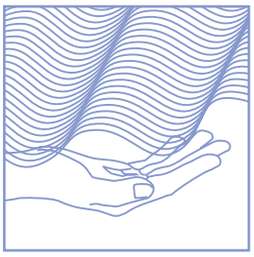
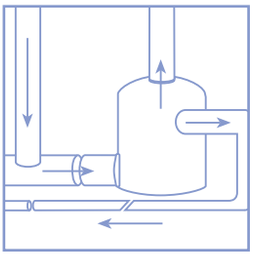


water resource management

water-linked ecosystems



water use & waste management

water utilisation in agriculture

water-centred knowledge

knowledge review 2003/04

water research commission

vision & mission
water research commission

our vision

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.

our mission

The WRC is a dynamic hub for water-centred knowledge, innovation and intellectual capital. We provide leadership for research and development through the support of knowledge creation, transfer and application. We engage stakeholders and partners in solving water-related problems which are critical to South Africa's sustainable development and economic growth, and are committed to promoting a better quality of life for all.

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Water Research Commission Knowledge Review

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contents

wrc executive

From left to right

Front row: ***Dr R Kfir (CEO), Dr I Msibi and Dr G Green***

Back row: ***Mr J Bhagwan, Mr A Rampershad, Dr K Pietersen, Dr G Backeberg and Dr S Mitchell***

introduction

Introduction

As reflected in the Water Research Commission (WRC) 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 and transferring knowledge to the water sector and the community at large, both locally and globally.

The WRC plays 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 competences/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

During 2003/04 the WRC further implemented its core strategy developed during 2002/03. While 2002/03 was a year of rapid transformation, 2003/04 has been a year where strong emphasis has been put on consolidation and positioning of the 'new' WRC, both internally and externally. The WRC has built a strong foundation for functioning as a water-centred knowledge hub locally, and positioned itself in Africa and globally, as reflected in the organisation's achievements to date. During 2003/04 great strides were made in positioning the organisation with a number of key stakeholders locally, including government departments, the SA Parliament and other segments of the water sector (SALGA, SAAWU). Internationally the WRC has built strong links with the Africa Water Utilities Partnerships, African representative partners of *Streams of Knowledge* and WARFSA and many other forums, while globally the WRC is involved in many initiatives of various UN organisations (e.g. UNEP, WHO, WWF) and other international coalitions and bodies (a few examples are WSSCC, GWRC, Penta-Party, IWMI). The organisation consulted widely with many of its stakeholders regarding the scope of its operation and its strategic direction. Feedback from internal and external stakeholders affirms the core strategy and operational modality as described in the *Core Strategy and Business Plan of 2002/03*. In the light of the above the WRC assessed its research portfolio and accordingly, no major changes were implemented in the core KSA structure, i.e. the four water-centred KSAs and the knowledge-centred KSA continued to form the base operating structure. Good progress has been made towards achieving the objectives set with regard to the key performance areas (KPAs), which indicate that the WRC is functioning in a manner which is true to its mission and advancing rapidly towards the strategic position set out in its vision. The organisation has improved its internal efficiency and its effectiveness as well as its relevance to its key stakeholders and South Africa at large. The WRC continues to strive towards being a highly relevant and effective organisation, highly sustainable and emphasising continuous renewal.

The WRC has initiated and implemented a number of drives regarding the strengthening of the water-centred knowledge base of South Africa. In the area of **capacity building** the WRC has greatly improved its support to students with special emphasis on historically disadvantaged students. Currently about 428 students are supported by the various WRC projects (an average ratio of about 2 students per ongoing active project). This represents a substantial increase from 300 students reported in the *2002/03 Knowledge Review* (an increase of 43%). Of the total number of students, about 280 students, i.e. 66%, are disadvantaged. In addition to capacity building which is project-specific, the WRC has been and is planning to continue to support student participation in local and international conferences, for example, the WRC sponsored the IWA Conference in September 2003, Cape Town, which included three conferences in one, i.e. *Health-Related Water Microbiology*, *Biofilm Formation* and *Sustainable Development*. The WRC sponsorship made provision for 25 young South African students (many from disadvantaged backgrounds) to attend the conference. The WRC also supported the youth (*Youth Water* award) and gender-linked awards such as the *Women in Water* award. The WRC is participating in and is planning to further strengthen its involvement in broadening the knowledge of the youth with regard to water issues and has published a short supplement in *The Water Wheel* focusing on role models enjoying successful careers in the water field. The WRC is currently developing a booklet giving a concise account of careers in the water sector.

Organisation	Number of disadvantaged Students	Total number of students
Council for Geosciences	1	2
C Swartz	5	5
Coaltech 2002	4	6
CSIR	10	19
Durban Institute of Technology	3	4
Du Pisanie	2	2
Ecosun cc		1
Envi-Sabi Scientific	3	3
Endocrine Consortium *	22	28
ERWAT	4	4
Highveld Biological Association	1	3
Institute for Water Research (Rhodes)	5	9
Institute of Natural Resources	7	9
Lowveld College of Education	2	2
McCracken Solar Stills	1	2
Northern Gauteng Technikon		1
Palmer Development	1	1
Pegasus	1	1
Peninsula Technikon	8	10
PE Technikon	1	1
Phillip Pybus	1	1
PU for CHE	3	5
Pulles, Howard & de Lange (CE) Inc.	9	10
Rand Afrikaans University		2
Rhodes University	13	24
SA Weather Services	1	1
SRK (CE) Inc.	1	2
Stewart Scott (CE) Inc.	1	2
Techikon Wits	2	4
Technikon SA	3	3
Technikon Pretoria	17	22
Umgeni Water	2	2
University of Cape Town	16	34
University of Durban-Westville	2	2
University of Free State	15	25
University of Fort Hare	6	6
University of Natal	28	42
University of the North	3	5
University of Port Elizabeth	5	14
University of Pretoria	25	35
University of Stellenbosch	13	26
University of the Western Cape	21	27
University of the Witwatersrand	8	17
University of Venda	4	4

In the area of **knowledge application/commercialisation**, the WRC established an Intellectual Property and Benefit Sharing Policy aimed at improving water-centred knowledge transfer and application and increasing revenue via such commercialisation activities. The WRC has reviewed its patent portfolio and identified a new modality for managing the portfolio. In the area of **knowledge dissemination** the feedback regarding the organisational drives supporting knowledge transfer and dissemination clearly indicate the importance of these activities as part of the WRC key role as a knowledge hub. While *Water SA* continues to be a flagship scientific and technical journal attracting global contributions and wide local and global readerships, *The Water Wheel* provides a route for disseminating popularised water-centred knowledge to the wider sector/public. The WRC *Knowledge Review* provides an accurate account of all WRC research activities on an annual basis and is indicated to be of very high value locally, in Africa and globally. The WRC plans to further improve such knowledge dissemination activities and widen their scope; for example, a book about water in SA from a historical and cultural perspective is to be compiled and published; linking water to the arts is another planned initiative in collaboration with the Department of Arts and Culture, libraries and other parties.

The WRC research portfolio

The research portfolio for 2003/04 (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.

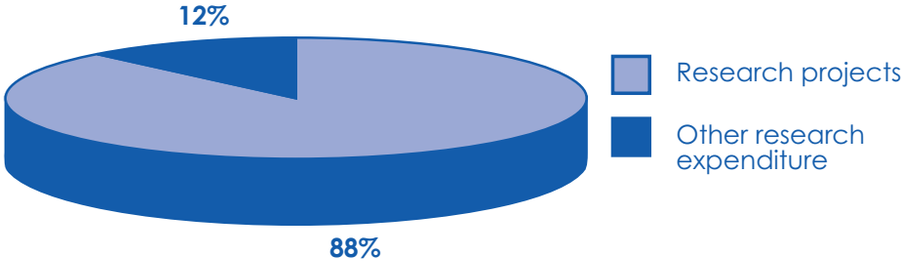
During 2003/04 the WRC assessed its research portfolio and consulted widely with many of its stakeholders regarding the scope of its operation and its strategic direction. In general, the portfolio as planned for the year under review was well received by the various stakeholders. The KSA-based structure, with its four water-centred KSAs and its knowledge-centred KSA, continued to form the core operating framework for WRC-funded R&D, was further consolidated and became accepted generally.

Through its various KSAs and crosscutting domains, the WRC supported 395 research projects, including 371 non-solicited and 24 new solicited projects during the year under review. This group of solicited projects was the first to be initiated in accordance with the WRC's new strategy, i.e. to allocate a significant proportion of available funding to solicited projects that are specifically designed to pro-actively address critical research needs. During 2003/04 solicited projects (to which 52% of available funds for new research was allocated), therefore, already comprised 44% of the 54 new projects which were initiated. Of the 395 projects supported, 341 are ongoing, multi-year research projects. However, the ongoing projects, despite making up 86% of all projects, have been allocated less than 50% of the available funds, reflecting a move to fewer, larger projects, and the fact that many projects were already in their final stages of completion during 2003/04.

The distribution of research project funds among the various categories of research providers (these being tertiary educational institutions, science councils, consultants, governmental institutions and NGOs) was in general similar to that of the previous year (2002/03), when higher education institutions (university and technikons) were the major contributors to WRC-funded research and thus also the major recipients of funds.

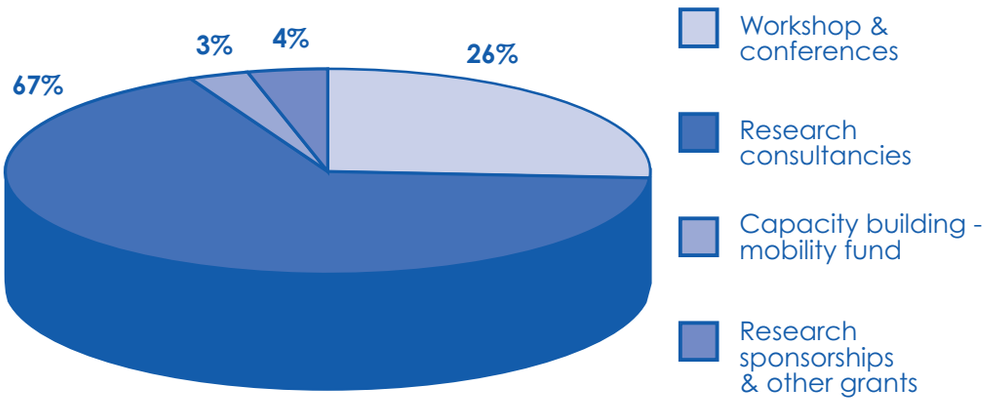
The strategic allocation of research project funds between the water-centred research KSAs for 2003/04 resulted in **Water Resource Management** receiving 31% of the funds, **Water-Linked Ecosystems** 13%, **Water Use and Waste Management** 40% and **Water Utilisation in Agriculture** 14%. The balance (2%) was allocated to the crosscutting domains (1%) and held in the central fund (1%). The relative allocation of funding to research focusing on water resources (including water-linked ecosystems) and water utilisation (domestic, municipal, industrial and agricultural, including effluent treatment and management) has remained very similar to that of the previous year (2002/03).

Percentage allocation of research funds to:

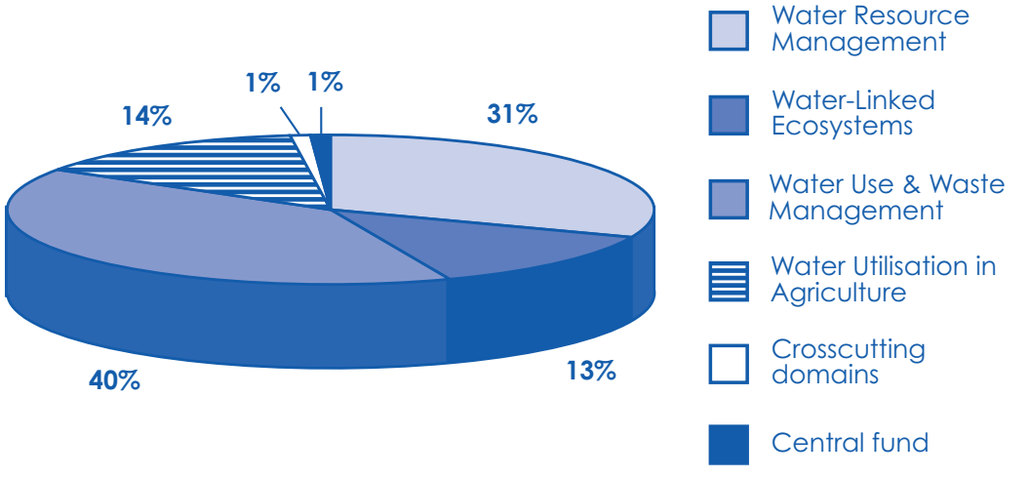


introduction

Percentage allocation of non-project research funds to other research-related activities



Percentage allocation of project funds to KSAs and crosscutting domains



During 2003/04 the KSAs consulted widely with many of their stakeholders regarding their scope of operations and strategic direction, and accordingly refined their strategic and business plans. As part of this process, numerous workshops were arranged and other knowledge-sharing activities undertaken in support of further development of each KSA's research portfolio. New KSA-specific research portfolios were initiated. The KSAs continued to operate as strategic units which place emphasis on knowledge generation, dissemination and transfer, as well as capacity-building. They have provided strong leadership, directing and supporting water-centred knowledge generation in South Africa, linking and networking with local players and supporting strong partnerships with global players. The **Water-Centred Knowledge** KSA, in particular, has supported a number of knowledge-sharing and dissemination initiatives, including the assumption of the leadership of WIN.

The call for research proposals during 2003/04 (for projects due to commence in 2004/05) was based on KSA-specific research portfolios and included a call for both solicited and non-solicited research proposals. During 2003/04 a call for research proposals based on current research portfolios was followed by a thorough selection process and the acceptance of 81 research projects for funding. This includes 60 non-solicited and 21 solicited projects.

Detailed business plans for each of the KSAs have been developed, providing an in-depth presentation of its research portfolio. The following section presents a short summary highlighting the scope for each of the KSAs.

water resource management

Scope

The strategic focus for research in this KSA was reviewed internally and externally and it was concluded that no major changes in focus are required. The focus will continue to be 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 utilisation. This KSA 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 stakeholder participation in water resource management; this requires effective participatory tools and approaches that can support multi-stakeholder 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.

