducing the filter into common use in society.

*Estimated cost: R350 000  
Expected term: 2002 - 2003*

#### **Full-scale investigation of the application of a simple chemical dosing system (CDS), and upflow roughing filtration in layers (URFL) and slow sand filtration (SSF) combination, in small and rural surface water treatment plants**

*Department of Building and Civil Engineering, Peninsula Technikon  
(WRC Reference No 1396)*

The principle objective of pilot-plant studies is to investigate how a system being investigated is likely to perform in full-scale application. The challenges that face pilot research in water treatment are therefore to achieve satisfactory full-scale application, which performs close to pilot observations and also opens the way for further innovation. Although pilot plants give indications of how full-scale facilities will perform, differences are usually inevitable due to the difficulties of duplicating field conditions, especially where pilot studies are done in laboratories. It is therefore important that pilot studies are also followed by full-scale studies to test pilot results and open the way for further innovation, which can be useful for further improvement of the system being studied.

This project is a sequel to an earlier WRC project and will explore the technology of the simple chemical dosing system developed and the viability of unconventional upflow roughing filtration in layers (URFL) in small and

rural water supply systems employing slow sand filtration (SSF). Some of these research needs, envisaged to be addressed by this project, include:

- Technological transfer of new or improved technologies of small water treatment system: The simple chemical dosing system is new and roughing filtration is a relatively emerging technology, hence the technology transfer is vital.
- On-going research on reducing costs of treatment processes for water systems but which can still supply safe and acceptable water.
- The project will also address education and training aspects with respect to the operation and maintenance of the simple chemical dosing system and the URFL-SSF processes.

*Estimated cost: R380 000  
Expected term: 2002 - 2004*

#### **Programme 4: Water distribution and distribution systems**

##### **The optimisation of water and wastewater treatment and supply systems using advanced process control techniques**

*Pollution Research Group, University of Natal  
(WRC Reference 1387)*

The rapid increase in pressure on natural resources from human economic activity has led to a growing need to manage such resources on an integrated basis. In the water field, the growing importance of disciplines such as integrated catchment management, demand management, life-cycle analysis and pinch analysis are evidence of this trend. The use of these, and other, strategic tools which attempt to ensure that resources are consumed with the maximum benefit and minimum environmental degradation, inevitably leads to technological systems with many complex interactions and constraints. To realise the benefits of integrated planning and design, it is vitally necessary to be able to control these systems effectively.

The aims of this project are to demonstrate the use of advanced process control for integrated management of water and wastewater systems in the South African water industry, to develop advanced control systems for selected water and/or wastewater treatment or management, and to develop advanced process control as a tool which will enhance the capacity of the South African water industry to achieve greater integration of the management of water and wastewater.

*Estimated cost: R300 000  
Expected term: 2002 - 2004*

#### **Integration of software packages for the probabilistic analysis of complex water supply systems**

*Department of Urban and Civil Engineering, Rand Afrikaans University  
(WRC Reference No 1389)*

South Africa recently has, and will still in future, be investing large amounts of capital into water supply systems. Systems will become progressively more expensive as they have to be lengthened and stretched to reach our most remote citizens. Already, South Africa already has some of the most complex and sophisticated water supply networks in the world. Two questions naturally emerge from this - how can new systems or extensions be made more affordable, and how is the reliability of the systems compromised as systems become larger and more complex.

The RAU Water Research Group has gone a long way in developing methods for the probabilistic (or reliability) analysis of water networks. Most recently, the progress made over almost 10 years was capped with a WRC contract recently completed, which demonstrated the added power and insight brought to water system analysis by this new approach. The project also produced a software package MOCASIM, by means of which simple, linear supply systems can be analysed. In summary, this just completed project clearly established probabilistic analysis as a viable, necessary approach for the design of better, more efficient systems.

It is now necessary to take this approach one step further, namely to broaden the application of probabilistic analysis from simple, linear bulk supply systems (which MOCASIM already does) to more complex, real-life systems which require a much higher level of hydraulic analysis (for example networks, pumps, multiple and complicated demand patterns, different hydraulic control strategies). This study aims to combine MOCASIM (with its innovative probabilistic features) with EPANET to produce a unique piece of software to take probabilistic analysis into the practical design domain.

*Estimated cost: R120 000  
Expected term: 2002 - 2003*

### **Thrust 3: Wastewater and Effluent Treatment and Reuse Technology**

#### **Programme 1: Biological sewage treatment processes**

##### **Material mass balances over and modelling of wastewater treatment plants**

*Department of Civil Engineering, University of Cape Town  
(WRC Reference No 1338)*

The objectives of this project are to develop a mass balance model for wastewater treatment plants, a model for sequential batch reactors, an integrated anaerobic digester model, and a model for characterising primary and secondary wastewater sludges.

*Estimated cost: R429 000  
Expected term: 2002 - 2005*

##### **Biofloc modifications for sludge settleability improvements from selected BNR process conditions and configurations, pilot - and full-scale based settling behaviour evaluations for final clarification enhancement**

*ERWAT  
(WRC Reference No 1340)*

Recent new DWAF legislative standards include lower permissible suspended solids and nitrate concentrations in effluents. Limited research has been done to determine the optimum levels of aeration necessary to keep solids in aerated suspension and produce the required flocculation. Alongside this, current biomass settling models are empirically based, the mechanisms postulated are not supported by representative plant data, and the settling process is very sensitive to variable process conditions and environmental factors. In this project a pilot plant will be operated to generate benchmark data which will be used to configure a comprehensive mathematical model describing both sludge settleability and settling behaviour. The pilot-scale tests will be conducted in parallel with full-scale verification trials at various ERWAT wastewater works.

*Estimated cost: R298 330  
Expected term: 2002 - 2004*

**The development and technology transfer of AIPS applications in upgrading water quality for small wastewater and drinking water treatment systems**

Department of Biochemistry, Microbiology and Biotechnology, Rhodes University  
(WRC Reference No 1362)

The aims of this project are to survey and identify the potential for applying integrated algal pond systems (IAPS) technology for low-cost upgrading of small community wastewater and drinking water treatment installations in the Eastern Cape Province, to carry out on-site pilot-scale evaluations at a number of selected sites using portable IAPS pilot plant facilities established for the purpose, and to transfer the technology to the end-users by training of managers and operators.

Estimated cost: R630 300  
Expected term: 2002 - 2005

**Evaluation of different commercial microbial or microbial-derived products for the treatment of organic waste in pit latrines**

Bio/Chemtek, CSIR  
(WRC Reference No 1377)

Pit latrines operate on the principle of anaerobic decomposition. However, this decomposition is very slow, with a consequent build-up of organic waste. Such a build-up is undesirable and can result in odour production and may pose health and environmental risks. It is claimed that the use of microbial or microbial-derived products for the treatment of organic waste in pit latrines, control odour as well as reduce the bulk of the organic material. There are several of these products on the market, but there is no, or very little, reliable information available on their efficacy. There is also no scientific information on the mode of action and efficacy of these products. This project will conduct a survey of the microbial products that are used in South Africa and compare them in a laboratory study in terms of their mode of action and efficacy to digest organic material and control odours. This study will be followed by a field study to test the efficacy of the more promising products in a pit latrine.

Estimated cost: R250 000  
Expected term: 2002 - 2003

**Programme 2: Sludge characterisation, treatment, utilisation and disposal**

**Scale-up development of the Rhodes BioSURE® process for sewage sludge solubilisation and disposal**

Department of Biochemistry, Microbiology and Biotechnology, Rhodes University  
(WRC Reference No 1336)

The overall aim is to derive process design criteria for full-scale implementation of the Rhodes BioSURE® process for sewage sludge solubilisation. To achieve this, the demonstration-scale BioSURE® plant established at Ancor Sewage Works (Springs) will be operated, monitored and optimized, and the facility will be extended to include sulphide bio-oxidation and sulphur recovery. A smaller pilot plant at Makana Sewage Works (Grahamstown) will be operated and monitored to study process variables in finer detail, to identify and investigate areas of sulphidogenic sewage sludge solubilisation that require further development for scale-up.

Estimated cost: R1 510 900  
Expected term: 2002 - 2005

**Survey and methodology for analysing organic pollutants in South African sewage sludges**

School of Chemical and Physical Sciences, University of Natal  
(WRC Reference No 1339)

Sewage sludges are contaminated with a wide array of organic compounds. Out of the 127 compounds listed by the United States Environmental Protection Agency as having the greatest potential to harm human health or to be detrimental to the environment, 111 are organic compounds. While the *South African Sludge Guidelines* of 1991 stipulated limits for organic pollutants, no mention is made of why these compounds were selected and how the recommended limits were arrived at. The limits of the same compounds were revised in 1997. The new limits were once again not tested for compliance or the *status quo* in South Africa. The maximum concentration limits as stipulated in the document are based on LC50 calculations and not on experimental values. This project will determine and quantify the composition of organic pollutants in sewage sludges. The investigation will also test and suggest the best method(s) of handling and determining these pollutants, so that uniformity can be introduced among the various producers and government laboratories. It is intended to use the same sludge samples that are being used in WRC Project No 1283 so as to reduce cost.

Estimated cost: R580 000  
Expected term: 2002 - 2005

**An investigation into the pyrolysis of sewage sludge**

Department of Chemical Engineering, Technikon SA  
(WRC Reference No 1406)

Some of the present sludge disposal methods may become more restricted in future. There is thus a need to identify and investigate alternative ways to utilise sludge and find solutions to the sludge disposal problem. The conversion of sludge to fuel products has been known for more than 50 years. It has been demonstrated that synthetic crude oil can be produced from a sewage sludge by heating it at 300 to 350°C in an oxygen-free environment for about 30 min. Thermal liquefaction of sewage sludge in a rotary reactor was tried at temperatures of 350 to 450°C and good quality oil has been produced from a dried mixture of raw and waste activated sludge using a retort type of reactor at atmospheric pressure. This project will investigate the pyrolysis of sludge and evaluate the potential to produce some useful materials such as hydrocarbon and oil from it. This research could thus provide an alternative outlet for the beneficial utilisation of significant quantities of the sludge that is produced annually.

Estimated cost: R49 500  
Expected term: 2002 - 2003

**Programme 3: Treatment and recovery of organics from agro-industrial processing**

**Monitoring, evaluation and verification of long-term performance of passive treatment plants at Vryheid Coronation Colliery**

Pulles, Howard & de Lange Inc.  
(WRC Reference No 1348)

Under conditions of relatively low volume or remote location, passive treatment of acid mine drainage is more appropriate than active treatment alternatives. The WRC, the mining industry and the Innovation Fund have consequently invested huge amounts in an effort to develop this technology to a level where it is cost-effective, reliable and predictable. The pilot-scale reactors at Vryheid Coronation Colliery (VCC) have been in operation since the end of 1996 and are presently the longest running, most closely monitored passive sulphate-removal reactors in the world. With the conclusion of the Innovation Fund project for passive treatment, funding for monitoring these reactors ran out by the end of 2001. While the VCC reactors have maintained their treatment capability, the actual performance was not always satisfactory. This project will extend the monitoring of reactor performance for a further two years, endeavour to understand erratic performance and introduce strategies developed in the Innovation Fund project with the aim of improving

performance of some cells by 60 to 80%. The successful completion of this project will hopefully conclude a 7-year research initiative (funded by the Innovation Fund, WRC and mining industry) and lead to the commercialisation of the product.

Estimated cost: R600 000  
Expected term: 2003 - 2005

**Development of a customised bioreactor for bioremediation of organic-containing effluents and conversion of constituents to high value chemicals**

Department of Chemical Engineering, University of Cape Town  
(WRC Reference No 1361)

This project focuses on the bioremediation of organic-containing effluents, phenolic effluents, and the conversion of constituents in the effluents to high-value chemicals. Not only do these wastewaters present serious environmental hazards, but their disposal also results in the loss of appreciable amounts of chemical components which have significant potential value. The project will investigate bioremediation methods for the treatment and chemicals recovery for olive and wine wastewaters. Both these effluents are not very amenable to normal biological treatment processing. The project therefore aims to exploit novel bioremediation techniques, using a customised bioreactor, suitable for application in functional processes, for the bioremediation of polyphenolic wastewaters and recovery of high-value chemical derivatives (including vanillin, vanillic acid and/or resveratrol) from them.

Estimated cost: R594 000  
Expected term: 2002 - 2005

**Treatment of food processing wastewaters by using combined UASB technology and ozonation scenarios**

Department of Food Science, University of Stellenbosch  
(WRC Reference No 1364)

The project aims to evaluate the combined use of upflow anaerobic sludge blanket (UASB) reactor technology with ozonation for the treatment of food and beverage processing effluents. The research group has been constantly improving on existing UASB technology and has developed a very efficient reactor system, utilising quick-adapting micro-organism pellets for organics breakdown. However, by nature the organisms have their limitations in the breakdown of recalcitrant and toxic compounds. Initial laboratory studies have shown good potential to combine ozone with the UASB reactor to enable the breakdown of these recalcitrant compounds. In a separate project funded by the WRC,

an innovative and inexpensive ozone generator has been developed, making the use of ozone much more economical. This development will improve the application potential of this promising UASB/ozonation technology even further. Should the intended research be successful, a very wide application of the technology is foreseen for all effluents containing high levels of organics.

Estimated cost: R353 000  
Expected term: 2002 - 2005

#### **Scale-up of a two-stage treatment process for treating wastewater from distillers involving fungal pretreatment followed by anaerobic digestion**

Oenozyme cc  
(WRC Reference No 1365)

The wine-distilling industry in the RSA annually produces large volumes of effluent that are strongly acidic and have a high organic strength including high colour. The aims of this project are to design and construct a pilot-scale fungal bioreactor and baffled anaerobic reactor for series treatment of wine distillery effluent, to develop and evaluate methods for harvesting high-value enzymes from the fungal bioreactor, and to evaluate the performance of the system over a 6-month period.

Estimated cost: R462 000  
Expected term: 2002 - 2004

#### **Development of a hybrid immersed-membrane bioreactor**

Institute for Polymer Science, University of Stellenbosch  
(WRC Reference No 1369)

The project is aimed at producing an innovative immersed-membrane bioreactor for potential use in the treatment of wastewaters as well as for potable water production from dirty surface water sources. This technology has particular potential for smaller systems. This project will take development to prototype stage. The product will combine the advantages of the newly developed immersed membranes with a novel cleaning, biofilm control and oxygen supply method. This technology has great potential in South Africa, and elsewhere in the world, because it is expected to improve significantly on the current immersed membrane efficiencies, coupled with a lower potential for fouling and lower maintenance and general attention requirements.

Estimated cost: R990 000  
Expected term: 2002 - 2005

#### **Dual-stage ceramic membrane bioreactor for the treatment of high-strength industrial wastewaters**

School of Environmental Sciences and Development, UP for CHE  
(WRC Reference No 1371)

Several industries produce high-strength effluents such as chemical process plants and textile industries, which may contain toxic organic materials and dyes that introduce unwanted colour to wastewater. Solid-liquid retention membrane bioreactors have proven to be highly efficient systems for the treatment of high-strength industrial effluent containing recalcitrant pollutants. The problem with long-term operation of membrane bioreactors treating high-strength effluents is, however, that a shift in the dynamics of the population of microbes which utilise the toxic pollutants as nutrients occurs. These changed populations do not break down the pollutants, but instead, they are predatory on the useful population of microbes that effect pollutant removal. This occurs because membrane bioreactors are typically operated at a low feed-to-biomass ratio. Thus, strategies for long-term operation of membrane bioreactors of this nature have involved regular re-inoculation of the correct consortium of microbes.

The project entails a new approach to the operation of solid-liquid separation bioreactors for the treatment of effluent-containing recalcitrant pollutants. This involves the use of a dual-stage membrane bioreactor, which uses ceramic membranes for cell recycle. Such a reactor can be used for on-site treatment of high-strength industrial effluent before discharge or to aid in water reuse programmes in industry. It is also a small footprint portable reactor configuration that can be used to treat landfill leachate where water bodies are contaminated until long-term solutions for landfill leachate generation are found.

Estimated cost: R885 000  
Expected term: 2002 - 2005

#### **Evaluation of a locally developed membrane system for oil-water separation for application in different industries**

Department of Chemical Engineering, Durban Institute of Technology  
(WRC Reference No 1373)

Oil in wastewater has traditionally been a major contribution to waste load on municipal water treatment works. International trends are to clean up these wastewaters at source so as to prevent downstream treatment at municipal facilities and to prevent problems that may arise due to the transport of this waste to such facilities.

"Off the shelf" membrane systems exist overseas for oil-water separation. Locally developed ultrafiltration membranes from the Institute for Polymer Science, University of Stellenbosch, have been successfully employed in potable water production. It has been suggested that these membranes could be effective in separating oil from wastewater. There is a potential for application of the local capillary ultrafiltration unit for the treatment of metal-finishing industry wastewaters. These wastewaters contain various components and in varied concentrations. Some solutions such as degreaser solutions, are emulsified while others have a high non-emulsified oil content. The effectiveness of the membrane system to effect a separation for these varied feed types needs to be investigated together with cleaning strategies for the membranes. The project therefore aims to evaluate the ability of this locally-manufactured ultrafiltration membrane to separate oil from metal-finishing industry wastewaters and to advise on possible changes which may be required to the system to ensure commercial use thereof.

Estimated cost: R200 000  
Expected term: 2002 - 2004

#### **Development of a combined activated carbon/microfiltration (ACMF) process for the treatment of industrial effluents**

Department of Chemical Engineering, Durban Institute of Technology  
(WRC Reference No 1374)

Many industrial effluents are fairly complex, containing suspended and colloidal solids, dissolved organics, and dissolved inorganic species. Hence, a multi-stage process is usually necessary for effective treatment of these effluents. This project concerns the development of a novel combined activated carbon/microfiltration (ACMF) process that can remove all suspended and colloidal solids as well as significantly reduce the organic content of an effluent in a single step.

The ACMF process is a very promising one-step process for organics reduction and the removal of suspended solids. The performance is superior to a microfilter without a precoat or a microfilter with an "inactive" precoat, both from the point of view of rejection and permeate fluxes. The removal of organics is seemingly superior to conventional PAC processes, due to the formation of a secondary dynamic separation layer. As such, the process holds great potential in the treatment/pre-treatment of "difficult" industrial effluents. This project will develop the ACMF process further, evaluate it on selected industrial effluents, and determine the overall economics of the process.

Estimated cost: R397 000  
Expected term: 2002 - 2005

#### **Programme 4: Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents**

##### **Final development and refinement of the floating sulphur biofilm reactor for sulphide oxidation, for use in integrated passive water treatment systems and the active Rhodes BioSURE® process**

Pulles, Howard & de Lange Inc.  
(WRC Reference No 1349)

South Africa has undertaken and spent much on research during the past decade to develop active and passive biological treatment technology aimed at removing sulphates, metals and acidity from contaminated mine and industrial wastewater. Funding was provided by the WRC, the Innovation Fund, ERWAT and the mining industry. Both active and passive processes require a process or stage to remove the sulphides (which are produced by sulphate reduction) to prevent them from being oxidised back to sulphates. Prior research has led to the development and construction of a floating sulphur biofilm pilot-plant reactor at Rhodes University. This technology has, however, not yet been evaluated and optimised to a point where its efficiency is acceptable. This project is aimed at the evaluation and refining of the sulphur biofilm technology to the point where it can be incorporated into either passive or active sulphate removal technologies.

Estimated cost: R241 400  
Expected term: 2002 - 2003

##### **Evaluation of microfiltration, ultrafiltration and nanofiltration for salt and chromium recovery from spent pickling and tanning effluents**

Environmentek, CSIR  
(WRC Reference No 1370)

The leather industry is under pressure from the authorities to reduce the salt and chrome load in the effluent discharged to inland public water bodies. Sodium chloride is commonly used as a pickling agent in the production of leather. Chromates are used in the tanning process. Brine effluents from these processes are commonly not reused, because of poor quality and the fear of affecting leather product quality adversely. Pickling stage effluent contains chrome salts and organic contaminants. Chromium and salt, however, have the potential to be recovered and recycled in the pickling/tanning process. It has been demonstrated in

laboratory-scale studies that microfiltration and/or ultrafiltration could function effectively for chromium and salt recovery from spent pickling/tanning effluent. The main aim of this project will be to perform a techno-economic study to establish the viability of developing microfiltration/ultrafiltration/nanofiltration process technology for the recovery of chromium and salt from spent pickling/tanning effluent for reuse in the process.

*Estimated cost:* R150 000  
*Expected term:* 2002 - 2003

#### **Prevention of calcium sulphate crystallisation in water desalination plants using slurry precipitation and recycle reverse osmosis (SPARRO)**

*Department of Chemical Engineering, University of Cape Town  
(WRC Reference No 1372)*

The project aims to further develop the slurry precipitation and recycle reverse osmosis (SPARRO) system, which can be used for the treatment of sulphate- and calcium-rich mining and a variety of other scaling effluents. The system has very good potential but needs to be adapted to newer, improved membranes. The latest fouling prevention techniques also have very good potential but need to be adapted to newer, improved membranes and evaluated on the system. This will be done in the proposed project. An effective SPARRO system will have wide application and be of great benefit in terms of factory water-cycle closure in the gold-mining, coal-mining, electricity-generating, petroleum, steel as well as pulp-and-paper industries. Current non-membrane techniques for the treatment of scaling effluents are either ineffective or too expensive.

*Estimated cost:* R822 000  
*Expected term:* 2002 - 2005

#### **Programme 5: Training in wastewater treatment plant operation**

**Development of a diagnostics-based knowledge management system for the efficient operation and training of staff associated with municipal sewage treatment facilities**

*Department of Biochemistry and Microbiology  
(WRC Reference No 1337)*

Pressures of rapid urbanisation and the provision of sanitation services have resulted in sewage treatment plants operating sub-optimally for a variety of reasons including not only installed hardware capacity but also insufficient operator training and expertise for consistent management of the facilities. This project aims to

support and strengthen the human resource base by generating a knowledge management database for capturing the experience of operators and engineers in running sewage treatment facilities; developing and applying a system for implementation of the database; and testing the system initially at a sewage treatment facility in the Port Elizabeth Municipality.

*Estimated cost:* R329 200  
*Expected term:* 2002 - 2004

### **Thrust 4: Industrial and Mine-Water Management**

#### **Programme 1: Quantification of water use and waste production**

**An investigation into the use of water at power-generating plants with special reference to the quality and quantity of effluent from these plants and the specific water use per megawatt electricity generated**

*Department of Chemical and Metallurgical Engineering, Technikon Pretoria  
(WRC Reference No 1390)*

The power-generating industry in the RSA is a substantial water user and effluent producer and impacts nationally both on water use allocations and the maintenance of resource water quality. The project aims to determine the volumes and breakdown of water taken in and discharged by major and minor power-generating plants, to determine pollutant loads and identify suitable wastewater management processes and strategies, and to compile the findings into a guideline document assisting both the industry and regulators in effective water and wastewater management of this sector.

*Estimated cost:* R170 000  
*Expected term:* 2002 - 2003

#### **Programme 2: Regulatory mechanisms to improve industrial and mine-water management**

**An investigation of the specific chemistry and geochemistry of manganese, the bearing that this has on suitable chemical techniques used in the classification of wastes containing manganese, and the determination of alternative characterisation techniques**

*Pulles, Howard and de Lange Inc.  
(WRC Reference No 1344)*

Manganese is considered a hazardous material, with a hazard rating of 2 according to the minimum requirements as published by DWAF. The test methods according to which waste is classified consist of the TCLP test (toxicity characteristic leaching procedure) and the acid rain test. Experimental work conducted by the project team on contract for a specific manganese-containing waste showed that this element, due to its specific geochemical behaviour in these tests, may give results not consistent with its behaviour in the environment. As a result, it was found that there is a risk that some wastes may have higher classifications than are required for the protection of the water resource. This proposal is aimed at establishing whether the current methods employed for the hazard rating and classification of wastes containing manganese are appropriate, and whether, under specific conditions, other methods which better represent the behaviour of such wastes exist, or can be devised. It will generate specific examples based on pyro-metallurgically generated wastes to develop a generic approach to the management of inorganic manganese-containing wastes.

The specific aims of the project are to:

- Establish whether the current methods employed for the hazard rating and classification of wastes containing manganese are appropriate
- Establish whether, under specific conditions, other methods which better represent the behaviour of such wastes exist, or can be devised.

*Estimated cost:* R297 100  
*Expected term:* 2002 - 2003

#### **Valuing water for South African industries: A production function approach**

*Environmentek, CSIR  
(WRC Reference No 1366)*

The industrial sector in South Africa is one of the fastest

growing sectors and relies to varying degrees (ranging from wet to essentially dry industries) on water resources as an input to many production processes. Industrial water use currently comprises about 10 % of the total water use in South Africa (WSAM 2000) and is therefore a significant water-using (and effluent-generating) sector. Very little is, however, currently known about the responsiveness to water pricing within the industrial sector in South Africa, probably because of historically low pricing structures and the perception that industrial water use is better suited to engineering rather than economic analysis. International literature offers mixed results, with industrial price elasticities ranging from very inelastic to more elastic. In the context of the National Water Act and its emphasis on economic pricing, and the significance of industrial water use in South Africa, it is necessary to provide econometric tools to decision-makers. The proposal aims to quantify and characterise the role that water plays in various local industries and their responsiveness to price changes; and to develop a set of indicators and judgement criteria for policy-makers, decision-takers and other stakeholders to use economic analysis for appropriate water resource management.

The project's overall aim is to determine the marginal value of industrial water in South Africa, in keeping with the National Water Act's objectives to price water correctly. The specific sub-goals are listed below:

- To assess the role that industries play in the overall water demand for South Africa, and to determine which industries are the most water-intensive industries and which industries are relatively water "dry"
- To determine price elasticities of demand for water for the respective industrial sectors within South Africa, and develop a set of indicators that can be used in existing models or assist existing techniques to ensure sustainable and equitable conservation of water resources
- To demonstrate through practical application how economics can be used to value water resources, and to document this application so that it may be applied across sectors
- To provide a value judgement for water resource management and policy based on the results and an extended analysis of the data
- To build capacity in all stakeholders and parties participating in the research project, through the transfer of knowledge.

*Estimated cost:* R549 600  
*Expected term:* 2002 - 2005

### Programme 3: Minimising the impact of waste on the water environment

#### Improving the performance of covers for the rehabilitation of coal-mine residues

Golder Associates Africa (Pty) Ltd  
(WRC Reference No 1350)

A joint WRC-Coaltech 2020 project utilising an experimental set-up built by DWAF in KwaZulu-Natal, proved that soil cover design, and specifically cover thickness, had a major effect in limiting the flow of water through the cover (thereby reducing the volume of potential acid mine drainage - AMD). The cover also had a major effect on the ingress of air, thereby limiting one of the essential elements for the formation of AMD. Internationally new soil cover designs have been developed which appear to be even more efficient. The current project will assess the performance and sustainability of existing in-field covers of coal discard dumps in the Mpumalanga coal-field, analyse the expected efficiency of the most promising new soil cover designs and, if viable configurations are identified, design and motivate for a new experimental facility which is to be established in the Mpumalanga Highveld, from materials which are readily available in this area. The general aim with his project is thus to measure and improve the effectiveness of various cover configurations in limiting rainfall infiltration and oxygen ingress into coal discards and spoils.

Estimated cost: R617 100  
Expected term: 2002 - 2003

#### Programme 4: Minimising waste production

Promotion of biodegradable chemicals in the textile industry using the Score system: Phase 1 - Pilot study  
School of Chemical Engineering, University of Natal  
(WRC Reference No 1363)

The score system is a management tool, developed in Europe, for monitoring the environmental pollution potential of a company based on the characteristics of the chemicals used and which could report to the effluent. The parameters assessed are the amount of substance used and its biodegradability, bio-accumulability and toxicity, each of which is given a logarithmic score between 1 (low environmental burden) and 4 (substantial negative environmental impact) to derive a composite "score". In this project the system is being tested for its applicability to the RSA, using textile companies as the initial pilot study. The objective is to reduce the environmental impact of a company, as

measured by its "score", by minimisation of the chemicals used and/or their substitution in favour of less environmentally-aggressive choices. If successful, the concept could be advanced for other industrial sectors as a generic environmental management protocol.

Estimated cost: R700 000  
Expected term: 2002 - 2005

#### Bioremediation and bio-utilisation of pulping and bleaching effluents

Department of Biochemistry and Microbiology, University of the Free State  
(WRC Reference No 1367)

The project aims to further develop micro-organism-based processes for the biological release of fibre from paper pulp and the bio-bleaching of pulp in order to limit bleaching effluents. At the same time valuable products such as enzymes are to be produced in the process. Initial success has been achieved in a pilot project recently completed and funded by the WRC but follow-up work is required to further exploit the potential. The current research being conducted in SA is in the forefront of international circles and a successful project will make a significant impact on limiting discharges of chlorine-based toxic and mutagenic substances into the environment internationally. The potential for recovery of valuable by-products will increase the economic viability and the potential application of the process. Techniques developed in this project will also be applicable to the food industry.

Estimated cost: R500 000  
Expected term: 2002 - 2004

#### Water conservation through energy conservation

Pollution Research Group, University of Natal  
(WRC Reference No 1368)

To meet the needs for increased thermal efficiency (because of firstly the first "energy crisis" in the 1970s and subsequently the global warming/carbon dioxide issues of the 1990s) and for reduced water consumption (initially as water intake in water-rich regions), two separate but similar process integration techniques (thermal pinch and water pinch) were developed to optimise the thermal/energy and water efficiencies in industrial complexes (improved thermal/energy efficiency also implies reduced water use at the power-generating stage). Thermal pinch is a mature technique, while water pinch is evolving rapidly. This research group has successfully applied and adapted water-pinch techniques to the water-scarce situation in South Africa. This project aims to combine these two

techniques and apply them to South African industry.

Estimated cost: R740 000  
Expected term: 2002 - 2004

#### Programme 5: Improved ability to predict and quantify effects

#### An empirical assessment of post-closure flushing effects on gold-mine decant water quality in the West Rand dolomitic region

Golder Associates Africa (Pty) Ltd  
(WRC Reference No 1346)

Most South African gold-mines are nearing the end of their economic lives. It is of great importance to the country to know what impact closed gold mines will have on surface and groundwater quality so that appropriate remedial action can be incorporated into mine closure plans. If appropriate action is not taken timeously, the situation may develop, as happened with older mines, that the state or society has to bear the cost associated with poor quality water emanating from closed mines. This project deals with an empirical assessment of the post-closure situation for gold mines in the West Rand dolomitic region. Present modelling predictions concerning the impact these mines will have on water quality after closure, are often contradictory and need to be tested under practical conditions which simulate the reality as closely as possible. The project provides for isolating a stope underground so that it can fill with recharge water, thereby simulating the situation that will occur when mining is stopped and the mine starts to refill.

A controlled outlet will allow water to flow through the isolated section, thereby simulating a flushing effect. The rate of filling, flushing and water quality changes will be monitored and used to obtain empirical measurements which can be tested against model predictions. Anglogold Ltd. will contribute the experimental site and establish the facility. The WRC will provide for the monitoring and research components.

Estimated cost: R352 400  
Expected term: 2002 - 2005

#### An investigation into the depth and rate of weathering on gold-tailings dam surfaces as key information for long-term risk assessments

Golder Associates Africa (Pty) Ltd  
(WRC Reference No 1347)

There are over 300 gold-tailings dams (slimes dumps) scattered over the gold-mining areas covering a total

area of some 180 km<sup>2</sup>. Tailings are mostly deposited in an alkaline state and during their operational phase tailings dams and their drainage are typically neutral to alkaline. However, when operations stop, oxygen ingress into the outer layers oxidises the pyrite present in the tailings to produce sulphuric acid which mobilises metals and consumes the neutralising potential in the rest of the dam. Research shows that the oxygen ingress reduces with depth, resulting in an oxidised outer cap. However, enough acidity can be produced in this oxidised cap to consume all the neutralising potential contained in the dump and cause an acid mine drainage (AMD) producing dump. There is considerable variation in the physical status and pyrite content of dumps depending on the processes employed during ore processing. This leads to large variation in both the depth of oxidation of dump covers and their acid-generating potential. This project will, through empirical research, develop relationships to predict the depth and rate of weathering and develop rapid procedures to assess the risk for a specific tailings dam to produce AMD. This information will be used by mines as a screening tool to assess their long-term liabilities and to plan rehabilitation, while government will be able to identify those dams that require most urgent attention.

Estimated cost: R169 000  
Expected term: 2002 - 2003

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# KSA 4

## Water Utilisation in Agriculture



**Dr GR Backeberg**  
Director:  
Water Utilisation in Agriculture

### Scope

The strategic focus in this KSA is on increasing the efficient use of water for production of food, fibre, fuelwood and timber; ensuring sustainable water resource use; reducing poverty and increasing wealth of people dependent on water-based agriculture. The needs and requirements of present and future generations of subsistence, emergent and commercial farmers will be addressed through creation and application of water-efficient production technologies, models and information systems within the following interrelated subsectors of agriculture, namely:

- Irrigated agriculture
- Dry-land agriculture
- Woodlands and forestry

- Grasslands and livestock watering
- Aquaculture

The challenge for applied research and knowledge dissemination is to provide solutions to practical problems which are experienced in the process of utilisation, development and protection of water resources, thereby contributing to productivity growth in agriculture.

### Objectives

The primary objective is to increase national food security and to improve the livelihoods of people on a farming, community and regional level through efficient and sustainable utilisation and development of water resources in agriculture.

The secondary objectives are to:

- increase biological, technical and economic efficiency of water use
- reduce poverty through water-based agricultural activities
- increase profitability of water-based farming systems
- ensure sustainable water resource use through protection and reclamation practices.

The research portfolio of current projects has been grouped into strategic thrusts and programmes which directly address the above-mentioned objectives and are summarised as follows:

### Thrusts and programmes

#### Thrust 1: Water Utilisation for Food and Fibre Production

- Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture
- Fitness-for-use of water for crop production, livestock watering and aquaculture.

#### Thrust 2: Water Utilisation for Fuelwood and Timber Production

- Water-efficient production methods and systems in agroforestry, woodlands and forestry plantations.

#### Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture

- Sustainable water-based agricultural activities in rural communities
- Integrated water management for profitable farming systems

#### Thrust 4: Water Resource Protection and Reclamation in Agriculture

- Sustainable water resource use on irrigation schemes and within river catchments
- Impact assessment and environmental management of agricultural production.

### Budget for 2002/03 and 2003/04

The approved funding of the research portfolio for 2002/03 leads to committed funding of R7 347 123 in 2003/04.

Funding for new projects of R2 750 000 in 2003/04 is requested to solicit research proposals under six specific themes. These proposed themes are:

- water harvesting and conservation
- aquaculture
- woodlands and forestry
- productive subsistence farming
- rehabilitation of irrigation schemes
- impact of agricultural production on the natural environment.

The consolidated budget for the research portfolio is presented below:

Research portfolio	Approved 2002/03 R	Committed and requested 2003/04 R
Current projects	6 552 951	7 347 123
New projects	3 498 550	2 750 000
Total	10 051 501	10 097 123

## CORE STRATEGY

### Strategic context

The water resource base is of key importance in agriculture. Together with other renewable and interdependent natural resources, it forms the ultimate support of the productive economic activity of people.

Water utilisation can best be quantified as rainfall-dependent, surface water- and groundwater-dependent use. Approximately 12% and 62% of rainwater in South Africa is used annually for respectively dry-land cropping and by natural grasslands, woodlands and forests. Rainwater runoff and deep percolation become available as surface- and groundwater. Approximately  $10.7 \times 10^9 \text{ m}^3$  per year of surface water (which is equivalent to 2% of rainwater, or 53.6% of total annual surface water requirements or 32.3% of the maximum annual yield) and  $1.6 \times 10^9 \text{ m}^3$  per year of groundwater (80% of the exploited volume or 29.6% of the maximum annual yield), is used for irrigation. It is therefore clear that the biggest share of water is used for both extensive and intensive production in agriculture.

Out of an economically active population of 13.8m. people in South Africa, at least 35% are directly or indirectly dependent on agriculture. This consists of small-, medium- and large-scale enterprises, which provide employment opportunities for 11% of formal labour. Furthermore, 59.9% of all households live in urban areas and 40.1% of households live in rural areas. In these rural areas, 64.2% of households or at least 10.5m. people are poor and are living below the headline income.

As is typical of an industrialised economy, the relative contribution of agriculture, forestry, hunting and fishing is low at 4 to 5% of gross domestic product (GDP). To this must be added the contribution of the agri-food industry at 9% of GDP. Agriculture is, however, a net exporter of food, contributing 10% of total exports of which 50% are processed products. The forward linkages to processing industries and backward linkages to input suppliers in agriculture are therefore of considerable importance for economic activity in urban and rural areas. This impact of agriculture on the economy can be illustrated by the GDP multiplier of 1.51 for agriculture as a whole, which varies, e.g. from 1.38 for maize, 1.55 for subtropical fruit, 1.63 for cotton, to 1.70 for forestry.

Critical issues in the forthcoming years and next two decades are increasing pressure on agriculture and forestry, in particular food and fuelwood production, due to population growth, urbanisation and increasing income levels of consumers. At the same time there is a dependence on agriculture in rural areas, particularly of the poor. This will also bring pressure on the water resource base.

It must be recognised that use and development of water resources by people have both beneficial consequences, as mentioned above, and detrimental consequences. Negative impacts of water use include soil erosion, sedimentation, water-logging and salinisation. Important issues, which must receive attention, are the nature of resource degradation, underlying causes and feasible reclamation practices. Consequently, although the quantity and quality of water resources available for agricultural use are limited, it is important to note that this is not a constraint for economic development. The requirement is that water resources must be utilised productively and greater efforts must be made to increase productivity growth and thereby the competitiveness of agriculture.

Against this background the strategic focus of agricultural water research is on:

- Increasing the efficiency of water use for food, fibre, wood and timber production (i.e. improving the knowledge of biological, technical and economic processes of production)
- Ensuring sustainable water resource use in rain-fed and irrigated areas (i.e. improving the knowledge of natural processes and man-induced impacts of resource use)
- Increasing the household food security and profitability of farming and thereby the livelihoods of people dependent on agriculture (i.e. improving the knowledge of management processes by people who are using water).

In drawing up plans to implement these strategies, cognizance has to be taken of the following factors:

### Needs analysis

During 2000 the Presidential Imperative Programme on Integrated Sustainable Rural Development was announced. The goal of the programme is to promote development and improve the quality of life of marginalised groups and communities. The objectives are to alleviate poverty through enhanced production, productivity, creation of employment opportunities and a

more equitable distribution of resources. Outputs which are envisaged include agricultural production systems and sustainable utilisation and management of natural resources and the environment.

At the end of 2001 the Strategic Plan for South African Agriculture was released by the National Department of Agriculture, Agri SA and the National African Farmers Union (NAFU). The strategic goal is to generate equitable access and participation in a globally competitive, profitable and sustainable agricultural sector, contributing to a better life for all. This strategic goal is expected to guide all relevant partners in their quest to deliver and implement a range of programmes in accordance with basic premises of amongst others:

- fair reward for effort, risk and innovation
- security of tenure for present and future participants
- the sustainable use of natural and biological resources
- sound research, science, knowledge and technology systems
- market forces which direct business activity and resource allocation.

The outcomes which are envisaged to flow from successful implementation of programmes include:

- increased creation of wealth in agriculture and rural areas
- increased sustainable employment
- increased income and foreign-exchange earnings
- reduced poverty and inequalities in land and enterprise ownership
- improved farming efficiency
- improved national and household food security
- increased investment in agricultural activities and rural areas.

One of the three core strategies in the strategic sector plan for agriculture is sustainable resource management which also impacts on water systems. Central to this strategy is *inter alia* the promotion of sustainable use of soil and water through increased crop and livestock productivity and intensified farming systems, while farmer participation is a key success factor. Degradation of soil and water resources is considered to be a serious threat and therefore programmes must be designed to overcome the causes of degradation. Such soil and water conservation programmes will focus on areas where there is a reasonable chance of success as determined by, e.g. available technologies and access to markets, inputs and services.

These needs as expressed by government and farmer representatives at a national level highlight the key issues which must be addressed in the WRC research portfolio.

### Technological trends

With growing demand for water in the domestic and industrial water-use sectors, the competition for water currently used for agricultural production will increase in future. Technologies, models and methods are available to improve the efficiency of water use in different stages of e.g. canal and on-farm water distribution, field application and irrigation scheduling. With the demand for food also increasing in a globalised trade environment, agricultural production will have to be competitive in both local and overseas markets. While irrigated agriculture contributes 25 to 30 % of gross production, technological and managerial innovations will be required in all subsectors of agriculture to reduce costs and increase income.

The impending challenge for research is therefore to develop and apply technologies which will enable water conservation in rain-fed agricultural production on dry-lands, grasslands and woodlands. In the case of irrigation, available technologies must be integrated and the financial benefit of efficient water use must be demonstrated over all stages of water distribution and application. Emphasis must be placed on making all technologies and models user-friendly. This requires attention to the specific needs of traditional subsistence farmers and modern commercial farmers.

The twofold effort to develop technologies for increased water-use efficiency in both rain-fed and irrigated agriculture, is also in support of global trends: As part of the water focus of the World Summit on Sustainable Development (WSSD), the recommended target is to increase water productivity in rain-fed and irrigated agriculture to enable achievement of food security for all people without increasing water use above levels for 2000. Furthermore, one of the four programmes identified within the New Partnership for Africa's Development (NEPAD), is to expand the extent and operation of integrated land and water management, with the main emphasis on eradication of poverty in Africa.

### Key stakeholders

Firstly, key stakeholders in this KSA are farmers who are represented by Agri SA and NAFU. Altogether these are an estimated 50 000 commercial farmers, 240 000

emergent farmers and 3 million subsistence farmers. Secondly, at local, provincial and national levels, key stakeholders are water user associations (WUAs), catchment management agencies (CMAs), provincial departments of agriculture (PDAs), the National Department of Agriculture (NDA) and the Department of Water Affairs and Forestry (DWAf).

Communication channels exist with officials in the representative organisations on a national level. A more effective range of communication strategies must be designed to reach farmers and their representatives on a provincial and local level. The purpose is to obtain an accurate indication of practical problems which they are facing and what their assessment is of the priorities for research, technology transfer and extension.

### Other players

Other organisations providing services to water users in agriculture are the PDAs, the NDA through its Directorate: Agricultural Water-Use Management and DWAf through its Directorate: Water Utilisation. One of the current activities of relevance to the WRC is an initiative by NDA to give policy direction to development through integrated water management for agricultural use and DWAf is undertaking five pilot projects to implement the water conservation and demand management strategy in agriculture. An Interdepartmental Co-ordinating Committee on support for small-scale irrigation has also been formed, and as part of this action a task team is revising guidelines for project evaluation.

Locally the Human Sciences Research Council (HSRC) has reorganised its research activities and regrouped its projects into interdisciplinary New Priority Areas (NPAs). The NPA of Integrated Development is to undertake research which is designed to promote sustainable development in rural and urban areas. In addition various Institutes of the Agricultural Research Council (ARC) obtain funding and undertake research on water-related subjects. Of particular relevance is water research in relation to soils and climate, engineering, field, horticultural and forage crops. At eight Universities across South Africa there are Faculties or Departments of Agriculture, many of whom have in the past mainly relied on WRC funding to undertake water research.

Globally the International Water Management Institute (IWMI) which is a member of the Consultative Group on International Agricultural Research, has established the Regional Office for Africa in Pretoria. Since the establishment of the IWMI Africa Office, the WRC is

serving on the IWMI-South Africa Consultative Committee with the main function to determine priorities for IWMI's work. The mission of IWMI is to improve water and land resource management for food, livelihoods and nature. Research is done under five themes:

- Integrated water resource management for agriculture
- Sustainable smallholder land and water management systems
- Sustainable groundwater management
- Water resource institutions and policies
- Water, health and environment.

The responsibilities of the South African Office include leadership and supervision of all work in Africa; promoting strategic, applied research, capacity building and professional development; and collaboration with national, regional and international organisations.

### Providers of research

The main suppliers of research projects to the WRC are universities (currently Universities of Pretoria, Free State, Stellenbosch and the North); science councils (various Institutes of the Agricultural Research Council (ARC) and Environmentek of the CSIR); as well as established and emerging private consulting groups. The distribution of approved WRC-funded projects among suppliers for 2002/03 is as follows:

Supplier	No of projects	% projects
Universities	26	48,1
ARC	15	27,8
CSIR	5	9,3
Private	8	14,8
<b>TOTAL</b>	<b>54</b>	<b>100,0</b>

### Links to Vision and Mission of the WRC

The strategic focus in this KSA is on the efficient use of water for production, sustainable water resource use and improved livelihoods of people who are dependent on agriculture. The scope of the research area emphasises that through applied research the purpose is to generate and disseminate knowledge and to solve problems which agricultural water users experience in practice. The research work is needs-driven, people-oriented, provides innovative solutions, fills gaps in knowledge for using

limited water resources productively and therefore promotes economic growth and development of agriculture in South Africa and Africa as a whole. Thereby a direct and strong contribution is made to achieving the WRC mission and fulfilling our vision.

## RESEARCH PORTFOLIO FOR 2002/2003

The primary objective is to increase national food security, improve livelihoods of people and to increase efficient growth and equitable distribution of wealth on a farming, community and regional level through efficient and sustainable utilisation and development of water resources in agriculture.

The secondary objectives are to:

- Increase biological, technical and economic efficiency of water use
- Reduce poverty through water-based agricultural activities
- Increase profitability of water-based farming systems
- Ensure sustainable water resource use through protection and reclamation practices.

An overview of KSA4 research thrusts and programmes for 2002/03 is presented in Table 1.

Table 1: Overview and description of KSA4 thrusts and programmes for 2002/03

Thrust 1: Water Utilisation for Food and Fibre Production	
<b>Scope:</b> The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the processes of production of field, horticultural and industrial crops	
Programme	Scope
1. <i>Water-efficient methods in relation to soils, crops and technology in rain-fed and irrigated agriculture</i>	Water productivity can be increased by producing more with the same use of water or by producing the same with less use of water. This requires understanding of water dynamics in the soil-water-plant-atmosphere continuum, the equipment which is used and the method of production which is followed. Research on all these aspects can contribute to higher water use efficiency in agriculture.
2. <i>Fitness-for-use of water for crop production, livestock watering and aquaculture</i>	Various processes and factors, which are site-specific, have an influence on the quality of water for crop, livestock and fish production. Significant shortcomings exist in assessment of the fitness-for-use of water sources and identifying water-related production problems. The emphasis in this programme is on the efficient use of water and management of water quality for irrigation of crops, livestock watering and aquaculture in rivers, ponds and dams
Thrust 2: Water Utilisation for Fuelwood and Timber Production	
<b>Scope:</b> The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the processes of production of trees in woodlands, plantation forestry and trees planted in combination with food and forage crops	
1. <i>Water-efficient production methods and systems in agroforestry woodlands and forestry plantations</i>	In catchment areas where trees are a prominent feature of land use, runoff and deep percolation of water can be reduced. Management of these so-called streamflow reduction activities necessitates an understanding of the water use by trees and the competitive or complementary relationship of water use by trees and water use by staple food and forage crops. Due to research specialisation, separate attention is given in this programme to increase the efficiency of water use by trees in woodlands and plantations for fuelwood and timber production
Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture	
<b>Scope:</b> The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the management processes undertaken by people who are using water	
1. <i>Sustainable water-based agricultural activities in rural communities</i>	Poverty, hunger and malnutrition amongst rural people are widely recognised as major problems. These members of rural communities, consisting mainly of women, children and the elderly, are also disadvantaged or marginalised for various social, economic and political reasons. A wide-ranging programme is required to support the sustainable development of rangeland livestock, rain-fed and irrigated crop production. Efficient use of water through a combination of agricultural activities can contribute to improving living conditions. Empowerment of rural people can further be promoted through participatory action research which improves knowledge, farming skills and leadership capabilities.

Table 1: Overview and description of KSA4 thrusts and programmes for 2002/03 (Continued)

Programme	Scope
2. Integrated water management for profitable farming systems	Commercial farming is a major user of water resources and faces a particular challenge to ensure that this share of water is used effectively and efficiently. There is invariably a close link between efficient use and allocation of water and whole-farming profitability. Water management on farms is also time-dependent and based on incomplete knowledge of changes in the weather, prices and technology. Under these circumstances modelling is a powerful tool to provide decision-support and management advice. The focus in this programme is therefore on developing procedures, methods and models to provide advice to farmers on best management practices and the optimal combination of crop and livestock enterprises within the constraints of water, land and capital resources.
<b>Thrust 4: Water Resource Protection and Reclamation in Agriculture</b>	
<b>Scope:</b> The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the natural processes and man-induced impacts of resource use	
1. Sustainable water resource use on irrigation schemes and within river catchments	Intensification of crop and livestock production processes can potentially contribute to higher levels of chemical residues of fertilisers, pesticides and herbicides in surface and groundwater. Knowledge and tools to manage the quantity and quality of water resources for agricultural production are therefore required. The focus of research in this programme is on developing methods and models to manage water distribution and prevent water resource degradation
2. Impact assessment and environmental management of agricultural production	Agricultural decisions to cultivate land and to conserve rainfall or to withdraw water from rivers, dams and boreholes, have wide-ranging impacts on the natural environment. Precautions must be taken as part of the agricultural production process to protect the terrestrial and aquatic ecosystems. This requires an understanding of the negative impacts of agriculture and guidelines for an assessment and mitigation of those impacts.

## Research projects

The findings of projects completed during the year under review are given, as well as a summary of current projects and the motivation and objectives for new projects which commenced between 01 April 2002 and 31 March 2003.

### COMPLETED

#### Thrust 1: Water Utilisation for Food and Fibre Production

##### Programme 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigation agriculture

**Water use efficiency of cultivated subtropical forage and pasture crops**  
Department of Plant Production and Soil Science, University of Pretoria  
(WRC Reference No 573)

In South Africa, before 1988, little was known on the water requirements of planted pastures. Applicable norms for irrigation scheduling were not in place and this resulted in ineffective use of irrigation water. To obtain a better idea of planted pasture water use, a project was started in 1988 with temperate fodder crops followed by tropical and subtropical fodder crops in 1993.

The objectives of this project were to compare different pastures to determine if a single set of irrigation guidelines could be used for all pastures; to determine the water production functions as a tool to determine the economic optimum irrigation level for the different crops and to identify alternative crops, best suited for dry-land and irrigation conditions.

The water use of five annual and five perennial subtropical crops was determined in two consecutive seasons in a trial conducted under a rain-shelter on the Hatfield Experimental Farm of the University of Pretoria, Pretoria. The annual crops used were soybean, cowpeas, maize, fodder sorghum and pearl millet. The perennial crops used were *Cenchrus ciliaris*, *Panicum maximum*, *Digitaria eriantha* ssp. *eriantha*, *Pennisetum clandestinum* and a *Cynodon* hybrid. Each crop was subjected to four irrigation levels, ranging from a stressed (W1) to a well-watered control (W4).

Dry matter water use efficiency (WUE<sub>DM</sub>) of maize was the highest for all the crops in both seasons, while that

of cowpeas was the lowest. From the yield data it could not be ascertained whether pearl millet or fodder sorghum was the more drought tolerant. With the aid of WUE<sub>DM</sub> data, however, this became more apparent. Pearl millet had a better WUE<sub>DM</sub> at all irrigation levels. Under severe stress (W1) pearl millet had a markedly better WUE<sub>DM</sub> than fodder sorghum. It may, therefore, be concluded that pearl millet would be a better choice under severe stress conditions than fodder sorghum, and definitely a better choice than maize. From a comparison between the WUE<sub>DM</sub> of soybean and cowpeas, one would expect soybeans to do better than cowpeas in drought conditions.

The water-use efficiency data confirm that there was no equal to *Cenchrus* under dry-land conditions. *Cenchrus* was able to use water far more efficiently under dry-land than under well-watered conditions in comparison to other grasses. From the water use efficiency data, it is not clear which of *Cynodon*, *Digitaria* or *Pennisetum* would be recommended for use under well-watered conditions. *Cynodon* and *Pennisetum* are often irrigated, while *Digitaria* is not generally recommended for irrigated conditions. These data indicate that *Digitaria* should be considered as a viable alternative where irrigation is available.

According to the economic analysis it is more expensive, in terms of specified cost per ton of dry matter as well as millimetre of water, to produce any of the five crops under severe drought (W1) than control (W4) conditions.

This study was conducted on a relatively small scale and did not include different cultivars, soil types, irrigation systems and climatic conditions. These variables influence evaporation, transpiration, drought tolerance and ultimately the quantity and quality of product produced. This emphasises the importance of scheduling methods, including models, to take advantage of available water.

With the application of new technologies in agriculture it is evident that a single set of guidelines for the irrigation of forages, or other crops, will not have universal application. There are clear indications that considerable variation in both yield and quality occurs between different regions and between seasons at the same location. By combining crop factors with comprehensive soil and climate parameters in simple, or complex predictive models, it should be possible to ensure the best possible yields (and quality) under specific conditions.

Cost: R677 600  
Term: 1994 - 2001

##### Investigation into the factors affecting the performance of drip irrigation systems in South Africa IAE, ARC (WRC Reference No 1036)

A drip irrigation system is considered to be the most efficient in terms of crop produced per volume of water used. However, the literature indicates that this system can create problems if there is poor quality water and poor management, coupled with low maintenance. Clogging of emitters is the most serious problem that often occurs.

A study was conducted to:

- Determine the performance of different drip types and ages under various water quality and typical farming conditions
- Develop operational guidelines to make the correct drip choice
- Enable irrigators to maintain drip system effectively, thus ensuring water use efficiency.

Popular drip-lines were selected and tested as new and used (old) pipes. Sampling of drip-lines from various drainage regions of South Africa was based on perceived and reported problems. Dripper type and age were also used as criteria for sampling. The used drip systems were also evaluated in the field before laboratory testing. This was repeated in the following year.

The emission uniformity (EU) as measured in the field declined over time for all dripper types. This indicates a decline in performance due to clogging or lack of proper maintenance. Regular type emitters showed a tendency to reduced discharge while pressure-compensated emitters showed a tendency to increased discharge as a result of clogging. This is probably due to objects getting stuck between the compensating membrane and the labyrinth, or the membrane losing its elasticity over time.

The relative clogging tests on new emitters indicate that regular drippers are resistant to clogging compared to pressure compensated drippers. Proper maintenance schedules and their implementation are of utmost importance for the long-term benefits of drip irrigation systems.

Cost: R 459 000  
Term: 1999 - 2002

## Thrust 2: Water Utilisation for Fuelwood and Timber Production

### Programme 1: Water-efficient production methods and systems in agroforestry, woodlands and forestry plantations

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

Environmentek, CSIR  
(WRC Reference No 780)

One of the major constraints of small-scale farming systems in temperate, frost-prone areas is the shortage of fodder during the dry winter season. This is further complicated by the shortage of land and water. Growing trees together with crops can greatly enhance productivity of small-scale farming systems, since tree roots can exploit water and nutrients below shallow roots of crops. Trees can also increase productivity through soil nitrogen fixation and the provision of fodder.

There has been virtually no research on agroforestry systems in the temperate, frost-prone, dry-winter areas. This study was aimed at examining agroforestry systems in terms of competition for water between trees and crops. Also, the study attempted to determine the comparative water use of multi-purpose trees in agroforestry systems for the purposes of recommendation on appropriate species.

A PRA workshop was held and species selected include indigenous (*Acacia karoo*), nitrogen fixing (*Leucaena leucocephala*), fruit-bearing (*Morus alba*) and a multi-purpose species (*Gleditsia trianthos*).

Results indicate that fodder yield in all species decreased with the wider intra-row spacing of trees. The most productive species was *Acacia karoo*. Fodder yield of *L. leucocephala* increased slowly but significantly over the period, indicating that once established, it is a productive species. The *M. alba* had the highest fuelwood production and was favoured by farmers because of its fruit production. There was little difference between the soil water content of the tree line and maize lines. However, at greater soil depths (75 to 125 cm) the trees in the wide spacing used less water than those in narrow spacing.

It is recommended that agroforestry species should be planted closer (0.5 m) in order to maximise fodder

production. In order for agroforestry to become widely accepted socially, it needs to exhibit clear financial benefits to the farmer. The results also show that agroforestry is economically viable where there is low maize production and high tree production. The relative profitability of agroforestry drops off as maize production increases.

In spite of any decrease of yield of maize, the study showed that increased fodder and fuelwood production could result in considerable benefits to the farmer.

Cost: R 630 000  
Term: 1996 - 2001

### Determining plantation water use and growth from integrated remote sensing, water use models, geographic information systems (GIS) and field data

Environmentek, CSIR  
(WRC Reference No 1194)

South Africa's water resources are severely limited and therefore need to be managed efficiently in order to meet the rising demand for water by the agricultural, urban and industrial sectors. One of the important factors to consider in optimising water resources is the pattern of land use in the high-rainfall, source-areas of SA rivers. Most of these areas were originally covered by seasonally dormant grasslands and fynbos, but have increasingly been established to forest plantations to meet growing demand for wood products. Experience has shown that such afforestation may result in major reductions in catchment water yields due to changes in evapotranspiration (ET).

It remains difficult to predict spatial and temporal patterns of ET in SA plantation forests since they are influenced by a very wide range of site factors, forest characteristics and management actions. A 3-PG (process-based) model shows great promise in practically predicting both growth and water use in forest stands.

The purpose of this study was to explore the potential of integrating remote sensing with spatial information of climate and site conditions (3-PG) through the use of GIS. Further, the study ascertains the usefulness in obtaining spatial estimates of the impacts of forest plantations on surface water resources in SA.

A research strategy was designed to test the practicality of modelling diverse assemblages of forest stands with the spatial versions of 3-PG. Twelve stands of *Eucalyptus grandis* X *camaldulensis* were selected. The stands varied in age and represented a wide range of site growth potential.

Realistic simulations were achieved for 11 of the 12 stands. Overall, simulated transpiration by trees in months associated with high soil water availability were realistic when compared to measured sap flow rates. In months of low soil water availability, however, simulated transpiration was too low.

It is concluded that the 3-PG model appears to be capable of describing the physiological state of trees growing in wide range of conditions, and believed that improved predictions of growth and water use at a compartment scale are possible.

There is a good reason to believe that 3-PG/remote sensing data/GIS approach to predict growth and water use by forests can be broadened to include all land-use options in a given catchment.

Cost: R 480 200  
Term: 2000 - 2002

## Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture

### Programme 1: Sustainable water-based agricultural activities in rural communities

Estimation of rainfall intensity for potential crop production on clay soil with in-field water harvesting practices in a semi-arid area

Department of Soil, Crop and Climate Sciences,  
University of the Free State  
(WRC Reference No 1049)

There is uncertainty about whether long-term rainfall data can be used to generate an amount of runoff water per storm per area. The theoretical relationships relating daily rainfall to rainfall intensity and runoff need to be tested under practical conditions of crop production. This is necessary for beneficial manipulation of runoff for water harvesting.

The study was aimed at:

- Analysing rainfall intensity and runoff data and testing theoretical relationships
- Generating rainfall intensity data from the historic record of daily rainfall, and therefore the expected amount of runoff

- Conducting a risk analysis for water harvesting techniques at selected sites using a climate crop model.

Rainfall intensity data for various areas were used for statistical analysis. The relationships of peak rainfall intensity to event rainfall for Glen were analogous to those for Bloemfontein. The results, however, make it difficult to estimate the rainfall intensity from the daily or event rainfall amounts in the historical records.

The amount of daily runoff at Glen is estimated to be 36% to 41% of the amount of daily rainfall, but as the amount of daily rainfall increased, the daily rainfall relationship was more variable. That is, the model could provide a good estimate at low rainfall amounts, but failed at high rainfall amounts.

The "area under the rainfall intensity curve" method provided acceptable daily runoff estimation from daily rainfall. This model may be used for estimating runoff from rainfall on different soil ecotopes by changing the index value used for final rate of infiltration.

Since rainfall intensity could not be successfully modelled deterministically using the hyetograph method, a stochastic model of rainfall was developed. This model gave a variety of time distributions of rainfall. Using the PUTU growth model together with the deterministic runoff model, hyetograph model and the area under the rainfall intensity curve model, the risk assessment of maize yield was done under several scenarios, including water harvesting, basin tillage, no till, mulching and conventional total soil tillage production techniques.

Cost: R 571 000  
Term: 1999 - 2002

### Programme 2: Integrated water management for profitable farming systems

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

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

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 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 goal of this research project was to further extend, consolidate and integrate computer aids that were developed in previous WRC projects to a total system in support of especially irrigation management. This goal comprised the following: Firstly, the establishment of the decision support system for the economic evaluation of farm management as a user-friendly computer program that can form the body of the FARMS system. Secondly, the inclusion of the SPILKOST 2.0 program in the system and further expansion of irrigation cost estimation (to micro-drip and flood-irrigation) for support of irrigation management at firm level. Thirdly, the integration of other computer programs (for instance crop growth models, scheduling models, and so forth) with the FARMS system or the accommodation of outputs (yields, irrigation quantities, and so forth) from such programs for use as inputs. Fourthly, incorporation of business and financial risk preferences in whole-farm planning. Lastly, performing relevant applications in South African agriculture to determine the trustworthiness and flexibility of the system. In this way the system can also be introduced to farmers and availability can be promoted.

Existing models were reprogrammed into Windows based programs. At the same time modules of one model were converted into two computer programs which function independently. Several functions were also added to the different programs. The outcome is the FARMS system. This system comprises the IrriCost (irrigation cost), FARMS (firm-level agricultural management simulator) and RiskMan (risk management) computer programs. These three programs are aids to irrigation cost estimation, whole-farm planning and risk management respectively. Each computer program operates independently. However, IrriCost inputs as well as outputs can be imported into FARMS and the inputs as well as outputs of both programs imported into RiskMan. Links were also

established between the SWB (soil water balance) computer program and FARMS as well as RiskMan and between the WAS (water administration system) program and RiskMan. Help functions and user guides further contribute to user-friendly programs

The FARMS system was successfully tested through co-operation with seven farmers in three irrigation areas. Based on the feed-back received from these case-study farmers (two of whom also served on the steering committee), the indication is that the models provide information which is useful for efficient irrigation management and therefore practically relevant.

Cost: R407 180  
Term: 1998 - 2001

**The development of an integrated information system using the WAS, SWB and FARMS computer models**  
*NB Systems*  
(WRC Reference No 946)

The development of an integrated information system using the Water Administration System (WAS), Soil Water Balance (SWB) model and RiskMan computer model is about further development and implementation of research from three different research projects (WRC Report Nos. 513/1/95, 753/1/99 and 894/1/02). All three models make extensive use of databases and the idea of this project was to consolidate the information into an integrated information system that links to a geographical information system (GIS). The main aim of this project was to integrate the WAS, the SWB model and the RiskMan model in such a way that they can be used as tools on an irrigation scheme to:

- Minimise water distribution losses
- Maximise efficient water-use on farm level by means of irrigation scheduling
- Incorporate risk in crop- and cash-flow planning.

The integration of WAS, SWB and RiskMan was successful. Modifications were made to WAS, SWB and RiskMan to make the integration possible. The different model can be used alone or where necessary read information directly from the other models. WAS saves crop survey data that can be accessed by RiskMan. SWB can create simulated crop yield records that can be accessed by RiskMan. SWB can generate water request forms that can be used by WAS. Once a farmer has used RiskMan to decide on the best crops to plant, SWB can be used for the day-to-day irrigation scheduling.

The geographic information system (GIS) was developed and implemented successfully at the Loskop and

Orange-Riet Irrigation Schemes. The canal networks of both schemes are captured and it is possible to query the different databases and display the information on the GIS map.

The GIS map consists of different layers that can be enabled or disabled depending on the amount of detail the user wants to see. The layers that were created for both schemes are a canal network layer, a farms layer and a river layer. The user can add additional layers and edit the objects on any layer such as lines, areas and points. The GIS program has a built-in help file that gives the basic information on how to operate the program.

Although the project team did not implement all the modules of the integrated information system on both irrigation schemes successfully, it managed to transfer new technology to both the schemes that will definitely grow and make a difference in their daily operations. Some of the technologies are new and it will take some time before the majority of farmers will accept it. This project has definitely proved that a visual tool such as the GIS program is easily accepted by irrigation schemes and has great potential in managing irrigation schemes and communicating information. The GIS program was the only program that was used without much persuasion by both irrigation schemes.

The current project has shown that the implementation of the integrated system at two very similar irrigation schemes produced different outcomes. What is important to one scheme is not necessarily important to the other. An irrigation scheme might just not be ready to implement the complete system but can take advantage of the parts that it can use. The integrated information system cannot be forced onto an irrigation scheme. It is therefore important to do the implementation in stages and in manageable parts. Factors that have an effect on the success rate are available resources such as hardware and personnel. Experience has shown that once a user has started using a model successfully they seldom go back to the old methods.

Cost: R636 000  
Term: 1998 - 2000

**The economic impact of changing water quality on irrigated agriculture in the Lower Vaal and Riet Rivers**  
Department of Agricultural Economics, University of the Free State  
(WRC Reference No 947)

In the Lower Vaal and Riet Rivers, rapidly fluctuating and generally poor irrigation water salinity has raised concern about the long-term financial sustainability of

irrigation farming due to reduced yields in certain crops and the withdrawal of other more profitable crops. The financial feasibility of irrigation farming is further under pressure due to the current economic conditions and mounting pressure to use water more efficiently.

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

Specific aims are to:

- evaluate the relationship between changing water quality, soil conditions and crop production
- determine the impact on yield, crop choice, agronomic and water management practices, expected income and costs
- develop models for typical farms in different river reaches.

Based on the results of the pilot survey conducted in the study area, five case-study farmers were selected, one from each of the different sub-areas of the Orange-Vaal Irrigation Board (OVIB). The case-study farmers were representative of their sub-areas with regard to the hectares of irrigation water rights held, and jointly, also sufficiently representative of the OVIB region.

SALMOD (Salinity And Leaching Model for Optimal Irrigation Development) was developed in GAMS (General Algebraic Modelling System). Using a linear programming model various management options and possible crops are weighed up against each other to find the profit maximising combination of crops and management options under different water quality (salinity) and external policy scenarios. Though not written in a user-friendly format, SALMOD is a generic model but requires a certain amount of initial setting up before being applied elsewhere. SALMOD is static, optimising only over one year, January to December (i.e. two production seasons) and relies on various assumptions, previously developed methodologies regarding salinity threshold and gradient values and is more mechanistic than empirical.

Results show optimal enterprise composition under various water quality (salinity) situations. Artificial drainage installation and leaching are financially justified under certain water/soil quality scenarios. The results are also a strong motivation for a change in the current water pricing and quota allocation system used in the study area and elsewhere in South Africa.

The dynamics of water use, -pollution and -control are so tightly interwoven by a multitude of external factors

that the traditional style of mono-disciplinary research is no longer suited to achieve overall satisfactory results. To proactively manage and implement policy to anticipate problems and sustainably introduce change, the correct research tools are also necessary.

By understanding the full dynamics and interactions between irrigation water quality and the soil salinity status on crop yield over time, mistakes made in the past by choosing unsustainable irrigation sites can be prevented. Furthermore the impact of various natural or artificial (e.g. policy mechanism) scenarios on existing schemes could be more accurately modelled, leading to increased economic efficiency and sustainability of the irrigation industry as a whole.

Cost: R417 000  
Term: 1998 - 2001

### Thrust 4: Water Resource Protection and Reclamation in Agriculture

#### Programme 1: Sustainable water resource use on irrigation schemes and within river catchments

The use of triploid grass carp as a biological control measure for excessive water weed growth in irrigation systems

Department of Zoology, Rand Afrikaans University  
(WRC Reference No 816)

Excessive growth of submerged aquatic plants in irrigation canals causes the loss of capacity leading to substantial losses at peak demand times in irrigation schemes. Research on the use of the Chinese grass carp to control this growth is part of the integrated control programme for the problem, other projects supported by the WRC in this programme examining the ecology of the main problem (the filamentous alga *Cladophora glomerata*) and investigating potential pathogens of the alga. There was considerable scepticism over the ability of the grass carp to survive in concrete-lined canals with high water velocities, so the first aim of this project was to investigate the suitability of these canals as habitat. The other three aims were to test sterile (triploid) grass carp as a bio-control agent, evaluate the economic feasibility of this approach and to propose an operational management plan if the previous aims were successful. The Ramah-3 canal on the Orange-Riet scheme downstream from the Vanderkloof Dam was selected as the study site. Flow reached  $0.8\text{m s}^{-1}$  at high flow, and a 16 km stretch was available for the research.

The carp did very well in this canal, increasing in mass by 300% in 6 months when stocked at a density of 3 to 7 fish per km of canal. At this density they effectively controlled algal growth, making it unnecessary to drain the canal to clear the growth. The recommended stocking rate is  $10\text{ fish km}^{-1}$  with a 10 to 15% annual supplementation stocking to account for attrition. A rudimentary economic assessment indicated that the use of grass carp would be more economical than the chemical controls currently practised, a finding in keeping with American experience, although the actual management must be adapted to each site.

Some problems were identified during the research. Being triploid, these fish are very valuable and so need to be looked after. The irrigation scheme managers did not always grasp this, and would drain the canals for cleaning without giving the scientists opportunity to collect the fish, so fish were lost. Farm labourers would catch the fish to eat, an offence carrying a high (US\$500 per fish) fine in the schemes in the South-Western USA. An unanticipated benefit was that in the presence of the grass carp other fish from the river were able to establish. Apparently the grass carp mobilised the nutrients in the system, making them available to the other fish.

Cost: R309 100  
Term: 1997 - 2001

#### Programme 2: Impact assessment and environmental management of agricultural production

Quantification of the water balance on rehabilitated mine soils under rain-fed pastures on the Highveld of Mpumalanga  
ISCW, ARC  
(WRC Reference No 798)

After returning the overlying rock and other waste materials to the pit created during open-cast mining methods, an effort is made to reshape the surface topography and rehabilitate the soil to a state approaching its former agricultural usefulness. Water which infiltrates through the rehabilitated surface would mostly replace acid and/or saline water that formed as a result of the oxidation of pyrite present in the backfilled waste material. This project determined the water balance of rehabilitated land under pasture at three sites over three growing seasons, and used the results to calibrate a mathematical model which can be used to make long-term water balance predictions. It formed part of a number of complementary projects which were

conducted by the Agricultural Research Council on behalf of the National Department of Agriculture to investigate problems identified by the Van Niekerk investigation into the effects that high coal extraction practices have on agriculture. High bulk density, coupled with hard-setting behaviour, was found to be a widespread phenomenon in replaced cover soils, and probably the number one problem affecting land use. Soil profiles typically had only a moderate plant-available water-holding capacity, while the actual profile extractable water capacity was further reduced by poor root distribution. This limited yield even when fertilisation levels were aimed at relatively high production levels. Measurements of runoff were somewhat inconclusive, but suggest that runoff does not exceed 10% of the annual rainfall and can be as low as 2 or 3%. The generally high density of the lower cover soils and upper spoil appears to restrict deep percolation, except where water accumulates due to lateral drainage and where settling cracks occur.

Cost: R387 077 (WRC), R491 400 (NDA), R330 200 (ARC)  
Term: 1997 - 2001

Influence of irrigation with gypsiferous mine-water on soil properties and drainage water in Mpumalanga  
Chamber of Mines of South Africa  
(WRC Reference No 858)

Huge quantities of acid mine drainage are being produced as a result of mining activities. These waters are mostly neutralised, either inadvertently, as a result of seepage through neutralising geological strata, or artificially, by the addition of lime. Mine drainage is, therefore, often saturated with gypsum. When released into the surface water environment, their high salinities are mostly responsible for unacceptable water quality degradation. On the other hand, irrigation provides for a novel approach to the utilisation and disposal of gypsum-rich water as demonstrated in an earlier WRC project (No 582). Irrigation of neutralised acid mine-water holds promise to significantly reduce the salt load emanating from mine drainage while at the same time extracting value from water that would otherwise be a polluting agent. This project aimed to ascertain on a semi-operational scale whether gypsiferous mine-water can be used sustainably on a commercial basis for the irrigation of crops and precipitation of a considerable portion of the applied salt (as gypsum) within the soil profile.

A field trial was set up at Kleinkopje Colliery from the summer season of 1997 until and including the winter of 2000, where several crops were irrigated with centre pivots using two mine-waters. Three different irrigation

management practices were adopted for each pivot: irrigation with a leaching fraction, irrigation up to field capacity and deficit irrigation (room for rain). The trials were intensively monitored for plant growth, yield, potential plant nutritional deficiencies and data sets obtained for validating the crop growth subroutine of the SWB model. Further measurements that were made to (*inter alia*) validate aspects of the SWB model, include soil physical characteristics, weather data and soil water and salt balances. Soil chemical changes as a result of irrigation with the gypsiferous water were monitored both within and below the root zone, while groundwater quality was monitored to determine possible leaching of salts to groundwater. Plant nutritional aspects were further investigated in a glasshouse trial. The SWB model was adapted for long-term predictions and linked to a groundwater model to predict the likely long-term effect that irrigation with gypsiferous water could have on soil properties and groundwater pollution.

Crop yields were generally high and commercially attractive except in the case where water-logging developed on rehabilitated land as a result of subsidence. No negative effects on crop growth or nutrition which could be linked to irrigation were observed. In soils with restricted drainage, salts were confined to the upper 1m, while a slight peak was observed at about 1.8m on well-drained soils. After 3 years a slight increase in only nitrate concentration was observed in some boreholes monitoring groundwater. The fact that the SWB model predicted crop growth, water and salt distribution quite well, gave confidence in its long-term predictive ability. Excellent agreement was, furthermore, obtained between the salt predictions of SWB and an FAO version of UNSATCHEM. Long-term predictions indicated that almost half the salt in the irrigation water could be retained in the soil under deficit irrigation vs. 35% under a leaching strategy.

This project thus demonstrated that irrigation with gypsiferous acid mine-water can be successfully managed on a semi-operational scale. The practice was found to be commercially viable, and present indications are that it is sustainable from a crop production and soil perspective, while a large percentage of the applied salt can be retained within the soil profile. However, because of the long-term implications that large scale implementation of the practice may have, it is deemed necessary to continue monitoring for a longer period and also to expand the range of soils and waters that are being tested.

Cost: R1 307 000  
Term: 1997 - 2001

### Evaluation of predictive models for pesticide behaviour in South African soils

PPRI, ARC  
(WRC Reference No 999)

Newly developed pesticides rely on microbial activity for their degradation. South African soils that generally have a low organic matter content thus provide conditions which are conducive to prolonged persistence of a pesticide. This project aimed to evaluate existing computer-based mathematical models for their efficiency and applicability to predict pesticide behaviour under local conditions. The intention was to identify and recommend the most suitable model for use by pesticide registration authorities. It was anticipated that this would reduce the risk of pesticide contamination of ground- and surface waters from pesticide application.

The study was conducted on three field soils, representing a sandy loam, a sandy clay loam and a clay soil. The pesticides were selected to represent a range of chemical characteristics with regards to their published persistence and soil mobility. The herbicides tebuthiuron and azafenidin and the insecticide fenthion were selected. Parameters required by models, such as the half-life and adsorption characteristics of the pesticides, were determined for the selected soils. The adsorption coefficients for fenthion indicated that adsorption will decrease with soil depth. Although  $K_{oc}$  values were highest on the clay soil,  $K_{oc}$  values were all higher than 100, indicative of limited mobility.  $K_{oc}$  values furthermore indicated that the oil-based formulation of fenthion is more mobile than the emulsifiable concentrate. The adsorption of azafenidin was similar for all soil depths and types, which implies that it will have similar leaching characteristics in all three soils. Similar results were obtained for tebuthiuron. Half-life determinations were highly variable. Those for fenthion and azafenidin were similar for the loamy soils, but significantly higher on the clay soil. The 4 to 7 day half-life for fenthion is longer than the published and accepted value of 1 day. The half-life for tebuthiuron was found to be in excess of 500 days for all soils, which is longer than the generally accepted published value of 365 days. The half-lives determined for azafenidin fell within the published range of 10 to 45 days.

Field leaching studies indicated that all three the compounds leached with ease in all three soils. During the first part of the trial period, the two loamy soils displayed similar leaching patterns for tebuthiuron, but during the latter part, the two clayey soils were more similar. There were indications of build-up in the deeper soil layers and a possibility of leaching past the deepest sampled layer at 120 cm. Fenthion was highly mobile in all three soils. This involved not only leaching, but also

upward movement in response to evaporation. Fenthion appeared to have a short residence time in all three the soils, probably as a result of its rapid degradation. The leaching patterns in the two loamy soils were similar for azafenidin during the first part of the trial period, although more leaching occurred in the sandy clay loam soil. However, after 30 days the patterns of the clay and sandy loam soils were more similar.

Linear regression analysis was performed on the observed (measured) data vs. model-predicted concentrations. Model predictions started to deviate from the observed values soon after the start of the experiment, partly because none of the three models tested provided for upward movement of compounds. The Pelmo model was insensitive to change in degradation rate and predicted only limited leaching in all three soils. Although it only allows for homogeneous soil profiles and tends to over-predict pesticide concentrations in especially the deeper layers, Prestan was the only model that predicted the observed leaching with some success. It should prove useful to predict the worst-case scenario regarding the leaching potential of pesticides at a screening level.

Cost: R357 000  
Term: 1999 - 2001

**The Orange River blackfly, *Simulium chutteri*: Investigations into the physiology of the aquatic and non-aquatic stages so as to adjust the existing control programme to overcome summer outbreaks**  
OVI, ARC  
(WRC Reference No 1019)

The aims of the project were to:

- Compare the size and physiological state of larvae throughout a full year and relate to water temperature
- Compare the size and physiological state of newly emerged adults throughout a full year and relate to final stage larvae
- Determine the longevity and physiological state of newly emerged adults fed 5% sucrose/glucose and maintained at different temperatures and relative humidities in the laboratory throughout a year and related to wild-caught adults
- Compare the size and physiological state of wild-caught adults at varying distances from the river throughout a full year and relate to newly emerged adults
- Select various representative vegetational transects along which to record plant species, density, foliage and flowering throughout a year

- Note and record the plants on which adult blackfly are seen resting and feeding
- Determine the effect of light intensity, humidity, temperature and wind speed on adult host-seeking and blood-feeding
- Make use of the knowledge gained to adjust the annual blackfly control programme to be more effective.

In 1996 the Northern Cape Agricultural Union estimated that blackflies accounted for up to R88m. loss per year in sheep production in the 800 km of the Orange River roughly between Hopetown and the Orange Estuary, with a further R19m. in taxes. The main pest is *Simulium chutteri*, a South African endemic which disperses up to 80 km on either side of the river depending on the wind direction. *Simulium chutteri*, in common with most species of blackfly, breeds in fast-flowing water where the larvae feed by filtering suspended particles from the current. Early control was practised by stopping flow from the large dams upstream, but changing agricultural patterns relied increasingly on water in the river, so this method had to be dropped.

The ARC-OVI started investigations in 1991 which led to the registration of two environmentally safe products for control of the larvae. Control started in 1993, and when timed correctly, excellent control was achieved. However, this is not always the case, and while some of the failures may be attributed to human error, lack of knowledge makes accurate planning actions difficult. This project aimed to address this by studying certain physiological traits of the organism (both larva and adult).

Strong inverse relationships were found to exist between developmental temperature and the following characteristics: Body size, mass, lipid content and glycogen content. Longevity trials showed that the over-wintering population with the largest mean size and mass, lipid and glycogen content, lived longest. Size and metabolic reserves declined through the summer and increased slightly in the autumn. Large variance was found in longevity under all conditions tested, but ranged from <10 hours (high temperature and low humidity) to >20 days at low temperature and high humidity. However, the over-wintering population (with the highest metabolic reserves) showed least resistance to stress, implying the diversion of resources from stress resistance.

Both sexes of *Simulium* feed on nectar and it was found that although there is a strong peak in the growth of plants along the lower Orange in late summer, the number of plants in flower remained remarkably constant throughout the year, ensuring that nectar was available throughout the year.

*S. chutteri* is active between 15.3 and 41°C with the optimum between 24 and 32°C. Activity was recorded for relative humidity of between 4.5 and 53.5%, wind speeds of between 0 and 4.1 m·s<sup>-1</sup> and light intensities of between 30 and 9 600 lux.

The results of this study can, to some extent, be used to predict outbreaks more accurately.

It is recommended that:

- Larvicide applications be considered in summer, but only after proper monitoring is in place to quantify the nature of summer outbreaks
- One dedicated and qualified person be responsible for the monitoring
- An improved monitoring system will allow more effective adaptive management
- Over-wintering population should be controlled as effectively as possible to prevent the large spring outbreaks
- Blackfly control operators be made aware of the limitations that high temperatures and low humidities place on adult blackfly survival.

Cost: R512 000  
Term: 1999 - 2000

**The risk of insecticide (pyrethroid) resistance for malaria control in South Africa**  
PPRI, ARC, MRC, KwaZulu-Natal Department of Health  
(WRC Reference No 1119)

The agricultural use of pyrethroids and other insecticides registered for crop protection increased in the emergent farmer sectors in KwaZulu-Natal. These areas are protected by the malaria control programme in which DDT and deltamethrin are used for indoor spraying of dwellings and constitute a worst-case scenario potential contamination of the water environment. Cases of pyrethroid and organophosphate resistance in the malaria vector *Anopheles* species were detected. Insecticide resistance in malaria vectors can originate from the selection of mosquitoes to agricultural pesticides.

The research objectives were to establish the patterns of agricultural pesticide used by emergent farmers in two areas, namely Ubombo and Ingwavuma to develop a protocol for sampling, analysis of insecticides and interpretation whereby areas at risk can be investigated for resistance potential within a short period. The residues of the insecticides in water sources near the communities were determined and selected for resistance in malaria vector larvae.

The study area was selected as being the most polluted with agricultural insecticides and anti-malaria chemicals. A questionnaire was used to gather information on a list of pesticides used in the area so as to select the pesticides for residue analysis. Water and sediment samples were collected and analysed for the residues. Results of the analyses show insecticide contamination of the water environment in the investigation area from pyrethroid, organophosphate, organochloride and carbamate chemical groups. Game reserves selected for control areas supposedly not contaminated were found to be contaminated.

It is believed that the major selection pressure for the development of mosquito resistance exists in the study area and it is crucial to ascertain the relative contribution of the different insecticide classes to the development of resistance. The identification of pyrethroid and organophosphate resistance reported in the study area is of great concern and poses severe consequences in designing an efficient mosquito vector programme. The detection of DDT in the samples shows contamination of the water sources resulting from anti-malaria control interventions and is a serious health threat not only in South Africa, but also internationally, taking into account that DDT is on the Stockholm Convention (2001) list of the 12 POP pollutants that circulate globally through air and water.

Cost: R200 000  
Term: 2000 - 2002

## CURRENT

### Thrust 1: Water Utilisation for Food and Fibre Production

#### Programme 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture

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

ARC  
(WRC Reference No 892)

In this project a mathematical model is being developed in order to predict water use by deciduous fruit trees with the help of meteorological data. The model will also be integrated with other existing models in a GIS-based farm-management system. Ultimately, the model will serve as guide for irrigation scheduling of deciduous fruit trees. The deciduous fruit industry contributes immensely to the GDP of SA - and improved water use within the industry will enhance economic growth.

Estimated cost: R561 500  
Expected term: 1998 - 2002

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

ARC  
(WRC Reference No 1046)

Fruit tree species (high-value crops) have different water needs. These needs also change with growth stages - and are subject to climatic and edaphic factors. Where water becomes limiting, a decision tool becomes paramount so that farmers can decide beforehand which crops to produce. Such a tool also enables authorities to plan future expansions better, based on sound water budgeting. The aim of this research is to provide information on plant water use at various stages of growth. Water use by mango, avocado, litchi and macadamia nuts is measured. Trees between one and twenty years old are used. This information will be used to develop guidelines for water budgeting within the fruit industry.

Estimated cost: R776 000  
Expected term: 1999 - 2005

##### Contribution of root-accessible water tables towards the irrigation requirements of crops

Department Soil Science, University of the Free State  
(WRC Reference No 1089)

The water requirements of crops, particularly in areas with high water tables, can be augmented through capillary movement of water. In dry-land areas, capillary contribution can account for the bulk of crop water needs. Even under proper irrigation, this contribution (particularly during/after normal rain seasons) can be significant. Such contribution has to be quantified - and taken into account during irrigation water budgeting or when estimating water-use efficiency for irrigated or dry-land cropping. This project aims to develop methods of quantifying the contribution of water tables to satisfying crop water requirements.

Estimated cost: R498 000  
Expected term: 2000 - 2003

##### Optimisation of irrigation management in subtropical fruit trees by determination of water and carbon demands to improve water-use efficiency and fruit quality

Department Soil Science and Plant Production, University of Pretoria  
(WRC Reference No 1136)

Adequate irrigation improves crop yield. In turn carbon demand (formation of fruits/harvested plant organ) influences water needs of crops, at specific times of the season. This supply and demand water-dependency system has often been used for manipulating ripening and quality of fruits. It allows a farmer to regulate water applications in order to induce certain physiological processes without compromising crop yield. Regulated deficit irrigation (RDI), if better understood, can improve water-use efficiency (WUE), the quality of fruits, as well as economic benefits through timing of harvesting. This project aims to determine optimum levels of RDI for mango, their effects on yield, ripening and fruit quality. The research is testing a model, developed for peach, which will be adapted in order to be used by the mango producers.

Estimated cost: R984 000  
Expected term: 2000 - 2003

##### Surface drip irrigation

ARC  
(WRC Reference No 1189)

The major factor in irrigation-water loss is evaporation. Depending on the evaporative demand of the

atmosphere as well as the soil type, up to 50% of the water application can be lost through evaporation. Subsurface drip irrigation is the best system of bypassing evaporation problems. However, subsurface drip irrigation is very "sensitive" to clogging of drip-lines. Crop type, emitter type, depth of drip-line and water quality are factors that determine the beneficial use of subsurface drip systems. The project, therefore, aims to investigate the occurrence of root penetration in terms of depth of drip-line installation, type of drippers and the influence of the application of various chemicals (during fertigation or disease control). Such information will allow better management and maintenance of subsurface drip systems.

Estimated cost: R343 000  
Expected term: 2000 - 2004

#### Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture

##### Application of risk assessment modelling in groundwater for humans and livestock in rural communal systems

NCE cc  
(WRC Reference No 1175)

This project concerns itself with quantifying the risk assessment to humans and livestock in communal areas through ingestion of poor natural water quality, and investigating means of applying solutions that will benefit the user groups. It is addressing the formulation of alleviatory treatments of a lower dosage and different chemical compositions that will still serve to significantly mitigate adverse impacts on livestock production, whilst making the water fit for human consumption.

Estimated cost: R1 600 000  
Expected term: 2000 - 2003

### Thrust 2: Water Utilisation for Fuelwood and Timber Production

#### Programme 1: Water-efficient production methods and systems in agroforestry, woodlands and forestry plantations

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

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

Multicroping is common among smallholder farmers. In most cases field crops are grown around fruit trees. In some cases, fodder is also planted along contours, then used as animal feed or windbreaks instead of fruit trees. Limited information is available about competition for water that takes place among crops. Although benefits of multicroping are obvious, yield reduction, particularly of poor competitors or drought-sensitive crops, may occur. Since farmers usually grow intercrops on the headlands or contour-lines, there is a need for understanding the optimum distances between the various crops. The hydraulic conductivity of the soil, the water content, and the root distribution of different crops influence their performance. This project evaluates locally adapted crops that may be incorporated into an agroforestry system, with emphasis on water requirements. This information will be used to develop a model that would predict the productivity and water-use efficiency of different agroforestry systems.

Estimated cost: R1 001 000  
Expected term: 1999 - 2004

### **Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture**

#### **Programme 1: Sustainable water-based agricultural activities in rural communities**

##### **Selection of drought tolerance in the germ-plasma of *Vigna unguiculata*, *Vigna subterranean* and *Amaranthus* spp.**

ARC  
(WRC Reference No 944)

Food security at household level is one of the primary goals of the government. Other than staple food (maize), a number of other summer crops are used by the rural poor as a supplement. Most of these crops have become a way of life for such communities. However, water stress has a severe effect on the production of such crops. This project focuses on the selection of cowpea, marog and bambara for drought tolerance,

particularly for dry-land production. This means that drought-tolerant lines are screened and propagated, thus ensuring production (yield) even under adverse water supply conditions

Estimated cost: R735 000  
Expected term: 1998 - 2003

##### **Cheap and simple irrigation scheduling using wetting front detectors**

Department of Soil Science and Plant Production, University of Pretoria  
(WRC Reference No 1135)

Scheduling of irrigation does not only ensure that adequate volumes of water are applied. It also ensures that many people who rely on the limited water resource can share. Much as irrigators are aware of the importance of scheduling, very few practice it. A wide range of reasons for not scheduling exists, the common ones being the high level of management required and the costs involved. With simple and cheap scheduling tools, water savings will be achieved and farmers will soon realise the importance of irrigation scheduling and its benefits. The project is aimed at improving adoption of irrigation scheduling through the introduction of a cheap and simple technique. It also evaluates factors affecting the acceptability of this irrigation scheduling technology by resource-poor and commercial farmers.

Estimated cost: R961 000  
Expected term: 2000 - 2003

##### **Investigation into the potential of sustainable irrigation in Black developing communities of two sub-catchments of the Pongola and Thukela Rivers**

Sineke Developments (Pty) Ltd  
(WRC Reference No 1138)

When government irrigation schemes started some decades ago, little or no attention was placed on the potential for the success of such initiatives. Stakeholders are aware that alternative processes and approaches should have been followed. It also implies that such development should not only be based on economic viability or feasibility studies (using climatic data). Socio-political evaluation should also be done in order to ensure the success of the project. The main aim of this project is to define the socio-economic aspects and their importance for developing sustainable irrigation-driven farming systems in rural communities. The project analyses farming systems and institutional arrangements within such systems. This will lead to the identification of processes to transform present irrigation farming systems among small-scale farmers.

Estimated cost: R995 000  
Expected term: 2000 - 2003

##### **Measurement of heterotrophic and autotrophic organism active biomasses in biological nutrient removal activated sludge systems**

ARC  
(WRC Reference No 1176)

Food production/security under dry-land cropping depends on the amount and the distribution (time and space) of rain. Both the rainfall amount and distribution are erratic in South Africa. Conservation of rain-water, particularly in arid areas is therefore paramount. This project aims to identify conservation techniques, their economic benefits and social acceptabilities. Yield improvements and water-use efficiency for various common crops will also be established.

Estimated cost: R1 000 000  
Expected term: 2000 - 2003

##### **Socio-economic impact study on water conservation cultivation techniques in semi-arid areas**

Department of Agricultural Economics & Sociology, University of the Free State  
(WRC Reference No 1267)

In order to promote sustainable crop production, rainfall use efficiency needs to be optimised. Rain-water harvesting and conservation are therefore important. In addition to water conservation techniques, land and human power requirements, and technology transfer, socio-economic implications of these conservation techniques need to be evaluated. The practical sustainability of and the extent to which these conservation practices will be supported and recommended by the relevant authorities, depend on their socio-economic acceptability.

The objectives of the project are to:

- Develop an appropriate methodology for the determination of the socio-economic implications of water conservation cultivation techniques
- Develop a simulation model to integrate biological productivity, entrenchment of risks, management of natural resources and social acceptability with economic sustainability
- Determine the socio-economic implications of employing water conservation cultivation techniques on small plots in semi-arid areas
- Determine the area of land needed to provide an average-sized rural family with food security, as well as the human power required for these cultivation practices.

Estimated cost: R425 800  
Expected term: 2001 - 2004

#### **Programme 2: Integrated water management for profitable farming systems**

##### **Evaluation of the economic efficiency of irrigation systems for large- and small-scale farming enterprises**

Department of Agricultural Economics & Sociology, University of the Free State  
(WRC Reference No 974)

With the implementation of the new 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. The economic analysis of small-farm irrigation is also a logical continuation of completed WRC projects on the technical aspects of irrigation. The objectives of the project are, *inter alia* a 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 and financial feasibility. Guidelines will be formulated on how to economically compare different irrigation systems to make correct investment decisions.

Estimated cost: R750 000  
Expected term: 1998 - 2002

##### **Sustainable local management of smallholder irrigation**

Department of Agricultural & Environmental Sciences, University of the North  
(WRC Reference No 1050)

Most "upliftment" irrigation schemes in South Africa are not viable. A few schemes that are in operation are under-performing. The main reason is that beneficiaries have never been involved in the management of the schemes. It is only recently that the government and other stakeholders realised a need to hand management over to the beneficiaries. In this way, the end-users will be responsible and accountable. However, other technical and social problems need to be identified and addressed. Once this happens, the potential of the smallholder irrigation schemes in this country will be unlocked. This project identifies economic, social, institutional and policy issues affecting smallholder irrigation. It will also determine the extent to which poverty alleviation and empowerment of smallholder farmers can be achieved through self-management of smallholder irrigation schemes.