During 2003/04 the research portfolio included new initiatives and current projects addressing the objectives mentioned above. Overall, about R21.6m was invested in 144 projects. Of these, 15 projects were initiated during the year under review while 129 were ongoing. During the year under review, 36 projects were finalised and 49 reports published.

water-linked ecosystems

Scope

Research undertaken within this KSA will continue to address the conservation of aquatic ecosystems in order to provide the knowledge for their sustainable functioning in terms of the national commitment to international conventions and the ongoing provision of goods and services which ecosystems deliver. In addition, the National Water Resource Strategy (NWRS) focuses on resource protection as one of its components. The research undertaken in this KSA provides knowledge for protection of the resource, and is therefore central to this aspect of the NWRS. No major changes in strategic direction are envisaged and the research portfolio as presented in the previous year's strategy was found to be sound and applicable. Deviation in programme focus or structure will be highlighted below.

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 this KSA to support the implementation of the national water policy to ensure sustainable resource use.

During 2003/04 the research portfolio included new initiatives and current projects addressing the objectives mentioned above. Overall, about R9.2m was invested in 51 projects, of which 8 projects were initiated during the year under review while 43 were ongoing. During the year under review 18 projects were finalised and 22 reports

published.

water use and waste management

Scope

The **Water Use and Waste Management** KSA focuses mainly on the domestic, industrial and mining water sectors. It aims to proactively and effectively lead and support the advancement of technology, science, management and policies relevant to water supply, waste and effluent management, for these sectors. This KSA also supports studies on institutional and management issues, with special emphasis on the efficient functioning of water service institutions and their viability. Research on infrastructure for both water supply and sanitation is included. A further focus is on water supply and treatment technology serving the domestic (urban, rural, large and small systems) as well as the industrial/commercial and mining sectors of our economy. This KSA also focuses on waste and effluent as well as reuse technologies that can support the municipal, mining and industrial sectors and improve management in these sectors with the aim of improving productivity and supporting economic growth while minimising negative effect on human and environmental health.

The research portfolio for 2003/04 included new initiatives and current projects addressing the objectives mentioned above. Overall, about R27.4m was invested in 144 projects, of which 24 projects were initiated during the year under review while 120 were ongoing. During the year under review 52 projects were finalised and 47 reports published.

water utilisation in agriculture

Scope

The strategic focus in this KSA has been reviewed and found to reflect current and future research needs. It was concluded that the strategic focus as described in the *2002/03 Knowledge Review* is appropriate. The focus is on increasing the efficient use of water for production of food, fibre, fuel-wood 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
- 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.

During 2003/04, the research portfolio included new initiatives and current projects addressing the objectives mentioned above. Overall, about R9.9m was invested in 48 projects. Of these, 7 projects were initiated during the year under review, while 41 were ongoing. During the year under review 16 projects were finalised and 10 reports published.

water-centred knowledge

Scope

This KSA continued to focus on knowledge management during the year under review in a similar mode and direction as described in the previous year, while there would be additional emphasis on the development and protection of knowledge resources. The WRC continues to function as a knowledge organisation and hence its fundamental business 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, i.e. the creation and dissemination of knowledge, requires both cultural and functional changes. The embodiment of the culture of knowledge forms the basis of the WRC mission and is the focus of the WRC

vision. During the next financial year management, creation and transfer of knowledge will continue to be the keys for the WRC in providing a valuable service to the South African water users.

Driven by external needs, the WRC will strive to 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 for the support of the cultivation and facilitation of the sharing of knowledge and organisational learning. Internally, 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, both internally as well as externally.

Crosscutting Domains

The core strategy of the WRC calls for specific mechanisms to address key strategic issues of national importance. These issues are dealt with in four crosscutting domains which were established specifically for this purpose. Apart from their national importance, the issues addressed by the domains also enjoy regional and international priority, as the agendas of major events and movements such as the WSSD, the 3rd World Water Forum and NEPAD have clearly shown. The crosscutting domains form integrating frameworks across the KSAs. They draw together programmes and projects which are under way within the portfolios of each of the KSAs and which address issues relevant to each of the domains. It is also the role of each of the domains to provide leadership and support for new KSA initiatives which can further knowledge with regard to domain-related strategic thrusts being addressed within the various KSAs. The domains may also drive specific programmes/projects that are overarching and relate to all KSAs in a general manner.

The crosscutting domains address the following key issues:

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

water and society

Scope

The scope of this domain continues to address water as a social good and the vital role water plays in social development. It provides an integrating framework for, and further facilitates expansion of, that research and development within the different KSAs which contributes to a sound balance between the manner in which water resources are used and cared for by society, and the benefits which society as a whole derive from the use of water. The domain endeavours to find ways to assist society in developing a sound understanding and appreciation of the various issues around water as a scarce resource, as these relate to the need for equitable (including transboundary) sharing of the resource, avoidance of conflict, promotion of co-operative water resource management and productive and sustainable resource use. Finding improved, sustainable and socially acceptable ways of meeting society's needs for water services is another important focus area because of the continuing service backlog. Furthermore, inter-linkages between poverty issues, gender issues and access to water and water services need to be established, and the knowledge gained applied in promoting poverty alleviation and better quality of life for society as a whole.

water and the economy

Scope

The scope of research addressed by this domain has remained unchanged from the previous year. 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 is 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. Almost without exception, there is an increasing interest in assessing the economic value of water, using water as a catalyst for the generation of wealth and prosperity, and using economic instruments to increase efficiency and effect desired behavioural change among water users. The use of water tariffs to effect changes in water consumption and the use of waste discharge charges to internalise pollution costs and, in so doing, effect pollution reduction and desirable improvements in water quality, are

management options worthy of investigation and are, in fact, provided for in the National Water Act along with the selling of water use licences under specific circumstances.

This domain will integrate the economic aspects of water-related investigations funded by the 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 and assess its role in wealth creation and the use of economic instruments in changing the behaviour of society at the appropriate micro-, regional and national levels.

water and the environment

Scope

The scope of research in this domain has been re-assessed and redefined following extensive stakeholder consultation and needs analysis.

Incomplete knowledge and understanding of the linkages between environmental components (atmospheric, marine, terrestrial, aquatic, subterranean) within the hydrological cycle, and between the hydrological cycle and governance systems, hinder sustainable water resource management. This crosscutting domain promotes enhanced understanding of whole-ecosystem functioning in the context of the broader environment and its effects on water resources, and supports the development and application of good environmental governance systems. Activities within this domain contribute to sustainable water resource management that meets the changing needs of society, by combining our understanding of good governance principles with our knowledge of environmental components (atmospheric, marine, terrestrial, aquatic and subterranean) and processes within the hydrological cycle.

The primary focus of the domain will be to integrate existing and new insights generated by research within and between the KSAs and by other institutions working in related fields. In addition, this domain will stimulate the generation of specific new knowledge and understanding that will equip the water sector to anticipate and respond appropriately to changes within the biophysical environment. Although this domain is characterised by integrating research at a high / meta-data analysis level, it is recognised that such research is only possible on the assumption that we have a sound foundation of appropriate basic research (and data) in place.

water and health

Scope

This domain continues to have an essential role to play in providing an integrating framework for all the WRC's health-related research and development initiatives, identifying gaps and negotiating the initiation of gap-filling research in crucial areas. In fulfilling this role, the domain assumes the responsibility for the structuring of a co-ordinated, needs-driven, dynamic health-related water research portfolio on behalf of the WRC, with contributing projects being funded and managed mainly at KSA level.

Health-related water research is undertaken with the aim of improving water quality and hygiene practices in order to save lives and reduce the cost and effort in treating symptoms of disease. The focus is on water-linked diseases associated with microbial or chemical contamination or transferred via water-associated vectors. The domain aims to improve knowledge regarding the origin, survival and persistence of microbial, biological and chemical agents that may pollute water and may affect human health. The domain supports the development and utilisation of methodologies to identify and quantify the occurrence of pathogens and contaminants in water, as well as risk assessment and epidemiological studies.

A holistic, multidisciplinary approach is followed in order to develop a comprehensive understanding of the origin/sources and spatial extent of pollution; water usage patterns; the effects of degraded water quality on animal and human health and the need for water treatment. The development of guidelines, protocols, manuals and pamphlets as tools to disseminate research findings is supported. The emphasis is on a pro-active approach to identify and address causes, rather than on a passive response to addressing symptoms. This approach should ensure research products that are relevant, user-friendly, practical and scientifically valid.

ksa 1

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 of the environment and efficient utilisation. This KSA 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 multi-stakeholder 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

Scope: 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. 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 review and refinement of national monitoring and information systems and the development of effective assessment techniques and predictive tools.

- 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

Scope: 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 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 critical 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.

- Integrated catchment management
- Low flows and streamflow reduction activities

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

Scope: 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. The research will also provide guidelines for moving away from the traditional "command-and-control" approach to a more oriented "stick-and-carrot" approach.

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

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

Scope: Research in this thrust focuses on supporting policy developments, implementation processes and evaluation of policy impacts. The research also investigates the following tools and institutional arrangements for resolving potential water-centred conflicts and for the management of shared international rivers and transboundary aquifer systems:

- 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

Research portfolio for 2003/04

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 also contribute to the development of a skilled and competent pool of experts who can support the implementation of national water policy and also provide leadership for the sector at regional and global levels. Current emphasis of the research portfolio is to support the implementation of the National Water Resource Strategy through the following

broad ways:

- Through integrated water resource assessment (developing knowledge of the different components of the resource in terms of quantity and quality and its condition in relation to reference conditions)
- By developing and refining tools and methods to support implementation of resource-directed measures (RDMs) and source-directed controls (SDCs)
- By providing greater understanding of threatening processes to water resources such as global climate change, water resource degradation, over-commitment of the resource, and impacts of land use and water storage and diversion on the water resource
- By providing tools for the assessment of policy and management options (such as modelling, decision support systems, and predictive tools)
- By providing data and tools for assessment of the progress of resource management programs, and their successful refinement.

The following research themes are to be addressed in 2003/04:

- Global climate change and water resources in Southern Africa
- Daily rainfall mapping over South Africa
- Fractured-aquifer characterisation (including protection and RDM measures)
- Flood nowcasting
- The development of a strategic research investment framework for basement aquifers.
- Flow conceptualisation and storage determination of Table Mountain Group (TMG) aquifer systems.
- Stakeholder participation in the establishment and governance of catchment management agencies (CMAs)
- Co-operative governance of CMAs

Budget for 2003/04

The approved funding of the research portfolio for 2003/04 leads to a committed funding budget of R21,6 m. The new projects will continue to develop tools, technologies and guidelines necessary to support sustainable water resource management.

Core strategy

Strategic context

South Africa's water resources are, in global terms, scarce and extremely limited in extent. There are no truly large or navigable rivers in South Africa and the total flow of all the rivers in the country combined amounts to approximately 49 200 x 106 m3/a ; less than half of that of the Zambezi River, the closest large river to South Africa. 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.

This KSA intends to provide its stakeholders with integrated solutions to the water resource management

challenges facing South Africa. The approach will address challenges in a multidisciplinary manner. This will enable the WRC to generate integrated solutions that will 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.

Needs analysis

Integrated water resource management (IWRM) is a process with biophysical and socio-economic dimensions. Maintaining the integrity of the eco-hydrological whole or unitary continuum of the hydrological cycle is essential to sustainable development. Simultaneously, IWRM is about the fact that water is a natural resource that belongs to all the people and management of the resource needs to ensure equity in access and equitable allocation of water for beneficial use in the public interest. The NWA provides the legislative framework in South Africa for the attainment of IWRM principles. 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 by 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.

The National Water Resource Strategy (NWRS) is required by the NWA. The NWRS provides information about ways in which water resources will be managed, including the institutions to be establishedError! Bookmark not defined.. It must also provide quantitative information about the present and future availability of and requirements for water in South Africa. This must be done for each of the water management areas, and propose interventions by which the two may be balanced ("reconciled"). The Strategy must also quantify the proportion of available water in each water management area which falls under the direct control of the Minister in terms of her or his national responsibilities. Research cannot provide management and immediate policy decisions. These have to be made on the basis of available information. However, the NWRS requires better information and improved information analysis tools that will allow detailed examination and evaluation of the consequences of the various policy and management options. This KSA will support the implementation of the NWRS in the following broad ways:

- Through integrated water resource assessment (developing knowledge of the different components of the resource in terms of quantity and quality and its condition in relation to reference conditions)
- By developing and refining tools and methods to support implementation of RDMs and SDCs
- By providing greater understanding of threatening processes to water resources such as global climate change, water resource degradation, over-commitment of the resource, and impacts of land use and water storage and diversion on the water resource
- By providing tools for the assessment of policy and management options (such as modelling, decision-support systems, and predictive tools)
- By providing data and tools for assessment of the progress of resource management programs, and their successful refinement

While providing research support to implement the NWA is crucial to the KSA's business, this KSA needs to support water resource management actions at global, regional and local level. The Ministerial Council which accompanied the 2nd World Water Forum identified the following challenges:

- Governing water wisely
- Valuing water
- Sharing water
- Managing risks
- Securing the food supply
- Protecting ecosystems
- Meeting basic needs

These challenges are being addressed in this KSA at appropriate levels. Current actions are placing special emphasis on integrating environmental, social and governance objectives into the benefits of water development. Water research must provide the necessary information base, guidelines, decision-support tools and technologies that will support the implementation of sustainable water actions. 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 related to needs

Numerical simulation modelling, geostatistics and GIS are indispensable tools 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. The Internet and new computer operating systems have meant that computer simulation models have to be developed to fit into this computing environment. These developments have had major implications on the choice of code and methodologies used in developing models such that some major water resource management stakeholders (DWAF) have developed clearly defined guidelines on which code to be used and how it will be used in new software development. The initiative to develop and improve water resource models that fit the dynamic computing environment will continue to receive support from the WRC.

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 and appropriate measurements will 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 "streamflow 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 its 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 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 KSA1 is conducted by Universities (about 46%). Science councils and consulting firms are responsible for approximately 42% of the research and there is limited participation by DWAF, water boards and Eskom.

Research portfolio for 2003/04

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. The research portfolio for 2003/2004 advances these aims by focusing on the following areas:

- 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 quality of South Africa's surface water resources

The changes in the portfolio from the previous *Knowledge Review* are:

- The change of **Groundwater resource development** programme to the **Low flows and streamflow reduction** activities programme in Thrust 2
- The addition of a programme on **Integrated flood management** in Thrust 3.

An overview of KSA 1 research thrusts and programmes for 2003/04 is presented in **Table 1**.

Overview and description of thrusts and programmes for the research funded within KSA 1

THRUST 1: WATER RESOURCE ASSESSMENT	
Scope: *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 assessment techniques and predictive tools.*	
Programme 1: Groundwater occurrence in fractured-rock aquifers.	**Scope:** 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.
Programme 2: Catchment hydrology	**Scope:** Essentially this programme establishes how much water is naturally available in South Africa and the possible impacts of human activities 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.