Estimated cost: R863 500  
Expected term: 1999 - 2002

**An investigation of the range and distribution of irrigation scheduling models in South Africa in general, with specific reference to the application of selected models**

*Dept of Agricultural Economics, Extension & Rural Development, University of Pretoria (WRC Reference No 1137)*

Much research has been done on the physical principles underlying irrigation scheduling and a range of techniques and methods have been developed. Nonetheless, available evidence shows that these tools are not widely applied in practice. The need has been highlighted to shift the emphasis in research from the technological (hardware and software) tools to the human and managerial factors which play a pivotal role in the application of irrigation scheduling technology. Apart from an audit of irrigation scheduling, it is important to determine under which circumstances and how effectively irrigation scheduling has been adopted and applied. Consequently the reasons for discontinuation or application of scheduling methods will be investigated and recommendations will be made to improve effective implementation of irrigation scheduling advisory services.

*Estimated cost: R586 000  
Expected term: 2000 - 2004*

**Technology transfer and development actions to promote and facilitate the use of SWB as an irrigation scheduling tool**

*Department of Plant Production & Soil Science, University of Pretoria (WRC Reference No 1203)*

There is general agreement that correct irrigation scheduling is essential for efficient water use. Most farmers decide when and how much to irrigate based on acquired knowledge and experience. In the past the WRC has funded research to develop irrigation scheduling tools, either for planning and design, or for real-time application. Although most of these irrigation scheduling tools have so far not been widely used, this position is now rapidly changing due to, amongst others, increasing water tariffs. A survey amongst farmers at the end of 1999 found that the biggest need for training was in the use of simple and practical irrigation scheduling methods. Clearly, the emphasis must now shift from research to technology transfer. For the purpose of real-time scheduling, the most recently completed project is the Soil Water Balance (SWB) Model (WRC Report No 753/1/99). The research has validated parameters for a wide range of crops which are grown on different soils and under varying climatic conditions. The model

follows a scientifically based, mechanistic approach, but has a user-friendly interface, which makes it accessible to any person with basic computer skills. Since the release of the SWB model, feedback from users has indicated several difficulties regarding, e.g. data capture. Only a small number of people are using the model for irrigation scheduling, and potential users have experienced problems with installing it and adapting it to their specific farming situation. Obviously there is presently a different perception between researchers and users regarding "user-friendliness" of the model. It follows that further refinement of the model and formal training courses are required. The intention is to present training sessions in all provinces. The target audience will be:

- Irrigation advisers and extension staff
- Irrigation farmers
- Final-year or honours-level students.

Care will specifically be taken to involve advisers who are serving subsistence farmers on irrigation schemes in the Northern, KwaZulu-Natal and Eastern Cape Provinces, which are the focus of the Presidential Initiative on Rural Development. The main aims of this technology transfer project are therefore to:

- Further refine and, where necessary, upgrade the SWB model as a user-friendly irrigation scheduling tool
- Promote the adoption and application of the SWB model for irrigation scheduling in practice, through training sessions.

*Estimated cost: R587 200  
Expected term: 2001 - 2003*

**Market risk, water management and the multiplier effects of irrigation agriculture with reference to the Northern Cape**

*Department of Agricultural Economics, University of the Free State (WRC Reference No 1250)*

An important aim of the Water Conservation and Demand Management Strategy for the agricultural sector is to provide a regulatory support and incentive framework to improve irrigation efficiency. This can be achieved by firstly ensuring that volumetric water tariffs reflect the financial cost of supply and, secondly, by promoting voluntary reallocation of water resources from lower-valued to higher-valued uses on farms and between farms within agriculture. For irrigation farming this means that farming operations must be restructured. However, production of, e.g. high-value

perennial crops also involves higher financial and business risks. This is caused by the high capital outlay and the time lag before full production is reached as well as variable export prices and changing consumer preferences over time. Although risk management through, e.g. crop diversification or market forecasts and price hedging can be implemented, the question is how far the shift to higher valued crops can be taken. Presently it is not known what the financial boundaries are within which water reallocations can be managed sustainably on a farm level and what the potential impact is on a regional economic level. Knowledge of these issues is of particular importance for irrigation areas in provinces such as the Northern Cape where agriculture is the dominant economic sector. Instability influences not only employment and income on farms, but also processing and input-supplying industries through forward and backward linkages. This is emphasised by the recent turmoil in the global deciduous fruit market, which has also affected table-grape production in the lower Orange River. The project will analyse the related production and marketing risks and develop models which link economic activities on a farming level to the regional level. The model will be tested in the particular study area but will be applicable in any area. The main aim of this project is to quantify the impact of market risk on the efficient use of irrigation water and to determine the multiplier effects of irrigation farming accompanied by a shift in production patterns.

*Estimated cost: R1 333 700  
Expected term: 2001 - 2005*

**Generalised whole-farm stochastic dynamic programming model to optimise agricultural water use**

*Department of Agricultural Economics, University of the Free State (WRC Reference No 1266)*

Models which adequately take account of features such as time and risk, have obvious merit, but also involve the greatest modelling difficulties. The intention is to construct a skeleton model of a representative farm. This means that the model can be applied on any irrigation scheme or homogeneous farming area, provided that the data as specified are available. Thereby a major contribution will be made to provide a tool to improve on-farm water use efficiency under varying conditions in South Africa

The main objective of this research is to develop a generalised whole-farm stochastic dynamic linear programming model to assist farmers and WUAs with optimal water use within the framework of integrated catchment management.

*Estimated cost: R877 300  
Expected term: 2002 - 2004*

## **Thrust 4: Water Resource Protection and Reclamation in Agriculture**

### **Programme 1: Sustainable water resource use on irrigation schemes and within river catchments**

#### **Development of models for economic evaluation of integrated management of quantity and quality of irrigation water within river catchments**

*Department of Agricultural Economics, University of the Free State (WRC Reference No 1043)*

Decisions by individual farming businesses to divert or withdraw water for cultivation and irrigation of different crops, has wide-ranging impacts on the natural environment. Changes in the type of land-use and cropping practices influence runoff while the choice of water distribution and irrigation methods as well as the efficiency of operations determines return-flow. With intensive production methods the level of nitrates, phosphates and chemical residues of pesticides and herbicides in surface and underground water is an increasing problem. Legislative prescriptions have therefore been specified in the National Water Act to protect aquatic ecosystems as part of the Reserve, regulate streamflow reduction activities and prevent pollution. Information on and tools to manage the quantity and quality of water are now clearly required to ensure sustainable use of water for irrigation in relation to all other use sectors.

In an on-going WRC-funded research project, dynamic stochastic decision models have been developed to analyse the influence of variable availability of the quantity of water, and the requirement to maintain minimum instream flows, on the economic viability of irrigation farming. The obvious next step is to extend the procedures and models to include the water quality dimension. In doing so, this research will address facets of research subjects which have been given a high priority rating by the Coordinating Committee for Research on Agricultural Water Management. User-friendly adaptation of models in order to provide practical decision-support, will furthermore assist with the implementation of water policy. This is in agreement with the shift in emphasis from formulation to implementation of policy as indicated by DWAF.

The aims of the research are to:

- Develop decision-making tools and evaluate the economic impact of policy strategies on the control of non-point pollution
- Apply agro-hydrological and economic models and assess the influence of a change in the allocation and use of water on integrated management of the quantity and quality of water resources and long-term profitability of irrigation farming.

Estimated cost: R683 000  
Expected term: 1999 - 2002

#### Determining accuracy whereby flow rate of electric pumps can be calculated

MBB (CE) Inc / Agricultural Water  
(WRC Reference No 1190)

Improved management of South Africa's water resources forms the foundation of the New Water Act. In this regard water metering is one of the most important aids to assist the water user in making optimal management decisions. Water metering is, however, poorly implemented in the agricultural sector.

This proposed project is based on the hypothesis that the equation used to calculate electrical power consumption, together with the characteristics of the pump, could be utilised for flow determination. Theoretically this hypothesis is sound, on condition that electrical current and voltage measurements, as well as hydraulic head measurements, are easily made and of acceptable accuracy.

The main aim of the project is to develop a procedure and its supporting instrumentation, by means of which water pumped with an electrically driven pump could be measured indirectly. This requires the measuring unit to be of acceptable accuracy, to be tamper-proof, simple to install and at a cost comparable to that of conventional meters.

Estimated cost: R600 000  
Expected term: 2000 - 2002

#### Irrigation water measurement: The application of flow meters in irrigation water management

Department of Agriculture Food Engineering, University of Pretoria  
(WRC Reference No 1265)

Effective management of water resources can be vastly improved if water use is measured accurately. This

applies in particular to efforts to influence the quantity of water demanded by levying tariffs on the volume of water actually consumed. However, on most irrigation schemes water flow is not measured and water tariffs are presently still levied on an area and not a volumetric basis.

A comprehensive study of water measurement in irrigation was initiated with the following objectives:

- Identify the methods and technologies for water flow measurement used in different water distribution systems on irrigation schemes under South African conditions
- Investigate the effectiveness of the various flow measuring methods and technologies through laboratory and field evaluations
- Determine the reasons for not measuring water use in practice by means of a field survey amongst farmers
- Establish directives for the correct choice and management of water flow meters for irrigation systems under different circumstances. NB Layout: Indent and align bullets

Estimated cost: R914 300  
Expected term: 2001 - 2004

#### Can effective management of riparian zone vegetation significantly reduce the cost of catchment management and enable greater productivity of land resources?

Environmentek, CSIR  
(WRC Reference No 1284)

Riparian zone management has become an important issue in water conservation in South Africa and water resource managers are under increasing pressure to assess the impacts of different land uses and management practices on catchment water yield. This has been exacerbated by the introduction of the new Water Act, which has prompted the Department of Water Affairs and Forestry to develop a framework for managing the use of water by streamflow reduction activities (SFRAs). This calls for the ability to predict and monitor the impacts of SFRAs on water and on the protection of water resources within each water management area.

Since riparian soils are mostly the wettest and most fertile within a catchment, and are therefore the most productive, there is great interest in moving away from the use of a standard width throughout the catchment, and rather to identify the required limits to the riparian zones on the basis of more objective criteria. What is unclear is the size and significance of this moderating

influence. This project will therefore investigate how effective management of riparian zone vegetation can reduce the cost of catchment management and enable greater productivity of land resources.

The aim of this research project will be to investigate the links among vegetation, saturated zone dynamics, and runoff generation for the different classes of riparian zone, and to test the hypothesis that riparian zone vegetation has a significantly variable effect on catchment water yields.

Estimated cost: R727 500  
Expected term: 2001 - 2004

#### Programme 2: Impact assessment and environmental management of agricultural production

##### Predicting the impact of farming systems on sediment yields in context of integrated catchment management ISCW, ARC (WRC Reference No 1059)

Sediment delivery to our water systems has always been considered a real threat to our sustainable water supply. Not only does it affect storage capacity of impoundments but it also acts as a transport mechanism for non-point pollution. It is important to note that the Working for Water Programme is starting to support the emerging Land Care Movement of the Department of Agriculture. This process will also give greater emphasis to water issues being addressed as part and parcel of land care, such as sediment delivery and groundwater recharge.

The project will make a concerted effort to address commercial farming, subsistence farming and small-scale farming impacts in a single unified approach.

Specific aims are to:

- Integrate and calibrate international and SA methodologies for quantitatively predicting the impact of subsistence and commercial farming systems on sediment yield from catchments
- Assess the impact of the following land-use types on sediment yield:
  - Subsistence farming systems: Communal grazing, communal cropping, traditional settlement
  - Commercial farming systems: Grazing, cropping (e.g. conventional tillage vs. minimum tillage, rotations, etc.)
  - Conservation areas

- Assess the impact of quality, availability and the spatial distribution of input data on the accuracy of sediment yield prediction results
- Develop a methodology for auditing the impact of land-use and management practices and monitoring the change thereof on sediment yield.

Estimated cost: R843 000  
Expected term: 1999 - 2003

#### Predicting the environmental impact and sustainability of irrigation with gypsiferous mine-water

Coaltech 2020  
(WRC Reference No 1149)

The coalfields in the Highveld of Mpumalanga generate significant quantities of surplus neutralised acid mine-water which is gypsiferous in nature. Because of their high salinity these waters cannot be freely discharged to river systems. However, irrigation with these waters holds much promise to significantly reduce the salt load emanating from mine drainage, while at the same time extracting value from water which would otherwise be a polluting agent. An initial rough estimate is that up to 10 000 ha of land could potentially be irrigated with coal-mine waters in the Mpumalanga Highveld. This project is building on successful previous and current field-scale research using gypsiferous water for irrigation, by addressing the following aims:

- Determine the impact of several gypsiferous water/soil combinations on soil conditions and groundwater quality
- Further develop and refine the soil-water-balance model for use in predicting gypsum precipitation, crop response, water quality and water balance
- Predict the likely long-term impact of gypsiferous irrigation waters on the groundwater system
- Determine whether these waters can be used to produce crops on a commercial basis
- Evaluate the sustainability of irrigation with gypsiferous water.

Estimated cost: R1 530 000  
Expected term: 2000 - 2003

#### Laboratory and field-scale evaluation of agricultural use of sewage sludge

ERWAT  
(WRC Reference No 1210)

The agricultural use of sewage sludge is a promising alternative use / disposal route for this product over the short-to-medium term, but several concerns currently restrict large-scale implementation. This project being

carried out by a multidisciplinary team comprising researchers from ERWAT, ARC and the University of Pretoria is a laboratory- and field-scale evaluation of the agricultural use of sewage sludge to establish the:

- Extent of metal uptake in different (winter and summer) crops grown on soils amended with sewage sludge
- Effect of soil properties on the mobility of nutrients and metals
- Safe sludge loadings to prevent nitrogen leaching to groundwater
- Persistence of sludge-borne pathogens during agricultural application
- Perceptions of farmers, commercial markets and urban and rural communities with regard to the beneficial use of sewage sludge for edible crops.

Estimated cost: R570 900  
Expected term: 2001 - 2003

**Use of isotope (13C) techniques to define the riparian zone in commercially afforested catchments**  
Environmentek, CSIR  
(WRC Reference No 1218)

Trees growing in riparian zones have continuous and free access to water. Because they are not restricted in their use of water, they make a disproportionate contribution to streamflow reduction. As a matter of policy, afforestation in riparian zones is therefore prohibited. A major difficulty, however, in implementing what is a sound policy, is the problem of delineating riparian zones. In this project, an isotopic (13C) technique is being investigated for riparian zone delineation.

Estimated cost: R200 000  
Expected term: 2001 - 2003

**Development of guidelines for treatment of scale in assessing the streamflow reduction impacts of alien infestations**  
Ninham Shand (Pty) Ltd  
(WRC Reference No 1221)

In South Africa, methods for estimation of streamflow reduction (SFR) impacts of both afforestation and alien infestations have adopted either of two different approaches: Relatively simple free-standing empirical relationships; or component modules in the physically-based, land-use sensitive ACRU daily rainfall-runoff catchment model. The CSIR has used sets of empirical curves to prepare national overviews of potential impacts on mean annual runoff, on a quaternary basis, for both commercial afforestation and alien infestations. It should be noted that these studies did not assess

potential impacts on "utilisable" runoff, e.g. on reservoir yield-reliability characteristics, or on water supplies from run-of-river schemes.

With the exception of a few *ad hoc* studies, there has been no systematic research into SFR impacts in terms of "utilisable water", as expressed in terms of reliability of reservoir/ system yield, or of water supplies from run-of-river situations, which are common in rural communities.

The aims are to:

- Develop generic guidelines for the treatment of scale and resolution in assessment of streamflow reductions due to alien infestation and commercial afforestation in integrated water resource management (IWRM) in South Africa
- Quantify streamflow reduction impacts caused by alien vegetation and commercial afforestation on reservoir and system yield-reliability characteristics, as well as for run-of-river water supplies for a range of South African river systems
- Assess and reconcile streamflow reduction impacts caused by alien vegetation and commercial afforestation, modelled at different levels of scale and resolution and over a range of bio-climatic regions.

Estimated cost: R599 700  
Expected term: 2001 - 2003

## NEW

### Thrust 1: Water Utilisation for Food and Fibre Production

**Programme 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture**

**Evaluation of the filtering and back-flushing efficiency of different irrigation filters**  
IAE, ARC  
(WRC Reference No 1356)

The growing usage of micro-irrigation systems

necessitates good quality water. Filtering of water before it enters the irrigation system (from the source) and efficient back-flushing of filters are, in most cases, needed in order to ensure better water quality. Suppliers of filtering systems, on the other hand, have various claims and specifications on their products. Experience has shown, however, that filtration equipment often does not live up to claims, resulting in poor performance of irrigation systems. For an irrigator to make a good choice, some form of standardisation of specifications is needed. The project will develop guidelines for choosing, operating and maintaining filters where water quality is poor. This will improve the management of irrigation systems.

The aims of the project are to:

- Determine the filtering and back-flushing efficiency of different types of filters under different water quality conditions in typical farming conditions
- Create directives for the choice and operation of filters with consideration of the water quality and maintenance requirements.

Estimated cost: R760 000  
Expected term: 2002 - 2005

**Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture**

**The effect of deteriorating irrigation water quality on the growth and water use of selected crops**  
Department Soil Science, University of the Free State  
(WRC Reference No 1359)

The water quality of most rivers in SA is gradually deteriorating, both in time and over space. This affects crop yields and the amount of water required to produce a crop. The magnitude of yield-loss depends on various factors - and has never been estimated comprehensively (for major crops and common poor-water quality problems). This project will determine the effects of deteriorating water quality on crop growth and water use efficiency. Effects of increasing salt content of irrigation water on the growth and yield of selected crops will be quantified.

The aims of the project are to:

- Quantify the effect of increasing salt content of irrigation water on the growth and yield of selected crops on two soils
- Determine the relationship between irrigation water with increasing salt contents and the water use of selected crops on two types of soils

- Measure the root water uptake from a shallow water table with varying salt contents
- Determine and model the salt balance for a range of irrigation water quality and soil type combinations, over a three-year period
- Quantify the leaching requirements for the two soils at five salinity levels.

Estimated cost: R980 000  
Expected term: 2002 - 2006

### Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture

**Programme 1: Sustainable water-based agricultural activities in rural communities**

**Integrating flood-plain agriculture into a diverse rural economy by enhancing co-operative management: A case study of the Pongola**  
Institute for Natural Resources  
(WRC Reference No 1299)

The effective management of the Pongola River flood plain has been unsatisfactory ever since the completion of the Pongolapoort Dam. This study aims at promoting effective co-operative management of the river system on a sustainable and democratic basis. Lessons learned here will contribute to formulation of policies and institutions to achieve sustainable use of river systems in rural South Africa. This project is strongly based on the principles of a participative action plan. The aims of the project are to:

- Learn about promoting effective co-operative management around sustainable use of river systems in rural areas
- Redirect the pattern of resource use on the Pongola River flood plain towards a shared vision reflecting a diverse and sustainable economy
- Establish a confident and capable team of researchers drawn from previously marginalised sectors;

Estimated cost: R880 000  
Expected term: 2002 - 2005

**The effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas. Phase II: On-farm trials of alternative agroforestry systems**

Environmentek, CSIR  
(WRC Reference No 1351)

One of the major constraints in rural farming systems of the Upper Thukela is the shortage of adequate and good quality grazing during the dry winter season. Unfortunately, supplementation of feed using commercial supplements is difficult because the supplements are expensive and not easily available in remote areas. Provision of alternative sources of fodder such as tree leaves and pods can increase production. The introduction of tree species for fodder should decrease the grazing pressure on the existing grassland. This will result in improved basal cover, decreased soil erosion and promote greater water infiltration.

The project aims are:

- To determine the effect of different agroforestry systems on increasing fodder production in rural farming systems
- To determine the effect of agroforestry practices on soil water availability to traditional crops (e.g. maize)
- To determine whether the inclusion of trees in traditional cropping systems can enhance the infiltration of rainfall and prevent soil loss
- To compare the water use of an indigenous fodder tree (*Acacia karoo*) and an exotic fodder tree (*Morus albus*), in order to test the hypothesis that indigenous fodder trees are more conservative water users than exotic tree species.

Estimated cost: R1 500 000  
Expected term: 2002 -2006

**On-farm application of in-field water harvesting conservation techniques of small plots in the central region of SA**

ISCW, ARC  
(WRC Reference No 1355)

Technology exchange and adoption are the best possible ways of evaluating the success of any research project. Water harvesting using in-field basins, has improved yield for a number of crops. The technique, however, needs to be communicated widely - and tested *in situ*. This project aims at engaging smallholder farmers, who often do not have irrigation facilities, and those who operate in dry areas, to use the technique under some guidance.

This project will disseminate knowledge and technologies that will improve productivity of rain-fed agriculture. Extension services, which have been identified as the weak link in rural agricultural development, will also be targeted by this project.

Estimated cost: R800 000  
Expected term: 2002 - 2003

**Implementing and testing the WRC guidelines on developing sustainable small-scale farmer irrigation in poor rural communities**

IWMI, ARC  
(WRC Reference No 1357)

Capacity development, particularly among smallholder farmers, demands well-trained development facilitators. This is because most of these farmers are illiterate, yet very experienced in farming. A lot of information is available at the WRC and elsewhere, which addresses the development needs of small-scale farmers within irrigation schemes. However, extension services have been identified as the weak link. If the problem of poor information flow due to poorly trained and limited extension officers is properly addressed, small-scale irrigators will improve their productivity with the same amount or less water.

The project will test and implement guidelines that will improve the development of sustainable small-scale farmer irrigation. It is aimed at exchanging technology and refining these guidelines. Agricultural extension services will also be improved through the training of extension officers.

The specific aims of the project are to:

- Test the role of the WRC guidelines in catalysing the economic revitalisation of rural areas with access to small-scale irrigation
- Build the capacity of previously disadvantaged individuals, communities, training institutions and local and provincial governments in the area below the Arabie Dam.

Estimated cost: R600 000  
Expected term: 2002 - 2004

**Programme 2: Integrated water management for profitable farming systems**

**Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers**

**Tlou Water Management**  
(WRC Reference No 1353)

Rural development in the Eastern Cape, KwaZulu-Natal and the Northern Provinces where widespread poverty occurs, has been held back due to institutional failures and collapse of many irrigation schemes. Consequently enormous social and development needs are experienced in respect of capacity building and entrepreneurial development; job creation; social upliftment of rural communities; poverty relief; and land redistribution. Government has shown its commitment to developing the rural areas by establishing an integrated rural development strategy (IRDS) in the President's Office. This initiative requires support through research of relevant models for social and economic development of the rural areas. The objective is to optimise use of scarce water resources and to develop previously disadvantaged communities. To achieve the objective this project will research models which take in account the multi-phased characteristics of the development process in order to re-establish small-scale irrigation farmers on a sustainable and financially viable basis. A concerted research effort is required to find acceptable solutions by working together with farmers, communities, local and provincial authorities to determine the requirements and formulate guidelines for sustainable development.

Aims of research project are as follows:

- Develop tenure models that would ease the management and operation of smallholding irrigation schemes, and settle small-scale irrigation farmers in a sustainable manner under South African land-tenure and rights conditions
- Develop suitable irrigation systems for small-scale irrigation farmers
- Determine an applicable on-farm support system, institutional setting and social framework to regulate the production, marketing financial and water resource needs of the small-scale irrigation farmers.

Estimated cost: R795 200  
Expected term: 2002 - 2005

**Water resource management for profitable small-scale farming along the banks of the Orange River**

Department Agricultural Economics, University of the Free State  
(WRC Reference No 1354)

The establishment of small-scale farmers on the Orange River in the Northern Cape and Western Cape Provinces

was identified as a very high priority. The study is motivated by the drive to utilise the water right allocation to establish small-scale irrigated farms and operate them efficiently and sustainably. Formal and appropriate methodologies will be developed to successfully establish small-scale farmers to ensure household food security and enable production of surpluses. Farm size, type of technology, access to markets and financing methods and procedures will be clearly defined. According to the Provincial Department of Agriculture in Kimberley an appropriate economic model is needed to successfully establish small-scale farmers. This project will directly address these issues by providing guidance and developing a model for evaluating the economic performance and efficiency of the farms prior to establishment.

The main aim of this project is to develop an appropriate methodology to successfully establish small-scale irrigation farmers in South Africa.

Sub-aims are to:

- Develop an appropriate land-tenure system for small-scale farmers
- Develop an appropriate marketing arrangement for inputs and outputs for small-scale farmers
- Develop a suitable financial arrangement for loan and credit acquisition to facilitate successful establishment of small-scale farmers
- Develop an economic model viable for successful establishment of irrigated farmers
- Determine the social acceptability of the proposed newly developed programme
- Determine the environmental impacts of the establishment of small-scale irrigated farms on undeveloped land.

Estimated cost: R970 000  
Expected term: 2002 - 2005

**The implementation of the FARMS system for decision support in the field of risk management, irrigation cost estimation and whole farm planning**

Department of Agricultural Economics, University of the Free State  
(WRC Reference No 1360)

Over the past 12 years, a number of research projects were funded by the WRC to develop decision-support models. These models enable efficient management of water through minimisation of irrigation cost, determining the appropriate exposure to risk and effectively combining resources and enterprises for food production. The models have reached a stage of

refinement where they can be applied in practice. In the current phase of implementation of the National Water Act, water user associations (WUAs) are being established and water tariffs are being restructured to ensure recovery of supply costs. Clearly there are financial incentives for farmers to improve water management on their own farms and on the irrigation schemes which they or their appointed agents have to manage. The total decision-environment therefore makes it opportune to introduce the WRC-funded models through technology transfer for whole-farm cost and risk management. This will be done by means of training courses at the main irrigation areas across South Africa and targeting advisers or extension officers of both emergent and commercial farmers in agribusiness and provincial departments. The technology transfer involves contact sessions with irrigation experts, compiling course material, presenting courses and demonstrations and arranging feed-back sessions to provide follow-up support.

The aims of the project are to:

- Train agribusinesses, bureau services and advisers in the main irrigation areas of South Africa to implement the RiskMan, IrriCost and FARMS computer software for decision-taking support in the field of risk management, irrigation cost estimation and whole farm planning respectively
- Give these organisations and individuals the necessary support in order for them to apply the above-mentioned computer software on a continuous basis.

Estimated cost: R800 000  
Expected term: 2002 - 2004

#### Thrust 4: Water Resource Protection and Reclamation in Agriculture

##### Programme 1: Sustainable water resource use on irrigation schemes and within river catchments

**Estimation of the contribution from dry-land salinity to water quality in the Berg River catchment: A pilot study**  
Department of Soil and Agricultural Water Sciences, University of Stellenbosch  
(WRC Reference No 1342)

Australia is suffering from a catastrophic dry-land salinity problem which is also affecting their surface water resources. The problem was caused by the clearance of natural deep-rooted trees and shrubs to make way for cultivated crops and grassland. Consequently a smaller portion of the stored, infiltrated water was extracted by the new vegetation and a larger portion drained to recharge groundwater. The result is that over decades the saline groundwater rose to decant into low-lying parts of the landscape, giving rise to saline patches. This project is based on the hypothesis that a similar process is operating in the drier parts of the Western Cape where shrubs were removed to make way for wheat fields (the wheat fields are known to contain saline patches). If this theory is correct, dry-land salinity can be expected to increase with time and manifest as a dry-land salinity problem similar to what is being experienced in Australia. This has potentially huge implications for the planned water schemes in the Berg River. This project plans to test the above theory and its implications by obtaining a preliminary estimate of the salt stored in typical topo-sequences and using models to predict how different vegetation cover and land-use scenarios are likely to affect future salt discharge to the river. As such this project presents a novel concept which is supported by sufficient circumstantial evidence to warrant serious consideration. Planning in the Berg River and its reliance on one of the research products, add urgency to the investigation.

The aims of the project are to:

- Obtain a preliminary estimate of the quantity of salts stored in the regolith of the Berg River catchment
- Calculate the current potential for decantation of these salts into the river
- Calculate, retrospectively and prognostically, the rate of change of salt discharge in response to changes in land-use practices

- Make a preliminary assessment of the applicability of the results of this study to other major river systems in the region (e.g. the Breede River) based on existing information on soil properties and the history of catchment land-use practices.

Estimated cost: R449 000  
Expected term: 2002 - 2004

**Multidimensional models for the sustainable management of water quantity and quality in the Orange-Vaal-Riet convergence system**  
Department of Agricultural Economics, University of the Free State  
(WRC Reference No 1352)

Current research on salinity management in irrigation agriculture fails to capture the stochastic nature of inter-seasonal changes in irrigation water quality as well as the cumulative economic effect of irrigating with varying water quality levels. This research will address the current gap in knowledge within a multidisciplinary framework and aims to determine the dynamic interactions between the hydrology, geohydrology, ecology and socio-economy for irrigated agriculture in the Orange-Vaal-Riet convergence system. The objective is to determine the current trends, private, social and regional impacts, externalities, and the long-term sustainability of agricultural practices. With these interactions having been determined, the impact of various policy measures and management practices, at farm, scheme, inter-scheme and at a regional level will be able to be modelled to determine the potential impacts on the sustainability of irrigated agriculture, local communities and the ecosystem of the Lower Vaal Riet & Middle Orange River systems. The proposed micro-level research follows a previous study on the economic effects of changing water quality on irrigated agriculture in the Lower Vaal and Riet Rivers by the UFS Dept of Agricultural Economics. The proposed macro-level research follows an Urban-Econ study that was successfully completed using economic simulation modelling to identify and quantify the economic impact of salinity in the Middle Vaal River System. The project therefore essentially consists of two separate projects, but it was deemed necessary for synergy and the achievement of optimal project results that the micro- and macro-level models be linked. Also the opportunity arises for Urban-Econ to extend the scope of their previous salinity research downstream and for the Department of Agricultural Economics to enhance their static model by developing a dynamic model for the area. The resulting models will be used to monitor the economic impact of changing water quality over time and the methodology can be applied with the necessary modifications to other river reaches.

The aims of the project are as follows:

The overall aim of the project is the development and integration of multi-dimensional models for the sustainable management of water quantity and quality in the Orange-Vaal-Riet convergence system. To achieve this the following sub-aims are identified:

- To research and document the polluting chemical processes and interactions in and in-between the plant and surface-, vadose zone- and ground-water, to achieve efficient and sustainable water quality management
- To develop new economic models at :
  - Micro (farm-level DLP based on SALMOD) level
  - Macro (regional dynamic input/output) level.
- To integrate these new economic models with the following existing models (which also are to be integrated):
  - Hydrology / hydraulic models
  - Vadose zone (unsaturated root zone) chemical balance models
  - Groundwater (saturated below water table) models
  - Crop growth models.
- To determine and prioritise best management practices at:
  - Micro (field and farm)
  - Macro (policy, catchment, irrigation board) levels.
- Through a better understanding of the multi-dimensional interactions, to enhance water use efficiency as the quantity and quality of water available for agriculture inevitably decreases
- To develop policy guidelines to ensure social, environmental and economic sustainability
- To achieve all these aims based on using the complex Orange-Vaal-Riet convergence system as a study area, but developing the methodology and models so that they can be applied elsewhere with relative ease.

Estimated cost: R1 297 950  
Expected term: 2002 - 2005

**Situation-analysis of problems for water quality management in the lower Orange River region (with special reference to the contribution of the irrigated foothills to salinisation)**

*Infruitec-Nietvoorbij, ARC  
(WRC Reference No 1358)*

With the implementation of the Lesotho Highlands Water Project, substantial volumes of low-salinity water are being diverted to the Vaal System, leading to reduced dilution and increasing salinity in the Orange River. A significant increase in salinity has been observed during the past number of years. This increase may have a detrimental impact on the grapes which are being produced under irrigation below the Boegoeberg Dam in the Lower Orange River. Grape producers rated problems related to salinity as 2nd out of 8 in their identification of research priorities for the Lower Orange River. The effect of increasing salinity on users downstream of the irrigated area is also of concern. There is, e.g. the potential for irrigation on the Namibian side of the Orange River which may be negatively affected by an increasingly saline Orange River. There is also concern regarding environmental considerations. A DWAF study predicted salt retention in the irrigated area and recommended further research in this regard as a high priority. This project will conduct a situation analysis of problems with water quality management in the study area by analysing and interpreting available data and by evaluating the potential of using satellite data to identify and characterise salinised land. From the understanding which is generated they will prepare guidelines for the management of existing water quality problems and (if necessary) identify further research needs.

The aims of the project are:

- Assess the land use, soil salinity and water quality, as well as salinity management practices, from a synthesis of existing information and by utilising satellite imagery and field surveys in selected areas
- Evaluate the present situation and likely future trends with regard to water quality and soil salinity management
- Based on the situation assessment, identify the need for policy development to protect soil and water resources in this area, and the need for research to support these.

*Estimated cost: R388 000  
Expected term: 2002 - 2004*

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# KSA 5

## Water-Centred Knowledge



*Dr IM Msibi*  
**Director:**  
**Water-Centred Knowledge**

### Scope

For the WRC, knowledge management is concerned with the development and exploitation of water-centred knowledge nationally, through:

- Identifying usable information from research studies
- Capturing the information
- Transferring the knowledge in a form that facilitates use
- Maintaining the information.

Driven by external needs, the WRC will continuously improve its position as the dynamic hub for water-

centred knowledge, innovation, and intellectual capital in South Africa. The knowledge to be managed is both explicit, documented knowledge and tacit, subjective knowledge. Management of knowledge in the WRC will therefore entail all the processes associated with the identification, sharing and creation of knowledge. This will require systems for the creation and maintenance of knowledge repositories, and to cultivate and facilitate the sharing of knowledge and organisational learning. For the WRC to succeed in knowledge management, it has to view knowledge as an asset and to develop organisational norms and values, which support the creation and sharing of knowledge.

The WRC is a knowledge organisation and hence the fundamental processes are knowledge-based, thereby creating value for the WRC and its stakeholders. Our knowledge capabilities determine our effectiveness at creating value through those processes. Knowledge management and creation require both cultural and functional changes. The embodiment of the culture of knowledge forms the basis of the WRC mission while focusing on the WRC vision. Management and transfer of knowledge are the keys to providing a valuable service to the South African water user.

### Objectives

Knowledge management in a knowledge-intensive organisation like the WRC is both a core business activity

as well as a support function, and IT is the enabler. The objectives of this KSA are as follows:

- To enhance the core processes of research support and management by improving access to relevant knowledge
- To ensure that all organisational learning can be leveraged when providing a service
- To provide the right knowledge (i.e. content) to the right people, at the right time in the right place at the right cost
- To develop and maintain consistent data architecture to enable the flow of content through a knowledge management system
- To develop a culture of sharing and networking supported by functional, user-friendly research information systems
- To improve knowledge transfer through the dissemination of research reports, guides, scientific and non-scientific journals, and by providing support to technology transfer initiatives
- To develop a strategic advice capability supporting studies regarding water-centred knowledge, i.e. assessment of capacity, foresight and/or scenario studies, etc.

### Thrusts

The following management "subgroups" or thrust areas form the general frame or scope:

- Thrust 1: Strategic Research Advice (SRA)**
- Thrust 2: Information and Communication Technology (ICT)**
- Thrust 3: Research Information and Document Management (RIDM)**
- Thrust 4: Publishing and Publications Centre (PPC)**
- Thrust 5: Water-Centred Media and Activities (WCM)**

This KSA focuses on key aspects of knowledge management that are of importance to the water sector and that affect the efficient and effective 'operation' of the organisation. The main focus will be on knowledge as a "value-adding component" that can be located and re-organised. It is possible to support the creation of, capture, distribute, measure and manage knowledge. This KSA will also focus on managing documents and their creation, storage and reuse in IT based systems. It will:

- Connect people with reusable codified knowledge
- Develop document management systems
- Recognise people for using and contributing to databases
- Be based on the view that "content is king" and should therefore be made explicit wherever possible.

## Budget 2002/3 (in Rand)

Fixed costs	516 631
Running costs	1 230 000
Printing & publishing (reports, etc.)	3 269 600
Human resource costs	1 968 206
Research funding	537 000
<b>Total</b>	<b>7 521 437</b>

## CORE STRATEGY

### Strategic context

The WRC has maintained very useful local and international contacts and networks, and further transferring its knowledge through dissemination of research reports, guidelines, technology transfer documents and initiating and supporting workshops and conferences. Our objectives as a knowledge hub will be to improve and enhance the understanding and communicating the value of a research project and how it fits into the body of knowledge. Significant value is added to research results by placing it in context.

Through this new strategic area, the WRC will not only support the creation of knowledge, but also address the transfer and dissemination of the created knowledge, through improved or innovative strategies to package and present knowledge in the right format, right place and right time. Continuous improvement in the ways of packaging and disseminating knowledge will be provided. The role of information and communication technology will be core to all WRC's activities. There is a need to take note of the positioning and role of information and communication technology (ICT) in knowledge-intensive organisations. The aim is also to enhance the strategic role of the WRC, towards the nation through the provision of strategic research advice regarding research needs and possible application of research results. The cultivation of a strong business culture, i.e. strategic marketing of knowledge products, will make the WRC, through this KSA, both proactive and responsive.

The following management "subgroups" or thrust areas form the general frame or scope:

### Thrust 1: Strategic Research Advice (SRA)

Internal and external knowledge sharing, to meet the objectives of the WRC in its knowledge creation and learning activities and the core process of research funding. Enabling systems and tools for knowledge sharing, and the development of a culture of sharing knowledge for achieving higher quality. Further, maintain access to the necessary information to make decisions internally as well as externally, and a resource centre to meet information requirements of the WRC and other external bodies. Working with a variety of institutions, internally and externally, exchange of information and data on developments around water management issues.

### Thrust 2: Information and Communication Technology (ICT)

To meet the information and communication needs of the stakeholders and also internal needs of the WRC regarding knowledge management, ICT has become the popular service delivery tool to the WRC stakeholders. Development of enabling systems and tools, E-publishing and E-business, and supporting the community of practice. Information processing abilities, information security and risk management.

### Thrust 3: Research Information and Document Management (RIDM)

Key focus will be on driving water-centred knowledge dissemination; linking external databases while in the long run building nation-wide knowledge engine /networks and increasing public understanding of water-related issues. This includes handling and storage of documents, archiving, and maintaining library and information services.

### Thrust 4: Publishing and Publications Centre (PPC)

Dissemination of knowledge created via the support of the WRC as well as other sources of water-centred knowledge. Development of a true virtual publications

centre, E-publishing, E-business and E-business promotion.

### Thrust 5: Water-Centred Media and Activities (WCM)

Dissemination of water-centred knowledge in the national and international arena through publication of an internationally rated journal and through increasing the public understanding of science. In addition this will include all other public understanding of science initiatives.

### Needs analysis

The level of knowledge of water management in the communities in general is minimal. The following issues are therefore considered high priority:

- Improvement of public understanding of water issues
- Effective dissemination of information (right place, right time)
- Providing the communities with information (information management)
- Culture of learning from each other.

Government departments, at all levels, need information for policy-making and analysis. They also need to be able to communicate issues back to the WRC, especially those which may require research intervention or advice. At community level, South Africa cannot change to sustainable water management without community co-operation and they cannot co-operate if they do not understand. The basis for understanding is knowledge. The water sector also faces the challenge of being able to link up and work globally and regionally.

### Technological trends

The emergence of knowledge management and knowledge as a key strategic resource, has influenced the way we view and handle information. Developments in ICT have changed the way we share information. These two key developments redefine a true knowledge hub. The way the WRC positions knowledge management and utilises IT will determine its success as a knowledge hub. Given that the WRC is focused on developing efficient internal systems to provide an improved service to the rest of the world, it needs to take

full advantage of IT and the knowledge management paradigm.

### Key stakeholders

Creation, transfer and dissemination of knowledge require an appropriate knowledge base, that is water-related experts, practitioners, academics, science councils, the government (at all levels) and other research organisations. The WRC has to be able to effectively translate needs into research ideas and further transfer research results and new technologies to end-users or end-user representatives and communities.

### Modus operandi

Our approach to knowledge management will be based on examining it in terms of "People, Process, and Technology" or "Culture, Structure, and Technology" in order to meet the WRC business requirements and stakeholder expectations.

### Links to the Mission and Vision of the WRC

From the vision and mission of the WRC, "to be a globally recognised leader in providing innovative solutions for sustainable water management to meet the changing needs of society and of the environment" and to be "a dynamic hub for water-centred knowledge, innovation and intellectual capital".

### Progress against set KPAs for 2002/2003

The following examples illustrate the progress to date:

- New user-friendly databases are being developed to pool together all the contacts for the WRC (the address database)
- All standard reports are on print-on-demand
- Draft archive policy, Intranet policy, E-mail policy and library policy are completed
- An IP policy is currently being drafted
- Patent review: This exercise will be completed by mid-February
- A new public understanding of science publication *The Water Wheel*, with improved design and advertising. Advertising revenue and wider distribution is already in circulation.

- Library/information services centre is currently being reorganised and is about 60% complete
- The annual *Knowledge Review*, the new format of communicating WRC research, was developed and widely disseminated. Very good feedback is being received
- Technicians, universities, local authorities and other relevant organisations were contacted and given access to all our free publications with a very good response.
- A first catalogue of special reports was distributed at the end of January 2003
- The Internet-based service for publications has been restored and is being used
- WATERLIT effectiveness now and in the future has been evaluated and a decision was taken to put it under new management

### Thrust 1: Strategic Research Advice (SRA)

This is a new initiative by the WRC, and will require achievement of most of the above-mentioned objectives, especially information management, before it can be planned for.

The new world of business imposes the need for variety and complexity of interpretations of information outputs generated by computer and other systems. Such variety is necessary for deciphering the multiple world views of the uncertain and unpredictable future. Instead of long-term prediction, the emphasis is on understanding the multiple future world views by using techniques such as scenario planning. There is a link between this and the shift in mindset described above, in terms of a faster cycle of knowledge creation and its application, by enabling continuous and rapid detection of developments caused by the dynamically changing water sector environment. In this approach, access to information/advice, authority to take informed action, and the requisite skills are embedded at the frontlines where real action takes place so that strategy is devised and implemented in real time.

With the rapid increase in dynamic and non-linear changes in the WRC/external environment, there is an increasing interest in designing information systems that can take dynamic and diverse interpretations of changing information into account. Hence in the short term the KSA will look at institutionalisation of "best practice" by embedding them in IT aimed to facilitate efficient handling of routine and predictable situations. However, proactive involvement of human imagination, interpretation and creativity are needed to facilitate

greater internal and external diversity to match the variety and complexity of the "wicked environment". With ongoing reassessment of key assumptions, the emphasis in the medium term will be more on ongoing renewal of existing knowledge, creation of new knowledge and its application in the water sector. The conceptualisation of knowledge management is based on the need for synergy between the capabilities of advanced information technologies and human creativity and innovation to realise agility demand by WRC stakeholders. Furthermore, in the long term this thrust will view their roles as those of a designer, teacher and steward who can build shared vision, and challenge prevailing mental modules.

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#### New WRC Website

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#### Intranet

The new WRC Intranet was launched, offering WRC staff the facility to consult internal policy documents and other official documentation from their desk-tops. Links to a wide range of interesting and useful local and international websites have also been installed.

### Thrust 3: Research Information and Document Management (RIDM)

#### WATERLIT Bibliographic Database - A new era!

The WATERLIT Bibliographic Database has a long history with the South African Water Research Commission (WRC). They were originally responsible for the development of the database by the South African Water Information Centre (SAWIC) in 1975, in collaboration with the CSIR. In July 1999, the WRC took over the compilation and maintenance of the database from the CSIR and continued to develop, fund and manage WATERLIT until the end of March 2003.

From 1 April 2003, the database is now compiled, maintained and published by NISC SA. WATERLIT is available both on CD-ROM (published under the product title 'Water Resources Worldwide') and for online searching via the NISC Internet Service BiblioLine.

WATERLIT is an essential resource particularly for those dealing with industrial and environmental aspects of water. Topics such as potable water, wastewater, sanitation, hydrology and limnology, are extensively covered. The database includes over 354 900 records and NISC SA plans to expand and enhance both the content and annual growth.

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- Tel - +27 (0)46 622 9698
- Fax - +27 (0)46 622 9550

# KSA 5

## Water-Centred Knowledge



Dr IM Msibi  
Director:  
Water-Centred Knowledge

### Scope

For the WRC, knowledge management is concerned with the development and exploitation of water-centred knowledge nationally, through:

- Identifying usable information from research studies
- Capturing the information
- Transferring the knowledge in a form that facilitates use
- Maintaining the information.

Driven by external needs, the WRC will continuously improve its position as the dynamic hub for water-

centred knowledge, innovation, and intellectual capital in South Africa. The knowledge to be managed is both explicit, documented knowledge and tacit, subjective knowledge. Management of knowledge in the WRC will therefore entail all the processes associated with the identification, sharing and creation of knowledge. This will require systems for the creation and maintenance of knowledge repositories, and to cultivate and facilitate the sharing of knowledge and organisational learning. For the WRC to succeed in knowledge management, it has to view knowledge as an asset and to develop organisational norms and values, which support the creation and sharing of knowledge.

The WRC is a knowledge organisation and hence the fundamental processes are knowledge-based, thereby creating value for the WRC and its stakeholders. Our knowledge capabilities determine our effectiveness at creating value through those processes. Knowledge management and creation require both cultural and functional changes. The embodiment of the culture of knowledge forms the basis of the WRC mission while focusing on the WRC vision. Management and transfer of knowledge are the keys to providing a valuable service to the South African water user.

### Objectives

Knowledge management in a knowledge-intensive organisation like the WRC is both a core business activity

as well as a support function, and IT is the enabler. The objectives of this KSA are as follows:

- To enhance the core processes of research support and management by improving access to relevant knowledge
- To ensure that all organisational learning can be leveraged when providing a service
- To provide the right knowledge (i.e. content) to the right people, at the right time in the right place at the right cost
- To develop and maintain consistent data architecture to enable the flow of content through a knowledge management system
- To develop a culture of sharing and networking supported by functional, user-friendly research information systems
- To improve knowledge transfer through the dissemination of research reports, guides, scientific and non-scientific journals, and by providing support to technology transfer initiatives
- To develop a strategic advice capability supporting studies regarding water-centred knowledge, i.e. assessment of capacity, foresight and/or scenario studies, etc.

### Thrusts

The following management "subgroups" or thrust areas form the general frame or scope:

- Thrust 1: Strategic Research Advice (SRA)**
- Thrust 2: Information and Communication Technology (ICT)**
- Thrust 3: Research Information and Document Management (RIDM)**
- Thrust 4: Publishing and Publications Centre (PPC)**
- Thrust 5: Water-Centred Media and Activities (WCM)**

This KSA focuses on key aspects of knowledge management that are of importance to the water sector and that affect the efficient and effective 'operation' of the organisation. The main focus will be on knowledge as a "value-adding component" that can be located and re-organised. It is possible to support the creation of, capture, distribute, measure and manage knowledge. This KSA will also focus on managing documents and their creation, storage and reuse in IT based systems. It will:

- Connect people with reusable codified knowledge
- Develop document management systems
- Recognise people for using and contributing to databases
- Be based on the view that "content is king" and should therefore be made explicit wherever possible.