THRUST 1: WATER RESOURCE ASSESSMENT (continued)	
Programme 3: Understanding and predicting rainfall variability	**Scope:** The ultimate goal of this programme is to achieve better forecast of rainfall variability (including rainfall events and amounts) and this 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 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.
Programme 4: Development of appropriate techniques for evaporation monitoring	**Scope:** 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.
Programme 5: Water quality assessment studies and information systems	**Scope:** It is imperative to identify emerging water quality issues and how to deal with them, and furthermore, how to improve the available tools to assess and manage water quality. It is imperative to develop comprehensive and practical National Monitoring Programmes (NMPs) to monitor and to report on the national status of pollutants as well as trends in South African water resources in order to support national strategic decisions and in respect of their management.
Programme 6: Real-time mapping of daily rainfall over South Africa	**Scope:** 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	
Scope: *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.*	
Programme 1: Integrated catchment management	**Scope:** 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.
Programme 2: Low flows and streamflow reduction activities	**Scope:** Scarcity of knowledge has been identified in licensing related to low flows, in surface water – groundwater interactions and in tools for measurement of low flows when physical structures can not be used. This research will seek to develop solutions to maintain high quality flows in river systems that comply with the Water Act of 1998. These Low flows and SFR studies will provide clear directions to the licensing of SFRA and the maintenance of high quality flows in rivers. These studies will focus on developing methods or/and equipment for defining and estimating streamflow reduction due to activities such as agriculture, forestry and industry that can be used by the licensing agents. The research will support the current initiatives in the compulsory licensing of streamflow reduction activities. Methods developed should clearly stand out as the preferred solutions in South Africa through how they are proposed, developed and implemented.

THRUST 3: MANAGEMENT OF NATURAL AND HUMAN-INDUCED IMPACTS ON WATER RESOURCES	
Scope: *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 "stick-and-carrot" approach.*	
Programme 1: Predicting the impact of global climate change	**Scope:** Predicting the impact of global climate change - The need to prepare the country to cope with global climate change is of paramount and strategic importance. Taking the view that water is South Africa's key resource implies the need to adapt water resource management progressively as global climate change progresses, in order to maintain optimal levels of both resource protection and beneficial use of water for society. The following key questions thus need to be considered and addressed in this programme: What confidence can be placed in current GCM-generated scenarios of global climate change? How reliable are current techniques for downscaling of scenarios from global to regional and catchment scales? At what point will anthropogenic climate change in the Southern Africa context become detectable and distinguishable from natural climate variability and what monitoring systems need to be in place in this regard? How will the frequency and magnitude of extreme rainfall events be affected? Can existing conceptual and numerical models utilise global change-related, downscaled, hydroclimatic information effectively, to provide information regarding likely inter-related land-use, ecosystem, hydrological (including geohydrological), and water yield and water quality changes at regional/catchment level? What are the main socio-economic impacts in the absence of coping strategies likely to be, given the structure of society in Southern Africa?
Programme 2: Groundwater protection	**Scope:** 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.
Programme 3: Pollution of surface water	**Scope:** Research in this programme is aimed at improving the 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. 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 the degree to which 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
Programme 4: Human-induced impacts	**Scope:** 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.
Programme 5: Integrated flood management.	**Scope:** Flooding is one of the major natural hazards to human society and an important influence on social and economic development. This programme focuses on research that will result in the development of integrated institutional frameworks and technological tools to reduce and combat floods and their negative effects while enhancing positive flooding patterns that are important to the natural ecosystem.

THRUST 4: POLICY DEVELOPMENT AND INSTITUTIONAL ARRANGEMENTS FOR WATER RESOURCE MANAGEMENT	
Scope: *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 remain 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.*	
Programme 1: Decision support for water policy formulation and implementation	**Scope:** 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.
Programme 2: Development and implementation of water policy instrument	**Scope:** 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.
Programme 3: Institutional arrangements for IWRM	**Scope:** 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
Programme 4: Transboundary water resource management	**Scope:** This programme will provide tools and guidelines for resolving potential water-centred conflicts for the management of shared international rivers and transboundary aquifer systems

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 2003 and 31 March 2004.

COMPLETED

Thrust 1: Water Resource Assessment

Programme 1: Groundwater occurrence in fractured-rock aquifers

The reliability of small spring water supply systems for community water supply projects
Division of Water, Environment and Forestry Technology, CSIR
No 859

This project addressed the factors affecting spring flow and developed ways of predicting the seasonality and reliability of flows from these springs. This was done through extensive field measurements. The hydrogeological and geological controls giving rise to springs were also described in particular to cold springs. The outcome of the research resulted in recommendations for improved spring construction and protection. Observations were made of numerous spring protection measures that had failed. This resulted in common errors being avoided in the spring construction.

Cost: R637 757
Term: 1997-2003

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
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. This research developed a method of integrating and analysing groundwater age data provided by isotopes, so that groundwater mixing ratios could be determined. Calculation of mixing ratios is important for determining the relative contributions of the different recharge years to the water balance of an aquifer. It further investigated, the application of these mixing ratios to groundwater resource evaluations so that these evaluations could be refined.

Cost R354 000
Term: 1999-2003

Hydrogeology of fractured aquifers and related ecosystems within dolerite ring- and sill- systems of the Eastern Cape
Council for Geoscience
No 1238

This study investigated the Qoqodala ring system situated within the Great Kei River catchment in the Eastern Cape. The aim of the project was to investigate ecosystem and spring/seepage dependency on shallow or deep fractured rock aquifers related to dolerite rings and possible vulnerability to abstraction.

The geological and structural analysis has shown that the sill- and ring- system comprises several coalescing and overlapping saucer-shape dolerite rings forming an intrusive network which is conductive to high yielding fractured aquifers at various depths and the emergence of many springs. The Qoqodala dolerite ring system exhibited a typical multi-layered aquifer system, where at least three hydraulically distinct aquifer units were evident. Ecosystem studies have shown that grassland is very common on high lying outer dolerite sills in recharge areas but do not, however, host large wetlands that could act as water reservoirs. Groundwater-dependant plants occur around perennial seeps where the vegetation consists mainly of grass and sedges. These seeps and small wetlands are vulnerable to drilling and groundwater obstruction. The location of wetlands or seeps at low elevation, the direction and density of fracturing the slope of the inclined sheet, and the presence of an outer sill at depth are all factors that should be taken into account when developing dolerite ring related groundwater.

The results of the study have confirmed that ring structures are potentially excellent targets for groundwater, provided that the associated hydrogeological domains and ecosystems are well understood.

Cost: R485 000
Term: 2001-2003

The application of Internet-based interactive mapping technologies for geohydrological research purposes
GEOSS
No 1290

The broad project aim was to use leading Internet-based mapping technology for the delivery of spatial and attribute data to a wide audience, i.e. from students to authorities and decision makers. This was done for the Namaqualand region where numerous studies have been carried out in the area and considerable data has been collected. The system developed has been titled "NamAqua". It has been developed not only as a web-accessible information system, for use by students, hydrogeologists, planners and decision makers, but also provides a forum for educating the public about groundwater and its occurrence. The website address is: http://namaqua.uwc.ac.za

Cost: R79 670
Term: 2001-2003

Programme 2: Catchment hydrology

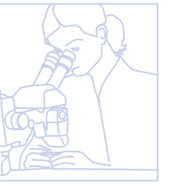
Model of the Orange River
BKS (Pty) Ltd
No 865

This study resulted in a modelling tool to ensure that the correct quantity of water is released from Vanderkloof

Dam (situated on the Orange River) to reach the demand points at a scheduled time without excessive loss to evaporation, infiltration, the ocean and/o any other loss and is still able to generate a healthy river ecosystem. The development of the Orange River hydraulic model involved the updating of the ISIS model using data and parameters generated from physical measurements and available literature. The ISIS model modifications and simulation updates in this study included the following:

- Development of a real-time hydraulic unit. The unit allows simulated flows to match actual stage flows where records exist.
- Development of an adaptive time stepping routine. This routine allows longer time steps, thus drastically reducing computational time
- Implementation of a decision support system for operating the Vanderkloof Dam to determine quantity of releases and their timing
- Development of a customized real time model for the Orange River where continuous updates of river simulations using real time data is possible.

Cost: R968 000
Term: 1997-2003



Flood forecasting system for the Vaal Dam
Department of Water Affairs and Forestry
No 908

This study supported activities of DWAF (training and installation costs) to install and operate a US-based flood forecasting system for the Vaal Dam.

Cost: R150 000
Term: 1998-2002

Monthly multiple-site streamflow model
BKS (Pty) Ltd.
No 909

The provision of synthetic hydrological data in areas where natural data do not exist or are missing using stochastic models has been one of the key competences of South Africa's hydrology community. This project involved further research on the hydrological stochastic generator developed in 1985 for the Water Resources Yield Model (WRYM), rewriting of the stochastic generator code, testing and repackaging as a stand alone stochastic model.

Cost: R300 000
Term: 1998-2004

Sediment-induced density current formation in reservoirs
Department of Civil Engineering, University of Pretoria
No 911

Reservoir sedimentation causes an average annual loss in storage capacity of 130 million m_ in South Africa. Density current venting is a management technique whereby high river sediment loads can be transported through a reservoir and released to the downstream river through bottom outlets, without water level draw-down. This study investigated the use of a theory based on minimum stream power at the plunge point, to predict the formation of a density current. Laboratory tests were carried out with sediment transport to verify the theory.

The guidelines provided in this study to determine density current formation were expected to become useful in the planning, feasibility and detailed design studies by DWAF in sediment management projects.

Cost: R91 000
Term: 1998-2003

A field study of two- and three-dimensional processes in hill-slope hydrology for better management of wetlands and riparian zones
and
Experimental and laboratory measurements of soil hydraulic properties
School of Bioresources Engineering and Environmental Hydrology, University of Natal
No 1061 and 1086

These two projects **(No 1061 and 1086)** were combined midway in the course of implementation because of complementary objectives.

Field and laboratory measurements were used in this study to examine the soil hydraulic properties and streamflow generation mechanisms. This enabled detailed insights into hillslope flow path mechanisms. The experimental findings were used to develop water resources estimation algorithms for hillslope, hillslope-wetland and hillslope-riparian zone models. A GIS-based database of the meteorological and hydrological data of the research catchments with detailed soil hydraulic properties and their assessments was developed for selected catchments in Natal (Zululand and Two-Streams Research Catchments) and the Eastern Cape (Weatherly Research Catchment). Soil hydraulic characterisation and the development of water status monitoring methods were done in the laboratory.

This study determined that the convolution integral analysis, which includes an advection-dispersion solution to flow generation from different sources, can be used to characterise the flow generation responses in various typical formations. These characterisations can be used to improve the parameterisation and algorithms in catchment scale models, which include time-related discharge responses.

Cost: R1 809 000
Term: 1999-2003

Design and testing of an installed hydrological modelling system
School of Bioresources Engineering and Environmental Hydrology, University of Natal
No 1155

This project produced a detailed national hydrological data and information system coupled to an upgraded windows-based ACRU model: This included a model output visualisation tool (ACRUView) and statistical packages for model post-processing. A further outcome of the project was an electronic model user support system which is expected to improve model use and the quality of outputs to be generated. The user support system will handle model user queries, disseminate and share simulation outputs as well as other agro-hydrological data.

Cost: R2 104 000
Term: 2000 -2003

Programme 3: Understanding and predicting rainfall variability

Modelling variability in the Agulhas current system and its influence on South Africa's climate
No 868

Atmospheric and ocean general circulation models were used to better understand the variability of the South West Indian Ocean, a region known to significantly influence Southern African rainfall and extreme event characteristics in the region. An eddy-permitting regional ocean model was applied towards understanding the mechanisms by which ocean variability and associated sea surface temperature anomalies in the region arise. An atmospheric general circulation model was applied towards studying the influence of warm and cool anomalies in the South West Indian Ocean on Southern African seasonal circulation and rainfall pattern, confirming that the South West Indian Ocean is an important source of moisture for seasonal rainfall over Southern Africa. In addition, a regional model was used to investigate the influence of low level moisture emanating from the Agulhas Current region and to model the resulting evolution of a particular extreme rainfall event over southern South Africa. Heat transported into the southeast Atlantic by the Agulhas Current may influence the evolution of weather systems approaching southern South Africa and further influence both winter and summer rainfall variability over the country.

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
No 904

This project aimed at improving the ability to forecast seasonal rainfall in South Africa through further model development and acquisition of modelling skills. The project team collaborated with CSIRO in Australia in the coupling of a dynamic atmospheric general circulation model (AGCM) with an ocean general circulation model (OGCM), both of which are CSIRO products. The coupled model (CGCM) was used to generate sea surface temperature forecasts; these proved to be superior to current statistically generated forecasts. The SST forecasts were then prescribed as boundary forcing in the high-resolution CSIRO Mark II AGCM, resulting in the successful generation of probabilistic rainfall forecasts for the 2001/02 season. Benefits of the project included not only advances in model-based seasonal forecasting techniques, but also the transfer of skills from experts at CSIRO to

South African project team members and students.

Cost: R252 000
Term: 1998-2003

The ocean's role in South Africa's rainfall
Department of Oceanography, University of Cape Town
No 953

The aim of this project was to investigate aspects of the role played by the Indian, the Atlantic and the Pacific Oceans as well as the Agulhas Current on rainfall over Southern Africa. It has contributed to unravelling some of the physical mechanisms linking the ocean and climate variability in South Africa. It has further elucidated the considerable effect of the Indian and Pacific Oceans on the yearly variation of rainfall over South Africa. The Agulhas Current has also been shown to play an important role, especially through enhancing local weather systems and storms.

This project has highlighted significant changes in the teleconnections linking Southern African rainfall variability to oceanic and atmospheric conditions. In particular, the most severe droughts affecting the region between 1950 and the 1970s were associated with regional oceanic-atmospheric anomalies, involving mainly the South-West Indian Ocean, whereas since the 1970s they are mostly related to El Niño – Southern Oscillation (ENSO) events. A stronger relation to ENSO is also diagnosed through an overall correlation between rainfall variability over Southern Africa and ENSO indices. Numerical experiments suggest that this enhanced relation to ENSO is linked to the long-term evolution of the SST background, which is a part of the observed global warming trend.

This project has contributed to a better understanding of some of the physical mechanisms responsible for drought in Southern Africa, the first step towards producing accurate forecasts for the rainy season with sufficient lead time.

Cost: R1 395 000
Term: 1998-2003

Climatology of water vapour sources, sinks and transport in Southern Africa
Department of Environmental and Geographical Sciences, University of Cape Town
No 1012

This project on moisture transport, sources and sinks, sought to investigate the underlying dimension of atmospheric moisture on which the South African rainfall is inherently dependent. The research followed two complementary pathways. Firstly, a trajectory model was developed and then applied to investigate the time-evolving transport paths of the atmospheric moisture, and the related sources of moisture. The trajectory model took advantage of low-cost computing infrastructure, and was developed to specifically address large-volume trajectory calculations. From this was developed a 20-year climatology of moisture transport for Southern Africa that was then examined in terms of seasonal and sub-seasonal attributes. Secondly, the large-scale seasonal mean moisture dynamics were examined to identify key source regions of moisture contribution to the atmosphere. Both approaches developed different insights into the climate system, which complemented and supported one another.

Cost: R562 000
Term: 1999 -2004

Regionalisation of rainfall statistics for design flood estimation
School of Bioresources Engineering and Environmental Hydrology, University of Natal
No 1060

This project sought to improve the accuracy of flood estimations to address structural failures caused by poor design flood estimates. Most design rainfall methodologies of the past were based on an individual station's hydrological records. This study investigates several design flood estimation techniques that are in use in South Africa, to develop flood estimates for the whole of South Africa on the basis of regionalised design rainfall depths. Since the last comprehensive processing of data on flood-producing rainfall took place in the mid-1980s, the project also presented the opportunity for a much-needed update.

The research outcomes enable users to estimate design rainfall at any location in South Africa for return periods of 2 to 100 years and for durations of 5 minutes to 7 days. The design rainfall estimates obtained through the

adoption of a regionalisation approach was compared with other methods. Favourable comparisons were achieved.

Cost: R1 072 700
Term: 1999 - 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.
No 950

The WQ2000 model that was developed as part of this project provides an interface between the user, a database containing a large amount of data for each quaternary catchment, a monthly time-step hydro-salinity model and DWAF's GIS Viewer. The main data sources used to populate the WQ2000 database for the Vaal River, which was used to demonstrate the applicability of the WQ2000 model as a planning tool, include WR90 (WRC Water Resources 90 reports and database), WSAM (DWAF Water Situation Assessment model) and the DWAF Vaal River System Analysis Update study.

WQ2000 is intended primarily to provide a rapid assessment of the expected salinity implications of a planned development, or to prepare an overview of the regional salinity status. Although it is a powerful and flexible tool, WQ2000 has limitations that need to be observed. It is not a large system simulation model and thus not intended to simulate month by month variations in water release between dams in highly regulated river reaches involving more than two major dams and it does not cater for feedback loops. While the standard WQ2000 system layout will in many instances be sufficiently accurate to yield the final results required to support investigations, more detailed evaluation of some development options may require a custom made system layout to more accurately describe the catchment features.

Cost: R775 000
Term: 1999 - 2002

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
No 1151

Since conventional meteorological infrastructure is dwindling at an alarming rate in South Africa, it became necessary to investigate the complementary use of conventional and less conventional infrastructure in sourcing rainfall data and mapping daily rainfall for the country as a whole (SIMAR programme). The complementary sources considered in this component project were surface networks and remote sensing sources, namely radar and satellite. The focus has fallen on maintaining current systems (rain-gauge networks included) as well as using new technologies and techniques to upgrade systems, where necessary, with a view to securing and sustaining a reliable data flow from the above-mentioned data sources

Improvements and upgrades were implemented at the majority of radars within the network in ensuring a reliable power supply to the systems. A remote control and monitoring system, whereby the functioning of individual radar systems could be monitored from a central point, has been implemented. This kind of information became available for the first time allowing objective evaluation the reliability of individual radar systems within the National Weather Radar Network (NWRN). The South African Weather Service during the course of this project drastically increased its funding for maintenance and upgrading purposes on the NWRN.

Cost: R1 647 000
Term: 2000-2002

Spatial interpolation and mapping of rainfall: Radar and satellite products
Meteorological and Technology Systems, SA Weather Bureau
No 1152

This component of the SIMAR programme aimed to improve products available from South Africa's National Weather Radar Network (NWRN), which incorporates 11 radars, representing a unique system that has been developed in-house, using a combination of South African innovation and shareware/freeware available from various sources in the world. A further aim was to enhance rainfall estimation products from satellite data and to merge enhanced products with rainfall fields derived from rain-gauge data. A major advance in radar rainfall

estimation was a unique methodology developed to filter the negative impact of ground clutter. Building on documented past South African and international experience, a technique (probably the most sophisticated satellite-rainfall estimation technique yet available for South Africa) that makes optimal use of all three Meteosat channels (IR, Visible, Water Vapour) was developed and implemented operationally. The rain-gauge-, radar- and satellite-derived rainfall information, after application of methods developed to address the major weaknesses in each data stream, provided the basis for generation of a merged satellite-radar-rain-gauge field as a stepwise process. The South African Weather Service (METSYS) website (http://metsys.weathersa.co.za) routinely displays the various individual daily rainfall fields (radar, gauge and satellite) together with the integrated fields. Archived data relating to these fields are also available.

Cost: R318 000
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
No 1153

Combining the precision of rain-gauge data with the coverage of satellite data and the detail of radar data was, in effect, an important objective of this research. As a means of achieving this, optimal spatial interpolation using a technique called "Kriging" and an associated one called "co-Kriging" was attempted. It turned out that "co-Kriging" was not a good option because of the large computational load. A method of "Kriging", exploiting the efficiency of the Fast Fourier Transform, was consequently developed and applied. This provided the basis for the coding of an algorithm to accomplish the massive computing task efficiently and speedily. Speed is of the essence in the delivery of the daily rainfall maps in real time. Information on the accumulated rainfall for the 24 hours until 08:00 SA time, derived from the recording rain-gauges around the country, arrives at METSYS (Bethlehem) by 09:00 daily. By that time, the previous 24 hours' satellite and radar images will have been used to produce the best estimates, respectively, of the rainfall totals per pixel over the whole area. The merging of the three fields: gauge, radar and satellite, is then done and the result posted on the METSYS website by 11:30.

Cost: R270 000
Term: 2000-2002

Caledon River catchment rainfall data linked with streamflow data
Eskom
No 1199

With the shortage of water in the Orange River, and DWAF's requirements of high operating levels (for increased assurance of supply) in the Gariep and Vanderkloof Dams increasing the probability of spillage, it was necessary to establish whether the use of radar rainfall measurements could be of benefit in obtaining greater lead time of potential flow in the river. The feasibility of the concept was investigated using the Caledon River catchment and radars situated in Bethlehem and Bloemfontein. A regression model instead of a more costly deterministic model was used to assist in the prediction of river flow. Despite having to contend with inadequate streamflow data quality and ground clutter-contaminated radar data, preliminary results suggested a better-than-expected 5-10 day lead time before a predicted increase in flow was observed at the downstream gauging station. Eskom, who provided the bulk of the funding for this project, intends to further pursue the research.

Cost: R76 000
Term: 2001-2002

Thrust 2: Integrated Water Resource Development

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)
No 1234

This was Phase 1 of a project which intended to improve process hydrological modelling in headwater catchments of the Table Mountain Group aquifers based on a proper understanding of flow paths, residence time and reservoir size. This would assist in developing a predictive capacity for TMG aquifers based on an understanding of flow mechanisms and flow paths in headwater catchments. This report represents the output of a preliminary phase to an envisaged field research study that had the above objectives in mind. Research was

aimed at the development of a sound knowledge base from which detailed field research could be initiated. Based on the study, a conceptual model of flow processes in TMG headwater catchments was developed.

Cost: R270 000
Term: 2001-2003

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

Programme 2: Groundwater protection

Mapping of naturally occurring hazardous trace constituents in groundwater
Council for Geoscience
No 1236

In South Africa groundwater is being heavily utilised for rural water supply. Some of these water supply schemes are located in geological units known or suspected to contain natural sources of trace constituents in economic or sub-economic concentrations. A qualitative knowledge of the natural sources of As, U and Se in South African geology and their potential mobility in groundwater would be of great value to national authorities as it permits water planners and health workers to identify regions where water should be screened for trace constituents. The study outcomes were:

- Geological target maps, based on an understanding of the South African geological environment to predict where As, and Se bearing minerals could be present
- Reviewing the SAMINDABA minerals database to plot known occurrences of As and Se bearing minerals
- Reviewing national-scale regional soil geochemistry sampling to identify regions of known trace constituent anomalies
- Reviewing the process by which these constituents are mobilised into the groundwater environment, the expected compounds they form, and the mobility of such compounds under natural hydrochemical conditions found in groundwater

Cost: R190 000
Term: 2001-2003

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
No 1120

Previous WRC research found consistent low level pesticide contamination of rural water sources in three Western Cape agricultural areas and highlighted the need for the monitoring of water sources for pesticides. This project was undertaken in response to this finding to evaluate cost-effective methods for monitoring pesticide pollution in rural water.

The utility of solid phase micro extraction (SPME) fibres was evaluated as a quicker and potentially more cost-effective alternative to solid phase extraction (SPE) of pesticides that could also yield a time-weighted average (TWA) concentration. Experimental results confirmed that in principle the SPME device could be adapted to obtain a TWA sample over a sampling period of up to 3 hours, while field tests over 24 hours showed that a TWA sample could be obtained with minimal effort. However, the TWA sample result significantly underestimated the average concentrations of 24-hourly samples. At the end of the study, insufficient experimental results were obtained to provide estimates of the accuracy and sensitivity of SPME for TWA sampling.

Enzyme-linked immunoassays (ELISAs) are capable of detecting low levels of pollutants with high specificity. Consistent detections by ELISA were made in the field samples. From the tests performed, it appeared that the ELISA method could be useful as a semi-quantitative screening tool.

A cost appraisal of the three analytical methods, found SPME to have the lowest cost per sample, followed by SPE and ELISA at appreciably higher cost. Despite an *a priori* expectation that the ELISA method would be useful if there was sufficient economy of scale, costing analysis has shown that there is little to save with high volumes of tests since the highest costs for ELISA are not personnel but reagents. Moreover, given that SPME and SPE produce quantitative data with good detection limits (SPME 0.01-0.02 µg/*l*), and that the ELISA measurements are semi-quantitative, there appears to be little advantage to promoting the wider use of ELISAs at this stage.

Cost: R500 000
Term: 2000-2002

Water-related impacts of small-scale mining – Nature of the impact and development of management options
Pulles, Howard & de Lange Inc.
No 1150

This study was undertaken to identify and characterise the critical aspects relating to water-related impacts of small-scale mining and to develop and recommend appropriate tools to assist in environmental management for small-scale miners.

The project team identified the small-scale mining types that have the greatest impact on the water environment through consultation with national representatives of DME and DWAF. A limited number of sites for in-depth regional site surveys were selected based on information gathered during initial screening site visits. The most important environmental impacts caused by small-scale miners appear to be related to accelerated erosion of areas adjacent to workings that have been de-vegetated for construction materials or fuel-wood. This leads to increased suspended sediment loads in nearby streams and rivers. Furthermore, alteration of river channels and excavation of flood terraces and riverbanks increases their instability and enhances the likelihood of increased flood scouring. While the communities living in close proximity to small-scale mining operations were aware of issues such as rehabilitation and the environmental impacts associated with mining activities, the miners largely ignored environmental issues and impacts. They viewed the required mining documentation, such as EMPRs, as a licence to mine only and not as providing further guidance on rehabilitation and closure. Regulators had difficulty in visiting, least of all regulating, the vast number of small-scale mining operations and concentrated on the more formal larger-scale mining operations.

Interested and affected parties assisted the project team with the design, planning and implementation of a handbook to assist small-scale miners in responsible mining. The contents of the handbook take into account the needs, interests, and values of the community, mining sector, regulators, etc. A stakeholder workshop with wide representation was convened to discuss possible education and implementation strategies and to engage in an understanding of the water-related issues of small-scale mining. This handbook is expected to play a significant role in assisting the regulating authorities to sensitise small-scale miners about their environmental impact and to assist them with devising environmentally responsible mining options

Cost: R738 000
Term: 2000 -2003

Determination of the known extent of cyanobacterial problems in SA water resources and identification of South African cyanobacterial knowledge, information and research needs
New shortened title: Cyanobacterial monitoring 1990-2000: Evaluation of SA data.
Department of Biochemistry and Microbiology, University of Port Elizabeth
No 1288

Toxic blooms associated with eutrophication during summer months in South Africa have been frequently reported. In several cases, deaths of livestock and fish kills have been reported, although toxicological data on fish does not preclude the possibility that these were not toxin induced. Much of the literature on the subject cites only events where severe blooms, or livestock or fish kills occurred. Despite the recognition that toxic blooms may be an increasing problem in SA, no effort has been made to identify trends in incidence or extent of events in recent years.

The aims of the project were to identify and, rectify the gaps in the current knowledge in these areas and to determine the need for guidelines for monitoring and managing water resources, and to identify the research gaps in this field.
In order to accomplish these aims, all available data pertaining to phytoplankton levels and selected associated parameters, were obtained from the DWAF database. Several water management bodies (municipal, and other treatment works, and water boards) in various parts of the country were visited and data from these visits were also included in the report.

Results from this study show that cyanobacterial problem events are widespread, frequent, prevalent and typically seasonal in water resources subject to eutrophication. Available data, however, were found to be unsuitable for detailed statistical analysis. The major problems in this regard were variation in sampling method and sampling frequency both spatially and temporally. The results therefore reflect trends only in as much as the data allowed for this.

Geographical variation in the frequency, duration and severity of the problems primarily due to the condition of the catchment, but also the nature of the water source, abstraction points, and regional climatic conditions exits. Insufficient data is available to establish the nature of this variation. No national trend in frequency of cyanobacterial bloom events, toxin, or taste and odour, could be established with the available data. Toxin and geosmin/MIB data are extremely limited due to the limited resources and cost of the analysis.

Recommendations to address the needs identified by the water fraternity were such as the development of a national monitoring, assessment and managing model with the associated administrative structures.

Cost: R70 000
Term: 2001

Programme 4: Human-induced impacts

Aerosols, recirculation and rainfall experiment (ARREX)
Climatology Research Group, University of the Witwatersrand
No 938

The objectives of ARREX were to determine the chemical and morphological characteristics of anthropogenic aerosols, to assess how these would influence cloud formation over Southern Africa and to quantify the relative contributions of natural and anthropogenic aerosols to effective (rain-producing) cloud condensation nuclei (CCN). Additionally, atmospheric transport characteristics over the subcontinent were examined in the context of measured aerosol concentrations over South Africa. A programme of airborne sampling was carried out over the period 1997 – 2001. A wealth of information on characteristics and transport of aerosols (especially of biomass-burning and industrial origin) was acquired. Anthropogenic aerosol emissions significantly enhance natural CCN concentrations over Southern Africa. CCN concentrations have strong seasonal as well as spatial distribution patterns over the subcontinent, with biomass burning playing an important role in late winter and spring. Depending on concentration and size distribution, models suggest that CCN will impact either negatively or positively on raindrop formation.