## Budget 2002/3 (in Rand)

Fixed costs	516 631
Running costs	1 230 000
Printing & publishing (reports, etc.)	3 269 600
Human resource costs	1 968 206
Research funding	537 000
<b>Total</b>	<b>7 521 437</b>

## CORE STRATEGY

### Strategic context

The WRC has maintained very useful local and international contacts and networks, and further transferring its knowledge through dissemination of research reports, guidelines, technology transfer documents and initiating and supporting workshops and conferences. Our objectives as a knowledge hub will be to improve and enhance the understanding and communicating the value of a research project and how it fits into the body of knowledge. Significant value is added to research results by placing it in context.

Through this new strategic area, the WRC will not only support the creation of knowledge, but also address the transfer and dissemination of the created knowledge, through improved or innovative strategies to package and present knowledge in the right format, right place and right time. Continuous improvement in the ways of packaging and disseminating knowledge will be provided. The role of information and communication technology will be core to all WRC's activities. There is a need to take note of the positioning and role of information and communication technology (ICT) in knowledge-intensive organisations. The aim is also to enhance the strategic role of the WRC, towards the nation through the provision of strategic research advice regarding research needs and possible application of research results. The cultivation of a strong business culture, i.e. strategic marketing of knowledge products, will make the WRC, through this KSA, both proactive and responsive.

The following management "subgroups" or thrust areas form the general frame or scope:

### Thrust 1: Strategic Research Advice (SRA)

Internal and external knowledge sharing, to meet the objectives of the WRC in its knowledge creation and learning activities and the core process of research funding. Enabling systems and tools for knowledge sharing, and the development of a culture of sharing knowledge for achieving higher quality. Further, maintain access to the necessary information to make decisions internally as well as externally, and a resource centre to meet information requirements of the WRC and other external bodies. Working with a variety of institutions, internally and externally, exchange of information and data on developments around water management issues.

### Thrust 2: Information and Communication Technology (ICT)

To meet the information and communication needs of the stakeholders and also internal needs of the WRC regarding knowledge management, ICT has become the popular service delivery tool to the WRC stakeholders. Development of enabling systems and tools, E-publishing and E-business, and supporting the community of practice. Information processing abilities, information security and risk management.

### Thrust 3: Research Information and Document Management (RIDM)

Key focus will be on driving water-centred knowledge dissemination; linking external databases while in the long run building nation-wide knowledge engine /networks and increasing public understanding of water-related issues. This includes handling and storage of documents, archiving, and maintaining library and information services.

### Thrust 4: Publishing and Publications Centre (PPC)

Dissemination of knowledge created via the support of the WRC as well as other sources of water-centred knowledge. Development of a true virtual publications

centre, E-publishing, E-business and E-business promotion.

### Thrust 5: Water-Centred Media and Activities (WCM)

Dissemination of water-centred knowledge in the national and international arena through publication of an internationally rated journal and through increasing the public understanding of science. In addition this will include all other public understanding of science initiatives.

### Needs analysis

The level of knowledge of water management in the communities in general is minimal. The following issues are therefore considered high priority:

- Improvement of public understanding of water issues
- Effective dissemination of information (right place, right time)
- Providing the communities with information (information management)
- Culture of learning from each other.

Government departments, at all levels, need information for policy-making and analysis. They also need to be able to communicate issues back to the WRC, especially those which may require research intervention or advice. At community level, South Africa cannot change to sustainable water management without community co-operation and they cannot co-operate if they do not understand. The basis for understanding is knowledge. The water sector also faces the challenge of being able to link up and work globally and regionally.

### Technological trends

The emergence of knowledge management and knowledge as a key strategic resource, has influenced the way we view and handle information. Developments in ICT have changed the way we share information. These two key developments redefine a true knowledge hub. The way the WRC positions knowledge management and utilises IT will determine its success as a knowledge hub. Given that the WRC is focused on developing efficient internal systems to provide an improved service to the rest of the world, it needs to take

full advantage of IT and the knowledge management paradigm.

### Key stakeholders

Creation, transfer and dissemination of knowledge require an appropriate knowledge base, that is water-related experts, practitioners, academics, science councils, the government (at all levels) and other research organisations. The WRC has to be able to effectively translate needs into research ideas and further transfer research results and new technologies to end-users or end-user representatives and communities.

### Modus operandi

Our approach to knowledge management will be based on examining it in terms of "People, Process, and Technology" or "Culture, Structure, and Technology" in order to meet the WRC business requirements and stakeholder expectations.

### Links to the Mission and Vision of the WRC

From the vision and mission of the WRC, "to be a globally recognised leader in providing innovative solutions for sustainable water management to meet the changing needs of society and of the environment" and to be "a dynamic hub for water-centred knowledge, innovation and intellectual capital".

### Progress against set KPAs for 2002/2003

The following examples illustrate the progress to date:

- New user-friendly databases are being developed to pool together all the contacts for the WRC (the address database)
- All standard reports are on print-on-demand
- Draft archive policy, Intranet policy, E-mail policy and library policy are completed
- An IP policy is currently being drafted
- Patent review: This exercise will be completed by mid-February
- A new public understanding of science publication *The Water Wheel*, with improved design and advertising. Advertising revenue and wider distribution is already in circulation.

- Library/information services centre is currently being reorganised and is about 60% complete
- The annual *Knowledge Review*, the new format of communicating WRC research, was developed and widely disseminated. Very good feedback is being received
- Technicians, universities, local authorities and other relevant organisations were contacted and given access to all our free publications with a very good response.
- A first catalogue of special reports was distributed at the end of January 2003
- The Internet-based service for publications has been restored and is being used
- WATERLIT effectiveness now and in the future has been evaluated and a decision was taken to put it under new management

### Thrust 1: Strategic Research Advice (SRA)

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## Thrust 4: Publishing and Publications Centre (PPC)

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 sections of this review and in the **Annexure**.

An effective marketing strategy for the knowledge assets was developed. A report catalogue of selected TT reports has been compiled and is being widely distributed. During the year under review 121 reports were published and approximately 40 000 reports were dispatched upon request from stakeholders; some of these were sold and the income generated in this way came to R145 681, compared to last year's R80 279.

An efficient printing strategy based on print-on-demand was implemented and has considerably reduced the overall costs for knowledge dissemination, e.g. storage and postage.

### List of WRC publications

A continuously updated list of WRC publications is posted on our Website ([www.wrc.org.za](http://www.wrc.org.za)) for perusal by users and orders for reports may be placed either electronically, telephonically or by fax.

The **Annexure** to this *Knowledge Review* contains a list of publications (articles, papers and published reports) which appeared during 2002/03 and which emanated from research supported wholly or in part by the WRC.

## Thrust 5: Water-Centred Media and Activities (WCM)

### Publications

The WRC's publications cater for three levels: Pure scientific, popular scientific and practical scientific.

### The Water Wheel

In 2002 the WRC decided to change its external marketing magazine, the *SA Waterbulletin*, into a public understanding of science and technology (PUSET) publication called *The Water Wheel*.

The first issue of *The Water Wheel* was published in December 2002 with articles on cyanobacteria monitoring, environmental biotechnology, fog collection and fluoridation of water in South Africa.

Material is sourced from outside the WRC and to guide contributors four editorial "principles" were established, namely:

- Preference is given to **Good News stories** - new developments, achievements, positive contributions to society and the improvement of life in general.
- The **Application of Science** and scientific processes, methods and research in the water field are highlighted.
- A **Visual Approach** is preferred, as opposed to long and complex articles which are difficult to read.
- The **Human Element** should always form a major part of every science article.

*The Water Wheel* is published bi-monthly, six times a year and is distributed throughout South Africa and the SADC countries to individuals, industrial companies, institutions with an interest in water, state departments, local authorities, water boards, mines, universities and technicians. The aim is to increase the current readership database of more than 5 300 subscribers. For the benefit of overseas readers the publication is included on the WRC website.

To try and defray the continuously escalating production costs and postage, *The Water Wheel* now also publishes paid advertisements. Advertising rates are available from the editor at the WRC.

A special supplement entitled: *Interviews with People Successful in the Water Field* appeared in the March/April 2003 edition of *The Water Wheel*.

### Water SA

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

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

It has a strict refereeing system whereby all articles submitted for publication are first referred to referees. Thereafter, a decision is taken on whether or not the article should be published. In 2002/03 *Water SA* published 79 articles written by 187 authors and reviewed by 160 international and Southern African reviewers. *Water SA* has an extensive local as well as overseas readership. Currently there are 3 047 subscribers to *Water SA* of whom 858 are abroad. It also enjoys world-wide coverage by all the major international abstracting services that publish and distribute summaries of articles which appear in *Water SA*. In addition it is abstracted on *African Journals Online (AJOL)* (<http://www.inasp.info/ajol>) and on SABINET (the main SA company facilitating electronic access to information) under E-publications.

Over a span of almost 30 years the journal has moved from the paper era to the electronic era, employing the most advanced publication technologies currently available. Since the beginning of 1997 the full text version of the journal is also available on the Internet via the WRC website (<http://www.wrc.org.za>).

A selection of papers presented at the Biennial Conference of the Water Institute of Southern Africa (WISA) held in Durban during 19 to 23 May 2002 was published in a special edition of *Water SA* (*Water SA Special Edition: WISA Biennial Conference 2002 (Vol 29)*).

### Contact persons:

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# XD A

## Water and Society



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Water and Society

### Scope

Water consumption world-wide is increasing. It is estimated that global water consumption doubles every 20 years. According to the UN, if current trends of water consumption persist, by year 2025 the demand for freshwater will rise by 56% and as much as 66% of the world's population will be living with serious water shortages or absolute water scarcity.

The challenge at the local and regional levels is how to protect the earth's limited freshwater. Water is both a social and an economic good, and is vital for its social, cultural and ecological roles within society. Because water is important to the process of economic

development, essential for life and health, and has cultural significance, it has often been provided at subsidised prices or free of charge in other situations. In theory, the idea is to make water available to even the poorest segment of society.

The shortage of freshwater in South Africa and elsewhere in the world has led to direct and strong government and NGO support and protection. The National Water Act (Act No 36 of 1998) is aimed at ensuring that South Africa's scarce water resources are protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner, for the benefit of all persons.

The **Water and Society** crosscutting domain (**XD A**) of the WRC focuses on social issues regarding water resources. WRC interventions and timeliness, and appropriateness of research in addressing water-related social issues and ensuring sustainability, are the major focus. Public communication and understanding of issues and research outcomes are paramount.

### Objectives

- Establish relationships with various stakeholders.
- Gather information on current water-related social issues in order to direct WRC investment into gap areas
- Improve understanding of common issues/shared sense of purpose by researchers, WRC, government and the public

The research portfolio of current projects has been grouped into strategic thrusts and programmes which directly address the above-mentioned objectives and are summarised as follows:

### Thrusts and programmes

#### Thrust 1: Public Perception and Awareness of the Water Issues

- Transboundary shared resource
- Inter-sectoral needs
- Water quality

#### Thrust 2: Social Needs Analysis and Water Services

- Water provision
- Payment for water

#### Thrust 3: Accessibility to Water

- Gender limitations
- Poverty alleviation

### Budget for 2002/03 and 2003/04

The XD A research portfolio (Table i) indicates that substantial investment is on **Public Perception and Awareness of the Water Issues**. Equal investment of

R5m. has been made in the new projects (starting 2002/03). The **Social Needs Analysis and Water Services** thrust is currently spending R2m.; R1m. is being invested in new projects. The third thrust, **Accessibility to Water**, is currently investing R3.5m. However, only R800 000 is invested in new projects (starting 2002/03 financial year).

A total of R6m. will be invested in this domain during the 2003/04 financial year (Table ii). Of this, R4m. will be invested in Thrust 1, **Public Perception and Awareness of the Water Issues** while R2m. will be invested in issues around accessibility to water. All KSAs will be investing in improving public perception and awareness of water issues while only **Water Resource Management (KSA1)** and **Water Utilisation in Agriculture (KSA4)** will invest in issues around accessibility to water.

Table (i): Current investment within XD A (Figures are in Rand)

Thrust	Budget			Budget distribution within KSAs										
	Total	Current projects	New projects	Current projects					New projects (Starting 2002/03)					
				KSA 1	KSA 2	KSA 3	KSA 4	Domain	KSA 1	KSA 2	KSA 3	KSA 4	Domain	
Perception and Awareness	10 574 800	5 812 100	4 762 700	969 300	50 000	-	-	-	-	3 262 700	-	-	1 500 000	-
Needs and Services	3 252 500	1 971 600	1 280 900	-	-	466 400	-	-	-	-	-	1 280 900	-	-
Accessibility	4 554 580	3 600 580	877 000	-	-	-	415 000	-	-	-	-	77 000	800 000	-
<b>Total</b>	<b>18 371 880</b>	<b>11 384 280</b>	<b>6 920 600</b>	<b>969 300</b>	<b>50 000</b>	<b>466 400</b>	<b>415 000</b>	<b>-</b>	<b>-</b>	<b>3 262 700</b>	<b>-</b>	<b>1 357 900</b>	<b>2 300 000</b>	<b>-</b>

Table (ii): Planned Investment for 2003/4 Within XD A (Figures are in Rand)

Thrust	Total	KSA 1	KSA 2	KSA 3	KSA 4	Domain
Perception and Awareness	3 800 000	1 800 000	600 000	600 000	800 000	-
Needs and Services	550 000	-	-	-	-	-
Accessibility	1 750 000	800 000	-	-	950 000	-
<b>Total</b>	<b>6 100 000</b>	<b>2 600 000</b>	<b>600 000</b>	<b>1 150 000</b>	<b>1 750 000</b>	<b>-</b>

**Key:**  
 KSA 1: Water Resource Management  
 KSA 2: Water-Linked Ecosystems  
 KSA 3: Water Use and Waste Management  
 KSA 4: Water Utilisation in Agriculture

## CORE STRATEGY

### Strategic context

The strategic context within which this crosscutting domain functions will be discussed in terms of three major thrusts which relate to water and society and the associated research and development needs.

### Thrust 1: Public Perception and Awareness of the Water Issues

#### Transboundary shared resource

The perfect water resource has to be adequate, sustainable, non-polluted and affordable in order to benefit society. The scarcity and mismanagement of freshwater resources, on the other hand, can lead to conflicts within and between societies, nations and regions. The challenge for research at the local, regional and national levels, therefore, is how to protect the earth's limited freshwater, conserve its use, improve its management and in the process move from potential conflict to active collaboration.

Rivers and catchments are shared between and among countries, provinces and districts. This indicates the need for transboundary planning, management and development of the water resources in a collaborative manner, involving the public. This further highlights the need for continued regional research focus in estimating both surface and underground water resources for Southern Africa.

#### Inter-sectoral needs

Water can be both a social and an economic good. Besides economic development, water has vital social, cultural and ecological roles to play that cannot be protected by purely market forces. This means that certain water management goals and social values require direct and strong government and non-governmental organisation support and protection, especially when water is scarce.

The value of water to society can be interpreted from various perspectives, namely, development, health and hygiene, environmental, economic growth, etc. Because water is important to the process of economic development, essential for life and health, and has cultural or religious significance, it has often been provided at subsidised prices or free of charge in other situations. In theory, though not always in practice, this

makes water available to even the poorest segment of society.

Water is also needed for industrial, agricultural and ecological development. Often, where water is limiting, prioritisation of development initiatives becomes paramount. Primarily, the riparian rights indicate that water needs for people (domestic use) have to be met prior to any other form of development. Tensions are often encountered during the allocation of water among industrial, agricultural and environmental development initiatives. Probably, due to difficulties in estimating water requirements for sustainable environmental development, industrial and agricultural development programmes usually get preference. Research is needed to support decisions and policy regarding amicable allocation of water resources towards various development sectors.

#### Water quality

Water quality determines whether the resource is suitable for usage or not. If the quality of water falls below certain standards, it may not be suitable for certain uses.

Tensions exist among different forms of development and their impact on the quality of water. Agricultural and industrial developments, because of large volumes of water used, tend to affect the water quality negatively. For example, where industry is located on the upper part of the catchment, poor quality water on the lower parts of the catchment will affect farming operations. If there is any form of water pollution, irrespective of its source, the environment is usually negatively affected. Where people rely on natural sources for domestic water, any pollution of the resource can directly or indirectly affect their health status.

Guidelines are needed for any form of development and its impact on water quality. These guidelines will inform environmental impact assessments which are undertaken prior to any major development.

### Thrust 2: Social Needs Analysis and Water Services

#### Water provision

The existence of a water resource does not necessarily mean that water is readily available to society. The currently poor and deteriorating state of water resources in many parts of the world demands integrated water resource planning and management. The impact of steady population growth on water availability is an

increasing challenge. In some urban centres, demand for water not only threatens to exceed supply, but the quality of the water itself is also a concern. If water supplies are polluted, inadequate, non-sustainable and not affordable, society and the surrounding environment can be affected directly or indirectly. In most developing countries, this usually leads to some privatisation of water, which passes the production and distribution of water services from public entities into private companies. Privatisation can be partial, leading to public-private partnerships, or complete, leading to the total elimination of government responsibility for water systems. This has caused concern in many circles. It has also encountered opposition. Opposition is based on doubts concerning whether purely private markets can address the many different socially good aspects of water, or whether some non-market mechanisms are necessary to serve social objectives. Sometimes opposition arises from concerns over the economic implications of privatising water resources, the risks to ecosystems, the power of corporate players, foreign control over the fundamental natural resource, inequities of access to water, and the exclusion of the public from decisions about their own resources.

Urbanisation and the establishment of informal settlements in South Africa have been occurring at relatively high rates. These make it difficult to plan accordingly in terms of infrastructural development based on water demand and the provision thereof. Research to improve understanding of the dynamic nature of water needs is necessary.

#### **Payment for water**

The South African government policy now entitles every household to 6 000 l/month free of charge from the bulk water supply system. However, the majority of poor people (in rural areas and informal settlements) do not have water meters and, as such, do not benefit from this entitlement of free basic water. Alternatively, they do not pay at all, irrespective of whether they exceed their free quota or not.

In cases where poor people have to pay, it has been established that rural people pay a lot more than urban residents since the payment is estimated on the basis of the replacement value of the potable water supply scheme. As a result of being unable to afford payment for water, rural people tend to resort to unhygienic sources even though purified water is available.

In urban areas where water meters are in place, it has been established that rich people tend to use more water than the poor. Theoretically, therefore the rich will pay more and subsidise poor households. However, large,

poor households may not be able to restrict water usage to below the 6 000 l/month limit, and may therefore not reap the full benefits of the free water policy. Research and guidelines are needed around the 6 000 l/month free basic water limit and the most effective way of meeting estimated costs for rural water supply systems.

Ensuring that water supply meets the social needs of all affected people has not always been a primary goal of development, nor is it a goal which is easily achieved. It is an area which requires ongoing investigation.

### **Thrust 3: Accessibility to Water**

#### **Gender limitations**

Participation and representation of individuals, in a gender-balanced manner, are crucial to the successful implementation of water-related policy decisions. Participation also improves equity and individual access to the resource. Although gender balance is a priority on the agendas of policy-makers, interventionists, leaders and researchers, the gap between positive intentions and concrete action is still considerable. Usually, the cause of the gap lies in the lack of adequate conceptualisation and methodological tools that provide the insights needed by policy-makers and change agents. Whether men or women are decision-makers or just provide support within a society (structure) is an underlying gender issue.

Surveys show that the poverty rate of female-headed households is higher than that of male-headed households. These poorer households also experience more intense problems of lack of access to safe water for drinking. In order to address existing inequity and gender imbalance within the water sector, the government is promoting equal representation in all the institutions where it is involved. A number of empowerment programmes exist where women have strategic roles. Poverty reduction, economic upliftment, improved health and reduced drudgery for women are the main four of the key goals of water supply, sanitation and accessibility initiatives by government. Research on factors that lead to poor participation of individuals based on gender, age and disabilities will be conducted.

#### **Poverty alleviation**

There is a direct link between poverty, lack of access to water, and the inability of the poor to secure adequate food supplies. The poor usually do not have adequate means to gain access to sufficient water of the required quality for domestic and food production purposes.

Most government irrigation schemes have been established with the aim of using limited water to address food security, poverty, joblessness and upliftment. Greater water availability also lowers constraints on agro-industrial development, and provides direct employment opportunities.

For sustainable food security to be achieved, investment should be made in improving the well-being and productivity of small-scale farmers, and in enhancing their access to remunerative employment and productive assets. While efforts to increase the adoption of drought-resistant crop varieties in the rain-fed regions could be initiated, investments in small-scale irrigation should be pursued to sustain production levels, increase income, food security and standard of living in the medium and long term.

On realising that irrigation resources are not efficiently and effectively utilised, the government has set about trying to solve the problem through empowerment, whereby people participating in these schemes are trained and given financial assistance. It is, however, too early to speculate on whether this approach will succeed or not.

Clearly, efficient and better ways of using limited water resources for poverty alleviation are important issues for South Africa and its people. Research is also needed on establishing guidelines to improve entrepreneurship among small-scale farming communities, which will sustain food security, economic growth and ensure poverty alleviation as a result of effective use of water resources.

### **Needs analysis**

Research and development needs have been articulated above, in the context of the three major issues. In summary, there is a need to undertake and co-ordinate research in the following areas:

- Enhancing public awareness and understanding of water issues such as transboundary allocations from shared water sources, the water requirements of different sectors and the consequences of water quality deterioration.
- Meeting social needs for water and difficulties surrounding payment for the provision of water.
- Promoting equitable access to water, especially from a gender perspective, and addressing the interlinked problems of restricted access, poverty and lack of food security.

### **Key stakeholders**

The key stakeholders for this domain include government departments (DWAF, NDA, DEAT, Population Development), IWMI, HSRC, ARC, NGOs, and community-based organisations such as water user associations, catchment management agencies, co-operatives and water service providers.

### **Research providers**

Currently, 40% of the research projects within this domain is conducted by consultants. The remaining projects are divided among universities, technicians, CSIR, ARC, water service providers and NGOs. Notably, academic institutions conduct 35% of the projects.

### **Links to the Mission and Vision of the WRC**

The scope of the **Water and Society** crosscutting domain will contribute towards the WRC's mission of becoming a dynamic hub for water-centred knowledge, innovation and intellectual capital. This domain facilitates and supports the process of knowledge creation through dialogue (to understand the current issues) and research (to provide solutions to current and future problems).

Effective communication and the engagement of broader stakeholder groups will ensure that the WRC and researchers understand the changing needs of society and the environment, and that the research being funded provides practical solutions for sustainable management of limited water resources

## **RESEARCH PORTFOLIO 2002/03**

### **General aims**

Research interventions, through co-ordination and integration, within XDA, will be based on the identified thrusts. The action plan for 2002/3 will be implemented through the following activities (**It is important to note that all the projects/arrangements, and therefore the budgets, are based within KSAs**):

Table 1: Overview and description of XD A thrusts for 2002/03

Thrusts	Scope
1. Public Perception and Awareness of the Water Issues	<ul style="list-style-type: none"> <li>- Effective methods of improving public awareness of the water scarcity and related issues (KSAs 1 to 4)</li> <li>- The usage of media, and the advantages and disadvantages will be assessed (KSA 5).</li> <li>- The involvement of stakeholders in research initiatives aimed at investigating transboundary co-operation during planning, management and development of the water resources (KSA 1).</li> <li>- Guidelines for policy and decision-making in the allocation of water resources towards various development initiatives (KSAs 1 to 4).</li> </ul>
2. Social Needs Analysis and Water Services	<ul style="list-style-type: none"> <li>- The acceptability of water supply systems by communities and the flexibility of such systems will be assessed (KSA 3).</li> <li>- Issues around affordability, management and operation and maintenance of water services will be investigated (KSA 3)</li> <li>- Contributions towards further development of water provision and payment policy will be made (KSA 3).</li> </ul>
3. Accessibility to Water	<ul style="list-style-type: none"> <li>- Issues around accessibility and impact of water on the social status of people will be investigated (KSAs 4, 3 and 2).</li> <li>- Access and participation to water (issues) by women, poorest of the poor, children and disabled will be investigated (KSAs 1 to 4).</li> <li>- Primary and secondary effects of water resources and water supply on poverty alleviation will be investigated (KSA 4).</li> <li>- Identification of poverty pockets and resource/water supply status maps will be developed (KSAs 4 and 1).</li> <li>- The involvement of local authorities, government and community-based organisations and its impact on water accessibility will be investigated (KSA 3).</li> </ul>

## Research projects

The findings of projects completed during the year under review are given, as well as a summary of current projects and the motivation and objectives for new projects commenced between 01 April 2002 and 31 March 2003.

### COMPLETED

#### Thrust 1: Public Perception and Awareness of the Water Issues

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

Environmentek, CSIR  
(WRC Reference No 780)

One of the major constraints of small-scale farming systems in temperate, frost-prone areas is the shortage of fodder during the dry winter season. This is further complicated by the shortage of land and water. Growing trees together with crops can greatly enhance productivity of small-scale farming systems, since tree roots can exploit water and nutrients below shallow roots of crops. Trees can also increase productivity through soil nitrogen fixation and the provision of fodder.

There has been virtually no research on agroforestry systems in the temperate, frost-prone, dry-winter areas. This study was aimed at examining agroforestry systems in terms of competition for water between trees and crops. Also, the study attempted to determine the comparative water use of multi-purpose trees in agroforestry systems for the purposes of recommendation on appropriate species.

A PRA workshop was held and species selected include indigenous (*Acacia karoo*), nitrogen fixing (*Leucaena leucocephala*), fruit-bearing (*Morus alba*) and a multi-purpose species (*Gleditsia trielanthos*).

Results indicate that fodder yield in all species decreased with the wider intra-row spacing of trees. The most productive species was *Acacia karoo*. Fodder yield of *L. leucocephala* increased slowly but significantly over the period, indicating that once established, it is a productive species. The *M. alba* had the highest fuelwood production and was favoured by farmers because of its fruit production. There was little difference between the soil water content of the tree line and maize lines. However, at greater soil depths (75 to 125 cm) the trees in the wide spacing used less water than those in narrow spacing.

It is recommended that agroforestry species should be planted closer (0.5 m) in order to maximise fodder production. In order for agroforestry to become widely accepted socially, it needs to exhibit clear financial benefits to the farmer. The results also show that agroforestry is economically viable where there is low maize production and high tree production. The relative profitability of agro-forestry drops off as maize production increases.

In spite of any decrease of yield of maize, the study showed that increased fodder and fuelwood production could result in considerable benefits to the farmer.

Cost: R 630 000  
Term: 1996 - 2001

Implementation of an operational prototype fog-water collection system: Project implementation  
Dept of Geography, University of the North  
(WRC Reference No 902)

The west coast of South Africa is the most arid of the regions with many places recording annual rainfall totals of 70 mm or less. As a result, there are not many natural sources of water. Even those natural water sources that exist are not reliable.

Fog collection and water harvesting can become vital sources for domestic and agricultural water needs in such areas.

The study shows the benefits of a fog-water collection system to provide water to a small rural community. It also looks at factors associated with water collection at the site. It indicates that water collection occurs either during fog or rainfall events. Both these events are summer phenomena.

In a relatively dry area of Tshanowa, Limpopo, more than 100 000ℓ of water was collected over a two-year period. This gives an average of 3ℓ of water/m<sup>2</sup> of collecting surface. Maximum daily yields of 3 000ℓ were recorded on a number of occasions. About 75% of the water deposited on the collector originated from rainfall rather than fog. This means that, together with rainfall harvesting, fog collection is appropriate for relatively dry, high-altitude foggy areas.

The study further indicates that water collected from fog is of higher quality. Due to very few dissolved salts, the pH of the water may be slightly low. No disease-causing organisms were present and the water was classified as being of ideal quality.

Cost: R500 000  
Term: 1998 - 2001

#### Thrust 2: Social Needs Analysis and Water Services

Capacity building needs of rural municipalities in the management of water and sanitation services: Case studies from the Eastern Cape  
Dept of Development Studies, University of Fort Hare  
(WRC Reference No 991)

In South Africa, capacity building of local authorities and beneficiaries of government-funded programmes is an important component of the policies and strategies of government.

The project investigated issues of capacity building and training needs for local authorities and some stakeholders to carry out their responsibilities of providing water services to their communities.

The results show that the question of capacity involves issues of staffing, equipment and training. It is also clear that the majority of members (both stakeholders and local authorities) are not well informed about their responsibilities beforehand.

According to the members, training is usually not done satisfactorily because the duration of training is too short to enable the participants to comprehend training modules. In most cases, indigenous languages are ignored during discussions and workshops, at the expense of the stakeholders. Women involvement is also usually low during training programmes.

The study recommends that training must be provided according to the job specifications and project requirements. It also emphasises the importance of the use of indigenous languages during training workshops and the involvement of tertiary institutions for training provision.

Cost: R209 000  
Term: 1998 - 2001

### Thrust 3: Accessibility to Water

#### The development of generic and sectoral competencies in the water supply and sanitation training section

*National Community Water and Sanitation Training Institute (NCWSTI)*

(WRC Reference No 1020)

The Department of Water Affairs and Forestry expressed a need for better co-ordination of training activities for the water and sanitation sector. The development of generic and sectoral competencies would provide a formal method for assessing the quality of training programmes offered. The aims of the project were to develop generic, sectoral and target modular-based competencies and to develop a model which would facilitate co-ordination and standardisation of training. The research developed a set of competencies that reflect the following characteristics:

- Ensuring that the learning processes are focused on helping people learn skills relevant to the water and sanitation sector
- Promoting flexibility that is nationally consistent with the requirements of the water and sanitation sector.

The study developed a database (CD) containing approximately 3 625 competencies and 77 occupational functions relevant to the water and sanitation sector. This database can be applied in water and sanitation sector in the following ways:

- Learnership and unit standard setting process
- Training
- Skills development
- Development of qualification packages
- Quality control of training in the water and sanitation sector

This research has made a valuable contribution to the establishment of Standard Generating Bodies and the Water Chamber of the Local Government Water and Related Services Education and Training Authority (LGWSETA).

Cost: R295 000  
Term: 1999 - 2000

## CURRENT

### Thrust 1: Public Perception and Awareness of the Water Issues

#### Short-term weather forecasting techniques dedicated to flood management systems

*Chair of Meteorology, University of Pretoria*  
(WRC Reference No 1011)

Short-term river flow forecasting is crucial for flood management, but to be useful, river flow models need to be driven by accurate quantitative rainfall forecasts up to 2 days ahead, continuously verified by areal rainfall measurement in the catchment. This project examines the feasibility of producing quantitative rainfall forecasts for introduction into comprehensive real-time river flow forecasting systems.

Estimated cost: R239 000  
Expected term: 1999 - 2002

#### Developing protocols for integrated catchment management (ICM) based on current initiatives and techniques

*Division of Water, Environment and Forestry Technology, CSIR*  
(WRC Reference No 1062)

This project, being undertaken in close cooperation with the DWA Regional Director in Mpumalanga, seeks to develop protocols for defining the present state of the environment and the desired state of the environment. The required management actions will be formulated and monitoring procedures will be designed. The Sabie River catchment is being used as a test case. Stakeholder participation is an important aspect of the protocol and the outcome of this project should be widely applicable in South Africa.

Estimated cost: R1 500 000  
Expected term: 1999 - 2001

#### Security, ecology, community: Contesting the "water wars" hypothesis in Southern Africa

*Centre for SA Studies and Department of Earth Sciences, University of the Western Cape*  
(WRC Reference No 1106)

Decision-making processes concerning allocation and use of scarce water resources within certain SADC river

basins are being investigated with a view to clarifying issues of potential conflict and common security relating to water scarcity. In the process, a number of graduate students are receiving appropriate training.

Estimated cost: R400 000  
Expected term: 2000 - 2001

#### An evaluation of the role of water user associations in water management in South Africa

*Pula Strategic Resource Management*  
(WRC Reference No 1140)

The institutional arrangements for water resource management adopted in the Water Act delegate many water resource management functions (particularly resource protection and allocation) to organisations within a water management area (WMA), namely catchment management agencies (CMAs) and water user associations (WUAs). WUAs are intended to operate at a restricted localised level, to facilitate co-operative associations of individual water users who wish to undertake water-related activities for their mutual benefit. This study is aimed at clarifying the roles of WUAs, evaluating the functioning of a number of established WUAs against this framework and the particular needs of the local conditions, and formulating guidelines for the institutional and management arrangements.

Estimated cost: R380 000  
Expected term: 2000 - 2001

#### Integrated socio-economic and cultural values as additional components of the criteria for estimating and managing the Reserve

*Institute for Natural Resources*  
(WRC Reference No 1195)

The National Water Act of 1998 aims to achieve sustainable use of water for the benefit of all users. It also guarantees the protection of aquatic ecosystems. Historically, the evaluation of the importance of river systems has been largely based on ecological importance, while ignoring social and cultural aspects. This study is establishing the importance of integrating ecological, socio-economic and cultural values in the estimation and management of the reserve. It is also providing information on the dependency of rural households on river system resources (contributes also to **Water-Linked Ecosystems** research).

Estimated cost: R300 000  
Expected term: 2000 - 2001

#### Managing rivers in rural regions through community involvement and community awareness programmes.

#### Phase One: Determining the influences and interactions of the factors affecting biotic integrity through an investigation of habitat requirements

*Department of Zoology, University of Venda*  
(WRC Reference No 1197)

Rural communities with low *per capita* income, such as those on the Luvuvhu and its tributaries, depend heavily on the natural resources provided by a river and its catchment. The aims of this project are to firstly identify the factors leading to the loss of biodiversity. Secondly, a draft management plan will be prepared based on the principle of strategic adaptive management as developed for the Kruger National Park.

Estimated cost: R100 000  
Expected term: 2000 - 2001

#### Umgeni flood now-casting using radar - An integrated pilot study

*Department of Civil Engineering, University of Natal*  
(WRC Reference No 1217)

An existing research programme on real-time spatial interpolation and mapping of rainfall addresses the infrastructural needs of a national real-time daily rainfall monitoring and mapping system, the refinement of radar and satellite rainfall-estimation technologies, and the merging of rain-gauge, radar and satellite data to provide the best possible integrated product from the point of view of resolution (both spatial and temporal) and reliability. The programme also makes provision for pilot applications of the real-time spatial rainfall outputs, in order to test and demonstrate their efficacy and promote technology transfer. This project, which addresses the issue of early flood warning as an aid to disaster management, is not only a pilot study linked to the above-mentioned research programme, but is also an extension of WRC-sponsored research on the development of a real-time flood forecasting model undertaken in the Department of Civil Engineering at the University of Natal. Umgeni Water and Durban Metro will participate, with a view to immediate implementation of the research products. The aims of the project, therefore, are to:

- Draw together new rainfall data sources and flood forecasting methodologies resulting from recent WRC-sponsored research and demonstrate their usefulness within the context of flood management.
- Provide decision-makers in Umgeni Water and Durban Metro with tools which will allow them to

be more pro-active and effective within the same context.

Estimated cost: R678 000  
Expected term: 2001 - 2003

#### Hydropolitical history of South Africa's major international river basins

Centre for International Political Studies, University of Pretoria  
(WRC Reference No 1220)

Much has been written about the history of Middle Eastern river basins, but not much about South African rivers. Studies have been conducted on the hydropolitics of international river basins (Kunene and Orange Rivers). Although a historical element has been attached, the focus has been mainly on international relations between the actors involved. The need is felt that the studies should be broadened to cover the hydropolitical history of the Orange, as well as of the Limpopo and Komati Rivers, to the present day.

Analysing the hydropolitical history of these rivers is needed to contextualise the current patterns of conflict and co-operation between the riparian states and users. Studying the hydropolitical history of the respective river basins can tell us how phenomena, operating in the past, may behave in future, and how they impact on the hydropolitical dynamics of the rivers at present. This is particularly relevant in light of the requirements of the SADC Protocol on Shared River Systems and elements of the National Water Act.

Filling of the knowledge gap in the South African hydropolitical history will assist water resource planners, hydropolitical scientists, catchment management agencies and government officials to provide reasoned justification for their actions regarding the management of international rivers.

The study has the following aims:

- To record the hydropolitical history of the major international river systems in South Africa in one coherent document
- To establish the past experience of water management in these river systems
- To establish a framework/backdrop that project planners, water service utilities, government departments and CMAs can use for the effective management of these international river systems
- To contribute to a multidisciplinary understanding of the dynamics of South Africa's major international river basins

- To build capacity by incorporating research assistants from previously disadvantaged communities into the research team.

Estimated cost: R398 100  
Expected term: 2001 - 2002

#### Developing and trialing guidelines for participatory water resource management at catchment and water management area scales

Geography Department, Rhodes University  
(WRC Reference No 1233)

In a previous WRC-funded study the establishment of a WUA in the Kat River valley, Eastern Cape was used to formalise community participation. A considerable number of valuable lessons were learned in the process. In this project guidelines for participatory water resource management are being developed that can be used throughout South Africa. The project leader is working closely with Australian counterparts.

Estimated cost: R 764 000.00  
Expected term: 2001 - 2002

## Thrust 2 : Social Needs Analysis and Water Services

#### Sustainable local management of smallholder irrigation

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

Most "upliftment" irrigation schemes in South Africa are not viable. A few schemes that are in operation are under-performing. There are a number of reasons for this. The main reason is, however, that beneficiaries have never been involved in the management of the schemes. It is only recently that the government and other stakeholders realised a need to hand management over to the beneficiaries. In this way, the end-users will be responsible and accountable. However, other technical and social problems need to be identified and addressed. Once this happens, the potential of the smallholder irrigation schemes in this country will be unlocked. This project identifies economic, social, institutional and policy issues affecting small-holder irrigation water use. It will also determine the extent to which poverty alleviation and empowerment of smallholder farmers can be achieved through self-management of smallholder irrigation schemes.

Cost: R863 500  
Term: 1999 - 2001

#### Institutional and social economic review of the use/application of electronic prepaid meter technology in the provision of water supply services to urban and peri-urban areas

Sigodi Marah Martin Development Consultants  
(WRC Reference No 1206)

The use of prepaid meter technology in water supply management is beginning to gain greater emphasis after its initial application achieved limited success. This could be attributed to the quick-fix approach adopted for the sole purpose of cost recovery during a period when the technology was not properly tested and experienced many technical teething problems. The problems were compounded by lack of community education and understanding and more important, the high cost of the technology. This situation created a great deal of uncertainty in many water suppliers regarding the use of the technology, stating the lack of knowledge around the institutional requirements and other support mechanisms required to sustainably support the technology as the main reasons. The objective of this study is not specifically to look at technical issues, but to look at the important services issues that make water services provision sustainable. Of importance is that the outputs will contribute towards development of policy and guidelines in the use of prepaid systems for provision of water supply services.

Estimated cost: R375 500  
Expected term: 2001 - 2002

#### The preparation of a guideline for water services providers dealing with customer services issues

Umgeni Water  
(WRC Reference No 1207)

Recent experiences internationally and locally emphasise the need for a customer focus in the provision of services. Moreover, related to water services provision, literature indicates that the importance of this customer orientation is contributing to the sustainability of services. This recognition has also influenced much of the new water legislation and will become a requirement with the enactment of the Municipal Services Bill, whereby all municipalities will have to develop and demonstrate a customer management plan. The fact that the concept of customer service has received little attention in South Africa is perhaps related to the historic situation where water supply and sanitation services were provided on a monopolistic take-it or leave-it basis, particularly in the case of poorer customers. It is now recognised

increasingly that successful water services provision is strongly associated with the application of good business principles. This implies a service orientation, with a primary focus on the customer. It also implies a mutually beneficial relationship between customer and service provider where the customers must fulfil their responsibility to pay for the service. The aims of the project are:

- To assess international best practice with regard to customer service by water services providers
- To undertake two case studies of water services providers in South Africa who are currently providing successful customer services locally
- Based on local and international findings, to communicate the findings relating to customer services through a guideline and workshops for water services providers in South Africa.

Estimated cost: R370 000  
Expected term: 2001 - 2002

#### Use of selected key performance indicators in the benchmarking of rural water supply schemes: An aid to development of meaningful local government capacity

Partners in Development  
(WRC Reference No 1222)

Since 1994, DWAF has spent large sums of money on training water committees to manage the new water supply schemes. As projects have moved into the operational phase, it has become apparent that training alone is not adequate to ensure proper management of water supply schemes. The new local authorities have limited knowledge on the nature of inspection needed to promote good management at community level. Therefore, the challenge is to develop simple and effective systems that are easily understood by water committees. These can be used to report to the community as well as to their local authority. This project will test a set of key performance indicators (KPIs) that have already been developed. These will be tested on a number of RDP projects that are presently being transferred from Umgeni Water to relevant district councils in KwaZulu-Natal.

Estimated cost: R271 000  
Expected term: 2001 - 2002

### Alternative approaches for sustainable water supply schemes

*Options to Solutions*  
(WRC Reference No 1223)

There is a need to be more creative in approaching the delivery of water services so that delivery encompasses the holistic objectives of ensuring sustainability. There are various options that could be explored, and this project is doing that. It reviews the different approaches that have the potential to render water supply schemes sustainable. Further, it carries out specific technical and economic analyses on identified projects representing an individual approach and will finally develop and disseminate the demand-led planning tool (guideline) that will promote and support a technically viable approach, integrating rural water supply with community activities.

*Estimated cost:* R 496 100  
*Expected term:* 2001 - 2003

### Sanitation demand and delivery in informal settlements

*Peninsula Technikon*  
(WRC Reference No 1280)

This project aims to broaden the benefits that may be derived from a particular project that is currently being implemented in informal settlements in Khayelitsha. The purpose is to derive added value from the project experience by means of rigorous research for evaluative purposes. The research approach and methodology is to develop a substantial research product from in-depth examination of each key component of sanitation delivery, so that the lessons may be applied by local authorities, both locally and more widely. The research methodology is based on action research, as appropriate for the adopted project-based learning approach. Qualitative research is appropriate to the scope of the initiative, which spans across the perspectives of sanitation role-players, and is based on their active participation in investigation and reflection. Quantitative data will be utilised to complement the investigation and its outcomes.

Aims:

- Community demand: Draw lessons from the collaborative and participatory approach and the creation of community demand for sanitation and hygiene awareness
- Service provider protocol: Investigate the institutional, technical, social and financial aspects of developing a sanitation protocol guiding sanitation options for local authorities in

peri-urban areas, based on evaluation of the current approach in relation to broader experience

- Community response to delivery: Evaluate the factors influencing sustainability of sanitation services, in terms of approach to delivery and options, by taking community responses and roles into account.

*Estimated cost:* R250 000  
*Expected term:* 2002

### Thrust 3: Accessibility to Water

#### The gender dimension of the water policy and its impact on water and sanitation provision and management

*Department of Development Studies, University of Fort Hare*  
(WRC Reference No 1021)

Although government policy on water and sanitation services delivery recognises the important role that women have to play, there are currently no enabling policies for promoting the participation of women. This study is undertaking a critical analysis of the gender dimension in the development of the water policy. It is also investigating strategies and institutional arrangements for water services delivery in terms of decisions concerning the location of the water supply scheme, choice of technology; operation and maintenance, community involvement and how these affect women as managers of households.

*Estimated cost:* R303 000  
*Expected term:* 1999 - 2001

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

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

Multicropping is common among smallholder farmers. In most cases field crops are grown around fruit trees. In some cases, fodder is also planted along contours, then used as animal feed or windbreaks instead of fruit trees. Limited information is available about competition for water that takes place among crops. Although the benefits of multicropping are obvious, yield reduction, particularly of poor competitors or drought-sensitive crops, may occur. Since farmers usually grow intercrops on the headlands or contour-lines, there is a need for

understanding the optimum distances between the various crops. The hydraulic conductivity of the soil, the water content, and the root distribution of different crops influence their performance. This project evaluates locally adapted crops that may be incorporated into an agroforestry system, with emphasis on water requirements. This information will be used to develop a model that will predict the productivity and water-use efficiency of different agroforestry systems.

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

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

*Networks for Development*  
(WRC Reference No 1087)

Water supply and sanitation projects are implemented as community projects; therefore, for the projects to be successful, both men and women should participate at all stages of the project planning and implementation process. This study assesses the impact of gender in water and sanitation services provision and maintenance. The findings of this assessment are being used to develop gender-sensitive approaches that would ensure effective participation of both men and women in water supply and sanitation projects. This study together with a project focusing on policy dimension of gender participation in water supply and sanitation projects are contributing to the achievement of a gender-balanced approach within the water sector.

*Estimated cost:* R150 000  
*Expected term:* 1999 - 2001

#### An investigation into the potential of sustainable irrigation in Black developing communities of two subcatchments of the Pongola and Thukela Rivers

*Sineke Development*  
(WRC Reference No 1138)

When government "upliftment" irrigation schemes started some decades ago, little or no attention was placed on the potential for the success of such initiatives. The government and farmers alike are aware that this should not have happened - or alternative processes and approaches should have been followed. It also implies that such development should not only be based upon economic evaluation or feasibility studies (using climatic data). Socio-political evaluation should also be done in order to ensure the success of the project. The main aim of this project is to define the socio-economic aspects and their importance for developing sustainable water-driven farming systems in rural communities. The project

aims at analysing farming systems and identifying institutional arrangements within such systems. This will lead to the identification of processes to transform present irrigation farming systems among small-scale farmers. The project will further develop action plans for the development of irrigation farming systems among Black communities.

*Expected cost:* R995 000  
*Estimated term:* 2000 - 2001

#### Innovative partnership to improve water and sanitation services in deprived urban and peri-urban areas: KwaZulu-Natal pilot project, Inanda-Ntuzuma, Durban, Edendale, Pietermaritzburg

*Durban Metro Water Services, Mvula Trust, Pietermaritzburg TLC, Compagnie Generale des Eaux, Umgeni Water*  
(WRC Reference No 1139)

The Business Partners for Development (BPD) project is an innovative approach and attempt to address water and sanitation issues in urban and peri-urban areas in developing countries. It is about bringing together private sector, public sector, non-governmental sector and civil society, towards addressing water and sanitation needs. The rationale is that sharing of experience and lessons between the Durban and Pietermaritzburg pilot projects will contribute towards improved services delivery in the future. An important aspect is the capturing of lessons and experience on the partnership. The key aspect is supplemented by aspects that transform services delivery from a beneficiary/recipient approach to a customer approach, where the customer is part of the development process. The project is a learning and exploratory exercise and findings will provide answers to local, as well as global questions on how to provide services to poor urban areas and informal communities.