Cost: R1 390 000
Term: 1998-2002

Hydraulics of the impacts of dam development on river morphology
Department of Civil Engineering, University of Stellenbosch
No 1102

The construction of a dam can drastically alter the flow regime and sediment load of the river downstream by altering flood peaks and durations, as well as trapping large amounts of sediment. The imposed changes in the flow can lead to riverbed degradation directly downstream, as a result of very low sediment loads, as well as narrowing of river channels due to decreased transporting capacities further downstream. The broad aim in this project was to obtain a better understanding of the river sediment transport processes due to the impacts of dam development. This entailed the development of a procedure to determine flushing flow magnitudes, duration and frequency downstream of a dam as well as predicting downstream river channel geometry with the objective of maintaining the river morphology as close as possible to the natural (or desired) conditions, based on fundamental hydraulic principles of sediment transport.

Cost: R660 000
Term: 1999-2002

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
No 749

This project investigated integrated catchment management (ICM) approaches within the framework of the National Water Act. Findings from ICM investigations and specialist field work were used in making further improvements to the ACRU model and the supporting climatic and soils database. The re-developed model was then applied to case studies to investigate several scenarios which included the following:

- Hydrological risk assessments in the Natal agro-industry
- Impacts of land uses on hydrological responses
- Impacts of veld degradation and rehabilitation on catchment sediment yields
- Water efficiencies of sugarcane and forestry as well as impacts on streamflows
- Application of seasonal rainfall forecasts to sugarcane yield forecasts and
- Threshold analysis on when, and where, climate change is likely to impact on water resources in South Africa

Cost: R2 899 930
Term: 1996 -2004

The value of water as an economic resource in the Vaal River system
Greengrowth Strategies
No 990

Water supply has traditionally been augmented in line with growing demand. However, in view of the increasing shortage of new supply options, water demand management and specifically the optimisation of water distribution is of increasing importance. Thus there is a growing need to understand the economic features of water demand in South Africa.

In order to address the objectives of the project, it was necessary that proper natural resource accounts be drawn up for the Vaal River system, for the period 1980-1998. Natural resource accounts, which supplement a country's traditional national economic accounting system, are designed to assist in the analysis and design of sustainable development strategies through the optimisation of natural resource utilisation over the long-term. For modelling purposes, a system dynamics model of the Vaal River system was developed. STELLA, a software package for developing system dynamics computer models, was used to model a variety of complex systems by attempting to understand the underlying relationships between the different parts of the system. For the purpose of this study, the total system has been consolidated into two "dummy dams" represented in the Upper and Middle Vaal systems by the Vaal and Bloemhof Dams, respectively. The economic value of water for the various users was calculated by estimating their demand schedules. The following procedures were used to derive demand schedules for the various use categories. By applying the demand schedules above, the economic value of water for the total Vaal River system was calculated to be R13.3 billion for 1998. Of this total the contribution of the Upper Vaal is R11.6 billion (87%) and that of the Middle Vaal R1.7 billion (13%). It is important to note that this is a flow variable, i.e. it is a recurrent value.

Cost: R807 180
Term: 1998-2002

Programme 2: Development and implementation of water policy instruments

Gender dimension of the water policy and its impact on water and sanitation provision and management
Department of Development Studies, University of Fort Hare
No 1021

The main objective of this study was to analyse the gender dimensions of the National Water Policy with special emphasis on the implementation aspect of the policy, and the impact it has on water and sanitation provision and management in the lives of men and women in the Peddie district. The study analysed five pieces of legislation that pertain to gender equity as well as the relevant sections of the Constitution. It also reviewed international literature on gender and development. This was followed with semi-structured interviews with men and women from the Peddie district to evaluate their perceptions on the implementation of the gender equity component of the policy within water supply and sanitation projects. The study identified several impediments to the implementation of equity within the water supply and sanitation sector. These included a lack of monitoring and evaluation systems for ensuring that the National Gender Equity Policy is adhered to by the project implementing agents. The study also showed that most water committees had achieved the 30% quota required in terms of the White Paper on Water Supply and Sanitation (1994). However, women's contribution to decision-making was minimal because of cultural constraints that prohibit women from addressing public gatherings of men and women. The lack of skills and high levels of illiteracy among women were identified as barriers to the achievement of gender equity at project level. The study highlights the importance of ensuring that gender policy requirements take cognizance of cultural norms that restrict women's freedom of expression and association. There is a need to create an enabling environment that can harness the meaningful participation of rural women in decision-making on water services delivery within the local context. The critical analysis of the implementation of gender equity policies at the local level provided by this study will guide the policy makers and project implementation agencies in ensuring that they become more mindful of the local context when implementing the national policy of gender equity within the water supply and sanitation sector. The study will also contribute

to the review of the National Gender Equity Policy.

Cost: R303 000
Term: 1999-2002

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
No 1106

The focus of this project was on issues of river basin security: examining and confirming the premise that water resources in a river basin can and should rather be a catalyst for cooperation and enhanced security than a source of conflict, irrespective of the particular water-resource management context under consideration. River-basin security is a condition closely allied to the achievement of the goals of integrated river basin management (IRBM) and integrated water resource management (IWRM). Field investigations and case studies were done in two Southern African river basins. Institutional reform, urban water supply and urban food security were the security-related foci for the case studies. On the whole, the project revealed a climate of cooperation which does not, however, negate the fact that smaller conflicts exist, many of them resulting, paradoxically, from moves to increase water security. There are many potential lessons to be learned from the project findings.

Cost: R400 000
Term: 2000-2002

CURRENT

Thrust 1: Water Resource Assessment

Programme 1: Groundwater occurrence in fractured-rock aquifers

Flow and transport characteristics of groundwater in Karoo formations
Institute for Groundwater Studies, University of the Free State
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

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
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
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
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
No 1168

Understanding the processes involved in groundwater-surface water interactions is becoming increasingly important for protecting the integrity of ecosystems. This project aims to develop models of typical groundwater-surface water 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
No 1237

Present knowledge of fractured-rock aquifers in Southern Africa is mainly restricted to the "shallow" (i.e. upper 100 m) 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.

Estimated cost: *R195 000*
Expected term: *2001-2002*

Deep artesian groundwater exploration for Oudtshoorn (Dageos) municipal supply
Umvoto Africa (Pty) Ltd
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^3). 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 150 m. Over the past few years, limited deep drilling below 150m has resulted in boreholes yielding >32 ℓ/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.

Estimated cost: *R550 000*
Expected term: *200 -2002*

Groundwater in the Olifants River basin: Assessing viable alternatives for small-scale irrigation
School of Environmental Sciences, University of Venda
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

Estimated cost: *R420 000*
Expected term: *2001-2002*

A synthesis of the hydrogeology of basement aquifers in Southern Africa: Research needs and priorities
Council for Geoscience
No 1418

Basement aquifers are found extensively in sub-Saharan Africa. The only viable water supply to many rural communities is located in these aquifer systems. To contribute to sustainable resource development all knowledge about the attributes and dynamics of groundwater occurrence in basement aquifers needs to be consolidated. This is necessary to identify the research needs, gaps and priorities. This project aims to synthesise current knowledge relating to basement aquifers in Southern Africa. The output of the synthesis will lead to a research strategy that will address shortcomings in our knowledge base. This is a necessary project to guide future research in the hydrogeological domain.

Estimated cost: *R 560 000*
Expected term: *2003–2004*

Flow conceptualisation and storage determination in TMG aquifer systems
Department of Earth Sciences, University of the Western Cape
No 1419

The TMG aquifer system is a regional aquifer considered to have potential to be a major resource for future water supply in the Western and Eastern Cape. This project addresses two key aspects, which are essential in order to manage TMG aquifers, i.e. conceptualisation of the groundwater flow system and determination of aquifer storage. The project will utilise a blend of fracture/analysis/remote sensing, field testing, use of hydrochemical/isotopic tracers and numerical modelling to address the research questions.

Estimated cost: *R3 500 000*
Expected term: *2003-2007*

Programme 2: Catchment hydrology

Flow measurement at natural river controls and the provision of fish-ways
Department of Civil Engineering, University of Stellenbosch
No 1270

South Africa measures its flow in rivers by means of constructed weirs but 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

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
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*

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
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
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
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.

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
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

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
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
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 eight (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
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
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 eight (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*

Origin and fate and clinical revelance of water-borne pathogens in South Africa
Collaboratotrs: University of Pretoria, University of Venda, Rand Water
No 1398

The introduction of water-borne pathogens through faecal pollution of surface water has serious haelth 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*

The development of a proto-type implementation plan for a National Toxicants Monitoring Programme (on behalf of DWAF)
AEC Burger Consultant
No 1423

The NWA specifically mandates the Minister to establish national monitoring systems that monitor, record, assess and disseminate information on water resources. This project develops a modular implementation plan for initiating the sustained execution of a National Toxicants (poisonous or toxic substances) Monitoring Programme. This will support national strategic decisions in respect of their management.

Estimated cost: *R 1 000 000*
Expected term: *2003-2007*

Review of research needs and priorities for water quality assessment studies and information systems
Umgeni Water
No 1424

Arising from the National Water Policy of 1997 (which can be termed "executive policy") is a suite of new component or "operational" policies, related to various aspects of the management, protection, development and use of water resources. Some very significant changes have occurred in the way in which water quality is managed, both from a resource point of view (through the resource-directed measures) and a source point of view (source-directed measures). Policy at the operational level has advanced in both these areas. In addition, the institutional landscape of water resources management, which includes the management of water resource quality (and water quality within that context) will change significantly in the short- and medium-term, as catchment management agencies and other local-level water management institutions begin to play progressively greater roles in everyday water resource management.

Estimated cost: R200 000
Expected term: 2004

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

Umgeni flood nowcasting using radar – An integrated pilot study
Department of Civil Engineering, University of Natal
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.

Estimated cost: *R350 000*
Expected term: *2001-2002*

Daily rainfall mapping over South Africa through radar, satellite and gauge measurements: (2) Modelling
Department of Civil Engineering, University of Natal
No 1425

The ability to optimally utilise all the latest remote-sensing platforms for rainfall measurement and to provide a fully integrated product of superior quality, is essential for meeting water resource management needs for more sophisticated rainfall information, despite the decline in conventional gauge networks. This proposed project is key to achieving the above goal set by the WRC-supported national rainfall-mapping programme.

Estimated cost: *R423 800*
Expected term: *2003-2005*

Daily rainfall mapping over South Africa through radar, satellite and gauge measurements: (1) Infrastructure and capacity building
Meteorological Systems and Technology (METSYS)
No 1426

This project is essential to bring about necessary refinement and ensure effective, sustainable application of a rainfall technology which will have to be relied upon to meet future rainfall monitoring and measurement needs for water resource and disaster management purposes.

Estimated cost: *R 1 214 000*
Expected term: *2003-2005*

Thrust 2: Integrated Water Resource Development

Programme 2: Low flows and streamflow reduction activities

Guidelines to set resource quality objectives for groundwater
Division of Water, Environment and Forestry Technology, CSIR (Stellenbosch)
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.

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

Pilot Study: Setting resource-directed measures for groundwater
Parsons and Associates
No 1427

This project was initiated in partnership with DWAF to pilot a case study to test and refine the methods for determination of RDM in priority catchments that are groundwater dependent. The methods were developed in previous WRC-funded research. The objectives of the project are to review and implement methods developed to set RDM for groundwater through an appropriate case study; refine/adapt methods as a result of lessons learnt through pilot study implementation; and align methods with other components.

Estimated cost: *R 900 000*
Expected term: *2004–2005*

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.
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 to the rest of South Africa.

Estimated cost: *R773 200*
Expected term: *2001-2002*

Global climate change and water resources in Southern Africa: Potential impacts of climate change and mitigation strategies
School of Bioresources Engineering and Environmental Hydrology, University of Natal
No 1430

The need to prepare South Africa to cope with global climate change is of paramount and strategic importance. This project will develop plausible climate change scenarios for Southern Africa; investigate the potential impacts of climate change on hydrological responses and associated water resources; investigate possible water-related socio-economic impacts in a designated Water Management Area; recommend appropriate strategies to adapt to, and cope with, water-related impacts of potential climate change; determine whether effects of climate change can already be detected; and recommend appropriate monitoring systems for its detection.

Estimated cost: *R 2 240 000*
Expected term: *2003-2005*

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
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
No 1122

De-watering of the dolomite aquifers overlying ore-bearing reefs has, since the 1960s, resulted in the formation of a large number of cavities in the dolomite 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 has 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*

To calibrate and verify a predictive model for the occurrence of naturally occurring hazardous trace constituents in groundwater
Council for Geoscience
No 1431

The South African groundwater database does not support identification of areas with high concentrations of trace metals that may form a potential hazard due to incomplete data and difficulties in detecting these trace metals. In this project a geochemical modelling approach will be adopted to determine the presence of trace metals in groundwater. The objectives of the project are: verification of prediction of naturally occurring trace constituents in groundwater by field sampling at appropriate test sites; setting up of leaching tests; verification of geochemical and geological models; and development of a GIS map that identifies areas of special concern.

Estimated cost: *R 900 000*
Expected term: *2003-2005*

Improved methods for aquifer vulnerability assessments and protocols for producing vulnerability maps, taking into account soils information
CSIR
No 1432

The main objective of this project is to assess the attenuation capacity of soil horizons and other regolith materials and describe the diagnostic value of key morphological and chemical properties of soils conveying information on their contaminant transport/attenuation potential. This will lead to improved methods for vulnerability assessments with special emphasis on urban catchments. The production of catchment-scale vulnerability maps, in particular, will provide crucial information for groundwater resource classification and the implementation of source directed controls as required by the National Water Act.

Estimated cost: *R 3 500 000*
Expected term: *2003-2005*

Programme 3: Pollution of surface water

Development of an estuarine water quality index for implementation in estuarine water quality management in Southern Africa
Department of Zoology, University of Zululand
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
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
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 dolomite areas
Council for Geoscience
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
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*

Cynaobacteria Programme: Investigation into toxin blooms and toxin promotion
Consortium members: PU for CHE; University of Port Elizabeth; Technikon Pretoria
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*

Programme 4: Human-induced impacts

Impact of urbanisation and industrialisation on the environment
Department of Chemistry (Mamelodi Campus), Vista University
No 717

An 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*

Integrated approach to biomonitoring of wastewater for the presence of biologically active agents
Highveld Biological Association
No 1121

Research undertaken in this project centres on the development of a rapid (<24 h) 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*

Programme 5: Integrated flood management

Updated guidelines and design flood hydrograph techniques for dam safety
Ninham Shand Consulting Engineers (Pty) Ltd
No 1420

Dam safety legislation promulgated in 1986 prescribes the safety evaluation of all registered dams. The Water Act of 1998 incorporated the original dam safety legislation. A set of guidelines on safety in relation to floods and a compendium of South African design flood determination techniques were issued by SANCOLD to guide those tasked to evaluate dam safety. These two documents have been the mainstay of design flood analysis related to dam safety evaluation and spillway design during the past 12 years. Shortcomings have been raised on techniques used in the documents which are partially attributed to the limited data available when these techniques were developed. This study, therefore, seeks to update guidelines for the safety evaluation of dams in relation to floods and will incorporate the main characteristics of design floods, that is, flood peak, volume and hydrograph shape using the latest available data and knowledge.

Estimated cost: *R 1 349 800*
Expected term: *2003-2006*

National flood nowcasting system towards an integrated mitigation strategy
Department of Civil Engineering, University of Natal
No 1429

This project fulfils a critical need for an effective flood-warning system to be integrated into a national system for managing floods which can be implemented at local authority level. It draws together results of WRC-sponsored research into stochastic rainfall modelling, real-time river-flow modelling and remote sensing of rainfall.

Estimated cost: *R 1 314 000*
Expected term: *2003-2005*

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

Programme 1: Decision support for water policy formulation and implementation

The value of water as an economic resource in the Great Letaba River catchment
Economic Project Evaluation
No 989

Apart from separate sectoral analyses in defined sub-regions, 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*

Water resource systems analysis: Training and transfer of the technology
BKS (Pty) Ltd.
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
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
No 1062

This project, being undertaken in close co-operation 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
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 that 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 1 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*

An evaluation of the role of water user associations in water management in South Africa
Pula Strategic Resource Management
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*

Evaluation of the requirements and mechanisms for co-operative governance between catchment management agencies and local government
Pegasus Strategic Management
No 1433

The recent demarcation process and the ongoing specification of the powers and functions between the district, local and metro councils have further clarified the roles and functions of local government. Local government is constitutionally responsible for the implementation and control of a range of activities that affect water resources. This research will, amongst others, provide recommendations on the requirements for co-operative governance and the most appropriate approaches and mechanisms to foster co-operative governance between CMAs and local government, to achieve a range of objectives under differing circumstances.

Estimated cost: *R 290 000*
Expected term: *2003-2004*

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
No 977

Availability of human resources (HR) suitably qualified at tertiary level (university or technikon) will determine the extent to which 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 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
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
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 Services, University of Cape Town
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 learnt 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
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 trialling guidelines for participatory water resource management at catchment and water management area scales
Geography Department, Rhodes University
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*

Stakeholder participation in the establishment and governance of catchment management agencies (CMAs): Best practice guidelines
Department of Geography, Rhodes University
No 1434

The NWA puts emphasis on the decentralisation of water resource management to the catchment level. This necessitates an adoption of participatory management approaches that can support a multi-stakeholder dialogue of diverse interest groups such as water user associations (WUAs), community-based organisations, NGOs, water resource managers, policy-makers and planners. Therefore, there is a need for appropriate tools that can be used to support meaningful participation of the public at different levels of decision-making. This project answers the following questions:

- What is the appropriate CMA level of organisation that will be effective in ensuring that voices of marginalised groups are also taken into consideration in the governance of CMAs?
- How can civil society be best organised to play a meaningful role in the management of water resources at a catchment and subcatchment level?

Estimated cost: *R 1 000 000*
Expected term: *2003-2005*

Programme 4: Transboundary water resource management

Hydropolitical history of South Africa's major international river basins
Centre for International Political Studies, University of Pretoria
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.

Estimated cost: *R398 100*
Expected term: *2001-2003*

NEW

Thrust 1: Water Resource Assessment

Programme 1: Groundwater occurrence in fractured-rock aquifers

Protocols assessing the sustainability of springs
Maluti Water
No 1488

This project intends to develop a protocol for defining a spring-flow sustainability index. The development of a sustainability index would assist with water resources planning and result in security of water supplies to communities. The successful outcome of this project can result in innovative approaches to protect and manage springs (both from a water supply and protection perspective.
The objectives are:

- The development of a protocol for defining a spring-flow sustainability index (i.e. a tool for assessing the sustainability of springs)
- Review all the factors that affect spring-flow
- Assess the value of isotopes in characterising the sustainability of springs, including testing the correlation of perennial and seasonal springs with the isotopic signature
- Develop a weighting system to assess the sustainability of spring-flow

Estimated cost: *R734 100*
Expected term: *2004 - 2008*

Programme 2: Catchment hydrology

Update of *SA Atlas of Agrohydrology and Climatology*
University of KwaZulu-Natal
No 1489

The South African Atlas of Agrohydrology and Climatology is one of the most extensively used WRC products. Over 1 000 hard copies have been sold, several 1 000s of map images distributed and some 50 CD Rom copies given to clients. Since its publication, however, considerable new information and technology, as well as new needs, have seen the light of day which would necessitate and facilitate not only an updated and extended, but also a greatly enhanced new *Atlas*. The primary objective is to collate agrohydrology- and agroclimatology-related data and information from diverse research projects of various organisations and WRC projects into one co-ordinated spatio-temporal database and to utilise that information for the production of a new, electronically interactive atlas.

Estimated cost: *R546 100*
Expected term: *2004 - 2006*

A synthesis and encapsulation of hydrological research findings into a DSS for application and operational/planning level
School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal
No 1490

Hydrological operation and planning levels in South Africa are in the process of being updated in line with the requirements of the National Water Act of 1998 (NWA). The NWA requires the establishment of catchment management agencies (CMAs) to protect, conserve, manage and control water resources in water management areas (WMAs). Developments of tools to equip CMAs have occurred, with limited integration, such that the value of these developments to water managers has been very limited. This study seeks to develop a

decision support system (DSS) that will be useful for the operation and planning at CMA level. The development of the DSS will integrate existing research findings, data and available tools and will also make improvements to these tools. While national planning within DWAF has dealt primarily with relatively large scales (i.e. catchment and quaternary level) using monthly time steps, this study will focus on finer spatial and temporal resolution than was the case in the past. The finer resolution is targeted to deal with water resources at a range of scales varying from points of use to the whole WMA. Similarly, the planning aspect will handle a range of time scales varying from daily to annual.

The objectives are:

The primary objective of this project is the development of a Hydrological Decision Support Framework (HDSF) which can incorporate relevant and appropriate modelling algorithms / modules which are linked by a common flexible and extensible database and integrated with a GIS for use at a planning and operational level by CMAs at spatial scales ranging from point of use to the entire WMA and at temporal time scales of one day. The coarsest catchment scale at which the modelling algorithms / modules within the HDSF will operate in a lumped mode is at a quaternary catchment level and, in order to model the complexities of hydrological responses within a catchment, it is envisaged that the modules will be applied at sub-quaternary catchment scales. The HDSF should simplify and ensure maximum flexibility in system configurations, utilise GIS to generate system / module inputs and have interfaces suitable for water resource managers to interrogate the system. It is envisaged that the framework developed will be able to accommodate modules not utilised in this study. The HDSF is to include a spatio-temporal database populated with quality controlled data.

The purpose of the HDSF will ultimately be to support CMAs in planning and managing water resources under their jurisdiction and to provide tools to facilitate planning and scenario analyses. Although this will require a number of different functions to be performed, the main focus in this project will be the development of an HDSF to support CMAs in the assessment of water resources and the allocation of water use licences under the new requirements of the NWA of 1998. This will require designing the framework, integration of relevant modules, or adding functionality to existing modules, design of a generic and extensible database and GIS structures and the population of these with quality controlled data at both quaternary and sub-quaternary catchment scales. A suite of relevant simulation modules best suited to the requirements of CMAs will be selected for incorporation into the HDSF. The selection of modules will be finalised after a review of user needs has been performed, but it is anticipated that a physical-conceptual process based on hydrological modules, integrated so that system analyses can be performed, will be required for the assessment of water resources and the allocation of water-use licences. It is envisaged that the HDSF will be applied on selected catchments within two WMAs which will give the opportunity to assess and refine the HDSF.

A further objective of the project is to extend the capabilities of the some of the modules so as to enable the assessment of water resources and the allocation of water use licences at the level of CMAs as well as to consolidate and encapsulate existing relevant research findings into the selected simulation modules in order to refine the simulation of hydrological processes. Within the constraints of the budget and available resources, these could include an easy-to-use methodology to simulate dynamics in the catchment, refinements to hydrological processes, addition/refinement of selected water quality modules, refinements to cater for proposed new water allocation and management options such as fractional water allocation and capacity sharing / water banking, and inclusion of dam operating rules to meet IFR and other water demands. Where necessary, additions and refinements will be made to the selected modules to extend the HDSF such that it can be used operationally. These include "ownership" of water in impoundments and near real time operations with links to climate forecasting systems.

An additional objective will be to provide user support and up to date user documentation for the HDSF and to assist users in the implementation of the HDSF. Thus this project will collaborate where possible with other WRC-funded research projects (e.g. **No 1318**, **No 1320** and **No 1430**) as well as with solicited proposals currently under consideration (**KSA 1: Water Resources of SA, 2005; KSA 1: Low flows and streamflow reduction activities; KSA 4: Standards and guidelines for improved efficiency of irrigation water use from dam wall releases to root zone application; KSA 4: Technology transfer and integrated implementation of water management models in commercial farming**) and with modelling efforts at DWAF (e.g. systems analysis) in order to reduce duplication of effort.

Estimated cost: *R2 597 000*
Expected term: *2004 - 2007*

Water Resources of South Africa, 2005 Study (WR2005)
SRK (CE) Inc.
No 1491

The *1990 Surface Water Resources of South Africa Study* (WR90) and its predecessors have played a major role in providing key hydrological information to water resource managers, planners, designers, researchers and decision makers throughout South Africa since the late sixties. The deliverables from the last nationwide water resource assessment in 1990, WR90, became essential tools for water resources management, planning and operational practitioners, researchers and decision makers. The 1990 study which basically focused on surface water resources has become less and less useful over the years as the water sector evolved with new legislation coming in (Water Act of 1998), changing land uses, improved knowledge and data, technological advances, and the need to answer new questions in a changing water sector. The WR2005 study seeks to quantify and assess national water resources in an integrated manner that takes into account the new water environment and addresses the shortcomings of the previous nationwide studies.

The objectives are to:

- Evaluate the WR90 project and its use. Critically review the outcomes of the WR90 project with regard to
  · Project implementation
  · Uses and users
  · Project impact on the water sector
  · Shortcomings and strengths
- Develop WR2005 project framework
- Develop WR2005 tools
- Develop WR2005 database
- Investigate and build a user support system for WR2005 products
- Document the project work and package products efficiently and cost effectively
- Introduce and build PDI capacity

Estimated cost: *R6 700 000*
Expected term: *2004 - 2007*

Programme 3: Understanding and predicting hydro-climatic variability

MOSMEPS (MOS multimodel ensemble prediction system)
South African Weather Services
No 1492

This project will combine single general circulation models (GCMs) into a multimodel ensemble since GCMs differ in their parameterisations and, therefore, differ in their performance under different conditions. Using a suite of several GCMs not only increases the effective ensemble size, it also leads to probabilistic simulations that are skilful over a greater portion of the region and a greater portion of the time series. Multimodel ensembles are nearly always better than any of the individual ensembles. The benefits from combining ensembles are a result of the inclusion of complementary predictive information since the scheme is able to extract useful information from the results of individual models from local regions where their skill is higher. The project seeks to assemble leading forecasting models and to put into place a scheme for using models operationally in a complementary way, and assess their skill in producing probabilistic ensemble climate forecasts.

The objectives are to:
- Investigate the operational predictability of seasonal to interannual rainfall and its extremes over Southern Africa through the use of multimodel ensembles
- Investigate the operational predictability of seasonal to interannual occurrence of tropical cyclones over the south-western Indian Ocean through the use of multimodel ensembles
- Test different recalibration methods linking GCM-simulated large-scale fields to rainfall
- Assess if the recalibration is an improvement over raw GCM rainfall forecasts
- Test various multimodel ensemble combination schemes
- To set up an operational multimodel prediction system at the SAWS to the benefit of the end-users of seasonal forecast products

Estimated cost: *R436 000*
Expected term: *2004-2007*

Hydro-climatic variation over Southern Africa at intra-annual and inter-annual time scales, with special reference to the role of the oceans
Department of Oceanography, University of Cape Town
No 1476

Climate variability is arguably the greatest problem faced by water resource managers in Southern Africa today. It has now been recognised that the heat content of the upper ocean and evaporation from the adjacent oceans may be of even greater value than previously anticipated in understanding the mechanisms by which the ocean influences the weather and climate variability of countries in Southern Africa. These variables may, therefore, hold the key to simulating the processes whereby sea surface temperatures influence rainfall variations which, as indicated, currently remain poorly understood. The methodologies are in line with the current state of the art and are able to accommodate possible future improvements in models, remote-sensing hardware and computational facilities.

This project aims to enhance the understanding of hydroclimatic variability and the prediction of climate variation in Southern Africa, with special reference to the role of the oceans and to addressing needs of water resource managers. Specific objectives are to:

- Assess the suitability of indices used to represent hydroclimatic variation over Southern Africa from a joint ocean/atmosphere system and water-resource management perspective and address shortcomings, where necessary
- Select, assess and apply the most promising of advanced remote sensing and modelling products which would assist in achieving the remaining objectives of this project
- Test hypotheses concerning the importance of the heat content of upper ocean layers, and evaporation from the oceans adjacent to Southern Africa, in influencing the weather and climate variability of countries in Southern Africa
- Assess the degree of improvement in the predictability of climate/rainfall variations through appropriate consideration of newly identified influential oceanic variables in conjunction with the refined use of dynamic models
- Familiarise water resource managers with advances in, and capabilities and potential benefits of using improved prediction tools

Estimated cost: *R2 000 000*
Expected term: *2004 - 2007*

Programme 5: Water quality assessment studies and information systems

Microbial groundwater monitoring protocols refinement
CSIR
No 1494

A project to develop a prototype implementation manual for the national microbial monitoring programme (NMMP) for groundwater has recently been completed. This desktop study produced a general framework for the design of the monitoring programme. Before this can be formally adopted the core design must be tested and researched in the field. This project aims to monitor the microbial quality of groundwater that reflects the degree of faecal pollution in a manner that will support strategic management decisions in the context of sustainable fitness for use.