*Estimated cost:* R880 000  
*Expected term:* 2000 - 2001

## Thrust 1: Public Perception and Awareness of the Water Issues

**Promoting democracy through the IWRM process: Developing a model for sustainable relationships for the management of a scarce natural resource**  
CSIR/Environmentek  
(WRC Reference No 1294)

A move towards democracy requires transformation. Transformation is not only about transforming institutional structures, but it is also about the way in which people do things. In South Africa, transformation has taken place at the levels of, e.g. government and organisations, but the challenge for resource management will be to further devolve this transformation so that it becomes part of the culture at the level at which people have an interest in, and act, in relation to the resource. This project provides an opportunity to show how this culture can be developed. In South Africa, the human relation dynamics around the water resource and the consequences thereof are magnified by past inequities around participation and access to the resource and the current need to redistribute the resource equitably. Added to this is the challenge of achieving long-term sustainable use through the realisation that the water resource needs protection in order to deliver a desired range of goods and services. The research team proposed for this project has spent the last 3 years building a relationship around these issues and their stakeholders. Through interaction with stakeholders and lessons from these experiences, the team has achieved success in promoting a co-operative spirit both in stakeholder groups as well as in the research team. This team is therefore ideally positioned to address the challenges presented here. Integrating elements of democracy and co-operative management within a resource management context requires multi-disciplinary, collaborative, action research. This project will provide a model for how human interactions in water resource management can be facilitated to promote behaviour changes that are in line with the principles and values of democracy. The project will also show what the role and opportunities are for research in this process and how collaborative research teams need to operate to fulfil those opportunities within the resource management context.

Estimated cost: R1 416 700  
Estimated term: 2002 - 2003

**Multicriteria decision support for reserve determination and other catchment management activities**  
Dept of Statistical Sciences, University of Cape Town  
(WRC Reference No 1298)

Strategic Environment Assessment (SEA) is a R5m. project of DWAF funded mainly by DFID. The project team has decided to work closely with Prof Stewart and Ms Joubert who have been developing multi-criteria decision analysis over several years with WRC support. This WRC project will, therefore, mainstream our research into a major strategic management initiative of DWAF. The major contribution is towards comparing social, economic and water resource issues and facilitating the choice of desirable management scenarios.

Estimated cost: R262 000  
Estimated term: 2002 - 2003

**Integrating flood-plain agriculture into a diverse rural economy by enhancing co-operative management: A case study of the Pongolo**  
INR  
(WRC Reference No 1299)

The effective management of the Pongolo River flood plain has been unsatisfactory ever since the completion of the Jozini Dam. This project will promote effective co-operative management of the river system on a sustainable and democratic basis. Lessons learned here will contribute to formulation of policies and institutions to achieve sustainable use of river systems in rural South Africa. This project will be strongly based on the principles of a participative action plan.

Estimated cost: R880 000  
Estimated term: 2002 - 2005

**Community-based research on the influence of rehabilitation techniques on the hydrology of degraded catchments**  
CSIR/ Environmentek  
(WRC Reference No 1316)

Due to mismanagement in the past many catchments in the KwaZulu-Natal midlands are degraded with serious negative impacts on sediment delivery and soil water regimes. In this project, and also as a contribution to the land-care programme, communities will actively take part in improving and observing the hydrological regimes of their lands. Successful rehabilitation will have

important benefits for large-scale catchments with regard to baseflow and groundwater regimes.

Estimated cost: R984 000  
Estimated term: 2002 - 2006

**Institutional arrangements for groundwater management in dolomite terrains**  
IUCN  
(WRC Reference No 1324)

The WRC in collaboration with DWAF previously initiated a project to understand issues related to management of groundwater resources over adjoining water management areas. A further objective was to ensure the most beneficial use of groundwater in order to achieve integrated water resource management. This project will comprise Phase 2 of the research, i.e. the field research component.

Estimated cost: R600 000  
Estimated term: 2002 - 2004

## Thrust 2: Social Needs Analysis and Water Services

**Researching payment strategies and price elasticity of demand for water for the lower income group at four selected urban communities**  
MSSA Water Research  
(WRC Reference No 1296)

The proposed research work is an expansion of two WRC-funded projects. The first is a completed project on the price elasticity of demand for water in Alberton and Thokoza (Report No 970/1/00) and the second is a current one-year project to determine payment strategies for the poor in the four metros of Tshwane, Durban, Johannesburg and Cape Town. In both cases it is clear that more information is required to assist local authorities in developing water tariff policies which will ensure:

- cost-recovery of water services provided to lower income households
- more efficient water use of high-income households.

Water tariffs can only be used effectively to manage both cost-recovery of services and volume of water consumed, if it is known how households will respond to

increases in water tariffs. It is therefore considered essential that further information on the price elasticity of demand for water and insight into the impact of different applied payment strategies, should be gained. To this end it is proposed that both a Participatory Payment Strategy Testing Methodology (PPSTM) approach as well as a Contingent Valuation Methodology (CVM) approach be used in this study. The PPSTM approach, as developed by MSSA, together with the CVM approach as used by EPE, would be the vehicle to provide both a short-term price elasticity of demand and a long-term payment strategy for residential water users in the major metropolitan areas of South Africa. It is recommended that both these approaches are undertaken, firstly for comparative purposes, and secondly so that decision-making, with respect of short-term and long-term water management policy, may be undertaken.

Estimated cost: R 700 000  
Estimated term: 2002 - 2004

**Developing indicators and measuring the impact of water provision on the livelihoods of rural households in SA**  
Mvula Trust  
(WRC Reference No 1375)

This research project will assess the impact of the different levels of water service to individual household livelihoods. This is a first attempt to provide policy makers and planners with feedback on the impact of investment in infrastructure for water projects. The study will also develop a set of indicators to measure whether provision of potable water at different levels of service is linked to increased household productivity. These indicators will provide government with a measure of the improvement in the quality of life for rural communities.

Estimated cost: R300 000  
Estimated term: 2002 - 2004

**The development and testing of an integrated approach to the sustainable provision of rural water services in the Amabele and Chris Hani district municipalities**  
Rural Support Services/ University of Fort Hare  
(WRC Reference No 1376)

This study will provide guidelines which will assist municipalities in planning and implementing water supply projects in an integrated participatory manner. It seeks to promote "ownership" of the development process by rural communities. The main objectives of this study are to pilot a people-centred development

planning approach and to enhance the sustainability of rural water supply projects by facilitating the integration of such projects into the overall development programme of the municipality. This study will provide researchers from the University of Fort Hare with an opportunity to build their capacity in applying a people centered development planning approach

*Estimated cost:* R430 000  
*Estimated term:* 2001 - 2004

**Review, consolidation and evaluation of key performance indicators for successful sanitation, health and hygiene promotion programmes**

*Rural Support Services  
(WRC Reference No 1378)*

International experience shows that success of the sanitation improvement depends on an effective health and hygiene awareness/education campaign. This study will involve communities in the development and consolidation of key performance indicators for successful sanitation programmes, which will empower communities to evaluate the quality of service they receive. The main objective of this study is to establish a framework within which to evaluate the sustainability of sanitation promotion programmes. Rural Support Services will collaborate with Mvula Trust in this project; Black researchers from both organisations will increase their research capacity

*Estimated cost:* R250 000  
*Estimated term:* 2002 - 2004

**The development of models to facilitate the provision of free basic water in rural areas, based on an investigation into the implementation of policy and an assessment of the real costs of this and a review of the process of transfer**

*Mvula Trust  
(WRC Reference No 1379)*

Most rural municipalities are faced with a big challenge of implementing the free basic water policy which was officially launched on 1 July 2001. Unlike their urban counterparts they lack the wealthy customer base which generates financial resources to cross-subsidise the poor households. Most households obtain their potable water from stand-pipes, therefore their water consumption level falls within the 6 kℓ limit prescribed by the free basic water policy. This study will investigate the actual costs of providing free basic water. The expected research product will be suitable, cost-effective institutional and subsidy models that will ensure financial sustainability of rural water supply schemes. The research output will

build the capacity of rural municipalities in the implementation of the free basic water policy

*Estimated cost:* R 500 000  
*Estimated term:* 2002 - 2005

**The development of a marketing plan for sanitation promotion - A participatory approval**

*Limakhozu Development  
(WRC Reference No 1382)*

This study will use participatory approaches to identify factors that motivate people to adopt safe hygiene practices. These factors will then be used to develop a social marketing plan for sanitation promotion in rural areas. The research output will be used to encourage households to invest their own financial resources in the improvement of their sanitation facilities. Limakhozu is an emerging black consulting group who will strengthen their research capacity during this project.

*Estimated cost:* R300 000  
*Estimated term:* 2002 - 2003

**Thrust 3: Accessibility to Water**

**The effect of the introduction of agroforestry species on the soil moisture regime of traditional cropping systems in rural areas. Phase II: On-farm trials of alternative agroforestry systems**

*Environmentek, CSIR  
(WRC Reference No 1351)*

One of the major constraints in rural farming systems of the Upper Thukela is the shortage of adequate and good quality grazing during the dry winter season. Unfortunately, supplementation of feed using commercial supplements is difficult because the supplements are expensive and not easily available in remote areas. Provision of alternative sources of fodder such as tree leaves and pods can increase production. The introduction of tree species for fodder should decrease the grazing pressure on the existing grassland. This will result in improved basal cover, decreased soil erosion and will promote greater water infiltration.

The project aims are:

- To determine the effect of different agroforestry systems on increasing fodder production in rural farming systems
- To determine the effect of agroforestry practices on soil water availability to traditional crops (e.g. maize)

- To determine whether the inclusion of trees in traditional cropping systems can enhance the infiltration of rainfall and prevent soil loss
- To compare the water use of an indigenous fodder tree (*Acacia karoo*) and an exotic fodder tree (*Morus albus*), in order to test the hypothesis that indigenous fodder trees are more conservative water users than exotic tree species.

*Expected cost:* R1 500 000  
*Expected term:* 2002 - 2006

**Investigation of different farm ownership models and support structures for sustainable small-scale irrigation farming on existing schemes**

*Tlou Water Management  
(WRC Reference No 1353)*

Rural development in the Eastern Cape, KwaZulu-Natal and Northern Provinces where widespread poverty occurs, has been held back due to institutional failures and collapse of many irrigation schemes. Consequently enormous social and development needs are experienced in respect of capacity building and entrepreneurial development; job creation; social upliftment of rural communities; poverty relief; and land redistribution. Government has shown its commitment to developing the rural areas by establishing an integrated rural development strategy (IRDS) in the President's Office. This initiative requires support through research of relevant models for social and economic development of the rural areas. The objective is to optimise use of scarce water resources and to develop previously disadvantaged communities. To achieve the objective this project will research models which take into account the multi-phased characteristics of the development process in order to re-establish small-scale irrigation farmers on a sustainable and financially viable basis. A concerted research effort is required to find acceptable solutions by working together with farmers, communities, local and provincial authorities to determine the requirements and formulate guidelines for sustainable development.

*Estimated cost:* R795 200  
*Estimated term:* 2002 - 2005

**Management for new establishment of profitable small-scale farming with reference to the Lower Orange River**

*Agricultural Economics, University of the Free State  
(WRC Reference No 1354)*

The establishment of small-scale farmers on the Orange River in the Northern Cape and Western Cape Provinces

was identified as a very high priority. The study is motivated by the drive to utilise the 4 000ha water right allocation to establish small-scale irrigated farms and operate them efficiently and sustainably. Formal and appropriate methodologies will be developed to successfully establish small-scale farmers to ensure household food security and enable production of surpluses. Farm size, type of technology, access to markets and financing methods and procedures will be clearly defined. According to the Provincial Department of Agriculture in Kimberley an appropriate economic model is needed to successfully establish small-scale farmers. This project will directly address these issues by providing guidance to obtain access to markets and finance and developing a model for evaluating the economic performance and efficiency of the farms prior to establishment.

*Estimated cost:* R970 000  
*Estimated term:* 2002 - 2005

**On-farm application of in-field water harvesting conservation techniques on small plots in the central region of SA**

*ARC/ISCW  
(WRC Reference No 1355)*

Technology exchange and adoption are the best possible ways of evaluating the success of any research project. Water harvesting (under dry-land production) using in-field basins, has improved yield for a number of crops. The technique, however, needs to be communicated widely - and tested *in situ*. Smallholder farmers, who often do not have irrigation facilities, and those who operate in dry areas, will use the technique under some guidance. This project will disseminate knowledge and technologies that will improve productivity of rain-fed agriculture. Extension services, which have been identified as the weak link in rural agricultural development, will be targeted by this project.

*Estimated cost:* R800 000  
*Estimated term:* 2002 - 2004

**The development of a strategy for effective public participation in rural water supply projects**

*Nemai Consulting  
(WRC Reference No 1381)*

Public participation and community "ownership" of the development process have been shown to be key requirements for sustainable development. However, there is a lack of appreciation of the views and concerns of affected communities in most infrastructure projects that are implemented with government funding. This

study will produce a strategy for public participation and community involvement in rural water supply and sanitation projects. This strategy will be developed from local and international best practice in public participation. The research output will provide guidelines for development agencies so that they can implement people-centred development approaches.

*Estimated cost:* R77 000  
*Estimated term:* 2002 - 2004

**Raising community awareness for the provision of potable water and empowerment communities to conduct water quality surveillance activities**

*Dept of Biochemistry and Microbiology, Univ of Fort Hare (WRC Reference No 1391)*

This is a follow-up to a previous project that evaluated a combined chlorine-monochloramine disinfection process for the inhibition of bacterial and biofilm regrowth in a laboratory-scale system. The emphasis is on the maintenance of an effective residual disinfectant throughout the water system. This project aims to develop strategies which will ensure sustainable effective disinfection in small municipal water distribution systems. If the situation at Alice can be analysed, understood and permanently improved, then these lessons can be recorded and applied to other local towns such as Fort Beaufort, Seymour, Stutterheim, etc. As the situation of Alice also remains similar to other small municipal water treatment plants in South Africa, these strategies can be developed to ensure sustainable effective disinfection in such water distribution systems around the whole country.

*Estimated cost:* R335 000  
*Estimated term:* 2002 - 2004

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# XD B

## Water and the Economy



Mr HM du Plessis  
Head:  
Water and the Economy

### Scope

In the SA context water is treated first and foremost as a common (social) good, which is recognised as being essential for sustaining life and to which people and the aquatic environment have a legally protected right. However, water is also recognised as an economic good, the use of which has a major impact on the creation of wealth and on the well-being of people. This domain will integrate the economic aspects of water-related investigations funded by the WRC's four water-related key strategic areas (KSAs). It will also identify overarching issues that need to be addressed at a higher level of integration. Projects and activities under this domain will determine the value of water, assess its role in wealth creation, the use of economic instruments to

effect behavioural change and to promote the equitable and efficient use of water, through investigations at the appropriate micro-, regional and national levels.

### Objectives

From an analysis of current and recently completed WRC research projects, it is clear that there is a need to better integrate and give greater recognition to the role that economic approaches should play in the WRC's research portfolio. It is especially in the key strategic areas for **Water Resource Management** and for **Water-Linked Ecosystems (KSAs 1 and 2)**, that appropriate projects need to be identified. It is envisaged to identify and to define these needs through a combination of interaction with KSA directors and workshops to identify needs on a national level with the help of experts in the field. It is foreseen that funding for projects under this domain will mostly reside within KSAs as projects should primarily be in support of the WRC's KSA objectives.

The research portfolio of current projects has been grouped into strategic thrusts which directly address the above-mentioned objectives and are summarised as follows:

- **Thrust 1: The Value of Water to Different Sectors of the Economy** (e.g. to agriculture, cities, ecology, forestry and industry, health services)
- **Thrust 2: The Economic Advantages and Disadvantages of Water Resource Development**

(e.g. the quantified economic benefit or cost which arises as a result of the chain effect that development has on wealth creation or pollution)

- **Thrust 3: The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation** (e.g. implementation of a sliding-scale water tariff in order to reduce water consumption or a waste discharge charge to reduce pollution)
- **Thrust 4: The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution** (e.g. the use of cross-subsidisation to promote equitable distribution, privatisation of water services to promote efficient service delivery and trading of water-use licences to achieve optimal utilisation).

Because of the limited number of current projects in this domain, thrusts have (for the present) not yet been subdivided into programmes.

### Budgets for 2002/2003 and 2003/2004

The distribution of funding for approved WRC research projects among the four thrusts within the XD B domain is displayed in Tables (i) and (ii). All of the funds originate from projects allocated to KSAs (i.e. no ongoing domain-specific projects have been identified and no funding for new projects is being requested). There is a

significant increase in the total for ongoing (i.e. committed) funding for 2003/04. The total for 2003/04 does not yet reflect the proposals for solicited projects within KSAs that are planned to start during 2003/04.

## CORE STRATEGY

### Strategic context

We live in a world where individuals perform increasingly specialised functions, so that people are becoming less self-sufficient and more reliant upon each other and societal structures to provide for their daily needs. Goods and services are purchased rather than self-generated. In a modern society, economic considerations thus play an increasingly important role in the daily lives of individuals, the decisions they make and the values they adopt. The same holds true for increasingly complex groupings of people and the relationship between countries.

Economic theory holds that the rigid application of economic principles will result in the most efficient and cost-effective system. The fact that environmental costs are difficult to quantify and for the sake of convenience therefore mostly ignored in classic economic evaluations, has given rise to a new field of environmental economics, which actively seeks to overcome this deficiency, while maintaining the inherent efficiency of economic analysis. Environmental economics suggests that flexible, economics-based

Table (i): Current investment within XD B (Figures are in Rand)

Thrust	Budget			Budget distribution within KSAs										
	Total	Current projects	New projects	Current projects					New projects (Starting 2002/03)					
				KSA 1	KSA 2	KSA 3	KSA 4	Domain	KSA 1	KSA 2	KSA 3	KSA 4	Domain	
Value of Water	410 000	-	410 000	-	-	-	-	-	-	-	205 000	205 000	-	-
Economic Benefit	528 502	528 502	-	58 000	-	-	470 502	-	-	-	-	-	-	-
Behavioural Change	720 000	310 000	410 000	-	-	310 000	-	-	-	-	-	410	-	-
Equitable	1 674 500	-	1 674 500	-	-	-	-	-	-	-	1 120 000	554 500	-	-
<b>Total</b>	<b>3 333 002</b>	<b>838 502</b>	<b>2 494 500</b>	<b>58 000</b>	<b>-</b>	<b>310 000</b>	<b>470 502</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>205 000</b>	<b>1 735 000</b>	<b>554 500</b>	<b>-</b>

Table (ii): Planned investment for 2003/4 within XD B (Figures are in Rand)

Thrust	Total	KSA 1	KSA 2	KSA 3	KSA 4	Domain
Value of Water	362 700	-	131 000	231 700	-	-
Economic Benefit	399 523	-	-	-	399 523	-
Behavioural Change	290 000	-	-	290 000	-	-
Equitable Allocation	765 600	-	-	100 000	665 600	-
<b>Total</b>	<b>1 817 823</b>	<b>-</b>	<b>131 000</b>	<b>621 700</b>	<b>1 065 123</b>	<b>-</b>

measures can achieve acceptable levels of environmental benefit with simpler administration and lower control costs than with more traditional regulatory approaches.

Water can be both a social and economic good. Access to clean water is fundamental to survival and critical for reducing the prevalence of many water-related diseases. Frustration during the last century over the failure to meet basic needs for water of all people and to stem the trend of water quality deterioration by using the traditional command-and-control regulatory approaches, led to rethinking international water priorities and policies. Consideration was given to the potential value of applying economic tools and principles. The International Conference on Water and the Environment (Dublin, 1992) concluded, among other things, that *Water has an economic value in all its competing uses and should be recognised as an economic good.*

Countries differ with respect to the degree to which they treat water as either a social or economic good. Countries with strong free-market inclinations that emphasise private ownership (also of water) mostly emphasise its economic value, while others emphasise its social characteristics.

However, almost without exception there is an increasing interest in using economic instruments to increase efficiency, to effect desired behavioural change among water users and to use water as a catalyst for the generation of wealth and prosperity. Increasingly the need to assess the economic value of water is also recognised. These issues are also important in the South African context.

In the SA context water is first and foremost treated as a common (social) good. Water is recognised as being essential for sustaining life and a commodity to which people and the aquatic environment have a legally protected right. However, water is also recognised as an

economic good, the use of which has a major impact on the creation of wealth and the well-being of people. The use of water tariffs to effect changes in water use and of waste discharge charges to internalise pollution costs and, in so doing, effect pollution reduction and desirable improvements in water quality, is also provided for in our National Water Act. The selling of water-use licences is also provided for under specific circumstances.

## Needs analysis

As the use of the economic approach is still relatively undeveloped in the South African context, there is a need to undertake projects and activities that will determine the value of water, assess its role in wealth creation and explore the use of economic instruments in changing the behaviour of society. It is foreseen that initiatives will be undertaken at the appropriate micro-, regional and national levels, under the following main thrusts. Examples of products that are foreseen are indicated for each thrust.

- **The Value of Water to Different Sectors of the Economy**
  - Determining the shadow price of water to irrigators of different crops in different climatic areas
  - Determining the worth of water to different industrial sectors
  - Assessing the value that rural un-served communities attach to water
- **The Economic Advantages and Disadvantages of Water Resource Development**
  - Determining the economic value associated with improved health and other benefits as a result of treating water to different levels
  - Determining the cost associated with certain forms of pollution, e.g. eutrophication, salinisation or microbial pollution of water resources
  - Determining the value-added effects of irrigation agriculture to the development of rural areas
  - Assessing the economic value of benefits accruing from the "free water" allocation
- **The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation**
  - Assessing the effectiveness of a sliding scale for water tariffs to reduce luxury or wasteful water use
  - Determining the effectiveness of payment for water as a means to curb unnecessary consumption
  - The effectiveness of pollution charges and tariffs to limit pollution

- **The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution**

- Assessing the feasibility of cross-subsidisation to achieve equitable water provision in communities with different "ability to pay" profiles
- Evaluating the benefits and disadvantages associated with privatisation of water delivery services
- Predicting the effect of trading in water licences on improved water allocation efficiency

It is foreseen that this domain will mainly be instrumental in integrating the economic aspects of water-related investigations that are under way within KSAs. It would, however, also identify overarching issues that need to be addressed at a higher level of integration.

## Key stakeholders

The key stakeholders who will help to determine the strategic direction, and who are also the primary beneficiaries of work in this domain, are the Department of Water Affairs and Forestry (DWAF), the Department of Environment Affairs and Tourism (who is investigating the use of economic instruments for environmental management) and the Development Bank of Southern Africa. International role-players are the World Bank and International Monetary Fund who are advocating economic efficiency, governments, environmental economic think-tanks (such as the Pacific Institute) and anti-globalisation NGOs.

Other players are the different water-user associations (WUAs) (sectors) and industry.

The providers of input for this domain will primarily be KSAs which fund economically linked projects. Other suppliers will be economic consultants, economics departments at universities and research organisations. South Africa is fortunate to have a group of environmental economists, who although small in number, are well-trained, dedicated and keep abreast of international developments in the field.

## Links to the Mission and Vision of the WRC

Because of its innovative nature, the economic domain links strongly with the WRC vision to *provide innovative solutions for sustainable water management to meet changing needs of society and the environment and our mission to assist with achieving sustainable development*

and economic growth leading to a better quality of life for all. South Africans, furthermore, need to find unique solutions to problems arising from the practical application of our trail-blazing Water Act, which provides several opportunities to become world leaders in specialised niches within the economic domain.

## RESEARCH PORTFOLIO FOR 2002/2003

Research in this domain will be addressed under the following thrusts:

- **The Value of Water to Different Sectors of the Economy**
- **The Economic Advantages and Disadvantages of Water Resource Development**
- **The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation**
- **The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution**

An overview of XD B thrusts for 2002/03 is given in **Table 1** (Because of the limited number of current projects in this domain, thrusts have (for the present) not yet been subdivided into programmes).

*Table 1: Overview and description of XD B thrusts for 2002/03*

Thrusts	Scope
1. <b>The Value of Water to Different Sectors of the Economy</b>	The value of water is different for the various sectors of the economy and for different parts of the country. It is important to know the absolute and relative price (or a surrogate thereof) that users are either willing or able to pay for water in order to assist decision-makers regarding the allocation and development of water resources. Earlier studies have determined the economic value of water in several of the important catchment areas in the country and for a few of the important economic sectors. Innovative means will have to be employed to establish the value that must be attached to water-linked ecosystems.
2. <b>The Economic Advantages and Disadvantages of Water Resource Development</b>	Because of the economic benefits, which mostly arise from water development together with the multiplier effect of these benefits, water development is often a powerful stimulus to wealth creation and secondary development. Conversely, water development can also have negative effects such as pollution or a reduction in the availability of water for the environment. Most of the projects to date dealt with the economic effects associated with irrigation developments. A study was also completed on the negative economic effects associated with salinity. New studies need to be undertaken to determine the economic costs associated with other forms of pollution (e.g. eutrophication and microbial pollution) and the economic value associated with improved health as a result of providing purified water, the "free water" allocation, etc.
3. <b>The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation</b>	Where an economic value is attached to the use of water, it also presents the opportunity to effect behavioural change. Increasing the water tariff on a sliding scale as consumption increases, is an economic instrument to encourage water conservation. Similarly pollution can be reduced in an economically efficient way by levying a charge on waste discharges. A diverse range of projects aimed at changing behaviour with respect to water use and at assessing the susceptibility of users to economic stimuli is presently being conducted. No urgent new needs have been identified.
4. <b>The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution</b>	Economic instruments can be powerful instruments to achieve equitable and efficient water utilisation, e.g. the use of cross-subsidisation to achieve equitable distribution, trading of water use licences to achieve efficient allocation of resources, etc. Several projects in this thrust were recently initiated. They cover a wide range of applications that will be extended as the need arises. No urgent new needs have been identified.

## Research projects

The findings of projects completed during the year under review are given as well as a summary of the motivation and objectives for new projects which commenced between 01 April 2002 and 31 March 2003.

## COMPLETED

### Thrust 1: The Value of Water to Different Sectors of the Economy

#### Development of a hydrological economic model based on the Mvoti catchment

*Umgeni Water  
(WRC Reference No 890)*

The motivation for this research was the realisation that the increased water scarcity in South Africa, and the implementation of the NWA (1998), which requires the equitable, efficient and sustainable management of water resources, requires the integration of hydrological and economic thinking, especially with regard to the assessment of water use efficiency.

The objective of this research was to build a Hydrological Economic Agricultural Model (HEAM). The model is to be used to assess the economic and hydrological impact of different water management options, targeting land-based water use (irrigation and SFRAs) with the purpose of evaluating the efficiency and equity implications of these options.

The Mvoti catchment was selected to undertake this research due to the water scarcity in the catchment (during the dry months of the year) and due to the availability of good hydrological data. After investigating various modelling options, it was decided to adopt a hydrological economic optimisation modelling approach at farm level. The HEAM is a linear programming (LP) model that operates on a farm level. Unique features of the approach adopted in setting up the LP model are that the economic component was simplified, and a hydrological component was added.

The HEAM was set up for 3 different farms, referred to as Farm A, B and C respectively. Farm A is a privately owned, small mixed farming operation. Farm B is a large company, which adopts mixed farming operations and Farm C is a relatively large, independent timber growing operation.

The water available in the stream during each of the 4 periods available for abstraction, the crop irrigation requirements and yields associated with the different irrigation land-use management practices (LUMPS), as well as the runoff for all LUMPS were modelled with ACURU.

It was found that the farms have vastly different marginal costs for increasing the flow during the low-flow months of dry years. Marginal costs are defined as the cost which the farmer would incur if he were to generate one additional unit of low flow by changing his LUMP mix. Marginal costs of producing low flows during dry years differ significantly across farm types.

A further test was undertaken in order to assess the merits of the afforestation permit system (APS), which was implemented during the previous Water Act, mainly out of a concern for low flows. As can be expected from the previous results, it has been very costly to protect low flows. The calculations showed that the current low flow from all 3 farms (which are currently regulated by the old APS) may be achieved by adjusting irrigation crops while at the same time giving rise to additional average farm income per annum.

The results generated by the study show that the cost of meeting Reserve requirements will be influenced by the strategy adopted. Irrigation seems to offer the most cost-effective options to generate more streamflow during critical dry periods (dry months during dry years). Pushing back forestry on non-arable land is prohibitively expensive. Clearing riparian zones seems to be a relatively cost-effective option but more economic and hydrological data would be required to conclude this with more certainty.

Within this report a definition of efficiency (which relates in this context specifically to the water use of land-based activities) has been proposed, and indicators for this efficiency have been developed. When it comes to assessing water-related policies targeting land-based water uses (i.e. irrigation and SFRAs), the impact of policy options on the land-use decisions of the holders of land-based water-use licences needs to be known, and following this the consequent impact of the new land-use on the hydrological cycle needs to be quantified. If this cause-and-effect relationship is known, one can evaluate the impact on efficiency of each policy option. Furthermore, if the requirements for the Reserve are known, an indicator can be developed regarding the sustainability of each policy option.

In this framework, the need for hydrological economic thinking is clear: One can only assess costs and benefits

of policy options (i.e. the impact on efficiency) if both the economic and hydrological impacts are known.

Cost: R159 000  
Term: 1999 - 2000

#### **The development of a methodology to determine the true value of water in the Berg River basin**

Department of Agricultural Economics, University of the Free State  
(WRC Reference No 943)

Water shortages are a looming threat for agricultural as well as urban users in South Africa, mainly for the following reasons:

- The high cost of new water supply infrastructure
- The high percentage of unaccounted-for water
- The pricing of water below its real value
- Central water allocation instead of transferable water rights (water market) systems.

The primary objective of this project was to develop a methodology to determine water values and the impact of a potential water market on efficiency. This included the methodology to analyse water values and water markets as well as the quantification of variables, which will be influenced by the implementation of water markets as an alternative for administrative water allocation in the Berg River basin.

The literature abounds with models for analysing alternative water allocation mechanisms. The positive mathematical programming (PMP) technique, which was introduced in this study, to calibrate a regional water market model, is a relatively new approach. The most important finding with regard to modelling is that in similar studies, without the PMP technique, response to policy and other external impacts on farmers' behaviour was probably overstated. The PMP technique causes a regional model, with incomplete information, to respond more smoothly to a change in parameters. Most of the previous studies also used regional linear programming models instead of typical farms to represent the water demand function for agriculture. In this study, typical farms are embedded in the spatial equilibrium model, and are aggregated to represent irrigation regions. This renders it possible to model farmers' behaviour more accurately.

This study clearly pointed out that there exist huge inefficiencies in the Berg River catchment. Without a water market the capitalised marginal value of agricultural water ranged between R0 and R20.2 with a median value of R1.6/m<sup>3</sup>. The capitalised marginal value for urban water is estimated to be R10.1/m<sup>3</sup>.

When there is relatively low water scarcity and a water market is introduced, the marginal value of water for all agricultural water users declines to either zero (typical irrigation farms where there is an infrastructure transfer restriction) or to 30c/m<sup>3</sup> for all other irrigators. The marginal value for agricultural and urban water can be explained through a difference in the transaction cost between agriculture to agriculture and agriculture to urban water transfers. The reduction in the marginal values for water when a water market is introduced indicates a huge increase in efficiency of the allocation system.

When a water market is introduced the market sends price signals to users, informing them about the scarcity situation. The value of water increases and the opportunity cost of inefficient users becomes too high to carry on with their inefficient practices. They react by using water more efficiently. The net disposable income per m<sup>3</sup>, which was used as measurement of efficiency, rises in response to the introduction of a water market. This creates "surplus" water, which can be traded to higher-valued uses. When a water market is introduced farmers change to lower-intensity irrigation as water becomes scarcer. When water trade is possible, farmers manage to keep a larger area under optimal irrigation than when it is not possible.

Water markets themselves tend to evolve over time. Even very simple water markets, if structured well, can be a stimulus for more efficient water use and can lead to continual refinements in the trading system. This concept was clearly indicated in this study. Even if the trade volume is low initially there are immediate gains in efficiency when water trade is permitted. The Berg River CMA can gain experience by instituting a relatively simple water market (only internal trade within for example the agricultural sector) and develop over time into a sophisticated market with trade between all user sectors and even trade with other catchments (e.g. the Breede River and possibly the Olifants River).

Cost: R664 500  
Term: 1998 - 2001

#### **The value of water as an economic resource in selected catchment areas in South Africa**

Department of Agricultural Economics, University of Natal  
(WRC Reference No 987)

As water scarcity increases, the need for a framework to judge beneficial use becomes more pressing. The answers provided by such a tool are the basis on which society decides who gets access to the resource and who does not.

This study analyses the economic efficiency of water allocation on the Fish-Sundays Scheme in the Eastern Cape Province of South Africa. The objective was to develop a basin-wide model of water use that calculates total and marginal water value. Estimates of total value were used to confirm financial feasibility while marginal values measure the efficiency of current allocation as well as gains from reallocation. A linear programming model shadow-prices commercial irrigation, which controls 97% of available water on the scheme. The value of water to commercial irrigation is interpreted as the opportunity cost of reallocating water to an ecological Reserve, irrigation equity and municipal demand. Value in these sectors is typically hard to quantify but the method developed here constitutes an easy procedure for obtaining a first estimate of the cost of meeting equity objectives.

Total water value is defined as residual farm profit after all fixed resources have been remunerated at their opportunity cost. Assuming the perfect competition of the Ricardian framework, residual profits are interpreted as payments to irrigation water, which pre-1998 was not sold in a separate market but traded as part of the bundle of resources associated with (irrigated) farmland. An accurate estimate of water value critically depends on identifying all other factors of production. Hence, risk is introduced through MOTAD, which penalises the objective function by an exogenous weighting according to risk preference. Accounting for risk reduces total and marginal water values, which are also sensitive to the value of crops and input prices.

Total water value for the scheme is estimated to be R27m. in 1999 Rand ( $\pm$  \$2.24m.) and irrigation shadow-prices range from zero to R0.2115/m<sup>3</sup> ( $\pm$  \$0.0176/m<sup>3</sup>). Results indicate that 77x10<sup>6</sup> m<sup>3</sup>/year can be transferred away from irrigation at zero opportunity cost. Two thirds of the current allocation to irrigation can be bid away at a price of R0.0352/m<sup>3</sup> (+ \$0.003/m<sup>3</sup>). Thus equity objectives can be satisfied at zero or very low opportunity cost to commercial irrigation.

The typical model of water value relies on a vast array of assumptions that all influence final values. While orders of magnitude and directions of reallocation are therefore meaningful, one should not attach too much meaning to any particular result. Administered prices are too data-intensive to be practical. Water markets represent a more reliable and cost-effective institution to derive subjective willingness to pay.

Cost: R443 190  
Term: 1998 - 2001

#### **The value of water as an economic resource in the Great Letaba River catchment**

Economic Project Evaluation  
(WRC Reference No 989)

Apart from separate sectoral analyses in defined subregions, no comprehensive comparison on the value of water for different uses has been undertaken in South Africa. The best option under these circumstances is to estimate water values through economic modelling. In view of the research backlog and the unacceptability of generalisations regarding water values, tenders were invited and approved according to specified guidelines. The outcomes of 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.

Estimated cost: R795 625  
Expected term: 1998 - 2002

#### **The value of water as an economic resource in the Vaal River system**

Greengrowth Strategies  
(WRC Reference No 990)

Apart from separate sectoral analyses in defined subregions, no comprehensive comparison on the value of water for different uses has been undertaken in South Africa. The best option under these circumstances is to estimate water values through economic modelling. In view of the research backlog and the unacceptability of generalisations regarding water values, tenders were invited and approved according to specified guidelines. The outcomes of 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.

Estimated cost: R807 180  
Expected term: 1998 - 2002

#### **An estimation of the value of water in the commercial forestry sector for selected areas in South Africa**

School of Economics and Management, University of Natal  
(WRC Reference No 1133)

The main objective of this project was to determine the value of water use for forestry in selected areas of South Africa. Two valuation methods were chosen:

- Residual value (RV) method
- Marginal value product (MVP) method.

The RV method is based on the premise that the residual value obtained as total revenue minus total cost, including the compensation for capital and management, is attributed to water. On the other hand, the MVP method is based on the assumption that water is rewarded according to its marginal productivity. Under this framework, the water values can be derived from the area under the MVP curve. Both approaches were used to estimate water values to selected sites of eucalyptus and pine on the eastern coast of the KwaZulu-Natal Province of South Africa. The four eucalyptus sites included: Kia-Ora, Baynesfield, Tanhurst, and KwaMbonambi. The three chosen pine sites were: Richmond, Greytown, and Usutu. These two species were selected as they dominate South African forestry, especially on the east coast. Furthermore, although both species can be grown on pulpwood and saw-wood regimes, only the pulpwood regime-based rotations were selected for computing water values.

The estimated evapotranspiration (ET) water values by the RV method for eucalyptus vary from 4c to 13 c/m<sup>3</sup> of water; 4 c/m<sup>3</sup> in a low-rainfall area such as Baynesfield and 13 c/m<sup>3</sup> in high rainfall areas such as the KwaMbonambi Site. The average value comes to 8c/m<sup>3</sup>. The ET value estimates by the MVP method vary between 4 and 60 c/m<sup>3</sup>, i.e. 4 cents for the low-rainfall Baynesfield Site and 60 cents for the high-rainfall KwaMbonambi Site - the average being 31 c/m<sup>3</sup>. The ET value estimates by the MVP method are roughly 4 times the estimates by the RV method.

The RV method measures the residual net value attributed to water after paying for all other inputs in the production process; on the other hand, the MVP measures the value before other costs are paid off. The streamflow reduction (SFR) values of water for eucalyptus vary between R1.90 and R4.44/m<sup>3</sup>, the average being R3.42/m<sup>3</sup>. These values are roughly 10 times the ET value estimated by the MVP method and 40 times the ET values by the RV method. Water value estimates for pine species are much lower than those estimated for eucalyptus. For example, the average ET value by the RV method comes to 1.7 c/m<sup>3</sup> and 15 c/m<sup>3</sup> by the MVP method. The average SFR value for pine is R1.79/m<sup>3</sup>. Interestingly enough, the water values for pine are well below the values for eucalyptus. The difference can be explained in terms of the growth pattern of two tree species; eucalyptus grows much faster and uses water more efficiently.

In brief, the value of water in commercial forestry depends upon the type of use - be it ET or SFR. The SFR use value is about 10 times that of the ET use value. The results of this study can be used in multiple ways:

- Firstly, results can be used to evaluate whether tariffs charged or proposed are reasonable. For example, the calculated catchment management charge, which comes at between 0.5 and 2.5 c/m<sup>3</sup>a is in line with the estimated values of water in this study.
- Secondly, water values can be used to decide on allocation of water for expansion of forestry as compared to expansion of other land uses. Here, water values for other crops or other land uses are needed.
- Thirdly, water values can also provide guidelines to evaluating which tree species should be located where for new projects (site selection).
- Fourthly, the information could also be used toward evaluating which tree species should be used for expansion at which sites (species selection).

Cost: R276 000  
Term: 1998 - 2000

**Ecological and economic evaluation of wetlands in the upper Olifants River catchment, with reference to their functions in the catchment and their management**  
*Wetland Consulting Services (Pty) Ltd.*  
(WRC Reference No 1162)

The need to assess the value of the wetlands in the Upper Olifants River Catchment (UORC) arose because many wetlands in the area face irreversible degradation due to developments in the catchment, and because wetlands are increasingly recognised as areas of economic and ecological importance. Whether degradation of wetlands in the UORC is reason for concern was uncertain, as neither the ecological nor the economic value of these wetlands was known. If decisions regarding the conservation vs. development of wetlands in the area are to be optimal for society, then it is necessary to develop an understanding of the sorts of costs and benefits that need to be traded off. This study aimed to classify and inventorise the wetlands in the UORC and to assess the net economic value of these wetlands.

The study relied mainly on existing information supplemented by limited fieldwork and limited liaison with stakeholders. It was recognised that a desktop study would provide ball-park estimates and guidance for future research.

Wetlands of the study area were mapped, and found to cover 64 813 ha (9.9% of the UORC). A total of 17 hydrogeomorphic wetland types were recognised which fall into 6 main categories: Floodplain or non-floodplain riparian, hill-slope seepage, pans, other non-riparian

and artificial wetlands. The highest concentration of wetlands is associated with dolerite intrusions.

A number of ecosystem services were valued, and the values compared with coal mining and agriculture, the two main land uses in the area. Wetlands cover about 10% of the entire study area, although individually they are small and disjunct. This is probably the single biggest contributor to their degradation.

Different types of wetlands are estimated to have a value (based on direct and indirect services) of between R1 000 and R32 000/ha<sup>-1</sup>. A rough estimate of the value of drained wetlands to agriculture is R725/ha<sup>-1</sup> for grazing land and R1 500/ha<sup>-1</sup> for cultivated land. The value for coal mining, however, is much higher. The price of coal varies, depending on quality, from R0.30 to R4.1 (R1.1 was agreed as a realistic average), giving the average opportunity cost of a wetland underlain by coal as R45 000/ha<sup>-1</sup>.

The proposal made is that the trade-off between conversion of a wetland or its conservation be made on the estimated values of the opportunity cost vs. the biodiversity costs. The assumptions in this equation are that it is very difficult to monetise all values of an ecosystem, particularly where there is also a scarcity value of a wetland (as more are converted, those remaining increase in value), and that the precautionary principle should apply.

Mined wetlands can be rehabilitated, but the extra cost of rehabilitating a wetland is likely to be more than the monetised value of the wetland.

Cost: R585 000  
Term: 2000 - 2001

## Thrust 2: The Economic Advantages and Disadvantages of Water Resource Development

**Updating of 1989 manual for cost benefit analysis in South Africa to 2000**  
*Conningarth Consultants*  
(WRC Reference No 1132)

The evaluation of water resource development projects is often a difficult task since costs and benefits occur over time. Furthermore, costs and benefits are often hidden, making them difficult to identify, and are also frequently difficult to measure. These problems are not limited to capital projects; they also occur when decisions have to be made regarding the merits of

current expenditure programmes. The cost benefit analysis (CBA) method, also known as benefit cost analysis, provides a logical framework by means of which projects can be evaluated, serving as an aid in the decision-making process.

The primary aim of this CBA manual is to provide the decision maker with practical guidelines and procedures to apply the CBA methodology. The secondary aim of this manual is to provide the user with an extensive and up to date data bank of shadow and surrogate prices in South Africa.

To ensure that this manual provides guidelines for the CBA practitioners the research was conducted in close cooperation with the research manager at the WRC, members of the project steering committee, the Development Bank of Southern Africa, the Department of Water Affairs and Forestry and leading CBA practitioners. As part of the process, four major workshops were held during the course of the project. At these workshops valuable inputs were given.

The main subjects discussed in this manual are the following:

- applications and limitations of CBA
- methodology of CBA
- criteria for project assessment
- shadow and surrogate prices for South Africa
- issues relating to water development
- practical examples.

As far as possible a practical approach is followed in this manual. This applies specifically to the guidelines for shadow and surrogate prices. In this regard the following shadow/surrogate prices are provided:

- shadow wages for unskilled labourers per province
- estimated annual remuneration for occupational categories in South Africa per province
- index of projected real effective exchange rate of the Rand
- index of projected prices for petrol and diesel
- index of estimated relative changes in electricity prices
- estimated time cost according to income groups
- economic value of productive life.

The researcher is assisted in the application of the guidelines in this manual by providing him or her with practical examples which appear on the website of the WRC ([www.wrc.org.za](http://www.wrc.org.za)). These examples include electricity, potable water, roads and municipal vs. irrigation water schemes.

Cost: R419 000  
Term: 2000 - 2002

## CURRENT

### Thrust 1: The Value of Water to Different Sectors of the Economy

#### Integrated socio-economic and cultural values as additional components of the criteria for estimating and managing the Reserve

*Institute for Natural Resources, University of Natal, Pietermaritzburg  
(WRC Reference No 1195)*

The National Water Act of 1998 aims to achieve sustainable use of water for the benefit of all users. It also guarantees the protection of aquatic ecosystems. Historically, the evaluation of the importance of river systems has been largely based on ecological importance, while ignoring social and cultural aspects. This study is establishing the importance of integrating ecological, socio-economic and cultural values in the estimation and management of the Reserve. It is also providing information on the dependency of rural households on river system resources (contributes also to Water-Linked Ecosystems ).

*Estimated cost: R300 000  
Expected term: 2000 - 2001*

### Thrust 2: The Economic Advantages and Disadvantages of Water Resource Development

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

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

The concept of "best possible use" of water involves more than productive use of water since it explicitly provides for weighing up of social, economic, and environmental objectives to promote equity, efficiency and sustainability. It is important to quantify direct and indirect benefits and costs to allow a fair comparison of water use between water-use sectors. It is also necessary to determine backward and forward linkages in the

economic activity of different water users within and outside the boundaries of catchment areas. The findings will therefore provide decision support for private and public management of water allocation within river catchments.

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

#### Market risk, water management and the multiplier effects of irrigation agriculture with reference to the Northern Cape

*Department of Agricultural Economics, University of the Free State  
(WRC Reference No 1250)*

An important aim of the Water Conservation and Demand Management Strategy for the agricultural sector is to provide a regulatory support and incentive framework to improve irrigation efficiency. This can be achieved by firstly ensuring that volumetric water tariffs reflect the financial cost of supply and, secondly, by promoting voluntary reallocation of water resources from lower-valued to higher-valued uses on farms and between farms within agriculture. For irrigation farming this means that farming operations must be restructured. However, production of e.g. high-value perennial crops also involves higher financial and business risks. This is caused by the high capital outlay and the time lag before full production is reached as well as variable export prices and changing consumer preferences over time. Although risk management through e.g. crop diversification or market forecasts and price hedging can be implemented, the question is how far the shift to higher valued crops can be taken. Presently it is not known what the financial boundaries are within which water reallocations can be managed sustainably on a farm level and what the potential impact is on a regional economic level. Knowledge of these issues is of particular importance for irrigation areas in provinces such as the Northern Cape where agriculture is the dominant economic sector. Instability influences not only employment and income on farms, but also processing and input supplying industries through forward and backward linkages. This is emphasised by the recent turmoil in the global deciduous fruit market, which has also affected table-grape production in the lower Orange River. This project will analyse the related production and marketing risks and develop models which link economic activities on a farming level to the regional level. The model will be tested in the particular study area but will be applicable in any area. The main aim of this project is to quantify the impact of market risk on the efficient use of irrigation water and to determine the multiplier effects of irrigation farming accompanied by a shift in production patterns.

*Estimated cost: R1 333 700  
Expected term: 2001 - 2005*

#### Socio-economic impact study on water conservation cultivation techniques in semi-arid areas

*Department of Agricultural Economics & Sociology, University of the Free State  
(WRC Reference No 1267)*

In order to promote sustainable crop production, rainfall use efficiency needs to be optimised. Rain water harvesting and conservation are therefore important. In addition to water conservation techniques, land and human power requirements, and technology transfer, socio-economic implications of these conservation techniques need to be evaluated. The practical sustainability of and the extent to which these conservation practices will be supported and recommended by the relevant authorities, depend on their socio-economic acceptability.

The objectives of the project are to:

- Develop an appropriate methodology for the determination of the socio-economic implications of water conservation cultivation techniques
- Develop a simulation model to integrate biological productivity, entrenchment of risks, management of natural resources and social acceptability with economic sustainability
- Determine the socio-economic implications of employing water conservation cultivation techniques on small plots in semi-arid areas
- Determine the area of land needed to provide an average-sized rural family with food security, as well as the human power required for these cultivation practices.

*Estimated cost: R425 800  
Expected term: 2001 - 2004*

### Thrust 3: The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation

#### Development of a framework for the introduction of waste discharge charge systems in South African catchments

*Stewart Scott  
(WRC Reference No 949)*

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. A WRC project laid the foundation for this provision by developing a philosophy and methodology for the implementation of the polluter pays principle. The current project was designed to build on the findings of the previous study by including a wider range of pollutants and by focusing on implementation issues. At an early stage of the project the WRC became aware the DWAF was about to start developing the protocol for implementing waste discharges. In order to prevent duplication, the WRC decided to integrate this project's activities with those of DWAF. Phase I of this initiative was completed with the publication of a *Framework Document* which describes the technical and legal frameworks for the waste discharge system, and the principles on which the development of the system is based. The WRC's contribution will end when the draft implementation strategies are completed under Phase II.

*Estimated cost: R400 000  
Expected term: 1998 - 2002*

#### Development of models for economic evaluation of integrated management of quantity and quality of irrigation water within river catchments

*Department of Agricultural Economics, University of the Free State  
(WRC Reference No 1043)*

Decisions by individual farming businesses to divert or withdraw water for cultivation and irrigation of different crops, has wide-ranging impacts on the natural environment. Changes in the type of land-use and cropping practices influence runoff while the choice of water distribution and irrigation methods as well as the efficiency of operations determines return-flow. With intensive production methods the level of nitrates, phosphates and chemical residues of pesticides and herbicides in surface and underground water is an

increasing problem. Legislative prescriptions have therefore been specified in the National Water Act to protect aquatic ecosystems as part of the Reserve, regulate stream flow reduction activities and prevent pollution. Information on and tools to manage the quantity and quality of water are now clearly required to ensure sustainable use of water for irrigation in relation to all other use sectors.

In an on-going WRC-funded research project, dynamic stochastic decision models have been developed to analyse the influence of variable availability of the quantity of water, and the requirement to maintain minimum instream flows, on the economic viability of irrigation farming. The obvious next step is to extend the procedures and models to include the water quality dimension. In doing so, this research will address facets of research subjects which have been given a high priority rating by the Coordinating Committee for Research on Agricultural Water Management. User-friendly adaptation of models in order to provide practical decision-support, will furthermore assist with the implementation of water policy. This is in agreement with the shift in emphasis from formulation to implementation of policy as indicated by the Department of Water Affairs and Forestry.

The aims of the research are to:

- Develop decision-making tools and evaluate the economic impact of policy strategies on the control of non-point pollution
- Apply agro-hydrological and economic models and assess the influence of a change in the allocation and use of water on integrated management of the quantity and quality of water

resources and long-term profitability of irrigation farming.

*Estimated cost:* R683 000  
*Estimated term:* 1999 - 2002

**Identifying examples of successful cost-recovery approaches in low-income, urban and peri-urban areas**  
*Sigodi Marah Martin Development Consultants (WRC Reference No 1131)*

In spite of a high level of publicity and political attention, the Masakhane campaign is perceived to have met with very limited success. Opinions vary on the cause of this, and although some work has been done in the field, the problem has not received the consistent, detailed study, that a matter of this importance deserves. In particular insufficient attention has been paid to the factors which generate success. This research is providing an opportunity to study these issues in depth. In particular, by concentrating on the successful models it will enable stakeholders to understand the role that the factors of political pressure, of administrative methods, of billing and collection systems, sanctions and community values will play in these issues. This study is expected to result in important gains in respect of understanding this problem, which can be translated into higher levels of payment and an increase in the level of development for the disadvantaged members of society. The outputs of this study are of relevance to the concept of customer management and complement the WRC study on customer management.

*Estimated cost:* R438 000  
*Expected term:* 2000 - 2001

#### **Thrust 4: The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution**

**An investigation of the supportive role of the market mechanism in implementing the provision of the New Water Act (NWA) in order to achieve efficient and equitable water utilisation**  
*Conningarth Consultants (WRC Reference No 1297)*

The NWA does not refer to any specific market-related mechanism as a tool to allocate water. In Section 26(n) of the Act reference is made that regulations may be made to allocate water by public tender. See also Section 45(2 F). The granting of water-use licenses will be the initial central allocation mechanism. This will be a crucial process because it is at this stage that the issue of equity and efficiency in water use will be addressed. The extent to which economic considerations will feature in this process is not specified. The role of the proposed water tariffs (administered prices) in assisting efficient water use is not yet analysed.

Once the initial allocations have been made it cannot be assumed that the allocation should stay unaltered over time as the initial circumstances change. To some extent the five-year review process envisaged can address this issue. The way in which this five-yearly revision process will take place in practice has not yet been determined. The market mechanism can assist in

providing a flexible mechanism for addressing this issue on an efficient basis.

It would therefore appear that the role of the market is not ruled out in the NWA. The issue is, however, to determine ways to strengthen its role. In this regard an incremental approach can be used by identifying areas where it will be relatively easy and gradually move towards the more complicated situations where the use of market forces might require (minor) adjustments in the Act.

The aims are to:

- Investigate the required institutional form and arrangements for water allocation based on international experience
- Determine the major concerns of DWAF in relation to the implementation of the efficient allocation of water use as envisaged by the NWA of 1998
- Investigate and propose adjustments to institutional arrangements in the NWA regarding water allocation to align them with the requirements to support the market to play a role in water allocation.

*Estimated cost:* R622 100  
*Expected term:* 2002 - 2004

### Thrust 1: The Value of Water to Different Sectors of the Economy

#### Valuation of changes to estuary services in South Africa as a result of reductions in freshwater inflows

Department of Economics, UPE  
(WRC Reference No 1304)

The renewable natural resource, river water, has been subject to persistent open access exploitation in South Africa. Inevitably, problems have arisen that are typically associated with poorly defined property rights and externalities. Inter alia, traditional water pricing policy in South Africa has been found to be inefficient.

The primary focus of attention of ongoing economic research is on identifying the benefits and beneficiaries of functional estuaries and the value of these benefits. In essence this work follows a two stage approach to valuing the benefits per estuary. Stage 1 is to value each estuary service individually and Stage 2 is to add these values together.

Estimated cost: R336 000  
Expected term: 2002 - 2004

#### Valuing water for South African industries: A production function approach

Environmentek, CSIR  
(WRC Reference No 1366)

The industrial sector in South Africa is one of the fastest growing sectors and relies to varying degrees (ranging from wet to essentially dry industries) on water resources as an input to many production processes. Industrial water use currently comprises about 10% of the total water use in South Africa (WSAM 2000) and is therefore a significant water-using (and effluent-generating) sector. Very little is, however, currently known about the responsiveness to water pricing within the industrial sector in South Africa, probably because of historically low pricing structures and the perception that industrial water use is better suited to engineering rather than economic analysis. International literature offers mixed results, with industrial price elasticities ranging from very inelastic to more elastic. In the context of the National Water Act and its emphasis on economic pricing, and the significance of industrial water use in South Africa, it

is necessary to provide econometric tools to decision-makers. The proposal aims to quantify and characterise the role that water plays in various local industries and their responsiveness to price changes; and to develop a set of indicators and judgement criteria for policy-makers, decision-takers and other stakeholders to use economic analysis for appropriate water resource management.

The project's overall aim is to determine the marginal value of industrial water in South Africa, in keeping with the National Water Act's objectives to price water correctly. The specific sub-goals are listed below:

- To assess the role that industries play in the overall water demand for South Africa, and to determine which industries are the most water-intensive industries and which industries are relatively water "dry"
- To determine price elasticities of demand for water for the respective industrial sectors within South Africa, and develop a set of indicators that can be used in existing models or assist existing techniques to ensure sustainable and equitable conservation of water resources
- To demonstrate through practical application how economics can be used to value water resources, and to document this application so that it may be applied across sectors
- To provide a value judgement for water resource management and policy based on the results and an extended analysis of the data
- To build capacity in all stakeholders and parties participating in the research project, through the transfer of knowledge.

Estimated cost: R549 600  
Expected term: 2002 - 2005

### Thrust 2: The Economic Advantages and Disadvantages of Water Resource Development

#### Integrating flood-plain agriculture into a diverse rural economy by enhancing co-operative management: A case study of the Pongola

Institute for Natural Resources  
(WRC Reference No 1299)

The effective management of the Pongola River flood plain has been unsatisfactory ever since the completion of the Pongolapoort Dam. This study aims at promoting

effective co-operative management of the river system on a sustainable and democratic basis. Lessons learned here will contribute to formulation of policies and institutions to achieve sustainable use of river systems in rural South Africa. This project is strongly based on the principles of a participative action plan.

The aims of the project are to:

- Learn about promoting effective co-operative management around sustainable use of river systems in rural areas
- Redirect the pattern of resource use on the Pongolo River flood plain towards a shared vision reflecting a diverse and sustainable economy
- Establish a confident and capable team of researchers drawn from previously marginalised sectors;

Expected cost: R880 000  
Expected term: 2002 - 2005

### Thrust 3: The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation

#### Payment strategies and price elasticity of demand for water in different income groups at three selected areas

Marketing Surveys and Statistical Analysis  
(WRC Reference No 1296)

Water pricing and payment strategies are currently receiving a very high profile in South Africa. Water Affairs Minister, Ronnie Kasrils, announced on 14 February 2001 that free water (the first 6kl) be supplied to households from 1 July 2001. Price elasticity of demand for water is an essential input into water price setting and management policy formulation. It is therefore considered essential that further investigation of the price elasticity of demand for water and insight into the impact of different applied payment strategies, should be gained without delay.

To this end it is proposed that both a participate payment strategy testing methodology (PPSTM) approach as well as a contingent valuation methodology (CVM) approach be used in this study. The PPSTM approach, as developed by MSSA, together with the CVM approach as used by EPE, would be the vehicle to provide both a short-term price elasticity of demand and a long-term payment strategy for lower income residential water

users in the major metropolitan areas of South Africa. It is recommended that both these approaches are undertaken, firstly for comparative purposes, and secondly so that decision-making, with respect to short-term and long-term water management policy, may be undertaken.

Estimated cost: R700 000  
Expected term: 2002 - 2004

### Thrust 4: The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution

#### Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers

Tlou Water Management  
(WRC Reference No 1353)

Rural development in the Eastern Cape, KwaZulu-Natal and the Northern Provinces where widespread poverty occurs, has been held back due to institutional failures and collapse of many irrigation schemes. Consequently enormous social and development needs are experienced in respect of capacity building and entrepreneurial development; job creation; social upliftment of rural communities; poverty relief; and land redistribution. Government has shown its commitment to developing the rural areas by establishing an integrated rural development strategy (IRDS) in the President's Office. This initiative requires support through research of relevant models for social and economic development of the rural areas. The objective is to optimise use of scarce water resources and to develop previously disadvantaged communities. To achieve the objective this project will research models which take into account the multi-phased characteristics of the development process in order to re-establish small-scale irrigation farmers on a sustainable and financially viable basis. A concerted research effort is required to find acceptable solutions by working together with farmers, communities, local and provincial authorities to determine the requirements and formulate guidelines for sustainable development.

Aims of the research project are as follows:

- Develop tenure models that would ease the management and operation of smallholding

- irrigation schemes, and settle small-scale irrigation farmers in a sustainable manner under South African land tenure and rights conditions
- Develop suitable irrigation systems for small-scale irrigation farmers
- Determine an applicable on-farm support system, institutional setting and social framework to regulate the production, marketing financial and water resource needs of the small-scale irrigation farmers.

*Estimated cost:* R795 200  
*Expected term:* 2002 - 2005

#### **Water resource management for profitable small-scale farming along the banks of the Orange River**

*Department Agricultural Economics, University of the Free State  
(WRC Reference No 1354)*

The establishment of small-scale farmers on the Orange River in the Northern Cape and Western Cape Provinces was identified as a very high priority. The study is motivated by the drive to utilise the water right allocation to establish small-scale irrigated farms and operate them efficiently and sustainably. Formal and appropriate methodologies will be developed to successfully establish small-scale farmers to ensure household food security and enable production of surpluses. Farm size, type of technology, access to markets and financing methods and procedures will be clearly defined. According to the Provincial Department of Agriculture in Kimberley an appropriate economic model is needed to successfully establish small-scale farmers. This project will directly address these issues by providing guidance and developing a model for evaluating the economic performance and efficiency of the farms prior to establishment.

The main aim of this project is to develop an appropriate methodology to successfully establish small-scale irrigation farmers in South Africa.

Sub-aims are to:

- Develop an appropriate land tenure system for small-scale farmers
- Develop an appropriate marketing arrangement for inputs and outputs for small-scale farmers
- Develop a suitable financial arrangement for loan and credit acquisition to facilitate successful establishment of small-scale farmers
- Develop an economic model viable for successful establishment of irrigated farmers
- Determine the social acceptability of the proposed newly developed programme

- Determine the environmental impacts of the establishment of small-scale irrigated farms on undeveloped land.

*Estimated cost:* R970 000  
*Expected term:* 2002 - 2005

#### **Development of models to facilitate the provision of free basic water in rural areas**

*Mvula Trust  
(WRC Reference No 1379)*

Most rural municipalities are faced with a big challenge of implementing the free basic water policy. Unlike their urban counterparts they lack the wealthy customer base that generates financial resources to cross subsidise the poor households. Most rural households obtain their potable water from standpipes, therefore, their water consumption level falls within the 6 kℓ limit prescribed by the free basic water policy. This research project will investigate the actual costs of providing free basic water. The expected research output will be cost-effective institutional and subsidy models that will ensure financial sustainability of rural water supply schemes. This research will contribute towards the building of the capacity of rural municipalities to implement the free basic water policy.

*Estimated cost:* R500 000  
*Expected term:* 2002 - 2003

#### **Economic regulation of water services models for South African municipalities**

*Palmer Development Group  
(WRC Reference No 1383)*

DWAF is currently engaged in a process of developing a water services regulatory framework for South Africa. The Department has set up an initial project which aims to:

- Establish an overall regulatory framework, addressing the functions of the various organisations which need to participate in regulation
- Integrate the regulation of water boards into the framework
- Integrate regulation of water resources institutions, such as catchment management agencies into the framework
- Review requirements for legislation (including regulations) to implement the regulatory framework.

For the regulation of water services to become effective in South Africa, considerable additional work needs to

be undertaken. In particular the methodology to be used in undertaking economic regulation needs to be addressed. This will define the manner in which water services authorities regulate water services providers, within the framework established by the above project. Of primary importance in this regard is the methodology for economic regulation and in particular regulating tariffs and associated financial parameters.

It is intended that the research will complement the work on regulation being undertaken by DWAF. The research will focus on appropriate mechanisms for economic regulation, an area which is not covered by the current DWAF investigation.

*Estimated cost:* R379 500  
*Expected term:* 2002 - 2003

#### **Effective cost-recovery in a changing institutional and policy environment: Municipal demarcation, the "Free Basic Water Policy" and financially sustainable service delivery**

*Sigodi Marah Martin  
(WRC Reference No 1384)*

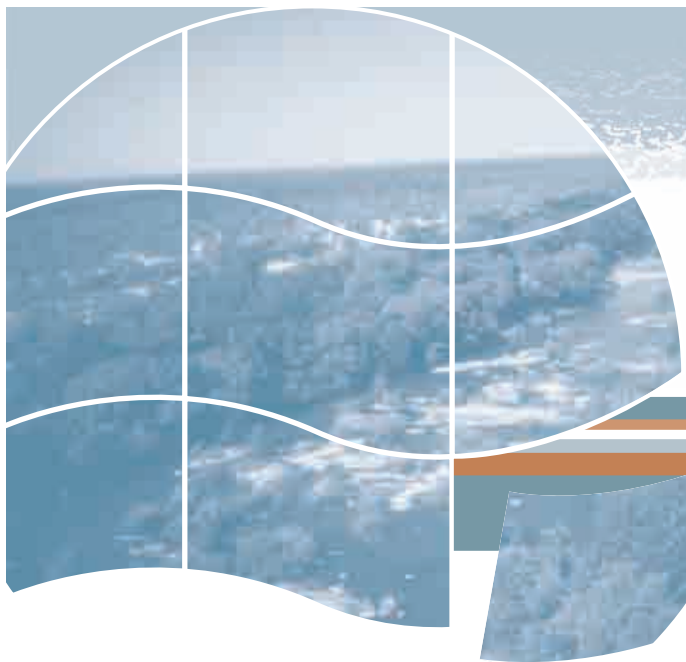
Effective cost-recovery is crucial to the financially sustainable provision of water services to all South Africans. Recent institutional and policy changes have profoundly altered the environment in which cost-recovery must take place - with municipal demarcation redefining the local and metropolitan units directly responsible for service delivery, and the adoption of a "free basic water" policy nationally substantially modifying the prevailing paradigm of cost-recovery. Because of these changes, very few municipalities enjoy the luxury of a viable status quo, and a thoroughgoing review of national and municipal cost-recovery is inevitable. The project will highlight and clarify the links between municipal restructuring, the "free basic water" policy, and the challenge of financially sustainable service provision. It will yield information and insights to assist and track the development of cost-recovery strategies during a period of major institutional and policy change. It will build upon existing research - in particular, WRC project K5/1131 - in using systematic data collection and analysis to estimate determinants of cost-recovery in a dynamic environment. Although sophisticated statistical modelling techniques will be applied, practical implications for national and municipal decision-makers will be presented in an accessible and non-technical way.

*Estimated cost:* R400 00  
*Expected term:* 2002 - 2004

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# XD C

## Water and the Environment



Dr HM MacKay  
Head:  
Water and the Environment

### Scope

This crosscutting domain will contribute to a holistic understanding of the environmental (air, land, marine, ecosystem, aquifer) linkages through the hydrological cycle, how environmental degradation impacts on water resources, how water-related activities impact on the environment and which methodologies need to be developed or can be used to minimise detrimental impacts. The approach will be based on the philosophy that "prevention is better than cure" through the development of appropriate source-directed controls and an understanding of the natural assimilative capacity of the environmental system. Maintenance and improvement of the atmospheric, land and ecological

environment will also be championed in this crosscutting domain. This will be done through understanding water-use practices and resultant disturbances that may occur as a result of improper use. Responsible use of natural resources associated with the water environment will be advocated through equitable allocation and appropriate conservation practices which take into account the consequences of depletion and degradation of the resource.

This crosscutting domain will closely link to the key strategic area (KSA) for **Water-Linked Ecosystems (KSA 2)**. Water-linked ecosystems are defined as in-stream (fully aquatic), riparian (dependent on water stored in the river banks and linked to the river) and water table-dependent (dependent on a water table, but not on the surface water). **KSA 2** focuses on the protection and sustainable utilisation of the aquatic environment and biota (in-stream, riparian and groundwater). The primary focus area will be "the provision of knowledge to enable the utilisation and sustainable management of the aquatic ecosystem in a water-scarce country in a time of demographic and climate change". **XD C** will differ from **KSA 2** by having a wider environmental perspective through inclusion of air, land, marine and terrestrial ecosystems.

### Objectives

In support of a broader understanding of the inter-linkages of the hydrological cycle in relationship to the

environment in order to facilitate sustainable development practices, the main aims of this crosscutting domain are therefore to:

- Support development of technologies and processes (including best practice) that minimise release of waste in the water environment (source-directed controls)
- Better understand the impact of various land uses on the different components of the hydrological cycle and subsequent risk to the environment functioning (e.g. biodiversity loss)
- Contribute to prevention of environmental degradation (atmosphere, land and terrestrial ecosystems) by water-related activities (reverse disturbance)
- Support use of the goods and services associated with the water environment in a responsible and equitable manner that takes into account the consequences of the depletion of the resources
- Assist in developing environmental governance systems (including communication systems) that are appropriate to SADC circumstances. This needs to include understanding issues that will hamper environmental governance (e.g. HIV aids; poverty and the depreciation of the Rand)
- Understand impacts of policy on the water environment, by establishing integration and co-operative mechanisms between the various legislative frameworks and policy directives.

Portfolios of current projects have been grouped into strategic thrusts which directly address the above-mentioned objectives and are summarised as follows:

- Thrust 1: Environmental Governance Systems**
- Thrust 2: Biodiversity Protection and Environmental Functioning**
- Thrust 3: Water Pollution and Ecosystems**
- Thrust 4: Resource Management and Use**
- Thrust 5: Ecosystem Functioning (terrestrial part).**

### Budgets for 2002/03 and 2003/04

The approved funding of the research portfolio for 2002/03 leads to committed funding of R4 552 700 in 2003/04. Funding in the KSAs for new projects of R14 685 700 in 2003/04 is planned to meet the objectives of this domain.

Research portfolio	Approved 2002/03 R	Committed and requested 2003/04 R
Current projects	3 691 900	4 552 700
New projects	3 874 850	14 685 700
<b>Total</b>	<b>7 566 750</b>	<b>19 238 400</b>

## CORE STRATEGY

### Strategic context

The environment produces the goods and services to sustain mankind. Ecosystems make the earth habitable: purifying air and water, maintaining biodiversity, decomposing and recycling nutrients and providing myriad other critical functions. The direct benefits that humans derive from the environment are harvested largely from plants and animals in the form of food and raw materials. Indirect benefits take the form of services such as erosion control and water purification. We have, however, put the environment under siege and in order to start lessening the impact, numerous international treaties and protocols have been developed.

South Africa has ratified the Convention on Biological Diversity, the Framework Convention on Climate Change, and the Convention to Combat Desertification and is moving to ratify the Biosafety Protocol 2. In addition, South Africa is supporting international efforts to establish a legally-binding instrument to control the discharge of certain persistent organic pollutants (POPS). To implement these international treaties will require new knowledge to be created and innovative solutions/measures to be generated.

South Africa is also the third most biologically diverse country in the world, mainly because of the number and types of plant found here. The Cape Floristic Kingdom and the Succulent Karoo particularly represent this biodiversity. South Africa also has a great diversity of mammals, birds, insects, reptiles, and amphibians, in the aquatic, terrestrial, coastal, and marine habitats.

The constitution entrenches the right of every South African to a healthy environment. The natural environment of South Africa has to date been significantly altered through various land-use impacts. Hence, water-related activities such as water exploitation, storage, allocation and various uses, must take place in ways which avoid further environmental (air, land and water) degradation. Addressing such and other environmental aspects is the cornerstone of sustainable development best practice. However, many pressures still exist that have the potential to negatively impact on the environment in South Africa. These include, amongst others:

- Population growth, with subsequent demand for resources, e.g. food, water and energy
- Current wasteful practices in utilising resources
- Uncontrolled generation of pollution and waste

The limited understanding of the functioning of the complex natural system exacerbates the pressures. Whatever the pressures and impacts on the environment, however, water is invariably part of the equation.

The State of the Environment report produced by the Department of Environment and Tourism (DEAT) presents three scenarios that South Africans could envisage:

- **Scenario 1** represents continued population growth, wasteful consumption patterns and exploitation of resources, and excessive generation of pollution and waste (i.e. sustainable development practices are not put into place). Ecosystem functions will be rapidly degraded and will be unable to support human life within one or two generations. Ecological collapse soon followed by social and economic collapse is the outcome of ignoring sustainable development principles.
- **Scenario 2** will prevail if sustainable development strategies are developed, but lack of human and financial resources means that they cannot be implemented fully. Thus resources will continue to be exploited and polluted, unchecked by regulatory authorities. A slower ecological and social demise will ensue.
- **Scenario 3** is the preferred outcome. The newly promulgated legislation (e.g. National Environmental Management Act and National Water Act) and sustainable development strategies will be supported by political will and human and financial resources, resulting in responsible, sustainable rates of resource use, minimised waste and pollution, and maintenance of healthy ecological services. This will ensure improved quality of life for present and future generations.

Freshwater is recognised as the most limiting resource in South Africa. In addition, we share transboundary water resources with neighbouring countries (e.g. Incomati, Limpopo, Orange, Ravuma and Maputo Rivers). Transboundary aquifer systems include: Precambrian basement aquifers, Karoo aquifers, dolomite aquifers and primary aquifers (Mozambique and Kalahari). These resources face over-exploitation, suffer from pollution, other human-induced pressures and invasion of alien species. As both a source and user of water, the environment's "rights" to its "equitable share" need to be determined and maintained in order to promote sustainable development.

The WRC recognises the value of the environment and that protection thereof is crucial for sustainable development. As the leading water-related research investment agency in South Africa, we will endeavour to develop technologies and methodologies to prevent degradation of the water environment, sustain its functioning and support sound management practices.

### Needs analysis

Water is an integral part of the environment and its temporal and spatial availability is indispensable to the efficient functioning of the biosphere. However, there are many threats to the water environment as a result of human-induced activities summarised below:

Ecosystem	Pressures
Agro ecosystems	<ul style="list-style-type: none"> <li>• Water pollution from nutrient runoff and siltation</li> <li>• Water scarcity from irrigation</li> <li>• Changing weather patterns</li> </ul>
Coastal ecosystems	<ul style="list-style-type: none"> <li>• Conversion of wetlands and coastal habitats</li> <li>• Water pollution from agricultural and industrial resources</li> </ul>
Forest ecosystems	<ul style="list-style-type: none"> <li>• Deforestation resulting in loss of biodiversity, release of stored carbon, air and water pollution</li> <li>• Acid rain from industrial pollution</li> <li>• Over-extraction of water for agricultural, urban and industrial uses</li> </ul>
Freshwater ecosystems	<ul style="list-style-type: none"> <li>• Over-extraction of water for agricultural, urban and industrial uses</li> <li>• Building dams for irrigation, hydropower, and flood control</li> <li>• Water pollution from agricultural, urban and industrial uses</li> <li>• Invasion of non-native species</li> </ul>
Grassland ecosystems	<ul style="list-style-type: none"> <li>• Soil degradation and water pollution from livestock herds</li> </ul>

It is thus crucial to understand the relationship of water to the key agents of global change, namely the greenhouse effect and climate variability; land-cover change; industrialisation and population growth; and the control of the natural water cycle through hydraulic engineering to cope, for example, with droughts and floods. How, when and where such human-induced changes, together with climatic conditions and

extremes, will influence key ecosystems, are poorly quantified.

A sustained knowledge base will be required to implement the sophisticated environmental policies and associated legislation developed in South Africa. Implementation needs to be supported by the development of appropriate tools and technologies, including adequate financial resources. Crucial to the success of implementing the strategies is the establishment of governance systems that support integrated approaches to exploiting opportunities and identifying risks across various national agencies and various spheres of government. Issues that require addressing include:

- Development of instruments and integrative mechanisms to ensure co-operative governance in management and protection of the water environment in the government sector
- Determining the value of the water environment to assist the decision-making process in broader environmental governance
- Identification of possible impacts or factors that may negatively influence environmental governance systems (e.g. poverty)
- Understanding the optimal scale and scope of environmental governance.

Protection of the indigenous biodiversity landscape and their environmental functioning (conservation ecology) is needed for sustainable development of water resources. Important issues to address are:

- Protection of the indigenous biodiversity landscape from alien infestation.
- Conservation of biodiversity, as well as equitable sharing of benefits arising from biodiversity use
- Promotion of indigenous knowledge systems and local protection of the water environment.

The continued development of robust technologies and processes (cleaner production) able to operate at various scales is needed to assist in the protection of the water environment. Issues that require resolution include:

- Developing protection measures preventing environmental impact from different land-use practices, including the reversibility or not of these impacts
- Supporting development of cost-effective (and needed) technologies that limit waste emissions within the assimilative capacity of the water environment

The value of goods and services associated with the water environment needs to be recognised and resources need to be utilised in a responsible manner. Understanding the loading capacity of environmental systems and the consequences of resource depletion are crucial. Consequently, the following issues need to be resolved:

- Support resource uses that are within the regenerative capacity of the water-related environment
- Understand the key agents of global change and potential consequences of climate variability and change for water resources in sub-Saharan Africa
- Understand cause-and-effect relationships, and where the impacts manifest themselves. This should include predictive capabilities
- Determine the irreversible impacts such as erosion and aquifer degradation on the water environment

Understanding ecosystem functioning is necessary to develop adaptive strategies for proper resource management. **KSA 2** has been established to deal with ecosystem management, utilisation and protection. This crosscutting domain will extend this focus to the terrestrial and atmospheric components of the environment and will consider the following issues:

- Water-related impacts of different scenarios of ecosystem loss (or change) through land-use impacts
- Understanding the environmental components (air, land and water) and their interlinkages through the hydrological cycle, on ecosystem functioning
- Understanding the impacts of disrupting the hydrological regime (quality and quantity) on ecosystem functioning (specifically through man-made interventions)
- Developing strategies and means to reduce net impacts of environmental change on ecosystems (terrestrial and aquatic) and water resources.

### Technological trends

It is enormously challenging to measure the overall condition or health of the environment. Managing ecosystems holistically and sustainably requires a detailed understanding of their function and condition. In some cases, our improved scientific understanding has allowed the development of detailed conceptual, numerical and management models (e.g. modelling spreading of invasive plants). These models, supported by environmental observation networks and high-quality

biophysical datasets, have emerged over the last decade. Coupled to this are high-resolution remote sensing imagery and data assimilation schemes which provide the opportunity to monitor the state of the hydrological cycle over broad domains and in near-real time, thus improving knowledge in this domain.

### Key stakeholders

The key stakeholders for this domain include the DEAT, DWAF, NDA and DME. These national departments have environmental responsibilities as their mandate. Further, in the constitution, provinces have environmental and agricultural responsibilities, which means that consultation needs to take place at the appropriate level. At local government level the bigger metros such as Johannesburg, have environmental functions. At global level relationships need to be established with SADC, UNEP, GEF and UNESCO.

### Providers of research

The providers of expertise will be a combination of universities, science councils and specialist consultants (established and emerging). The distribution of approved WRC-funded projects among suppliers for 2002/03 is as follows:

Supplier	No of projects	% projects
Universities	19	43
ARC	5	11
CSIR	7	16
Private consultants	9	20
Chamber of Mines	2	5
Government departments	2	5
<b>TOTAL</b>	<b>44</b>	<b>100.0</b>

### Links to Vision and Mission of the WRC

The care for the environment is central to the vision and mission of the WRC. The research facilitated and conducted by **XD C**, will provide the necessary intellectual capital in solving water-related problems which are crucial to South Africa's sustainable development. The necessary research support will be given to implement the policies and legislation, including international protocols.

## RESEARCH PORTFOLIO FOR 2002/03

The main aims of this crosscutting domain are given above. At this stage only thrusts are formulated but as the domain develops, programmes may result.

An overview of XD C research thrusts for 2002/03 is given in **Table 1**.

*Table 1: Overview and description of XD C thrusts for 2002/03*

Thrusts	Scope
<b>1. Environmental Governance Systems</b>	The development of integrated governance systems between national agencies responsible for implementation of "environmental" related legislation and treaties is crucial for sustainable development. However, the multitude of multilateral environmental agreements at global level and legislation at national levels has resulted in considerable diffusion and overlap, meaning that decision-making and policy implementation is fragmented. The focus of this thrust will be to facilitate the creation of institutions that enable the participation of civil society in democratic and accountable water-related environmental decision-making and to develop integrative mechanisms to "simplify" environmental governance.
<b>2. Biodiversity Protection and Environmental Functioning</b>	Species diversity influences ecosystem stability and underpins essential ecological services. Diversity also bolsters resilience - an ecosystem's ability to respond to pressures - offering insurance against climate change, drought and other stresses. The threat to biodiversity is growing due to human-induced pressures - over-exploitation, invasive species, pollution, global warming, and habitat loss. This thrust area will focus on the protection of the indigenous biodiversity landscape from alien infestation; conservation of biodiversity, as well as equitable sharing of benefits arising from biodiversity use; and promotion of indigenous knowledge systems and local protection of the water environment.
<b>3. Water Pollution and Ecosystems</b>	The urban environment is under threat from persistent contaminants like pesticides, polychlorinated biphenyls (PCBs) dioxins, heavy metals and radioactive wastes. Pollutants affect ecosystems in a variety of ways such as acid rain which can act at a system-wide level, disrupting soil acidity and water chemistry - both critical environmental factors that affect the nutrition and physical development of plants and aquatic life. Eutrophication is a problem resulting in oxygen-depleted waters. Innovative technologies provide a means for cleaner production of the uses of water and hence improved water quality in the environment. This thrust will focus on developing protection measures preventing environmental impact from different land-use practices, including the reversibility or not of these impacts; and on supporting development of cost-effective and needed technologies that limit waste emissions within the assimilative capacity of the water environment.
<b>4. Resource Management and Use</b>	Human-induced global environmental change has led to concern about the implications of change in temperature and precipitation on water resources. These impacts are thought likely to have a large impact on water quantity and quality but are poorly understood. Similarly, irresponsible use of water resources can lead to serious pressure on the environment. The value of goods and services associated with the water environment needs to be recognised and resources need to be utilised in a responsible manner. Understanding the loading capacity of environmental systems and the consequences of resource depletion are crucial. Consequently the following issues need to be resolved: Support resource uses that are within the regenerative capacity of the water-related environment; understand the key agents of global change and potential consequences of climate variability and change for water resources; understand cause-and-effect relationships and where the impacts manifest themselves (predictive capabilities); and determine the irreversible impacts such as erosion and aquifer degradation on the water environment.
<b>5. Ecosystem Functioning</b>	Managing ecosystems holistically and sustainably requires a detailed understanding of their function and condition. <b>KSA 2</b> has been established to deal with ecosystem management, utilisation and protection. This crosscutting domain will extend this focus to the terrestrial and atmospheric component of the environment. Better scientific understanding of ecosystem-carrying capacity and threshold for change would greatly benefit management efforts. This thrust will focus on water-related impacts of different scenarios of ecosystem loss (or change) through land use; understanding the environmental components (air, land and water) and their interlinkages through the hydrological cycle, on ecosystem functioning; understanding the impacts of disrupting the hydrological regime (quality and quantity) on ecosystem functioning (specifically through man-made interventions); and developing strategies and means to reduce net impacts of environmental change on ecosystems and water resources.

## Research projects

The findings of projects completed during the year under review are given, as well as a summary of current projects and the motivation and objectives for new projects which commenced between 01 April 2002 and 31 March 2003.

### COMPLETED

#### Thrust 2: Biodiversity Protection and Environmental Functioning

**Cultivation of high-value aquatic plants in restored urban wetlands for income generation in local communities**

Abbott Grobicki (Pty) Ltd  
(WRC Reference No 1054)

##### Rationale

Wetlands are very valuable areas because of the biodiversity of bird life, insects, and wetland plants that they contain. They also offer benefits to our precious water, because they act as filters and are capable of purifying water that flows through them. Yet wetlands in urban areas are under great pressure due to competition for land resulting from poverty, and inadequate infrastructure and services, particularly housing. Wetlands are routinely filled in, and as a result South Africa has lost some 50% of all its wetlands, including the majority of its wetlands in urban areas. As a way to remedy this situation it has been suggested that wetland conservation and rehabilitation would be encouraged, if urban wetlands could be turned into economic assets.

The project aims were as follows:

- To create a stand-alone database with information on plants with economic potential appropriate for cultivation in urban wetlands
- To develop methods to turn urban wetlands into economic assets though the cultivation of economically valuable plants
- To evaluate projects and develop guidelines to select wetlands and optimise their design for urban agricultural activities and wetland rehabilitation
- To evaluate the improvement in water quality in terms of litter control and microbial and nutrient loading as a result of urban wetland horticulture;

- To assess the ecological benefits of urban wetland horticulture schemes
- To assess the economic benefits of urban wetland horticulture schemes to communities and to local authorities, and to evaluate the sustainability of such schemes
- To develop training procedures to assist communities and local authorities in setting up and maintaining wetland horticulture schemes.

##### Approach

The project team from the consulting firm Abbott Grobicki (Pty) Ltd worked closely with the local authorities of the Cape Metropolitan Council and the Tygerberg Administration (now part of the City of Cape Town), using the guidelines which we developed, to assess wetland sites around the Cape Metropolitan Area. Six sites were chosen as suitable for cultivation projects, to grow arum lilies, and the one that was made immediately available was the Khayelitsha site. A private donor then made funds available to set up a pilot project on the site. The team worked closely with local community structures in the area, including SANCO and the RDP, and the pilot project was launched by the then Mayor, Clifford Sithonga, in May 2000.

##### Main results

**Ecological effects:** The immediate ecological benefits of wetland cultivation consisted of cleaning the area of litter, human waste, and alien invasive plants. Cultivation and management of the area prevents new dumping, alien plant growth, and grazing and trampling by domestic stock, which preserves the wetland area from further degradation.

**Economic effects:** Although the Inyibiba Pilot Project did not become economically sustainable in its 12 months of operation, in that time it provided employment and wages to members of a community with high levels of unemployment. It also established an area of 1 ha containing over 36 000 arum lily plants which can be harvested for flowers in future seasons.

**Social effects:** Staff were employed from the local community and trained in all aspects of planting, growing and harvesting arum lilies. Setting up the Inyibiba Pilot Project contributed to the capacity of the local authorities, particularly the Tygerberg Administration and Cape Metropolitan Council, to set up and administer projects such as this.

##### Conclusions

- It is possible to cultivate economically valuable plants at high density in an altered urban wetland, and if growing conditions are optimised then it should be possible for such a project to become a sustainable source of employment and wetland protection.
- Wetland cultivation projects can provide at the very least the ecological benefit of preserving the wetland from further degradation or from settlement, and create an opportunity to rehabilitate the wetland in the future.
- Cultivation of economically valuable plants creates a source of employment and skills development for communities near the wetland. Wetland cultivation projects have the potential to become a focus for other business and entrepreneurial activities in the surrounding communities.
- Thus cultivation of economically valuable plants in wetlands can provide the economic incentives needed to ensure the continued preservation and rehabilitation of wetlands.

##### Expected impacts

- The database of wetland plants is now available to anyone who is interested in starting up a similar project in a wetland. The database is organised by the different climatic regions of South Africa, and contains 68 wetland plants that can be considered for cultivation, together with their uses, and much other valuable information. It has been used by a number of wetland experts, who have approved its contents and agreed that it is a very useful tool. This database can be downloaded from the WRC website at [www.wrc.org](http://www.wrc.org)
- The wetlands of the Cape Metropolitan Area are now being increasingly protected and viewed as potentially valuable resources by the local authorities. Planners are no longer allowed to re-zone wetlands and schedule them for drainage and in-filling.
- The guidelines for setting up a cultivation project in a wetland are also available from the WRC, in a straightforward step-by-step format. They include the necessary authorisations that may be required, and how to assess and evaluate a site. These guidelines have been tested in a real-life situation - however, every situation is different, and every wetland site is unique.
- We hope that people and organisations will find the database and the guidelines to be useful tools, in a bid to save precious wetland areas.

Cost: R550 000  
Term: 1999 - 2002

**Rule-based modelling of riparian vegetation and technology transfer to enable strategic adaptive management of Kruger National Park Rivers**  
*Dept of Botany & CWE, University of the Witwatersrand (WRC Reference No 1063)*

Rivers flowing through the Kruger National Park are expected to change in response to development outside the KNP with consequences in the KNP. This project aimed to address two important questions, firstly, whether the riparian zone would become invaded by terrestrial species, and secondly the transfer of ecological knowledge into the strategic adaptive management (SAM) system through rule-based models (RBM). The two RBMs transferring knowledge into SAM were the *Breonadia* model (to address the Threshold of Probable Concern - TPC - of increased sediment deposition in the river channels) and the terrestrialisation RBM (to address the invasion of the riparian zone by terrestrial species in response to reduced flow in rivers). The *Breonadia* model measures the extent of the negative J-curve of plants recruited to the population, with recruitment only occurring on clean rocky substrate, not on sediment. The *Breonadia* model was tested in the KNP together with the staff of Scientific Services, but the very severe floods of 2000 (predicted by the model to exceed the TPC for four years) put an end to meaningful field testing during the life of this project. However, the response monitored was within the prediction of the RBM for a flood of this magnitude.

The terrestrialisation RBM is based on the proportion of the riparian and terrestrial species at any point in the catena, with colonisation at any point on the catena dependent on the degree of inundation or lack thereof. Four key species were selected, all of which have established seed banks and occur across the macro-channel floor. The two selected to represent the riparian (R) flora are able to survive inundation, and the two selected to represent the terrestrial (T) flora are very sensitive to flooding, so will not establish in areas which have flooded recently. The degree of terrestrialisation is gauged by the T:R ratio.

Cost: R710 500  
Term: 1999 - 2002

### Thrust 3: Water Pollution and Ecosystems

**Development of a guide to assess non-point source pollution of surface water resources in South Africa**  
*Sigma Beta Consulting Engineers and the Department of Water Affairs and Forestry (Institute for Water Quality Studies)*  
(WRC Reference No 696)

Up to fairly recently the efforts to protect the quality of our water resources were concentrated mainly on the control of effluents from point sources. Despite these efforts an apparent deterioration in the water quality of South Africa's surface waters is being observed. It transpired that in many catchments there are zones where non-point (diffuse) source contributions are significant or even dominant. An obstacle for rapid progress with research in this field appeared to be the lack of a conceptual framework which can link together factors such as process understanding, quantification approaches, management needs/options and decision support tools, such as simulation models. Consequently, despite employing state-of-the-art remote sensing and GIS technologies to quantify spatial data related to non-point source areas, certain projects might not fulfil their potential as a result of inappropriate linkages with decision-support procedures that are meaningful to the water resources management and planning environment. Furthermore, consultants and researchers participating in DWAF-funded water quality management studies make use of diverse analysis, predictive and simulation techniques. There is a distinct need to systematically document the preferred and more successful analysis and predictive methods, to integrate individual insights and findings, and to develop an updateable set of estimates of non-point loadings of selected water quality variables in heavily impacted basins. This project aimed at fulfilling these needs.

The scope and complexity of the topic led to the project being conceived in three phases, each of which concluded with the documentation of its outcome.

- **Phase I** was to perform a situation assessment of the current state of knowledge about nonpoint sources and their assessment in South Africa. This is presented in:  
Pegram, GC, Quibell G and Görgens AHM (eds.) (1998) *Non-Point Sources in South Africa: A Situation Assessment*. Project Working Document.
- **Phase II** involved a series of case studies to evaluate and illustrate the application of assessment techniques in South Africa. This is presented in the last report of the project, to be

published as a result of this finalisation report, viz.:  
Quibell, G (ed.) (2000) *Development of a Non-Point Source Assessment Guide: Test case studies*. WRC Report No. 696/2/03.

- **Phase III** was to develop the non-point source Guide itself. This is presented in:  
Pegram, GC and Görgens, AHM (2001) *A Guide to Non-Point Source Assessment to Support Water Quality Management of Surface Water Resources in South Africa*. WRC Report No TT 142/01.
- In addition, the project team was requested to provide input to the *Water Law Review* process, and the policy options for non-point source management in particular: This is presented in:  
Pegram, GC and Görgens, AHM (1999) *Policy Considerations for Non-Point Source Management in South Africa*. WRC Report No 696/1/98.
- Towards the end of the project, the project team was also requested to explore the provisions for non-point source management in the National Water Act. This is presented in:  
DWAF (1999) *A Framework for Implementing Non-Point Source Management Under the National Water Act*. WRC Report No TT 115/99.

Cost: R840 000  
Term: 1995 - 1999

**Quantification of the water balance on rehabilitated mine soils under rain-fed pastures on the Highveld of Mpumalanga**  
*ISCW, ARC*  
(WRC Reference No 798)

After returning the overlying rock and other waste materials to the pit created during open-cast mining methods, an effort is made to reshape the surface topography and rehabilitate the soil to a state approaching its former agricultural usefulness. Water which infiltrates through the rehabilitated surface would mostly replace acid and/or saline water that formed as a result of the oxidation of pyrite present in the backfilled waste material. This project determined the water balance of rehabilitated land under pasture at three sites over three growing seasons, and used the results to calibrate a mathematical model which can be used to make long-term water balance predictions. It formed part of a number of complementary projects which were conducted by the Agricultural Research Council on behalf of the National Department of Agriculture to investigate problems identified by the Van Niekerk investigation into the effects that high coal extraction practices have on agriculture. High bulk density, coupled with hard-setting behaviour, was found to be a

widespread phenomenon in replaced cover soils, and probably the number one problem affecting land use. Soil profiles typically had only a moderate plant-available water-holding capacity, while the actual profile-extractable water capacity was further reduced by poor root distribution. This limited yield even when fertilisation levels were aimed at relatively high production levels. Measurements of runoff were somewhat inconclusive, but suggest that runoff does not exceed 10% of the annual rainfall and can be as low as 2 or 3%. The generally high density of the lower cover soils and upper spoil appears to restrict deep percolation, except where water accumulates due to lateral drainage and where settling cracks occur.

Cost: R387 077 (WRC), R491 400 (NDA),  
R330 200 (ARC)  
Term: 1997 - 2001

**Influence of irrigation with gypsiferous mine-water on soil properties and drainage water in Mpumalanga**  
*Chamber of Mines of South Africa*  
(WRC Reference No 858)

Huge quantities of acid mine drainage are being produced as a result of mining activities. These waters are mostly neutralised, either inadvertently, as a result of seepage through neutralising geological strata, or artificially, by the addition of lime. Mine drainage is, therefore, often saturated with gypsum. When released into the surface water environment, their high salinities are mostly responsible for unacceptable water quality degradation. On the other hand, irrigation provides for a novel approach to the utilisation and disposal of gypsum-rich water as demonstrated in an earlier WRC project (No 582). Irrigation of neutralised acid mine-water holds promise to significantly reduce the salt load emanating from mine drainage while at the same time extracting value from water that would otherwise be a polluting agent. This project aimed to ascertain on a semi-operational scale whether gypsiferous mine-water can be used sustainably on a commercial basis for the irrigation of crops and precipitation of a considerable portion of the applied salt (as gypsum) within the soil profile.

A field trial was set up at Kleinkopje Colliery from the summer season of 1997 until and including the winter of 2000, where several crops were irrigated with centre pivots using two mine-waters. Three different irrigation management practices were adopted for each pivot: irrigation with a leaching fraction, irrigation up to field capacity and deficit irrigation (room for rain). The trials were intensively monitored for plant growth, yield, potential plant nutritional deficiencies and data sets

obtained for validating the crop growth subroutine of the SWB model. Further measurements that were made to (*inter alia*) validate aspects of the SWB model, include soil physical characteristics, weather data and soil water and salt balances. Soil chemical changes as a result of irrigation with the gypsiferous water were monitored both within and below the root zone, while groundwater quality was monitored to determine possible leaching of salts to groundwater. Plant nutritional aspects were further investigated in a glasshouse trial. The SWB model was adapted for long-term predictions and linked to a groundwater model to predict the likely long-term effect that irrigation with gypsiferous water could have on soil properties and groundwater pollution.