Estimated cost: *R500 000*
Expected term: *2004 - 2006*

WQ2000: enhancement, training and user support
Umfula Wempilo Consulting cc
No 1495

The WQ2000 interactive system has been successfully developed for the Vaal River catchment (WRC **Project No 950**). This system provides a means of rapidly assessing salinity at a quaternary catchment level. WQ2000 runs the sophisticated WQT monthly time step hydro-salinity model in the background, without any need for the user to be proficient in its use. Salinity characteristics are given for natural and present-day development conditions for off-channel conditions and taking account of cumulative upstream inflows. The need to disseminate this system among state, university and consultant users has been identified as a high priority. Part of the project will entail the preparation of suitable training material and the presentation of a training course. A number of beneficial enhancements have been identified and will be implemented. These include incorporation of metadata (to indicate where the default data was obtained), change lists (to record what changes were made and the

reasons), an option for specifying time series releases and inclusion of graphical results presentation. The enhanced system needs to be thoroughly tested. A sustainable user support system also needs to be set up to deal with user queries, rectify identified problems, provide ongoing training and distribute revisions. Refinement and dissemination of WQ2000 should facilitate much better integration of water quality with the earliest stages of water resource planning. This should reduce the cost of the planning process and assist in the identification of optimal solutions, thereby avoiding costly inappropriate developments.
The objectives are to:

- Transfer the WQ2000 technology (WRC **Project No 950**) to Government and private sector users
- Enhance and test the WQ2000 salinity assessment system and resolve problems identified by users
- Establish a working and sustainable user support system

Estimated cost: *R328 000*
Expected term: *2004 - 2006*

Thrust 2: Integrated Water Resource Development

Programme 1: Integrated catchment management

A catchment management strategy for the Kat River
Kat River Valley Water Users Association
No 1496

For the past six (6) years, a process of community education and capacity building has been pursued by the communities in the catchment, aided by the Geography Department at Rhodes University. This process has resulted in the establishment of a water users association (the Kat River Valley Water Users Association –KRVWUA). It, therefore, offers the opportunity on a pilot scale to develop and apply methods of establishing a co-operative catchment management strategy, including water allocations, the Reserve requirements and Resource Quality Objectives, and a monitoring programme.

The objectives are to:

- Continue to develop the socioeconomic capacity of the community of the KRV
- Establish cooperative governance of the resources of the Kat River between DWAF, the KRVWUA and the communities of the catchment, within the context of the Fish Keiskamma WMA
- Establish the criteria for acceptance by DWAF of the allocation schedule and the catchment management strategy
- Undertake a yield analysis to establish the water yield that can be reliably provided by the Kat River
- Assess the Reserve for the Kat River
- Develop RQOs for the Kat River
- Establish existing lawful use of the water resources of the Kat River
- Reach agreement among the WUA members on a water allocation schedule for license applications
- Establish strategic and contingency water requirements for the Kat River
- Establish the downstream water requirements of the users of the Great Fish River, into which the Kat River flows
- Design and initiate a monitoring programme that will assess the various water uses, Reserve flows and water quality, and the resulting state of the river.

Estimated cost: *R2 100 000*
Expected term: *2004 - 2007*

Programme 2: Low flows and streamflow reduction activities

An investigation of *Jatropha curcas*: A case study
CSIR
No 1497

Recent business initiatives have proposed the introduction of so-called "wonder-crop" exotic species for large-scale planting in South Africa. Specifically, *Jatropha* has been identified for introduction in the KwaZulu-Natal Province. The plant has potential as bio-fuel, and thus a source of renewable energy. The motivations behind these initiatives have been the laudable themes of poverty alleviation, job creation and business development. However, questions around the potential hydrological and ecological effects of the associated land-use changes remain unanswered due to a lack of information. Due to the significant area being proposed for planting *Jatropha* and other species, DWAF (Sub-directorate: Streamflow Reduction Allocations) has drafted a discussion paper proposing that all such species be declared streamflow reduction activities (SFRAs).

The objectives are to:

- Develop predictive capability with respect to the impacts of large-scale planting of *Jatropha curcas* on water resources through hydrological process studies and modelling using appropriate techniques
- Provide information regarding the biophysical requirements of *Jatropha curcas* and produce maps through an ARC-View GIS modelling framework
- Gauge the perceptions and levels of understanding of SFRA processes and licensing amongst users of *Jatropha*
- Provide recommendations to the WRC, DWAF, the SFRA licensing committee and other stakeholders with regards to potential SFRA declaration and regulation and specifically *Jatropha*.

Estimated cost: *R750 000*
Expected term: *2004 - 2007*

Quantification of the groundwater contribution to baseflow
Parsons and Associates
No 1498

Through research and development undertaken to develop tools and methods required to quantify the Ecological Reserve, it has emerged that surface – groundwater interaction is poorly understood and even more difficult to quantify. It is now apparent that baseflow (as determined by baseflow separation techniques) is not equivalent to groundwater discharged into rivers and interflow plays a contributing role to low flows in rivers. By implication, this means that the role of groundwater in sustaining the Reserve (particularly during low-flow periods) varies significantly across South Africa. The outcome of the project will permit the RDM office to prioritise their groundwater-related efforts. The proposed research will rely on and integrate results of both previous and current research, as well as provide support of current and proposed research.

The objectives are:

- To develop a prototype tool to identify rivers in South Africa dependent on groundwater for sustaining baseflow and to demonstrate methods that can be used to quantify the contribution
- Using currently available national-scale data, prepare a set of GIS-based maps indicating the degree of groundwater contribution to baseflow
- Develop methods and models to quantify the groundwater contribution to baseflow (including modification of the Pitman model) and include the modelling routines into the SPATSIM model
- Test the developed tool in at least 10 catchments
- Develop a set of management tools to ensure the groundwater contribution to baseflow is not impacted by abstraction.

Estimated cost: *R198 000*
Expected term: *2004 - 2005*

An investigation and formulation of methods and guidelines for the licensing of SFRAs with particular reference to low flows
School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal
No 1428

Section 36 of the National Water Act, Act 36 of 1998 (NWA) gives the Minister of Water Affairs and Forestry the powers to declare a land-based activity as a streamflow reduction activity (SFRA) if that activity is likely to significantly reduce the availability of water in a watercourse to the Reserve, to meet international obligations, or to other water users. While afforestation has so far been declared an SFR activity, scarcity of knowledge has been identified as a major constraint in this regulatory process. The available licensing methods have been noted to be too coarse and, besides spatial scales, have also failed to handle issues such as soil textures and varying temporal scales. Questions surrounding the licensing process, the basis of the methods in use, the future of SFRA licensing and the need to evaluate other land uses continue to build up. This study seeks to develop scientifically robust (generic too) and legally defensible methods of assessing low flow reductions and ultimately develop guidelines for the licensing of SFRAs.

The objectives are:

- To re-analyse, and improve upon, conceptual modelling methods and input data utilised in WRC **Project No 1110** (**Estimation of streamflow reductions resulting from commercial afforestation in SA**) and the reconsideration of methods used for the derivation of confidence limits from the above project, and the incorporation of these into the proposed guidelines
- Analyses of different flow components (quickflow, interflow, baseflow & groundwater discharge) to

determine how these are affected by afforestation and by dry and wet cycles as well as the determination of the relative importance of the flow components between catchments and the impacts of afforestation on the flow components
- Through these analyses, and with input from related process study research, to improve the simulation of low flows in the ACRU Agrohydrological Modelling System through improved conceptualisation of low-flow generation processes and the translation of these into model code
- To devise and implement a process whereby research and management needs are pursued in parallel in order to ensure optimal applicability and usability of the products of SFRA-related research
- To provide a link between researchers involved in hydrological process studies (e.g. WRC **Project No K8/577 Weatherley catchment: Soil organic carbon and vegetation baseline study** and **K5/1317 The relationship between soil water regime and soil profile morphology in the Weatherly catchment**, an afforestation area in the North-Eastern Cape) of the effects of land-use change on low flows, and managers and other interested and affected parties involved in this field
- To refine the guidelines for dealing with scale and resolution in the quantification of SFRs developed by Ninham Shand and the University of Stellenbosch
- To provide guidelines for the declaration of additional SFRAs that may be declared in the context of recent DWAF discussions and their authorisation in the context of the above guidelines
- To develop and implement in DWAF national and regional offices, and existing CMAs, a decision support system and associated guidelines, to assist in hydrological assessments for the consideration of water use authorisations These will form an SFRA component of the planned Water Allocation Toolkit, the components of which can be applied consistently across regions, are transparent in approach and are adaptable in that they can be upgraded or amended with minimum disruption
- To ensure the compatibility of Reserve determination methodologies and the results thereof with SFRA and other water use estimates and available hydrological information through consideration of specific months and daily flow records for various assurance of supply levels
- To test these products through the application of the guidelines in at least four catchment case studies
- To improve the research capacity in South Africa in the field of land-use hydrology and integrated water resources management and the skills of water resource managers involved in water-use licensing, particularly SFRAs.

Estimated cost: *R3 800 000*
Expected term: *2004 - 2007*

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

Programme 1: Preceding the impact of global climate change

Climate change and small town water resources
Energy and Development Research Centre, University of Cape Town
No 1500

The climate change scientific discourse has revolved around the Intergovernmental Panel on Climate Change (IPCC) through its first, second and third assessments. Bringing development into the third assessment as a cross-cutting theme was attempted, but success was quite limited. In the fourth assessment to be carried out during the period 2003 to 2007, it is proposed that the interaction between sustainable development and climate change be given a priority. The most severe impacts are likely to occur along the western part of South Africa, were small towns and subsistence farmers are most vulnerable. This study intends to investigate the adaptive capacity of small towns and communities in the Western and Northern Provinces to climate variability, specifically drought. By extrapolation of these strategies, planning policies for national and water resource planning and management will be developed to ensure water security against the impacts of climate change. The proposal was considered highly relevant by reviewers. The emphasis on local authorities and providing them with the necessary tools/knowledge to address the possible impacts of climate change are considered critical.

The objectives are:

- Show the relationship between the change in temperature and rainfall and available water resources in small towns in the Northern and Western Cape for the past 30 to 50 years
- Document existing coping strategies in times of climate variability, i.e. drought in small towns in the Northern and Western Cape
- Propose long-term strategies for dealing with the impacts of predicted climate change in small towns in the Northern and Western Cape

Estimated cost: *R261 260*
Expected term: *2004 - 2005*

Programme 2: Groundwater protection

Field investigations to study the fate and transport of DNAPLs in groundwater
Institute for Groundwater Studies, University of the Free State
No 1501

Studies on the fate and transport of organic pollutants in groundwater have, to date, been done on an *ad hoc* basis. DNAPL movement in the subsurface is density-driven and extremely complex. This project will consolidate knowledge about the fate and transport of DNAPLs in groundwater in a systematic manner.

The objectives are:

- Identify flagship field sites where DNAPL site characterisation methods and natural attenuation processes will be evaluated and tested during the project
- Evaluate rapid methods for the delineation of DNAPL-contaminated zones
- Conduct field- and laboratory-scale based studies in order to identify and predict critical factors for DNAPL flow and transport under South African aquifer conditions
- Assess the viability of natural and enhanced attenuation processes of DNAPL-contaminated zones
- Establish methodologies for DNAPL site characterisation
- Develop guidelines for the construction of conceptual models of DNAPL-contaminated sites
- Develop appropriate guidelines for monitoring systems of DNAPL-contaminated sites

Estimated cost: *R3 058 000*
Expected term: *2004 - 2007*

Programme 3: Protection and management of surface water quality

PCR-based markers for identification of toxic cyanobacterial
Department of Genetics and the Forestry and Agriculture Biotechnology Institute (FABI), University of Pretoria
No 1502

The quality of many water sources in South Africa is declining. The decline is primarily as a result of eutrophication and pollution by trace metals. During April 2003 a blue-green algae bloom of 30 cm thick and a diameter of 4 ha was detected in the Hartbeespoort Dam. This cyanobacterial bloom did not only cause a health risk to both animals and humans, but may also result in other problems for suppliers and users of potable water. The current cyanobacterial taxonomy does not provide an unequivocal system for the identification of toxigenic and bloom-forming genus *Microcystis*. The ambiguities that exist in the cyanobacterial taxonomy are due to the expressed variability, minor morphological and developmental characteristics used for identification, classification of the genus or species level. The increasing occurrence of toxic *Microcystis aeruginosa* blooms in major water resources make identification and prediction of these toxic blooms very important. The research will contribute to the development of techniques that will aid in the rapid identification of toxic cyanobacterial strains and in assessing the potential toxicity of the strains.

The objectives are to:

- Assess the genetic diversity of a wide variety of geographically unrelated strains of *Microcystis aeruginosa* collected from selected South African dams (e.g. Gauteng and North-West Province).
- Develop an unequivocal identification system for toxigenic and bloom-forming genus *Microcystis* with the objective to manage cyanobacterial blooms by ensuring early detection of toxic strains.
- Correlate the observed fingerprint obtained using the toxin-producing mcyb gene to toxin levels measured in the specific strains.

Estimated cost: *R668 000*
Expected term: *2004 - 2007*

Land-use impacts on salinity in Western Cape Waters
Department of Soil Science, University of Stellenbosch
No 1503

The importance of dry-land salinity on water resources has been recognised for quite some time. Its importance is especially visible in the dryer parts of the country and in Western Cape rivers. Earlier research attributed the mobilisation of salt to ploughing of land, which increases infiltration and accelerates the mobilisation of salts contained in the underlying geologic strata. Another potential mechanism is that changes in land use from extensive pastoral use to intensive cropping over the last century or more may have triggered the same process of salt decantation being experienced in Australia. As the salinisation of some Western Cape dams is intimately linked to salinity releases from agricultural land it is important to gain a better understanding of the mechanisms

that are operative. The central aim of this project is to develop a thorough understanding of soil water and salinity dynamics, salt sources and salt storage in dry-land profile and hillslope transects, as well as corresponding groundwater salinity dynamics. This understanding should inform future large-scale modelling and enable the development of land-use practices that would reduce/prevent degradation of land and water resources.

The objectives are:

The central objective of this project is to develop a thorough understanding of water and salinity dynamics in the regolith (soil plus vadose zone) of a small dry-land catchment representative of semi-arid conditions in the Berg River basin. The perspective will include both salt sources and storage and groundwater fluxes and catchment runoff, in order to inform future large-scale modelling and to guide the development of land-use practices that would reduce the degradation of land and water resources.