Crop yields were generally high and commercially attractive except in the case where water-logging developed on rehabilitated land as a result of subsidence. No negative effects on crop growth or nutrition which could be linked to irrigation were observed. In soils with restricted drainage, salts were confined to the upper 1m, while a slight peak was observed at about 1.8m on well-drained soils. After 3 years a slight increase in only nitrate concentration was observed in some boreholes monitoring groundwater. The fact that the SWB model predicted crop growth, water and salt distribution quite well, gave confidence in its long-term predictive ability. Excellent agreement was, furthermore, obtained between the salt predictions of SWB and an FAO version of UNSATCHEM. Long-term predictions indicated that almost half the salt in the irrigation water could be retained in the soil under deficit irrigation vs. 35% under a leaching strategy.

This project thus demonstrated that irrigation with gypsiferous acid mine-water can be successfully managed on a semi-operational scale. The practice was found to be commercially viable, and present indications are that it is sustainable from a crop production and soil perspective, while a large percentage of the applied salt can be retained within the soil profile. However, because of the long-term implications that large-scale implementation of the practice may have, it is deemed necessary to continue monitoring for a longer period and also to expand the range of soils and waters that are being tested.

Cost: R1 307 000  
Term: 1997 - 2001

### Evaluation of predictive models for pesticide behaviour in South African soils

PPRI, ARC  
(WRC Reference No 999)

Newly developed pesticides rely on microbial activity for their degradation. South African soils that generally have a low organic matter content thus provide conditions which are conducive to prolonged persistence of a pesticide. This project aimed to evaluate existing computer-based mathematical models for their efficiency and applicability to predict pesticide behaviour under local conditions. The intention was to identify and recommend the most suitable model for use by pesticide registration authorities. It was anticipated that this would reduce the risk of pesticide contamination of ground- and surface waters from pesticide application.

The study was conducted on three field soils, representing a sandy loam, a sandy clay loam and a clay soil. The pesticides were selected to represent a range of chemical characteristics with regards to their published persistence and soil mobility. The herbicides tebuthiuron and azafenidin and the insecticide fenthion were selected. Parameters required by models, such as the half-life and adsorption characteristics of the pesticides, were determined for the selected soils. The adsorption coefficients for fenthion indicated that adsorption will decrease with soil depth. Although  $K_{oc}$  values were highest on the clay soil,  $K_{oc}$  values were all higher than 100, indicative of limited mobility.  $K_{oc}$  values furthermore indicated that the oil-based formulation of fenthion is more mobile than the emulsifiable concentrate. The adsorption of azafenidin was similar for all soil depths and types, which implies that it will have similar leaching characteristic in all three soils. Similar results were obtained for tebuthiuron. Half-life determinations were highly variable. Those for fenthion and azafenidin were similar for the loamy soils, but significantly higher on the clay soil. The 4 to 7 day half-life for fenthion is longer than the published and accepted value of 1 day. The half-life for tebuthiuron was found to be in excess of 500 days for all soils, which is longer than the generally accepted published value of 365 days. The half-lives determined for azafenidin fell within the published range of 10 to 45 days.

Field leaching studies indicated that all three the compounds leached with ease in all three soils. During the first part of the trial period, the two loamy soils displayed similar leaching patterns for tebuthiuron, but during the latter part, the two clayey soils were more similar. There were indications of build-up in the deeper soil layers and a possibility of leaching past the deepest sampled layer at 120 cm. Fenthion was highly mobile in

all three soils. This involved not only leaching, but also upward movement in response to evaporation. Fenthion appeared to have a short residence time in all three the soils, probably as a result of its rapid degradation. The leaching patterns in the two loamy soils were similar for azafenidin during the first part of the trial period, although more leaching occurred in the sandy clay loam soil. However, after 30 days the patterns of the clay and sandy loam soils were more similar.

Linear regression analysis was performed on the observed (measured) data vs. model-predicted concentrations. Model predictions started to deviate from the observed values soon after the start of the experiment, partly because none of the three models tested provided for upward movement of compounds. The Pelmo model was insensitive to change in degradation rate and predicted only limited leaching in all three soils. Although it only allows for homogeneous soil profiles and tends to over-predict pesticide concentrations in especially the deeper layers, Prestan was the only model that predicted the observed leaching with some success. It should prove useful to predict the worst-case scenario regarding the leaching potential of pesticides at a screening level.

Cost: R357 000  
Term: 1999-2001

### A guideline for the development of rehabilitation management strategies for reclaimed gold-mine dump sites in South Africa

Pulles, Howard & De Lange  
(WRC Reference No 1001)

An earlier preliminary assessment of pollution contained in the unsaturated and saturated zones beneath reclaimed gold-mine dumps, indicated that this pollution can have a significant negative environmental impact on the underlying vadose zone and subsequently the groundwater system. This study identified five alternative rehabilitation strategies to deal with this pollution and modelled their expected impact at three study sites. The strategies were found to represent mainly two opposing alternatives, i.e. those that result in the pollutant remaining within the confines of the residue deposit area, and those in which the pollutants are transported to the deeper aquifer, away from the source. The preferred management option would thus depend on whether containment or dilution and migration of pollutants would be the desired option. The problems associated with reclaimed mine residue deposits were also assessed by evaluating the various risks that are associated with the source of contamination, the pathway it would follow and the receptor that would be

adversely affected by the contaminated substance. Site-specific variation in physical characteristics was found to have a marked influence on the resultant risk assigned to individual aspects. The introduction of a risk assessment approach, a phased and chemically orientated approach to site investigation, and the selection of remediating strategies from a number of technologies, were identified as intrinsic components of the rehabilitation process. This would require that rehabilitation be conducted on a site-specific basis. The basic methodology for this approach is outlined in a companion document to the project report.

Cost: R959 000  
Term: 1999 - 2001

### Tier 1 risk assessment of radionuclides in selected sediments of the Mooi River

Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 1095)

An investigation into the fate of radioactive metal releases into the Mooi River conducted by DWAF, indicated that the radionuclides in the water column dissipate with distance from the source - presumably because the radionuclides bind to sediments. The implication is that large quantities of radionuclides which have been removed from the water phase in this way, may be remobilised under a different set of conditions. It is important to know under which conditions these radionuclides may be remobilised, and if this occurs, how much of a risk to human health they may pose.

The Mooi River catchment has received the impacts from mining operations for more than 60 years. The river of interest is the stream called the Mooi River Loop and the Wonderfontein Spruit. This stream provides input into the Boskop Dam, from which the town of Potchefstroom derives its drinking water.

The aims with of this project were:

- Determination of the concentrations of selected radionuclides ( $^{238}\text{U}$ ,  $^{235}\text{U}$ ,  $^{234}\text{U}$ ,  $^{223}\text{Ra}$ ,  $^{232}\text{Th}$ ,  $^{210}\text{Pb}$  and  $^{210}\text{Po}$ ) in the sediments of the Mooi River at three sites.
- Determination of the risk represented by the radionuclides in the Mooi River sediments to man

In all of the scenarios, modelled by chemical equilibrium modelling, there was the possibility of uranium being solubilised by environmental processes that fall within the bounds of reason. The scenario under which uranium is least likely to be mobilised is that of strongly

reducing environmental conditions. The scenario under which uranium is most likely to be solubilised is that of high oxidation potential and low-to-intermediate pH. This scenario is likely if the sediments of an impoundment are exposed by drainage, or by dredging operations. Increased oxidation potential automatically enhances the potential for low pH conditions. Thorium is expected to remain in the chemically inert fraction, and transport of thorium is most likely to be as a particulate with comparatively limited migration potential.

In all of the sediments tested, uranium was mobilised during sequential chemical extraction, by reaction with a weak acid. Uranium was also mobilised by both an increase in oxidation potential, and by a decrease in oxidation potential. There is evidence that uranium is transported in a soluble form along the length of the Wonderfontein Spruit and the Mooi River Loop.

It was concluded that:

- Radionuclides do accumulate in the sediments of the Mooi River catchment
- The main radionuclide of interest, being uranium, seems to be adsorbed to the environmental phases: Carbonate, iron and manganese oxyhydroxides, and organics (with a slight possibility of being included in sulphur components)
- Uranium may be remobilised into the water column by perturbation of TDS, pH and oxidation potential
- Because they had  $^{238}\text{U}$ -levels higher than the Nuclear Energy Act stipulation, six of the study sites had a positive Tier I Risk Quotient.

Cost: R115 000  
Term: 1999 - 2000

### A survey and preliminary investigation into biodegradation of pesticide wastes

Pollution Research Group, University of Natal  
(WRC Reference No 1128)

This desk study reviewed pesticide use and waste generation in Southern Africa, and existing technologies for their disposal, from local and international information and consultation with interested and affected parties including suppliers, users, regulators and environmental lobbies. The report includes: A general overview of pesticides; a brief review of their toxicological and hazard classification; a survey of local pesticide producers, distributors and users; pesticide use by category in the RSA; a status review of obsolete pesticide stocks in Southern Africa 1997-2000; some

options for reducing pesticide use or minimising the dangers posed; a schedule of local suppliers; and a world-wide survey of technologies available for disposing of pesticide residues and remediating contaminated soil and groundwater sites.

Pesticide sales figures (1994-1998) indicate that *per capita* use in Africa is predictably lower than in Europe and the USA but that South Africa is a leading user in Africa. The agricultural and forestry sectors are major users in pesticide categories covering insecticides, herbicides, fungicides, nematocides, ascaricides, and plant growth regulants. Little or no information could be obtained regarding use by the government sector. Existing technologies for treatment and disposal include thermal, chemical, physical and biological methods, but all are expensive and require expert management. Remediation of pesticide-contaminated soil or groundwater is particularly slow and costly.

An integrated hazardous waste disposal approach covering policy and practice is therefore strongly indicated. The report details recommendations encompassing legislation (adequate, but requires more capability for controlled enforcement without placing undue costs on the manufacturer/supplier and/or the user and thereby potentially threatening food security), cleaner production preventative techniques (e.g. education, training, regulation and monitoring; promotion of integrated pest management; incentive schemes for reducing pesticide use; stringent monitoring programmes; etc, the provision of appropriate treatment and disposal facilities for existing and residual pesticide wastes (e.g. 'best available technology' facilities on a user-pays basis, responsibly controlled by the manufacturer, end-user and/or government, and clean-up technology (e.g. bioremediation expertise being made accessible for decontaminating soil and groundwater sites).

Cost: R114 000  
Term: 2000

### Thrust 4: Resource Management and Use

**The importance and role of water resources in the environment - A training course for social facilitators**  
*Institute for Water Research, Rhodes University*  
(WRC Reference No. 1180)

Social facilitators are used extensively in rural upliftment programmes, but they usually have limited understanding of the environment. This means that they

are unable to adequately educate rural communities about limited water resources. The aim of this project was to develop material for use in courses to train people in this position to be able to carry the correct message to communities. This in turn would enable the communities to participate in processes such as are required by catchment management agencies in the management of the resource.

The booklet produced, which was distributed at the DWAF-run workshops on the National Water Resources Strategy, addresses the interface between people and the various aspects of water resource management in a simple way which has been shown to be effective. It begins with a short section on the water law, then addresses the goods and services provided by rivers to people. Further chapters deal with river health and water in the environment, and the final section exhorts people to become involved in water resource management at their own levels, especially locally.

Cost: R68 000  
Term: 2000 - 2001

## CURRENT

### Thrust 2: Biodiversity Protection and Environmental Functioning

**Use of grass species for rehabilitation after wattle control**  
*Agricultural Research Council (ARC)*  
(WRC Reference No 1016)

The Working for Water Programme removes alien vegetation from riparian zones. This leaves many river-banks vulnerable to erosion and this project develops guidelines for the establishment of a suitable grass cover after wattle removal. The WRC is a co-funder of the project, together with the National Department of Agriculture and the SA Wattle Growers Union. This project is linked to **Water-Linked Ecosystems**.

Estimated cost: R214 000  
Expected term: 1999 - 2002

**Rule-based modelling of fish: Facilitating strategic adaptive management of the Kruger National Park Rivers through model development and technology transfer**  
*Institute for Water Research, Rhodes University*  
(WRC Reference No 1065)

A management model based on fish was developed for the country's East-flowing rivers early in the 1990s, but not along the lines of strategic adaptive management (SAM), the highly effective and currently accepted method. This project specifically aims to express the problems surrounding fish biodiversity within the context of SAM, and develop appropriate thresholds of probable concern to inform the process. This project is developing a technology transfer product

Estimated cost: R552 000  
Expected term: 1999 - 2003

**Use of isotope (13C) techniques to define the riparian zone in commercially afforested catchments**  
*Environmentek, CSIR*  
(WRC Reference No 1218)

Trees growing in riparian zones have continuous and free access to water. Because they are not restricted in their use of water, they make a disproportionate contribution to streamflow reduction. As a matter of policy, afforestation in riparian zones is therefore prohibited. A major difficulty, however, in implementing what is a sound policy, is the problem of delineating riparian zones. In this project, an isotopic (<sup>13</sup>C) technique is being investigated for riparian zone delineation.

Estimated cost: R200 000  
Expected term: 2001 - 2002

**Improving the basis for predicting evapotranspiration from dry-land crops and veld types in South African hydrological models**  
*Environmentek, CSIR*  
(WRC Reference No 1219)

Evapotranspiration or "green water" represents between 50 and 99% of our natural water balance in South Africa. Hydrology, rain-fed agriculture and irrigation have in the past followed somewhat different methods to estimate evapotranspiration of plants and plant covers. This project aims at building a common base from which the integration of various catchment management activities (afforestation; wetland rehabilitation and alien vegetation control) can be quantitatively understood and prioritised.

Estimated cost: R530 600  
Expected term: 2001 - 2004

### Thrust 3: Water Pollution and Ecosystems

**The impact of urbanisation and industrialisation on the environment**  
*Department of Chemistry (Mamelodi Campus), Vista University*  
(WRC Reference No 717)

Increase in urbanisation results in a dramatic increase in industrial and domestic waste. Of major concern is the generation of toxic chemicals and heavy metals. This study aims to investigate the occurrence of polynuclear aromatic hydrocarbons (PAHs) as an indicator of pollution of urban water catchments. PAHs are potentially carcinogenic and the outputs will provide information on a subject area lacking knowledge.

Estimated cost: R380 000  
Expected term: 1996 - 1997

**Reduction of urban litter in drainage systems through integrated catchment management**  
*Department of Civil Engineering, University of Cape Town*  
(WRC Reference No 1051)

In **Volume 1** of the final report (Report No 691/1/98) on the project entitled **The removal of urban litter from stormwater conduits and streams**, reference is made to the dearth of information on litter wash-off rates in urban areas, and the need to reduce the quantity of litter that finds its way into stormwater drainage systems. In addition to amounts, more detailed information is required, not only on the source and types of litter encountered in urban catchments, but also on the efficiency of various catchment management techniques to ensure a reduction in urban litter reaching drainage systems.

Further research in the above regard was strongly supported at a workshop in March 1998. In 1991 it was estimated that 780 000t of litter annually enter drainage systems in South Africa, and at a current removal cost of approximately R1 000/m<sup>3</sup>, it amounts to a total annual cost of R780m. Ways to reduce litter loadings through better management are, therefore, urgently required - not only from a cost point of view, but also as far as its negative impact on the environment is concerned.

This project will be focusing on the above-mentioned needs, and has the potential to drastically reduce urban

litter pollution in streams, resulting in considerable cost savings to local authorities.

Against this background the project addresses the following aims:

- To improve the knowledge of the source, type and amount of urban litter coming from different types of urban catchments
- To provide scientific data on the efficacy of various management techniques in reducing the amount of urban litter reaching drainage systems. This information, together with that of the first aim, would enable the development of Litter Management Plans (LMPs) resulting in reduced litter loadings and realising considerable cost savings.

The project will be executed in partnership with the Cape Metropolitan Council which will be contributing to installation costs of the various litter-removal structures.

*Estimated cost:* R690 000  
*Expected term:* 1999 - 2002

#### **The assessment of short-, medium- and long-term impacts on groundwater quality associated with the filling of dolomite cavities**

*Metago Environmental Eng*  
*(WRC Reference No 1122)*

De-watering of the dolomitic aquifers overlying ore bearing reefs has, since the 1960s, resulted in the formation of large numbers of cavities in the dolomitic compartments on the West Rand. Some of these cavities have in the past been filled with, inter alia, various mine waste materials including slimes and waste rock. The State Technical Committee for Sinkholes had raised the alarm about the potential for groundwater contamination as a result of this practice. Filling of cavities is necessary for safety reasons as well as to prevent further inflows of surface water. Slimes material is the most economical material which is available for filling cavities and until its impact is proven to be harmful or irreversible, the State cannot intervene to prevent this practice. This investigation focused both on the impacts arising from the future filling of cavities as well as an assessment of the effectiveness of alternative fill materials

*Estimated cost:* R440 000  
*Expected term:* 2000 - 2002

#### **Design and development of an implementation plan for a national eutrophication monitoring programme for South Africa's water resources**

*Environmentek, CSIR*  
*(WRC Reference No 1147)*

Under the National Water Act, DWAF is required to establish national monitoring networks to collect relevant information on the quality of water resources. The Minister is required to provide guidelines, procedures, standards and methods for monitoring water quality. Data have to be stored in a National Information System where they can be used for the development and implementation of the National Water Resource Strategy and Catchment Management Strategies. This project is providing the required technical and scientific support to design and implement a National Eutrophication Monitoring Programme. It will dovetail with other networks, such as the National Rivers and Reservoir Water Quality Monitoring Network, the National Microbiological Monitoring Programme and the National River Health Programme.

*Estimated cost:* R724 000  
*Expected term:* 2001 - 2002

#### **Development of guidelines for the disposal of water treatment sludges to land**

*School of Applied Environmental Sciences, University of Natal*  
*(WRC Reference No 1148)*

South Africa's turbid waters give rise to the production of huge quantities of sludge during the water treatment process. Chemical precipitants are added to the turbid waters to promote flocculation. Once flocculated, the solid fraction that settles under gravity is transferred to drying beds, while the supernatant is filtered and clarified for domestic consumption. The dewatered solids (sludges) are regarded as industrial wastes and must be disposed of accordingly. The traditional method of sludge disposal has been by landfilling, but given the economic constraints associated with landfill maintenance, alternative methods of sludge disposal have to be considered. A disposal option that is gaining increased acceptance internationally is the application of sludge directly onto land. Land disposal is based upon the fundamental tenet that the physical, chemical and biological properties of the soil can be used to digest the applied waste without inducing negative effects on soil quality, groundwater or plant growth. Sludge could have two opposing physical effects on soils, viz. the polyelectrolyte could improve soil structure, or the fine silt and clay could lead to structural degradation.

Chemically, the behaviour of heavy metals and the high phosphorus-fixing ability of the sludge also give rise for concern. These concerns will be evaluated as part of this project.

*Estimated cost:* R650 000  
*Expected term:* 2000 - 2003

#### **Predicting the environmental impact and sustainability of irrigation within gypsiferous mine-water**

*Coalttech 2020*  
*(WRC Reference No 1149)*

The coalfields in the Highveld of Mpumalanga generate significant quantities of surplus neutralised acid mine-water which is gypsiferous in nature. Because of their high salinity these waters cannot be freely discharged to river systems. However, irrigation with these waters holds much promise to significantly reduce the salt load emanating from mine drainage, while at the same time extracting value from water which would otherwise be a polluting agent. An initial rough estimate is that up to 10 000 ha of land could potentially be irrigated with coal-mine-waters in the Mpumalanga Highveld. This project is building on successful previous and current field-scale research using gypsiferous water for irrigation, by addressing the following aims:

- Determine the impact of several gypsiferous water/soil combinations on soil conditions and groundwater quality.
- Further develop and refine the soil-water-balance model for use in predicting gypsum precipitation, crop response, water quality and water balance.
- Predict the likely long-term impact of gypsiferous irrigation waters on the groundwater system.
- Determine whether these waters can be used to produce crops on a commercial basis.
- Evaluate the sustainability of irrigation with gypsiferous water

*Estimated cost:* R1 530 000  
*Expected term:* 2000 - 2003

#### **Water-related impacts of small-scale mining: Nature of the impact and development of management options**

*Pulles, Howard & de Lange*  
*(WRC Reference No 1150)*

Small-scale mining already takes place widely in South Africa. The White Paper on Mineral Development in South Africa, identifies small-scale mining as an important sector of the mining industry. The interests of the country and the community, however, require that all forms of mining, whether large-, small- or micro-scale, should be subject to the same requirements in respect of

licensing, safety, health and the environment. It is also the view of Government that small-scale mining, like the rest of the mining industry, will be required to adopt measures that will promote environmental sustainability by means of the application of consistent standards and acceptance of the concept. This project has identified and characterised the critical water-related impacts of small-scale mining and is developing appropriate tools to assist in their environmental management. The project has focused primarily on the water-related issues of peat extraction, clay-mining for brick making, alluvial diamond mining and other small-scale mining activities associated with gravels, alluvial sands and sediments.

*Expected cost:* R738 000  
*Estimated term:* 2000 - 2002

#### **An evaluation of dedicated land-disposal practices for sewage sludge**

*Institute for Soil, Climate and Water, ARC*  
*(WRC Reference No 1209)*

Most sewage sludge produced in the RSA is presently disposed of on dedicated (i.e. sacrificial) land. It is the least expensive of the available alternatives, but has several undesirable environmental consequences and is, furthermore, not viewed as sustainable.

The objectives of this project are to:

- evaluate the extent of the current practice
- evaluate the potential risk the practice poses to the water environment at selected sites covering the range of climatic and other conditions
- estimate the potential future impact of dedicated land disposal of sewage sludge on the water environment.

*Estimated cost:* R959 000  
*Expected term:* 2001 - 2004

#### **Laboratory- and field scale evaluation of agricultural use of sewage sludge**

*ERWAT, Research and Development*  
*(WRC Reference No 1210)*

The agricultural use of sewage sludge is a promising alternative use / disposal route for this product over the short to medium term, but several concerns currently restrict large-scale implementation. This project being carried out by a multidisciplinary team comprising researchers from ERWAT, ARC and the University of Pretoria is a laboratory- and field-scale evaluation of the agricultural use of sewage sludge to establish the:

- extent of metal uptake in different (winter and

- summer) crops grown on soils amended with sewage sludge;
- effect of soil properties on the mobility of nutrients and metals; safe sludge loadings to prevent nitrogen leaching to groundwater;
- persistence of sludge-borne pathogens during agricultural application;
- perceptions of farmers, commercial markets and urban and rural communities with regard to the beneficial use of sewage sludge for edible crops.

Estimated cost: R570 900  
 Expected term: 2001 - 2003

#### Development of an appropriate procedure for the closure of deep underground gold mines

Pulles, Howard & De Lange  
 (WRC Reference No 1215)

There are a number of regions within South Africa where large-scale cessation of mining activities at deep underground gold mines has occurred and can be expected to continue to occur in future. Although these mines pose long-term threats to the surrounding ground-and surface-water environment, there is currently no clear procedure that can be applied to successfully close these mines. Contributing reasons for this are that adjacent mines are mostly hydraulically interconnected, making it difficult to apportion responsibility for water volumes and contaminant loads. Mines are, furthermore, often partially flooded, making it difficult to collect certain data and to apply certain pollution prevention measures. There is also uncertainty regarding assessment procedures that should or could be applied to assess the long-term problems and to evaluate alternative management strategies. The premise of this project is, therefore, that the closure of gold mines should be planned and evaluated on a regional and not on a mine-by-mine basis, unless a mine can clearly and unequivocally prove that it is hydrologically and geohydrologically isolated from all other surrounding mines. This necessitates the development of strategies that encompass and enforce the principle of regional co-operation between mines - a concept that has implications for mine environmental planning and management (EMPRs) and closure. This project therefore aims to develop an appropriate and agreed procedure that will enable mines to plan and implement closure in a responsible manner and in a way agreed to by all stakeholders.

Estimated cost: R503 800  
 Expected term: 2001 - 2003

#### A life-cycle assessment of a secondary water supply

Department of Chemical Engineering, University of Natal, Durban  
 (WRC Reference No 1252)

Life-cycle assessment (LCA) methodology provides a holistic basis for policy-making and decision-taking. In this project, previous work carried out into developing a customised RSA database for various industrial processing activities is being applied to investigate a rational (LCA) approach to options for water supply and wastewater disposal in a coastal RSA city, using Durban as the case study. LCA comparisons are being made of the environmental trade-offs involved in providing secondary (reclaimed) wastewater rather than potable water to industry for processing purposes, and the treatment of wastewater at conventional land-based sewage treatment works as opposed to direct marine disposal.

Estimated cost: R1 239 000  
 Expected term: 2001 - 2004

### Thrust 4: Resource Management and Use

#### Sediment-induced density current formation in reservoirs

Department of Civil Engineering, University of Pretoria  
 (WRC Reference No 911)

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 - 1999

#### Aerosols, recirculation and rainfall experiment

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

Through a programme of airborne sampling various seasonal and atmospheric chemical and microphysical data have been collected which are now being analysed with a view to establishing whether transport and recirculation of long-lived, fine-fraction atmospheric aerosols, over South Africa and adjacent areas, may create conditions favouring a long-term diminution of rainfall over the region.

Estimated cost: R1 390 000  
 Expected term: 1998 - 2002

#### Oceans' role in SA rainfall

Department of Oceanography, University of Cape Town  
 (WRC Reference No 953)

The investigation of ocean processes impacting on South Africa's rainfall is being assisted through development of satellite-remote-sensing methodologies, firstly to observe, study and monitor the hydrological cycle from ocean evaporation to advection of water vapour over South Africa and secondly to further elucidate mechanisms causing sea surface temperature (SST) variability in those regions where SST anomalies are linked to drought in South Africa.

Estimated cost: R1 395 000  
 Expected term: 1998 - 2002

#### Climatology of water vapour sources, sinks, and transport in the atmosphere over Southern Africa, and evaluation of GCM and regional model skill in simulating the moisture characteristics

Department of Environmental and Geographical Sciences, University of Cape Town  
 (WRC Reference No 1012)

To be relevant and useful within the context of climate forecasting, atmospheric models have to be able to accurately represent (simulate) flows of water vapour over Southern Africa. This project uses all available data and especially developed trajectory models to establish a unique and important climatology of water vapour sources, sinks and pathways which will be used to further elucidate rainfall processes over Southern Africa and to serve as a diagnostic frame of reference for analysing the performance of regional atmospheric models.

Estimated cost: R562 000  
 Expected term: 1999 - 2003

#### Reconstruction of long-term, high-resolution records of summer rainfall and its variability in South Africa from cave speleothems

Department of Archaeology, University of Cape Town  
 (WRC Reference No 1013)

As a further contribution to climatic record reconstruction, cave speleothems in the Northern Province have been sampled and are being analysed in order to establish long-term changes in moisture availability, temperature, rainfall and vegetation responses. Unprecedented temporal resolution (subdecadal or 5-year time scales) appears achievable using this technique.

Estimated cost: R375 000  
 Expected term: 1999 - 2002

#### Predicting the impact of farming systems on sediment yields in context of integrated catchment management

Institute for Soil, Climate and Water, ARC  
 (WRC Reference No 1059)

Erosion and sediment delivery is one of the major land-use impacts in South Africa. The WEPP model was developed in the SA and this project is testing the model against field observation data in several trial areas both in commercial and traditional farming systems. The adequacy of the required input data is being evaluated for South African conditions. If successful the model can make a major contribution in better land-use management to curtail erosion losses.

Estimated cost: R843 000  
 Expected term: 1999 - 2003

### Hydraulics of the impacts of dam development on the river morphology

Dept of Civil Engineering, University of Stellenbosch  
(WRC Reference No 1102)

Utilisation of a man-made structure, such as a dam, is very often unavoidable in water-source developments. The impact of the dam is that it alters the river flow regime and with it the sediment transport characteristics, thereby resulting in changes in the river morphology and the river's conveyance capacity.

Both of these factors affect the aquatic habitat of the river. Under regulated flow conditions as a result of a dam, removal of fine sediment through flushing flows does not occur - flows that are very important for the maintenance of several characteristics of the river channel. Flushing flows, one of the facets of in-stream flow requirements (IFRs), has up to now not received adequate attention from a fundamental hydraulics point of view.

Flushing flows are important for a number of reasons. In addition to maintaining a suitable fishery habitat, maintenance of channel geometry and riparian vegetation, formation of pool areas and retention of adequate habitat heterogeneity, are all dependent on the occurrence of flushing flows of the required intensity and frequency. Current methodologies for the determination of the IFR of a river do not fully utilise acceptable hydrodynamic approaches based on sound theory of sediment transport.

The main objective of this project is thus to obtain a better understanding of the river sediment transport processes and the impacts of dam construction thereon. From this will emanate a methodology for determining flushing flow magnitudes, duration and frequency, thus ensuring maintenance or restoration of river morphology as close as possible to natural or desired conditions. In this regard fundamental hydraulic principles of sediment transport will play a very important role.

This project also emanates from the Workshop on Research Needs in the Field of Hydraulics which took place in March 1998. This workshop identified, *inter alia*, flushing flow IFR, river morphology, river restoration, sediment "management" and computational hydraulics as high priorities in hydraulics research.

Estimated cost: R660 000  
Expected term: 1999 - 2002

**The dynamic modelling of present and future climate system variability at inter-annual and inter-decadal time scales**

Department of Environmental and Geographical Sciences, University of Cape Town  
(WRC Reference No 1154)

Outputs from general atmospheric circulation or global climate models must be "downscaled" before results can be meaningful for prediction of impacts of climate change at regional or catchment scale. This project continues to investigate, and build capacity in the nested use of global and regional-scale dynamic atmospheric models for downscaling purposes in order to complement and refine empirical techniques already developed and in use. It does not attempt to refine regional models, developed overseas, for South African conditions.

Estimated cost: R1 655 000  
Expected term: 2000 - 2004

### Dealing with estuarine sedimentation assessment of the hydraulics of estuarine sediment transport processes and the development of water reserve management guidelines

Department of Civil Engineering, University of Stellenbosch  
(WRC Reference No 1257)

River flow reduction resulting from increasing abstraction combined with the increased erosion caused by unsustainable veld management, has negatively impacted on the sediment transport dynamics in estuaries. This results in both an increase in the accumulation of fine sand derived sediments, which are often cohesive, as well as an ingress of marine sediments which may or may not result in mouth closure. The accumulation of sediments in estuaries has negative economic impacts for the region (commercial fishing and recreation), as well as negative impacts for ecosystem stability (reduction of habitat by sediment accumulation and reduced tidal prism). The cohesiveness of the fine sediments makes this trend effectively irreversible, as they do not erode at all easily.

This project aims to generate knowledge on the sediment transport and flushing processes of estuaries, and then to develop guidelines on how to manage the ecological Reserve of the estuaries to ensure the maintenance of a long-term equilibrium.

Estimated cost: R950 500  
Expected term: 2001 - 2004

### Regional model development for simulating atmospheric behaviour and rainfall over Southern Africa

Department of Earth Sciences, University of Pretoria  
(WRC Reference No 1261)

There is an increasing demand by hydrologists, the agricultural community, disaster managers and the public for more accurate spatial projections of anomalous rainfall. The complex distribution of surface characteristics over Southern Africa such as topography, coastlines, inland water bodies and vegetation, induces atmospheric circulation and rainfall patterns unique to the region. To better simulate local circulation patterns and rainfall over the Southern African region, it is necessary to develop or adapt a regional atmospheric model to suitably capture the unique surface characteristics of the region. An issue as important as the development of a regional atmospheric model for Southern Africa, is the broadening of the skills base needed for continuous refinement and use of such models. It is intended to use this project to create opportunities for interested scientists and students from various institutions to familiarise themselves with atmospheric modelling concepts and practices.

The aims of this project, therefore, are to:

- Modify the dynamical formulation and physical parameterisation schemes of an internationally competitive regional atmospheric circulation model (DARLAM from Australia) in order to improve the simulation of water-related atmospheric variables over Southern Africa.
- Equip scientists and prospective students from the Southern African community with the necessary knowledge and skills to develop, maintain and use such regional atmospheric models.

Estimated cost: R678 000  
Expected term: 2001 - 2004

## NEW

### Thrust 2: Biodiversity Protection and Environmental Functioning

**Development of a system of simplified methods of vegetation water use based on the principle of limits to evapotranspiration**

Division of Water, Environment and Forestry Technology, CSIR, Stellenbosch  
(WRC Reference No 1319)

Water resource managers will increasingly need to assess whether proposed changes in land use within catchments are likely to significantly reduce the quantity and temporal availability of water to downstream users. Such decisions need to be based on the relative annual (and perhaps seasonal) water use of the existing and proposed new crops or vegetation. The National Water Act makes provision for declaring certain land-covers (crops) as SFRAs (e.g commercial afforestation) but it is likely that other land-cover changes may also have a significant impact in some situations. The principle of limits to evapotranspiration will allow for the limiting factors to be identified in particular situations and thus for a screening of land-cover changes based on the likely impacts. It could also provide a useful framework for interpreting the impacts of regional climate change in South African situations

The aim of this project is to develop a framework of understanding about the major controls of evapotranspiration in different types of vegetation and crops in South Africa. This work will lead to:

- A better understanding of when a change in land-cover may have a significant impact on surface water yields from a land parcel
- Recommendations for simple models to use in assessing these impacts, easing the task of simulating water use in the wide variety of vegetation, both indigenous and alien, existing in South Africa.

Estimated cost: R1 013 000  
Expected term: 2002 - 2005

**An investigation into the impact of landfill leachate on the physical, chemical and microbiological quality of the Soutpan Stream and its immediate surroundings**  
Department of Chemistry, Technikon Northern Gauteng  
(WRC Reference No 1341)

The Soutpan Stream runs past a very poorly managed landfill site which serves the local Soshanguve community. The landfill is used for dumping of domestic and industrial wastes. Visible leachate is observed on a regular basis running into the Soutpan Stream. The Soutpan Stream serves a huge informal settlement as sole water source and thus presents a health hazard. The community uses the water for household practices, gardening and for animals to drink.

This project aims to improve the situation and make the water and the landfill practices acceptable according to set guidelines. This will serve as an upliftment project for the community as we will make use of their experience and knowledge.

The research aims to:

- Conduct an environmental inventory and audit of the study area
- Obtain information on how the landfill site is managed, the hydrogeological conditions, attenuating factors, weather patterns, volume and type of waste dumped, the volume and characteristics of leachate produced
- Investigate the direct and indirect physical, chemical and microbiological impacts and consequences over a defined range of temporal and spatial scales of the leachate generated at the poorly managed landfill site on the Soutpan Stream and its immediate surroundings
- Suggest measures which will help to minimise any adverse impacts on the environment and human health

*Estimated cost:* R386 000  
*Expected term:* 2002 - 2004

**Estimation of the contribution from dry-land salinity to water quality in the Berg River catchment: A pilot study**  
*Department of Soil and Agricultural Water Sciences, University of Stellenbosch (WRC Reference No 1342)*

Australia is suffering from a catastrophic dry-land salinity problem which is also affecting their surface water resources. The problem was caused by the clearance of natural deep-rooted trees and shrubs to make way for cultivated crops and grassland. Consequently a smaller portion of the stored, infiltrated water was extracted by the new vegetation and a larger portion drained to recharge groundwater. The result is that over decades the saline groundwater rose to decant into low-lying parts of the landscape, giving rise to saline patches. This project is based on the hypothesis that a similar process is operating in the drier parts of the Western Cape where shrubs were removed to make way for wheat fields (the wheat fields are known to contain saline patches). If this theory is correct, dry-land salinity can be expected to increase with time and manifest as a dry-land salinity problem similar to what is being experienced in Australia. This has potentially huge implications for the planned water schemes in the Berg River. This project plans to test the above theory and its implications by obtaining a preliminary estimate of the salt stored in

typical topo-sequences and using models to predict how different vegetation cover and land-use scenarios are likely to affect future salt discharge to the river. As such this project presents a novel concept which is supported by sufficient circumstantial evidence to warrant serious consideration. Planning in the Berg River and its reliance on one of the research products, add urgency to the investigation.

The aims of the project are to:

- Obtain a preliminary estimate of the quantity of salts stored in the regolith of the Berg River catchment
- Calculate the current potential for decantation of these salts into the river
- Calculate, retrospectively and prognostically, the rate of change of salt discharge in response to changes in land-use practices
- Make a preliminary assessment of the applicability of the results of this study to other major river systems in the region (e.g. the Breede River) based on existing information on soil properties and the history of catchment land-use practices.

*Estimated cost:* R449 000  
*Expected term:* 2002 - 2004

**An investigation into the depth and rate of weathering on gold tailings dam surfaces as key information for long-term risk assessments**  
*Golder Associates Africa (Pty) Ltd (WRC Reference No 1347)*

There are over 300 gold tailings dams (slimes dumps) scattered over the gold mining areas covering a total area of some 180 km<sup>2</sup>. Tailings are mostly deposited in an alkaline state and during their operational phase tailings dams and their drainage are typically neutral to alkaline. However, when operations stop, oxygen ingress into the outer layers oxidises the pyrite present in the tailings to produce sulphuric acid which mobilises metals and consumes the neutralising potential in the rest of the dam. Research shows that the oxygen ingress reduces with depth, resulting in an oxidised outer cap. However, enough acidity can be produced in this oxidised cap to consume all the neutralising potential contained in the dump and cause an acid mine drainage (AMD) producing dump. There is considerable variation in the physical status and pyrite content of dumps depending on the processes employed during ore processing. This leads to large variation in both the depth of oxidation of dump covers and their acid generating potential. This project will, through empirical research, develop relationships to predict the depth and rate of weathering and develop rapid procedures to assess the risk for a

specific tailings dam to produce AMD. This information will be used by mines as a screening tool to assess their long-term liabilities and to plan rehabilitation, while government will be able to identify those dams that require most urgent attention.

*Estimated cost:* R169 000  
*Expected term:* 2002 - 2003

**Improving the performance of covers for the rehabilitation of coal-mine residues**  
*Golder Associates Africa (Pty) Ltd (WRC Reference No 1350)*

A joint WRC-Coaltech 2020 project utilising an experimental set-up built by DWAF in KwaZulu-Natal, proved that soil cover design, and specifically cover thickness, had a major effect in limiting the flow of water through the cover (thereby reducing the volume of potential acid mine drainage - AMD). The cover also had a major effect on the ingress of air, thereby limiting one of the essential elements for the formation of AMD. Internationally new soil cover designs have been developed which appear to be even more efficient. The current project will assess the performance and sustainability of existing in-field covers of coal discard dumps in the Mpumalanga coalfield, analyse the expected efficiency of the most promising new soil cover designs and, if viable configurations are identified, design and motivate for a new experimental facility which is to be established in the Mpumalanga Highveld, from materials which are readily available in this area. The general aim with his project is thus to measure and improve the effectiveness of various cover configurations in limiting rainfall infiltration and oxygen ingress into coal discards and spoils.

*Estimated cost:* R617 100  
*Expected term:* 2002 - 2003

## Thrust 4: Resource Management and Use

**Development of guidelines for the design and operation of river diversion structures to deal with the problem of sedimentation**  
*Ninham Shand (Pty) Ltd (WRC Reference No 1302)*

Many communities abstract water directly from rivers, usually by means of a pump. Due to the highly variable flow conditions and high sediment loads in our rivers, sediment deposition often occurs at the abstraction point. The same applies to larger water diversion &

transfer schemes such as on the Olifants River, currently under construction, or the Thukela water diversion schemes which will be constructed in the near future.

There are, however, lessons to be learned from serious sedimentation problems experienced at a number of our major transfer schemes, such as the Tienfontein Pump Station on the Caledon River. Slow approach flow velocities at the pumps usually create an area of sediment deposition, which is detrimental to the sustainable use of the pumps, with resulting high pump replacement costs and inefficient operation.

The research aims to develop hydraulic guidelines for the layout, design and maintenance of river diversion structures in South Africa to limit the influence of sedimentation. These structures include small pump stations to large hydraulic structures for major water transfer schemes. Specific techniques to be investigated to ensure sustainable operation include hydraulic flushing within the diversion structure (pump station).

*Estimated cost:* R598 000  
*Expected term:* 2002 - 2004

**Appropriate, cost-effective and environmentally friendly technology and management systems for the removal of marine sediments in SA estuaries**  
*Institute for Natural Resources (WRC Reference No 1305)*

Ingress of marine sediments into estuaries was the single most important issue in estuary management identified in the western part of the Eastern Cape during the early stages of the EC Management Programme. The local authority for the Port Alfred / Boesmans River area has committed funds to develop the predictions of the effect of interventions on the problem. If the predictions indicate that an intervention may be successful, then the EIA around the planned intervention will be undertaken within this project. Thereafter, the implementation of any technology will be for the expense of the local authority.

*Estimated cost:* R160 000  
*Expected term:* 2002 - 2003

**Consultative project to situate, contextualise and plan for a river rehabilitation program in SA; to link this to relevant water-related initiatives; and to trial the Australian procedure for river rehabilitation on a small degraded urban stream**  
*Laughing Waters (WRC Reference No. 1309)*

Australian procedures for river rehabilitation are ahead

of those in South Africa. The project leader has spent time in Australia working with the Australians, and the aim of this project is to introduce, as applicable, their concepts to our situation. This will enable us to develop more rapidly than would otherwise have been the case. In addition to the widespread consultation process, a pilot rehabilitation exercise will be commissioned on a small urban river.

*Estimated cost:* R372 650  
*Expected term:* 2002 - 2004

#### **Analysis of groundwater level time series and the relation to long-term climatic conditions, climate change and recharge**

*Division of Water, Environment and Forestry Technology, CSIR*  
(WRC Reference No 1323)

DWAF has for many years regularly monitored groundwater levels and water quality in some 400 boreholes country-wide. In most cases at least monthly records are available, although in several cases daily water level recordings are kept. These boreholes are mostly located in undisturbed hydrogeological environments, upstream of major catchment developments or groundwater abstraction schemes.

It is believed that an analysis of this information could give invaluable information pertaining to the cause for this trend, both on a local as well as a regional scale. In particular the possible link to long-term climatic changes is of interest. A possible explanation for this declining trend can be the role or effect of, or the link to longer term climatic changes over the last few decades, and even centuries. Closely linked to this is the concept of groundwater drought, which may have important management implications, but has not been properly explored. The groundwater drought concept is not new and has previously been addressed in an African context by the British Geological Survey. The decreasing trends that have been recorded in some boreholes may also be explored as part of the longer-term fluctuations established by paleo-geohydrological studies. Numerous studies have been documented over the last decade on paleo-climatic conditions (covering the last say 3000 years) in Southern Africa and Africa.

The research aims to:

- Determine whether the long-term declining trends observed in SA groundwater level data are indicative of a current and/or longer-term groundwater drought cycle(s) or whether other factors are contributing to this trend

- Collate and develop new methods if required, that can be used to correlate long-term water level fluctuations with rainfall and climatic cycles
- Document the analytical techniques available and used to analyse relevant geohydrological information to assist planners in the long-term planning of groundwater utilisation as part of integrated water resource management.

*Estimated cost:* R233 000  
*Expected term:* 2002 - 2003

#### **Skills comparison of dynamic and empirical down-scaling methods for Southern Africa from a seasonal climate modelling perspective**

*SA Weather Services, Pretoria Office*  
(WRC Reference No 1334)

Droughts and floods have long been distinctive features of the climate of Southern Africa. Variability of the climate has been accentuated by the occurrence of the El Niño / Southern Oscillation (ENSO) phenomenon, but is by no means dominated by them. Climate variations have an important impact on agriculture, housing, water supply, industry and tourism. With an ever-increasing population that is putting an associated increase in demand on freshwater resources, effective water management has become essential. The need for providing improved seasonal rainfall forecasts, both temporally and spatially, is becoming more and more necessary in the region.

The main emphasis of the project is to assess the ability of an advanced state-of-the-art, albeit computationally expensive, method as a seasonal rainfall forecasting tool for Southern Africa in order to improve seasonal outlook information for hydrological purposes. Down-scaling the large scale to more localised seasonal rainfall over Southern Africa has been shown to be viable, but further research in down-scaling, with both improved spatial and temporal resolution, is required.

The main aims of the project are:

- Compile an appropriate GCM climatology of a sufficiently large ensemble
- Nest dynamic regional climate models in the GCM simulated large-scale fields
- Compare the nested scheme's forecast skill with base-line skill levels
- Set base-line forecast skill levels, using statistical models.

*Estimated cost:* R450 000  
*Expected term:* 2002 - 2005

#### **The implementation of bichromatic scintillation as an operational tool for the measurement of spatially averaged evaporation**

*Department of Soil Sciences, University of Natal (Pietermaritzburg)*  
(WRC Reference No 1335)

The need for increased food and timber production has led to dramatic increases in irrigated and forestry lands in South Africa. Agriculture and forestry face increased competition for water by industries, municipalities and other groups. This ever-growing demand for water makes it imperative that water resource management procedures and policies be wisely implemented and improved. The accurate assessment of evaporation is essential if this is to be done. Although the proposed investigation into bichromatic scintillometry to measure evaporation will focus on the more fundamental aspects of micrometeorological research, advances in this field will ultimately have direct benefits to water resource assessments and management processes.

The research aims to:

- Provide catchment researchers and consultants with a practical, accurate and operational tool to improve our understanding of comparative evaporative losses of water from land surfaces and water bodies associated with various forms of land use and a range of catchment conditions
- Make recommendations on the feasibility to provide guidelines for the use of, and to specify limitations of bichromatic scintillometry for the estimation of, a really averaged sensible heat flux over heterogeneous surfaces.

*Estimated cost:* R652 600  
*Expected term:* 2002 - 2004

### **Thrust 5: Ecosystem Functioning (terrestrial part)**

#### **Ecological and environmental impacts of large-scale groundwater development in TMG aquifer systems**

*CSIR / Umvoto*  
(WRC Reference No 1327)

There is currently a debate concerning the extent to which groundwater abstraction from TMG aquifers will lead to environmental impacts. This debate will continue and inhibit better understanding of the water resources

as well as inhibit development of the groundwater resources. Appropriate investigations are required to adequately inform key players and interested and affected parties, and to move the debate constructively forward.

This project aims to assess the dependency of aquatic and terrestrial TMG ecosystems on groundwater and predict impacts of groundwater abstraction. These ecosystems include wetlands, highland seeps, the riparian zone and spring discharge sites, amongst others. Specific objectives are:

- The development of predictive tools to assess the impact (or risk) of groundwater abstraction on the environment
- To improve our understanding of groundwater-dependent ecosystems (GDEs) in the TMG and the sensitivity to groundwater level fluctuations
- The use of innovative techniques to determine the impact of groundwater abstraction on the environment
- The development of indicators to monitor the effect of abstraction on sensitive ecosystems
- Coupling time series and spatial databases in order to ascertain the impacts of low flows (groundwater and surface water interaction) on the environmental system
- Improved understanding of the impact of changing low flows on freshwater ecology
- Improved understanding of the relationship between surface flow, event discharge from high-lying TMG unconfined aquifers and deep confined-aquifer discharge in maintaining wetlands or seeps
- Improved understanding of subsurface TMG discharge in maintaining coastal plain wetlands and vleis.

*Estimated cost:* R2 201 327  
*Expected term:* 2002 - 2005

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# XD D

## Water and Health



Ms APM Moolman  
Head:  
Water and Health

### Scope

The protection of health is often the overarching reason why research on water issues is undertaken, and its importance led to the establishment of the crosscutting domain **Water and Health (XD D)**. Health-related research has both defined and vested interests in all four of the WRC water-related key strategic areas (KSAs) and also has strong linkages to the other three crosscutting domains in the WRC structure.

This domain focuses mainly on research that will assist in the protection of quality of water, the prevention of health-threatening water quality deterioration and the delivery of safe and acceptable water to users.

### Objectives

The main aims of the domain following from the broad terms of reference of health-related research are:

#### Primary objectives

- To protect human and animal health and that of the aquatic environment by investigating the sources, persistence, and control of water-borne diseases
- To study effects of epidemics and epidemiology of water-borne diseases
- To conduct risk assessment of pollutants in water
- To assess the effectiveness of treatment and intervention procedures.

#### Secondary objectives

- To obtain adequate understanding of the origin, survival and persistence of microbial, chemical and other biological and toxic pollutants in water
- To develop appropriate techniques, technologies and systems using applied science
- To assess the extent of impact of pollutants on human health and health risk through epidemiological studies
- To co-ordinate the integration, collation and interpretation of water quality information gathered for monitoring risk assessment and management of water resources.

The research portfolio of current projects has been grouped into strategic thrusts and programmes which directly address the above-mentioned objectives and are summarised as follows:

### Thrusts and programmes

#### Thrust 1: Microbial Water Quality and Risk Assessment.

- Development and application of techniques for the detection of *Cryptosporidium* and *Giardia*
- Development and application of analytical techniques for the detection of viruses
- Method development for known and emerging micro-organisms causing water-borne diseases.

#### Thrust 2: Detection and Prevention of EDCs and Toxins in Water Sources

- Development of the EDC programme, development of bio-assays and validation of chemical analyses for the detection of EDCs.

#### Thrust 3: Water Quality Risk Assessment and Management

- Guidelines.

#### Thrust 4: Eutrophication and Algal Blooms

- Detection and management of cyanobacteria.

#### Thrust 5: Water Resource Protection and Reclamation in Agriculture (KSA 4 Thrust 4)

- Fitness-for-use of water for crop production, livestock watering and aquaculture.

### Budgets for 2002/2003 and 2003/2004

The approved funding of the research portfolio for 2002/03 leads to committed funding of R3 159 200 in 2002/03 and R2 200 000 in 2003/04.

Funding for new projects of R2 100 000 in 2003/04 is requested for the proposed projects on inflammatory reaction tests, fluorides and the toxicology programme.

## CORE STRATEGY

### Strategic context

Until 1999 health-related water research was being addressed under a number of WRC research fields. During late 1998 it became apparent that there was a need to focus and co-ordinate health-related research and provide leadership and direction in this research area in South Africa. The WRC **Health-Related Water Issues Field** was officially recognised in April 2000.

The protection of health is often the overarching reason why research on water issues is undertaken, and its importance led to the establishment of the crosscutting domain **Water and Health (XD D)** with the restructuring of the WRC in 2002. Health-related research has both defined and vested interests in all four of the WRC water KSAs and also has strong linkages to the other three crosscutting domains in the WRC structure.

The total crosscutting nature of this domain requires strong leadership and innovation to integrate the health-related projects within the 4 water KSAs and 4 domains.

Research is done with the aim to improve water quality and hygiene practices in order to save lives, reduce costs and efforts in treating the symptoms of disease, and in purifying and disinfecting affected waters.

A holistic, multidisciplinary approach is followed to develop a comprehensive understanding of the origin/sources and spatial extent of pollution; its effects on water quality; water usage patterns; the effects of degraded water quality on animal and human health and the need for water treatment. The emphasis is on a pro-active approach to identify and address "causes", rather than on a passive response to "symptoms". This approach should ensure research products that are relevant, user-friendly, practical and scientifically valid.

The scope of health-related water research in terms of the percentage of WRC research funds allocated to this topic has increased over the past years. The main reason for this increase is that health is one of the national imperatives that needs to be addressed for the well-being of South Africa. Recent development and improvement of analytical techniques to detect the origin and causes of diseases and substances that have a detrimental effect on health have added to the growth of this important water research field. The interest in this topic has expanded over the past six years and is

reflected in the increasing involvement of research institutions, especially historically disadvantaged institutions (HDIs). Growing interest is also reflected in the growth in the number and diversity of research institutions and other bodies funded by the WRC.

The strategic focus of XD D has been formed with the support of inputs from representatives of government departments (Department of Water Affairs and Forestry (DWAF) and the Department of Health (DoH)), leading academics, water suppliers and practitioners in the water industry. Consultations and workshops took place during 2001 and early 2002.

### Needs analysis

Water treatment for safeguarding the health of ecosystems, animals and humans, is extremely costly and not always practical. Preventing the pollution of South Africa's water resources must therefore be the primary consideration. For this to be effective, several needs must first be addressed.

Firstly, the total implementation of the legislative framework is necessary. This can only be undertaken with full co-operation among the various government departments. The WRC is in the unique position of being able to view issues from the outside and to identify key issues as well as stakeholders who need to play important roles in the integration of implementation strategies of government.

The 2nd important aspect is the development of tools for implementing strategies developed in the different departments. Co-operation between key stakeholders is again of importance.

Thirdly, the cost-effective and sustainable use of the implementation tools needs to be ensured. Available and developing technologies must be identified, evaluated and tested, before being implemented by competent people.

The availability of competent people identifies the 4th need. This translates to capacity building, not only of researchers, but also of practitioners and workers in the water industry. The issues of job availability and sustainability also need to be taken into account.

A 5th need concerns awareness building and understanding of the really important issues that have to be addressed in the short-, medium- and long-term, not only at government level but also in the private sector and at community level. Several strategies need to be

Table (i):

Summary of 2002/03 budgets for ongoing projects and new projects starting during 2002/03 within XD D as distributed between KSAs and the domain (figures in Rand)

Thrust	Budget			Budget per KSA and XD D									
	Total	Ongoing	New	KSA 1		KSA 2		KSA 3		KSA 4		Domain: XD D	
				Ongoing	New	Ongoing	New	Ongoing	New	Ongoing	New	Ongoing	New
Microbial Water Quality	R1 283 250	R945 250	R338 000					R754 500				R191 000	R338 000
Water Quality Assessment	R1 310 600	R393 600	R917 000	R393 600									R917 000
Endocrine Disrupting Contaminants	R1 435 000	R18 500	R1 250 000									R185 000	R1 250 000
Eutrophication & Algal Blooms	R278 200	R28 200	R250 000			R9 500							R278 200
Water Resource Protection and Reclamation in Agriculture (KSA 4 Thrust 4)	R50 000			R50 000								R50 000	
Subtotal												R376 000	R2 783 200
Total													R3 159 200

Table (ii):

Summary of 2002/03 budgets for current and new projects within XD D as distributed between KSAs and the domain (figures in Rand)

Thrust	Budget			Budget per KSA and XD D									
	Total	Ongoing	New	KSA 1		KSA 2		KSA 3		KSA 4		Domain: XD D	
				Ongoing	New	Ongoing	New	Ongoing	New	Ongoing	New	Ongoing	New
Microbial Water Quality	R282 000	R282 000										R282 000	
Water Quality Assessment	R688 000	R688 000										R688 000	
Endocrine Disrupting Contaminants	R1 000 000	R1 000 000										R1 000 000	
Eutrophication & Algal Blooms	R240 000	R240 000										R240 000	
Water Resource Protection and Reclamation in Agriculture (KSA 4 Thrust 4)													
Total	R2 200 000											R2 200 000	

developed for the different levels. Ideally, scientific knowledge that is becoming available must be conveyed to, and be understood by, every level of society. This includes the development and application of highly effective technology transfer mechanisms and media.

The 6th need is the evaluation of the outputs and the benefits gained, in terms of added value, poverty alleviation, wealth creation and most importantly the improvement of health, which remains the fundamental underlying element for all research undertaken in this domain.

Finally, it is imperative that global trends, related to all of the above needs, must be taken into account. Since a great deal may be lost by working in isolation, international collaboration and co-operation are imperative. A number of implementation manuals have been developed recently, to assist water suppliers and users to comply with legislation; more are in the pipeline.

Recently published, user-friendly guidelines on water quality have to be expanded to serve water suppliers, educators, researchers and related stakeholders

## Technology trends

This domain has anticipated global research trends. Technologies of importance to this domain are:

- Analytical detection methods to determine contaminated water. New detection methods that are either more sensitive, more rapid or more economical are continuously being developed, and these need to be evaluated.
- Bio-assays to determine the detrimental health effects of endocrine-disrupting contaminants (EDCs), including chemicals and other toxic substances. The trend is to use chemical analytical detection methods and bio-assays in parallel to identify substances and effects simultaneously and consecutively.
- Inflammatory reaction tests to determine the effects of chemical substances on human and animal health are new developments in the water field. The application has been extended to the field of air pollution.
- Epidemiological and health risk-assessment studies to determine the impact of water-borne micro-organisms and chemical pollutants on human health for the preparation of management tools.

## Key stakeholders

Key government stakeholders, such as DWAF, Department of Environmental Affairs and Tourism (DEAT), Department of Agriculture (DoA), and DoH are involved and give guidance in developing implementation manuals and guidelines, in order to assist water providers such as water boards, water suppliers, catchment management agencies (CMAs) local authorities (LAs) and water committees to apply new legislation. Environmental health officers (EHOs) play an important role in the implementation of legislation and awareness-building programmes.

International funding and research ties have been strengthened with the International Water Association (IWA), the Assessment Centre for Hazardous Substances in Water (ACHSW) and the Global Water Research Coalition (GWRC). Researchers from Australia, Britain, Finland, Canada, the USA, Germany and the Netherlands have been interacting with South African researchers and have been involved in technology transfer workshops.

The WRC **XD D** is a stakeholder in the new international Global Water Research Coalition (GWRC) and is a lead agent for their first programme to identify global endocrine disrupting contaminants (EDCs). Collaboration with the IWA specialist Assessment Centre for Hazardous Substances in Water (ASCHW) and the CGIAR (IWMI) System-Wide Initiative on Malaria and Agriculture (SIMA) has been established.

The WRC contributes to government department action plans. A contribution has been made, for instance, in setting the DoH research priorities and ensuring the inclusion of diarrhoeal diseases in their top 10 research priorities. The WRC and DWAF are also working together in developing manuals for the implementation of the Water Act in so far as water quality and health-related issues are concerned.

## Research providers

The above-mentioned government stakeholders, as well as water suppliers and LAs are not only end-users of research in this domain, but also research contributors. Various forums, laboratories and the Health-Related Issues Technical Committee of the Water Institute of SA (WISA) represent other stakeholders.

Researchers contributing to this domain are from the CSIR, Medical Research Council, universities, technikons and several government departments, as well as

independent consultants. Research and funding partnerships exist with DWAF and DoH, Department of Agriculture (NDA), Rand Water and Umgeni Water as well as with some of the smaller water boards and water suppliers. Of the 20 research institutions, five are categorised as previously disadvantaged institutions (PDIs).

## Links to the Mission and Vision of the WRC

**XD D** contributes to the realisation of the WRC's vision to be a globally recognised leader by providing innovative solutions for sustainable water management in order to meet the changing needs of society and the environment. The domain further contributes to the WRC's mission that pursues leadership and innovation through support of water-centred knowledge creation and technology transfer, engagement with stakeholders and partners, and the promotion of economic growth and a better quality of life.

It does so by providing an integrating framework for water-centred knowledge directly relating to health, which is one of society's highest priorities and crucial for quality of life. In the absence of this crosscutting domain, each of the WRC's water KSAs would be required to address health-related water issues on their own, with a real danger of greater fragmentation and duplication, and inadequate co-ordination. By providing the integrating framework, the domain also promotes integrated approaches to problem-solving, which are essential if the WRC is to carry out its mission effectively.

The health-related issues of major concern to each water KSA are as follows:

### KSA 1

- Assessment of health-related risks regarding water quantity/quality
- Management of water resources
- Development of protocols, guidelines and manuals for water quality management.

### KSA 2

- Protection of the aquatic environment
- The relationship between aquatic pollution/contamination and human as well as animal health.

### KSA 3

- Protection of the aquatic environment
- Interpretation of water quality information and health risk analysis

- Management aids including the development of protocols, guidelines and manuals to promote water quality at all levels of society and the development of technologies to adequately treat water and waste.

### KSA 4

- Investigation of the effect of water quality on human, animal, aquatic and product health in the context of agriculture-related activity and industry.

By supporting specific research thrusts, **XD D** contributes towards the integration of areas of interest of the three other crosscutting domains (**XD B**, **XD A** and **XD C**). The thrusts and domains concerned are:

- Reducing the burden of disease - cost and symptoms (**XD B**, **XD A**)
- Reducing the cost of purification of affected waters (**XD B**, **XD A**)
- Protecting water quality (**XD C**)
- \* Preventing health-threatening water quality deterioration (**XD C**, **XD A**)
- Assuring safe and acceptable delivery of water to users (**XD A**).

## RESEARCH PORTFOLIO FOR 2002/03

The main aims of the domain follow from the broad terms of reference mentioned above.

An overview of **XD D** research thrusts and programmes is given in **Table 1**.

Table 1: Overview and description of XD D thrusts and programmes for 2002/03.

Thrust 1: Microbial Water Quality and Risk Assessment	
<p><b>Scope:</b> This thrust strives towards a better understanding of the micro-organisms associated with water, the associated epidemiology, the health risks and the development of management strategies for the protection of water resources and human health in a cost-effective way, whilst focusing on applied science. This is being done by development of rapid, reliable, cost-effective and standardised methods for detection of indicator organisms for known and emerging pathogens in drinking water.</p>	
Programme	Scope
1. Development and application of techniques for the detection of <i>Cryptosporidium</i> and <i>Giardia</i>	<i>Cryptosporidium</i> and <i>Giardia</i> are self-limiting disease-causing pathogenic parasitic protozoa for which no medication is available. Presently expensive test methods are available to detect these pathogens. Additional knowledge is needed for the detection and removal of pathogens during wastewater treatment processes and evaluation of the contribution of sources to their occurrence in the aquatic environment to prevent possible pollution from these sources Simple testing kits for use by rural communities are also required.
2. Development and application of analytical techniques for the detection of viruses	Viruses are more resistant to water treatment and disinfection processes than faecal bacteria. Tests for viruses are relatively expensive and complicated and better indicators are being sought, such as F-RNA phages. There is also a need for simpler, more economic, but effective viral detection methods.
3. Method development for known and emerging micro-organisms causing water-borne diseases	Rapid, simpler, and less expensive techniques for the detection of potentially harmful pathogens in surface water used are needed, particularly by rural communities. Methods have to be developed and evaluated. Studies will also provide information on the health risk of direct and indirect consumption and use of contaminated water.
Thrust 2: Detection and Prevention of EDCs and Toxins in Water Sources	
<p><b>Scope:</b> The overall objective of this thrust is to protect the health of human, animals and the aquatic environment by investigating the sources, persistence, effects and epidemiology of disorders linked to endocrine disrupting chemicals in water and to assess the effectiveness of mitigation on the chemical quality of water. This includes inorganic and organic analysis, biomarkers and bio-assays, as well as the development of management strategies for the protection of water resources and public health, in a cost-effective way.</p>	
1. Development of the EDC programme, development of bio-assays and validation of chemical analyses for the detection of EDCs	Literature studies to review the state of the art internationally and locally in order to develop a strategy for the EDC programme. Selection, development and validation of bio-assays Assessment of the extent of environmental pollution by EDCs emanating from industrial, agri-chemical, and sewage treatment works effluent.
Thrust 3: Water Quality Assessment and Management	
<p><b>Scope:</b> This thrust sets out to collate and interpret water quality information for risk assessment and management of water resources and protection of human and animal health and the aquatic environment. The scope of the programme is to develop and disseminate tools, (procedures, applications and guidelines) for assessment (include monitoring and interpreting), management (include decision support and operational procedures) and communication (include education, awareness and empowerment) by means of water quality information systems, guidelines, quality control, quality assurance, good practices and models.</p>	
1. Development of guidelines	This programme focuses on the development of a series of guidelines and protocols to promote and advocate the safe use of water and with the aim to build awareness and to transfer technology to the public to minimise water-related health risks.

Table 1: Overview and description of XD D thrusts and programmes for 2002/03 (Continued).

Thrust 4: Eutrophication and Algal Blooms	
<p><b>Scope:</b> This thrust addresses the pollution of water sources by nutrients that contribute to the production of algal blooms which can result in detrimental consequences for human and animal health, as well as water treatment plants. Prevention and treatment of algal blooms are investigated.</p>	
Programme	Scope
1. Detection and management of cyanobacteria	Research is conducted into the physiology and metabolism of cyanobacteria, micro-algae and macrophytes in order to understand the dynamics that give rise to cyanobacterial and other algal blooms and factors that contribute to the formation of lethal toxins, odour - and taste - producing Geosmin and other compounds. The outcome will be the development of management tools and practices to mitigate and control causes of algal blooms.
Thrust 5: Water Resource Protection and Reclamation in Agriculture (KSA 4 Thrust 1, Programme 2)	
<p><b>Scope :</b> The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the processes of production of field, horticulture and industrial crops.</p>	
1. Fitness-for-use of water for crop production, livestock watering and aquaculture	Various processes and factors, which are site-specific, have an influence on the quality of water for crop, livestock and fish production. The emphasis in this programme is on the efficient use of water and management of water quality for irrigation of crops, livestock watering, aquaculture in rivers, ponds and dams.

## Research projects

The findings of projects completed during the year under review are given, as well as a summary of current projects and the motivation and objectives for new projects which commenced between 01 April 2002 and 31 March 2003.

## COMPLETED

### Thrust 1: Microbial Water Quality and Risk Assessment

#### Programme 1: Development and application of techniques for the detection of *Cryptosporidium* and *Giardia*

**Occurrence and source of *Cryptosporidium* and *Giardia* in catchment areas and wastewater works Umgeni Water (WRC Reference No 927)**

**Evaluation of alternative disinfection processes for the removal of protozoan oocysts, cysts and other micro-organisms in the treatment of final wastewater effluents Umgeni Water (WRC Reference No 1030)**

The project aimed to adequately disinfect wastewater effluents in terms of parasitic cysts (*Giardia* and *Cryptosporidium*), viruses (coliphages) and bacterial indicator organisms (*E.coli*, faecal streptococci and coliforms), whilst not exceeding the DWAF general standards for chlorine residuals. Alternative disinfectants and combinations were assessed both in the laboratory and at pilot plant.

A number of conclusions were made from this investigation and can be summarised as follows:

- The most promising disinfectants for use in wastewater, which show potential for meeting the DWAF standard for effluent discharge in terms of both chlorine residual and faecal coliforms are: Ozone, medium-pressure UV irradiation, bromine, and peracetic acid.
- Work conducted on membranes for the treatment of potable water sludges made it clear that the nature of the sludge is vitally important and that serious operational problems, such as membrane fouling, could be expected when using membranes for these applications and it was, therefore, not included in this investigation.

A cost assessment was conducted on ozone, UV, peracetic acid and bromine and chlorine were included to provide a benchmark. Design and basic operational guidelines for simple and effective disinfection of wastewater effluents are listed in this report.

#### Project No 927

Cost: R 300 000  
Term: 1998 - 2001

#### Project No 1030

Cost: R207 000  
Term: 1999 - 2001

### Programme 2: Development and application of analytical techniques for the detection of viruses

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

Department of Medical Virology, University of Pretoria;  
Department of Microbiology, University of Venda  
(WRC Reference No 928)

The project dealt with the upgrading of techniques for the detection of F-RNA phages in water, as well as the typing of the phages into four serological groups described to date to be used to distinguish between faecal pollution of human and animal origin.

Data obtained in this study were combined with studies in Spain to assess the value of F-RNA coliphage genotypes as a tool for the assessment of water quality. Despite differences between SA and Spain such as geographic location and climate and population, there is no statistical significance in the occurrence of F-RNA bacteriophages and their genotypes in comparable samples of faeces and wastewater. Although the association of genotypes with animal or human excreta was statistically significant, the results for a variety of samples suggest that the association cannot be used for absolute distinction between faecal pollution of human and animal origin in raw and treated wastewater or environmental water sources. However, in combination with other indicators the association may prove useful for determining the origin of faecal pollution.

The detection of F-RNA coliphages has been established as an integral part of the routine monitoring of several water suppliers including reclaimed drinking water in Windhoek, Namibia.

Cost: R162 200  
Term: 1998 - 2001

### Programme 3: Method development for known and emerging micro-organisms causing water-borne diseases

#### Occurrence of emerging viral, bacterial and parasitic pathogens in source and treated water in South Africa Division of Water, Environment and Forestry Technology, CSIR; Department of Plant Pathology and Microbiology, University of Pretoria (WRC Reference No 1031)

This project aimed at selecting specific examples of emerging viral, bacterial and parasitic pathogens, to establish techniques for detecting their presence in water and to monitor a number of source and treated water samples from different localities in South Africa. Environmental isolates from *Campylobacter* were compared with clinical isolates in order to establish the importance of water in the transmission of these pathogens. Although detection techniques were established for all the selected pathogens apart from Hepatitis E virus, the sensitivity of a number of these techniques was highly unsatisfactory, because the methods used were unreliable. The only method that was suitable for routine monitoring of water samples was the one developed for the human Astrovirus, but to date only a few laboratories have the infrastructure and capacity to perform this type of analysis. The current information suggests that the Astroviruses only occur sporadically and mainly in winter months.

From this study it can be concluded that the emerging pathogens investigated in the study are most likely to be found in surface and wastewater and not in treated drinking and borehole water. This, however, could have serious implications for communities that consume untreated source water. It was, however, noticed that in all the cases where these emerging pathogens were detected, faecal coliform data already indicated serious water quality problems. This suggested that current water quality guidelines and management procedures based on normal microbial water quality indicators should provide the necessary protection.

Cost: R400 000  
Term: 1999 - 2001

#### Isolation of microbial extra-cellular enzymes for possible use in dairy cleaning-in-place (CIP) applications

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

Processing of dairy products is complex with respect to production requirements. Dairies have to improve their CIP systems cost efficiency whilst maintaining high sanitation standards, reducing effluent outputs and delivering high quality products.

- The project aimed to produce an economically viable biological cleaning system for dairy plants based on lipases and proteases, which would result in a more acceptable effluent being discharged while still providing effective cleaning for all surfaces in the dairy industry.
- A mini dairy system was constructed and milk and cleaning solutions were pumped through the system.
- The twin enzyme lipase/protease CIP system, proposed and investigated in this study, produced an equivalent clean whilst producing a more acceptable effluent when compared to the current chemical CIP practices.
- The primary user group for the products envisaged from this project are the small- and medium-sized dairy processors in SA

Considering the efficacy of the two-enzyme CIP in cleaning stainless steel in dairies, this research can now be expanded to be further developed for the fruit juice, breweries, soft drinks and bottled water markets. This CIP technology also has the potential to be applied in open-area-cleaning with multi-enzyme cleaners.

Cost: R82 000  
Term: 1999 - 2000

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

Department of Medical Virology, University of Pretoria  
(WRC Reference No 1068)

This project was restricted to the incidence of *E. coli* pathogens in selected water sources.

Enterohaemorrhagic strains of *E. coli* (EHEC) cause health-threatening haemorrhagic colitis and haemolytic uraemic syndrome and infections have also been associated with transmission by water and food. There is no meaningful information on the incidence of pathogenic *E. coli* in water sources in South Africa. The study aimed to screen selected river and sewage water samples for the presence of *E. coli* pathogens and to optimise and establish practical molecular techniques for the detection and typing of *E. coli* pathogens. A new procedure was developed for the isolation of *E. coli* 0157:H7 from water.

For the first time in SA it was confirmed that a variety of these pathogens are present in sewage-contaminated river water. The incidence of *E. coli* 0157:H7 appeared to be lower than expected, but the results obtained and experience gained suggests that the findings may underestimate the situation. A major benefit of the project is that expertise and technology have been established in an area of water quality analysis of particular public health importance

The cost estimates revealed that the test is relatively expensive and not feasible for all laboratories engaged in routine water quality analysis.

Cost: R150 000  
Term: 1999 - 2001

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

Scientific Services, Rand Water  
(WRC Reference No 1069)

Heterotrophic plate counts (HPCs) are commonly used to assess the general microbiological quality of drinking water. The purpose of the project was to determine the presence of HPC bacteria showing potential pathogenic features in treated drinking water samples that exceeded the South African HPC water quality guidelines.

A total of 339 bacterial colonies were isolated at random from selected drinking water supplies in South Africa using routine heterotrophic plate count tests. A screening was done to determine whether these bacteria are potentially pathogenic.

The most commonly isolated genera displaying potentially pathogenic features were *Aeromonas*, *Acinetobacter*, *Aureobacterium*, *Bacillus*, *Chryseobacterium*, *Corynebacterium*, *Klebsiella*, *Moraxella*, *Pseudomonas*, *Staphylococcus*, *Tsukamurella*, and *Vibrio*. Many of the bacterial strains included in these genera are known opportunistic pathogens and can, therefore, constitute a health risk for consumers.

Cost estimates for the various analyses used in the study were done for use in routine monitoring by water utilities and the implication is that it is not feasible; however if needed, they could be done at the Department of Medical Virology, University of Pretoria.

Cost: R500 000  
Term: 1999 - 2001

### Thrust 3: Water Quality Risk Assessment and Management

#### Programme 1: Development of guidelines

##### Assessing the cures and pathways of water-borne diseases in rural settlements with limited formal water supply and sanitation

*Umgeni Water*  
(WRC Reference No 925)

This project was designed to monitor the implementation of water reticulation to evaluate the water supply scheme from a community and environmental health perspective. One of the objectives of this study was to evaluate the usefulness of diarrhoeal disease as opposed to other health indicators for water-associated diseases.

The innovative methodology followed in the study, viz. 'a stepped wedge design', compares four discreet areas of water reticulation implementation over a 15-month period. Five surveys, including a baseline and four follow-ups at each household, were carried out. Water samples were taken and analysed for microbiological and chemical constituents. Each survey included health questionnaires.

The overall findings were that there was no direct correlation proven between water quality and diarrhoea per se. However, there was a marked decrease in diarrhoea with the introduction of the new water supply. There was a definite correlation between hygiene behaviour and diarrhoea.

Some improvements to water supply interventions were recommended such as where to put the taps, the need for the provision of a drainage system for public health reasons and hygiene education, as the causes of diarrhoea would appear to be correlated with many basic hygiene procedures, rather than water quality per se.

A post-construction audit process be introduced to assess all aspects of the scheme; its effectiveness in operation, appropriateness and its effect on health.

Cost: R 204 750  
Term: 1999 - 2001

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

*Department of Environmental Sciences, Technikon Free State*  
(WRC Reference No 1039)

The project aims were to assess the applicability of the existing SA Guide for the Permissible Utilisation and Disposal of Treated Sewage Effluent (1978) to encourage the safe use of treated wastewater rather than to prohibit and to assess whether the Guide criteria are adequate to protect both the consumer public and the health of workers involved with the use of treated wastewater in agriculture

Existing national and international guidelines, references and research reports are collated on all the possible aspects relating to the reuse of treated and other wastewater from holding institutions.

New draft guidelines were drafted and include prescriptions on treatment system configurations, consideration of permit applications for wastewater reuse, quality indicators for the various biological pathogens and hazardous residual chemical and physical constituents in discharged wastewater at various levels of treatment, and potential uses to be allowed based on the configurations and indicators stated

Shortcomings identified such as the lack of guidelines available for the deteriorating microbial quality of the SA water sources used to irrigate edible crops that most probably have more serious implications and health risks, need also to be addressed in the development of guidelines for all irrigation waters. Therefore the current guidelines need to be revised by the Departments of Health, Agriculture and DWAF to include these and to be relevant for the needs of the country

Cost: R80 000  
Term: 1999

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

*Department of Chemistry, University of Fort Hare; Collaborating Institutions/Departments: Department of Microbiology, UFH*  
(WRC Reference No 1067)

The project aimed to identify primary and secondary users and uses of water in the catchment area to identify major sources of pollution as well as facilities and options to ensure that the water is safe for use.

A questionnaire approach (in the mother tongue of the communities) was used to identify the uses and users of the water from the river. The major primary users of the water from the river were the Umtata local authority and informal settlements along the riverbanks. Uses other than domestic are livestock watering, recreation and agriculture and, to a lesser degree, industry. The Umtata local authority supplies water to the secondary users, e.g. industry, and the Umtata Township and its inhabitants.

The study revealed that the incidence of diarrhoea is prevalent in the catchment. Other pollutants identified are high nutrient levels, high turbidities and high cadmium levels. Several options were recommended to ensure that the water from the Umtata River is safe for use such as:

- Improvement in the sanitation practices of the rural and peri-urban areas, land-use management to prevent erosion, control and safe use of pesticides and fertilisers in the agricultural sector
- Improvement in the operation of sewage plants, prevention of pollution by industry, monitoring and removal of waste sites close to the riverbank and planning of appropriate waste disposal sites in the catchment
- Development of educational programmes for the rural communities on the prevention of pollution, and hygiene and sanitation practices.

Cost: R540 000  
Term: 1999 - 2000

##### Development of a field kit for microbial water quality assessment in small and rural communities

*Division of Water, Environment and Forestry Technology, CSIR*  
(WRC Reference No 1105)

The WRC previously funded two projects to evaluate the H<sub>2</sub>S strip test and to develop a field test kit for use as a rapid indicator of the quality of drinking water in rural areas. This test kit is relatively inexpensive and the test is highly recommended and could be a useful screening test in monitoring the microbial quality and microbial pollution of water. The aim of the project was to test the field test kit for the with environmental health officers for its use in monitoring and managing small water supply systems, particularly in areas where water monitoring would not normally take place. Technology transfer was a major component of the project and environmental health officers were invited to participate in the study to assess the H<sub>2</sub>S strip test and provide feedback.

The general experiences with this test as a tool for monitoring water quality were exceptionally positive. Negative experiences were minor. The general consensus was that the test was easy to carry out and user-friendly and that it is extremely useful as an 'early warning' system. The major concern was that, on occasion, the results differed from the standard indicator organism tests (either total or faecal coliforms) i.e. the laboratory tests would be negative for total and faecal coliforms whereas the H<sub>2</sub>S test was positive.

An end-user guide for the H<sub>2</sub>S strip test is included in the report.

Cost: R70 000  
Term: 2000

### Thrust 4: Water Resource Protection and Reclamation in Agriculture

#### Programme 1: Fitness-for-use of water for crop production, livestock watering and aquaculture

##### Risk of insecticide (pyrethroid) resistance for malaria control in South Africa

*Unit Pesticide Impact, Agricultural Research Council (ARC)*  
(WRC Reference No 1119)

The agricultural use of pyrethroids and other insecticides registered for crop protection increased in the emergent farmer sectors in KwaZulu-Natal. These areas are protected by the malaria control programme in which DDT and delmethrin are used for indoor spraying of dwellings.

The research objectives were to establish the patterns of agricultural pesticide used by emergent farmers in two areas, namely Ubombo and Inguma to develop a protocol for sampling, analysis of insecticides and interpretation whereby areas at risk can be investigated for resistance potential within a short period. The residues of the insecticides in water sources near to the communities were determined and selected for resistance in malaria vector larvae.

A questionnaire was used to gather information on a list of pesticides used in the area so as to select the pesticides for residue analysis.

Results of the analyses show insecticide contamination of the water environment in the investigation area from

pyrethroid, organophosphate, organochloride and carbamate chemical groups, as well as DDT derivatives resulting from anti-malaria control interventions. Game reserves selected for control areas were also found to be contaminated.

Mosquito resistance exists and it is crucial to ascertain the relative contribution of the different insecticide classes to the development of resistance and the consequences in designing an efficient, mosquito vector programme.

Cost: R200 000  
Term: 2000 -2002

## CURRENT

### Thrust 1: Microbial Water Quality and Risk Assessment

#### Programme 2: Development and application of analytical techniques for the detection of viruses

Assessment of the risk of infection associated with viruses in South African drinking water supplies  
University of Pretoria, Potchefstroom University for CHE, University of Fort Hare, University of Venda, Technikon Free State, Technikon Soshanguwe, Technikon ML Sultan, Rand Water and Umgeni Water  
(WRC Reference No 1164)

The aims are to:

- Develop simpler, more sensitive, more economical techniques for the detection of small numbers of viruses in large volumes of drinking water
- Determine indicators of virological quality of drinking water supplies
- Examine the incidence of a spectrum of enteric viruses in selected representative drinking water supplies
- Obtain new data for guidelines on drinking water quality and monitoring programmes
- Transfer techniques to previously disadvantaged educational institutions.

Estimated cost: R1 000 000  
Expected term: 2000 - 2002

### Programme 3: Method development for known and emerging micro-organisms causing water-borne diseases

#### Incidence of enteric pathogens in domestic water, water sources and stools of residents of urban and rural areas in the Venda region of the Northern Province

Department of Biochemistry and Microbiology, University of Venda  
(WRC Reference No 1126)

The project aims to:

- Examine microbiological water quality in selected communities
- Determine the extent of enteric bacterial infection and related diarrhoea and dysentery among infants in rural and urban regions of the Northern Province
- Determine the incidence of enteric pathogens in domestic water and water sources
- Explore the use of viruses as indicators of water quality
- Examine antibiotic susceptibility and plasmid profiles of the enteric bacteria (for improved health care).

Estimated cost: R350 000  
Expected term: 2000 - 2002

#### Prevalence, survival and growth of bacterial pathogens in biofilms in drinking water distribution systems

University of Pretoria, University of the Western Cape, CSIR, Umgeni Water and Free State Technikon  
(WRC Reference No 1276)

In summary the project aims to determine the occurrence, survival and growth of bacterial pathogens in drinking water biofilms.

Specific aims are to:

- Determine the prevalence of pathogenic bacteria in biofilms both in drinking water distribution systems and in containers used for distribution and storage of water in informal settlements
- Study the growth of biofilms on PVC surfaces of water storage containers
- Assess the survival of general water quality indicator bacteria in biofilms within water distribution systems
- Determine the fate, survival and possible growth of specific pathogenic bacteria in:

- Drinking water distribution systems
- Containers used for distribution and storage of water in informal settlements.

Estimated cost: R721 800  
Expected term: 2001 - 2003

#### A study of microbial communities and related water quality of the Mhlathuze River

Department of Biochemistry and Microbiology, University of Zululand  
(WRC Reference No 1282)

The aims of the project are to:

- Monitor the microbial quality and the related physical and chemical variables of the Mhlathuze River
- Combine modern technology and traditional culture to study the microbial population, and diversity, the survival and transmission of pathogens in the river and lakes in the Mhlathuze catchment
- Improve undergraduate and postgraduate training and to develop research capacity within the Department of Biochemistry and Microbiology of the University of Zululand
- Help create capacity and infrastructure for the implementation of the National Microbial Water Quality Monitoring Programme (NMMP).

Estimated cost: R316 000  
Expected term: 2001 - 2003

### Thrust 2: Detection and Prevention of EDCs and Toxins in Water Sources

#### Programme 1: Development of the EDC programme, development of bioassays and validation of chemical analyses for the detection of EDCs

Endocrine disrupting contaminants in South African water resources: Development, validation and implementation of bioassays to detect and characterise physiological disruption in humans and wildlife

University of Stellenbosch, University of Pretoria, MEDUNSA, Rand Water, Windhoek Municipality  
(WRC Reference No 1253)

The aims of the project are to:

- Produce a review of the global and local status of EDC research
- Prioritise South African research needs regarding EDCs
- Develop a framework for research on endocrine disruptors in South Africa
- Evaluate techniques for detecting EDCs in water resources in South Africa, particularly by screening a battery of bioassays for endocrine disruptors applicable to South African conditions
- Develop and to validate biomarkers to be employed eventually in a battery of bioassays for detecting EDCs and undertaking risk assessment of EDCs in water resources
- Screen "hot spot" areas or other problem areas in South Africa
- Initiate laboratory training programmes and the development of a standardised EDC monitoring programme.

Estimated cost: R585 000  
Expected term: 2001 - 2002

### Thrust 3: Water Quality Risk Assessment and Management

#### Programme 1: The development of guidelines

Pilot study to demonstrate implementation of the National Microbial Monitoring Programme (NMMP)  
Division of Water, Environment and Forestry Technology, CSIR  
(WRC Reference No 1118)

The NMMP and manual were developed in a previous project and consultancy. A pilot study to demonstrate the implementation of the NMMP was regarded as an important link between the concepts described in the manual and a full-scale implementation of the monitoring programme.

- Through the first project the implementation of the NMMP is being demonstrated in 8 high-priority health risk areas and involves the community and other stakeholders.
- The existing NMMP for surface waters also needs to be extended to include groundwaters. The specific aim of this phase is to develop a prototype manual that formally describes the detailed groundwater monitoring system design and all

aspects of subsequent implementation of the programme.

Estimated cost: R303 000  
Expected term: 2000 - 2001

#### Extension of the South African national microbial water quality monitoring programme (NMMP) to include groundwater

Division of Water, Environment and Forestry Technology, CSIR, DWAF and the Department of Health (WRC Reference No 1277)

The link between the concepts described in the *Manual for the National Microbial Water Quality Monitoring Programme* and a full-scale pilot implementation has been undertaken in 8 high-priority health-risk areas and involves the community and other stakeholders. There is a need to extend the existing NMMP for surface waters to include groundwaters. The specific aim of this phase is to develop a prototype manual that formally describes the detailed groundwater monitoring system design and all aspects of subsequent implementation of the programme.

Estimated cost: R600 000  
Expected term: 2001 - 2003

### Thrust 4: Eutrophication and Algal Blooms

#### Programme 1: Detection and management of cyanobacteria

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

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

This project aims to investigate the scope and degree of toxicity of cyanophytes: Methods for growth and cultivation of toxic and non-toxic cyanophytes on a laboratory-scale are being developed to provide a constant supply of these bacteria to research laboratories to be used as standards. The project also addresses the control of pesticide synthesis as a prelude to determine genetic control of the algae.

- Gather information on the occurrence, treatment and management options to address algal blooms

from all the water suppliers, agricultural sectors and DWAF for the development of a management manual that could be of benefit to both smaller rural drinking water treatment plants and the larger water suppliers.

- Investigate if microcystins modulate the immune system of mammals and whether this modulation of the immune system can be used for diagnostic and analytical purposes.

Cost: R372 000  
Term: 1999 - 2001

#### Effect of microcystins on the immune system using the pro-inflammatory hormone Interleukin 6 as biomarker

Department of Zoology, Stellenbosch University (WRC Reference No 1200)

The aims of this project are to:

- Determine whether microcystins affect the immune system of animals
- Undertake an in vitro assay for microcystin immuno-modulation on human whole blood
- Write standard operating procedures for microcystin immuno-modulatory assays (techniques, equipment and chemicals).

Estimated cost: R84 200  
Expected term: 2001 - 2003

#### Determination of the known extent of cyanobacterial problems in SA water resources and identification of South African cyanobacterial knowledge, information and research needs

Department of Biochemistry and Microbiology, University of Port Elizabeth (WRC Reference No 1288)

This study aims at:

- Determining the current extent of, and trends in cyanobacterial-related problems in South African water resources
- Identifying the information needs of all stakeholders, specifically of water resource management organisations
- Identifying currently available resources for cyanobacterial problem events
- Determining the need for, and direction of, future cyanobacterial research.

Estimated cost: R70 000  
Expected term: 2001

### Thrust 5: Water Resource Protection and Reclamation in Agriculture

#### Programme 1: Fitness-for-use of water for crop production, livestock watering and aquaculture

Health risk assessment in connection with the use of microbially contaminated source waters for irrigation  
Department of Medical Virology, University of Pretoria; Department of Community Health, University of Stellenbosch; and Department of Microbiology, Venda University (WRC Reference No 1226)

This project aims to:

- Assess the presence of pathogens on crops irrigated with microbially polluted water, viz., Hepatitis A, human Calicivirus, human Astrovirus and selected indicator organisms
- Identify the most likely pathogens in the Plankenberg River by investigating patient records of the community of Kayamandi, Stellenbosch and analysing river water for related disease-causing organisms
- Determine antibiotic susceptibility patterns of organisms obtained from the river water
- Recommend remedial actions and to guide future research.

Estimated cost: R100 000  
Expected term: 2001

## NEW

### Thrust 1: Microbial Water Quality and Risk Assessment

#### Programme 3: Method development for known and emerging micro-organisms causing water-borne diseases

The origin, fate and clinical relevance of water-borne pathogens in South Africa  
University of Pretoria, University of Venda, Rand Water (WRC Reference No 1398)

The introduction of water-borne pathogens through faecal pollution of surface water has serious health and economic consequences for communities who rely on such water sources for drinking water, irrigation or recreation. This project will investigate potential sources, build-up and transport, and the fate of three pathogens, viz. *Salmonella* spp; *Vibrio cholerae* and *Cryptosporidium*. The association between environmental factors and social determinants and water-borne diseases will also be investigated.

Estimated cost: R620 000  
Expected term: 2002 - 2004

### Thrust 2: Detection and Prevention of Endocrine Disrupting Contaminants (EDCs) and Toxins in Water Sources

#### Programme 1: Development of the EDC programme, development of bio-assays and validation of chemical analyses for the detection of EDCs

An investigation into cadmium levels in the Umtata River, and its associated health impact on rural communities who are primary users of water from the river

University of Fort Hare (WRC Reference No 1399)

An initial study of the water quality of the Umtata River

(WRC Ref No. 1067) has indicated that high levels of cadmium are present in the Umtata River. This is a cause for concern because of its toxicity and endocrine disruptive effects on humans and animals. This project is intended to identify the point and diffuse sources of the cadmium and to investigate the health impact of chronic cadmium poisoning on the primary users of the river water. An epidemiological survey of cadmium-related diseases will be conducted.

Estimated cost: R250 000  
Expected term: 2002 - 2003

#### Programme for endocrine disruption contaminants (EDC)

Consortium Members: US; UFH; MEDUNSA; Technikon Free State; Technikon Pretoria; SABS; CSIR Environmentek; ARC-PPRI; Consultant manager (WRC Reference No 1402)

This is a follow-up of the preliminary studies of the EDC programme. This programme will focus on the present status of EDC pollution in the aquatic systems of the country and will address the wide variety of chemicals involved to determine those crucial for the SA environment and the special techniques and skills needed for the detection thereof. It will be a combined effort between laboratories country-wide with specific capabilities and skilled researchers to develop a battery of bio-assays and chemical analyses that could be used to determine the extent of the EDC pollutions in SA. Each laboratory will be expanding on their special capabilities and building capacity to form a centre of expertise, but not working in isolation, to the benefit of this research in SA.

Estimated cost: R3 000 000  
Expected term: 2002 - 2005

### Thrust 3: Water Quality Risk Assessment and Management

#### Programme 1: Development of guidelines

Monitoring environmental water on the East Rand for the presence of toxic agents: A pilot study  
Highveld Biological Association  
(WRC Reference No 1397)

Environmental monitoring is normally only carried out by institutions with substantial resources, which in South Africa has tended to create a top-down approach to

water quality problems. Decisions are taken and priorities assigned by people who are not themselves affected by the problems they are investigating. Small disadvantaged communities have become passive participants in a process that impacts directly upon their constitutional right to safe water.

In a previous WRC project the project leader has developed a rapid low-cost method of monitoring the toxicity of water prior to and after human use. This project is a pilot study intended to demonstrate the effectiveness of the method with the co-operation of disadvantaged communities.

Estimated cost: R250 000  
Expected term: 2002 - 2003

#### Programme for the development of health-related guidelines

Lenehan Engineering and Environmental Consulting; Pulles, Howard & de Lange Inc.  
Consultancy members: Umgeni Water; CSIR; BKS; ARC; DWAF  
(WRC Reference No 1400)

This programme focuses on the development of a series of guidelines and protocols to promote and advocate the safe use of water with the aim to build awareness and to transfer technology to the public to minimise water-related health risks. This programme is intended to meet the needs of practitioners and will consider aspects of water use and health, hygiene, hazards and risks as well as epidemiological studies, communication protocols and education guidelines.

These projects are concerned with translating scientific data into accessible formats.

The following products will be developed:

- Management of *Legionella* and health-risk assessment guidelines (TT 174/02)
- Guides on the management of water-related microbial diseases (TT/175/02)
- Risk communication guidelines (1400A)
- Linking human health and ecosystem health risks (1400B)
- Child-centred course for teachers to promote basic health in rural communities (1400C)

Estimated cost: R1 167 000  
Expected term: 2002 - 2004

#### Sub-project: Management of water-related microbial diseases series:

The development of risk communication guidelines  
CSIR Division (Environmentek)  
(WRC Reference No 1400 A)  
Other Consortium members: Rand Water, WRC Reference No 1028; Technikon Free State/ DWAF, Consultancy No 431

#### Sub-project: Protocol manual for the transfer of methodology required to link ecosystem and human health

Pulles, Howard & de Lange  
(WRC Reference No 1400 B)

#### Sub-project: The development of a child-centred course for teachers to promote basic health and hygiene awareness in rural communities

Lenehan Consulting  
(WRC Reference No 1400C)

### Thrust 4: Eutrophication and Algal Blooms

#### Programme 1: Detection and management of cyanobacteria

##### Cyanobacteria programme: Toxin blooms and toxin promotion

Consortium members: PU for CHE; University of Port Elizabeth; Technikon Pretoria  
(WRC Reference No 1401)

The first part of this programme will investigate, *in vitro*, algal physiological aspects concerning phosphorus and nitrogen nutrition as part of an ongoing study as to why problem algae form harmful blooms. A model for the prediction of toxic bloom events based on the cellular mechanisms of the modulation of toxin production by nutritional environmental parameters will also be developed. The third part will be an investigation of algal blooms and release of decomposition products and cellular material with consequent effect on water quality during lysis of the bloom in the Hartbeespoort Dam.

Estimated cost: R630 000  
Expected term: 2002 - 2005

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# ANNEXURE

Publications emanating from research financed wholly or partially by the WRC. This Annexure contains a list of publications released during January 2002 to 31 March 2003.

Requests for articles and papers should be directed to the authors.

## KSA 1

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