Subsidiary objectives include the following:

- Determine and map the spatial distribution of salts across the whole Berg River catchment
- Spatially relate salt distribution to salinity-generating factors (soils and soil-forming processes, geology, climate, topography, vegetation and land use) across the whole Berg River catchment
- Develop an improved understanding of how local tillage and other dry-land farming practices augment or reduce the mobilisation of salts
- Conduct mechanistic modelling of salinity dynamics
- Use the model to create small catchment-scale salt flux scenarios for various land use and water management practices that will serve to inform modelling of salt fluxes on a regional scale

Estimated cost: *R2 347 068*
Expected term: *2004–2007*

Novel silicone rubber integrative passive field sampler
School of Environmental Sciences/Department of Ecology and Resource Management, University of Venda
No 1504

Time-weighted average (TWA) passive field samplers provide vital information in ecological risk assessment of chemical pollutants. The passive field samplers quantify the freely dissolved pollutant in water that approximate the bio-available fraction in longer exposure times. They therefore give vital information also on changes in pollutant level over time. However, not many passive field samplers are available and those that are available are mostly not very selective. They furthermore require additional clean-up steps before analysing the extracted samples. This project aims to develop, construct and test a simple and cheap TWA passive field sampler that will require no mechanical device and can be used in remote sites. The sampler will utilise silicone rubber in the form of a hollow fibre as absorbing medium. The inside of the hollow fibre will serve as the receiving phase and the outside as the donor phase. The pH of the solution in the receiving phase will be set such that target analytes are ionised and trapped. It is anticipated that this will result in very high enrichment factors over longer exposure periods. The developed sampler will be evaluated under laboratory conditions for its trapping efficiency for a range of pollutant groups as well as potential synergism and antagonism associated with trapping combinations of pollutant groups.

The objectives are:

- Develop a time-integrated sampling device based on silicone rubber for measurements of pesticide concentrations at environmental levels under field conditions
- Evaluate the efficiency of the sampling device for trapping representative examples of pesticides and other pollutant groups
- Determine the synergism and antagonism associated with trapping combinations of pollutant groups
- Evaluate the release of high concentrations during subsequent exposure to lower environmental concentrations

Estimated cost: *R250 000*
Expected term: *2004-2006*

Programme 4: Human-induced impacts

Chemical and biological assays and sentinel species for EDCs
Department of Urology, University of Pretoria
No 1505

There is growing international concern over persistent bio-accumulative chemicals, their potential for bio-

magnification, and, even more perturbing, synergistic/additive effects of endocrine disruptor chemical (EDCs) in mixtures. EDCs are chemicals that interfere with the structure or function of hormone-receptor complexes. These EDCs can be disruptive at very low exposure levels. The crucial question is whether sufficiently high EDC levels exist in the general environment to exert adverse health effects on aquatic or terrestrial animals or humans. The application of selected techniques for EDC activity for monitoring purposes of the Rietvlei Nature Reserve water system will assist in developing a strategy for monitoring other areas in SA. A comparative assessment of EDC biomarker responses and sentinel animals to EDC exposure may contribute to a battery of South African tests and bio-sentinel animals. In addition, information will be gathered on the efficacy of a wetland to remove EDC activity under South African conditions.

The objectives are to:

- Perform chemical residue analysis and biological testing for oestrogenicity in water, sediment and biota samples from the Rietvlei and Marais Dams, as well as three sites along the wetland area in RNR, compare EDC assessment techniques and propose an integrated, standardised SA relevant toolkit of tests for wider application.
- Determine aquatic and terrestrial animal health in and around the dams and wetland.
- Perform a scenario-based risk analysis

Estimated cost: *R2 000 000*
Expected term: *2004-2007*

Mine-water irrigation return flow
Institute for Groundwater Studies, University of the Free State
No 1507

A current project (**No 1149**) is evaluating the practice of irrigating with neutralised acid mine water on a commercial scale with different water qualities and on different soil types. The rationale behind this project is that most of the dissolved calcium and sulphate in the neutralized acid mine drainage will precipitate within the soil profile, thereby causing a significant reduction in the salt load percolating to groundwater. The current project aims, amongst others, to evaluate the environmental impact and sustainability of such an irrigation practice and will extend these investigations with more detailed groundwater observations, the description of aquifers, plume migration and the final impact of various pivot arrangements on groundwater resources. This information is required in order to assess the impact large-scale irrigation with mine effluent will have on water quality over the long term, so that informed decisions about its application can be made.

The objectives are:

- Determination of hydraulic interaction of irrigated mine water with the underlying aquifers
- Assessment of the effect of irrigation on the hydrology and water quality at opencast colliery spoils
- Determination of salt migration and attenuation from irrigated areas under natural and spoils conditions
- Quantification of the potential regional effects of large-scale mine water irrigation on the groundwater quality and quantities in Mpumalanga
- Compilation of a comprehensive database and document which can be used as decision- making platform for future mine water irrigation in the Mpumalanga coalfields
- The establishment of criteria for site selection/operation, monitoring, determination of impacts and mitigation methods for mine water irrigation areas

Estimated cost: *R445 650*
Expected term: *2004–2007*

Eco-hydraulic modelling in river systems
Centre for Water in the Environment (CWE), University of the Witwatersrand
No 1508

The ecological response to catchment river management and river rehabilitation measures is determined largely by the relationship between organisms and local hydraulic variables. Effective measures in these areas, therefore, require quantitative descriptions of the relationships between local hydraulics, discharge, river form and prediction of responses of local hydraulics to changes in discharge and/or river form. In the case of regulated river systems there is very limited knowledge on the variability of flow regimes required to maintain a healthy river ecosystem at any given time. A sustainable ecosystem would be better promoted through improved understanding of the many processes that interact in the river system as the flow regimes are varied. This study intends to build understanding on river ecosystems and develop eco-hydraulic simulation routines which will be useful in supporting initiatives such as the reserve determination process, In-stream and ecological flow requirements as well as the river strategic adaptive management systems.

The objectives are:

- Review findings and issues generated by previous research on the subject of eco-hydraulic modelling in river systems. This involves assessing existing eco-hydraulic models that can be modified for use in eco-hydraulics, locally and internationally. Determine suitability of tools to solve the targeted problems, especially those associated with IFR assessments, reserve determination, flow regulation procedures and mitigation of human impact on rivers. This task will seek to identify and clarify the real requirements of eco-hydraulic modelling under South African conditions. In this objective the suitability of existing models to meet local requirements will be assessed. Approaches to modelling biotic response and feedback will be investigated.
- Develop tools/methods for eco-hydraulic assessments at stream level. The methods should take into consideration Biotic-Abiotic links using stream power principles. The interaction of hydraulics, vegetation and water quality should be well appreciated to suit the required application scales. The velocity-depth regime should be well captured in the methods. The tool development process should clearly identify and seek to solve problems associated with flow regime regulation and human impact on rivers. The tools/methods are expected to be packaged as a simulation model.
- Apply the tools/methods to at least two sets of case studies. The case study application should aim at developing the methods for national use. The application should seek to capture habitat impacts of water resources developments and natural events.

Estimated cost: *R1 800 000*
Expected term: *2004–2007*

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

Programme 1: Decision support for IWRM at catchment and WMQ level

Decision support for water policy making
Department of Agricultural Economics, University of Stellenbosch
No 1509

It is not possible to make effective and objective water management decisions by considering the different economic sectors of the Western Cape in isolation. A holistic and integrated analytical framework became necessary to analyse the economic impacts of water management decisions such as the introduction of water restrictions (which became a yearly phenomenon during the last 5 years), the development of additional storage capacity and the implementation of a demand-oriented approach to water management. The agricultural sector forms an important part of the Western Cape economy with close links with regard to water use existing (through forward and backward linkages) between the rural and the urban economies of this Province. A need has been identified to quantify these links and to test the impact of several water management scenarios. The main objective of the study is to develop an analytical methodology (model) that could be used to analyse alternative (different) water allocation scenarios in the Western Cape. The focus will be on the economic implications of water demand management and the potential reallocation of water between agriculture and urban use in the Western Cape. It will assist in water policy development and institutional arrangements for water resource management by providing decision support for water policy formulation and implementation.

The objectives are to:

- Ascertain what is the strategic managerial challenge for service providers to ensure sustainable water resource utilisation in the long-term in the Western Cape
- Develop an integrated model for the purpose of analysing different water allocation scenarios for the Cape Metro and surrounding irrigation regions.
- Survey the necessary data for testing the model and to generate different water management scenarios.
- Identify and analyse the implications of different approaches to water allocation and use by making use of analytical methodology and tools developed in this project and in consultation with key stakeholders.

Estimated cost: *R122 000*
Expected term: *2004-2006*

Approval and licensing of groundwater development and use
Parsons and Associates
No 1510

Currently, granting approval for groundwater development and use falls within the responsibility of DWAF, DEAT

and their delegated regional and local authorities. Authorisation is legislated under the National Water Act (Act 36 of 1998), the Environment Conservation Act (Act 73 of 1989, and amendments) and the National Environmental Management Act (Act 107 of 1998). Unfortunately, current procedures for granting approval for groundwater use are unnecessarily restricting groundwater development. This is because the two departments follow different procedures with respect to assessing groundwater use applications. Neither department has clear procedures, guidelines and /or definitions, thus preventing their officials functioning in a standardised manner. In many instances, the officials who make decisions regarding procedures to follow or information required have no basic understanding of geohydrology. Lack of clear guidance regarding procedures, information requirements and co-operative governance result in officials adopting conservative, uninformed attitudes regarding information they require before considering approval for groundwater development and use. It is thus proposed that a multi-disciplinary research project be undertaken so that a solution can be found and developed and efficient and effective cooperative governance promoted. Resulting documentation will be the industry standard for exploring, developing and usage of groundwater supplies in South Africa.

The objectives are:

- To identify legal requirements for authorising groundwater developments, and develop a decision-support system that will allow officials, applicants and the general public to ascertain information that the officials require to assess applications to develop and use groundwater
- Development of workable definition for the term "bulk water supply", an activity for which an environmental impact assessment is required
- Review the general authorisations, as applied by DWAF to groundwater
- Review of DWAF licence information requirements and licensing procedures
- Review the EIA regulations applicable to groundwater
- Develop a decision-support system that will allow users to ascertain information officials require to assess applications to develop and use groundwater
- Develop a standardised code of practice / standard operating procedure so that as little environmental damage as is practically possible results from exploration drilling and pumping tests
- Compile a set of required and best practice with respect to managing small or low volume groundwater abstraction schemes.

Estimated cost: *R390 000*
Expected term: *2004–2006*

Programme 3: Institutional arrangements and processes for IWRM at catchment, WMA and national level

Human rights and equitable access to water
AWARD
No 1512

A key concept evident in the South African Constitution is that National Government is committed to providing adequate food and water "… to meet basic human needs". Arguably the most crucial resource, in terms of human need, is water. This commitment in providing water for basic human needs is captured by the National Water Act (1998) in the concept of the "Basic Human Needs Reserve" (BHNR). This concept is an expression in real terms of the constitutional intention to provide water to meet basic human needs (currently taken to be 25 _ per person per day) before water can be allocated for use by the various sectors. The notion of the BHNR essentially elevates the status of water for basic human needs to that of a human right. Although an orientation that accepts access to water as a human right is enshrined in South African law, it represents a very new concept in water management in South Africa (and the world). One of the major obstacles hampering implementation is a lack of familiarity and understanding of the notion of the BHNR by the very people tasked with the responsibility for ensuring that it is honoured, i.e. local government. An informal, preliminary survey conducted by AWARD indicates that most members of local government have not heard about the BHNR.

The objectives are:

- An exploration of the concept of "water as a human right" within the context of the South African legal framework
- Enhanced understanding, capacity and competence within Local Government to implement the National Water Act and allocate water resources with consideration for the concept of "The Reserve"
- To produce and test learning support materials regarding the concept of the Reserve
- To research, understand and document the way that access to water resources as a human right can be implemented in South Africa
- To share findings generated by a research orientation with other catchments and local governments in South Africa

Estimated cost: *R173 000*
Expected term: *2004-2005*

Water Law of South Africa
Maritza Uys
No 1513

South Africa's suite of new and emerging water legislation represents a radical departure from previous legislation. There is not yet any significant body of case law to assist in interpretation, understanding and implementation. There is an urgent need for development of insights, knowledge and capacity amongst not only the technical IWRM community, but also the legal community in South Africa. The outcome of this project will be the design for a broad national programme of water law research, which will support the building of capacity to develop and implement water law and regulation.

The objectives are to:

- Compile **Volume 1** of Water Law of South Africa, consisting of present and past water law legislation up to 2003, and indexes; and to write section-by-section annotations
- Compile **Volumes 2** to **7** of Water Law of South Africa, consisting of all Water Court cases since 1913, all cases on water law by other Supreme/High Courts, and Water Tribunal cases of general application, and indexes; and to write summaries and case annotations to precede all cases
- Write **Volume 8** of Water Law of South Africa, being a complete textbook on water law consisting of the history of South African water law; the management of water resources (being a full explanation of the effect and working of the National Water Act, 1998); and the Common Law concerning water (including riparian rights, servitudes, stormwater, underground water, damming, and navigation)
- Publish, on behalf of the WRC, each volume of Water Law of South Africa as soon as it is ready, in print and on the Internet
- Update the data on the Internet of **Volumes 1** to **8** of Water Law of South Africa on a continuing basis from 2004, and to make proposals to the WRC when it is necessary for revised and/or additional volumes of the printed edition.

Estimated cost: *R200 000*
Expected term: *2004-2005*

Strategic review of current and emerging governance systems related to water in the environment in South Africa
Pegasus Strategic Management (Pty) Ltd
No 1514

This project includes review and evaluation of all relevant governance elements (principles, policy, legislation, regulation and practice) at international, national and provincial level that are presently in place and which directly relate to, or potentially impact upon, water in all phases of the hydrological cycle. The outcomes of this project will provide the baseline for development of strategic research priorities related to further development of water-related governance elements and systems.

The objectives are to:

- Review and evaluate all relevant governance elements at international, national, provincial and local level in South Africa that directly relate to or have an impact on all phases of the hydrological cycle.
- Identify and prioritise key issues, areas of conflict or gaps that require research to support harmonisation of existing governance elements or to develop new governance elements.

Estimated cost: *R500 000*
Expected term: *2004-2005*

Programme 4: Transboundary water resource management

International freshwater agreements
CSIR
No 1515

South Africa shares four rivers with its five neighbours – the Incomati, Orange, Limpopo and Maputo Rivers. The quantity and quality of the water in these international rivers are increasingly under pressure due to increased water demands in South Africa as well as in the neighbouring states. These pressures will increase as the region

develops, possibly leading to a clash of interests between the basin states. South Africa has signed and ratified the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (UNCSW 1997), which promotes the principles of equitable and reasonable utilisation and the obligation not to cause significant harm (to downstream states). Additionally, the convention calls for the establishment of a framework for the exchange of data and information, the protection and preservation of shared water bodies, the creation of joint management mechanisms, and the settlement of disputes (UNEP, 2002). Essential tools in the pursuit of the objectives of the UN Convention are the various treaties, protocols, memoranda and agreements entered into between basin states (collectively referred to as agreements in this proposal). South Africa is also a signatory to a range of bilateral, multilateral and regional agreements guiding issues of quantity, quality, infrastructure and management of shared freshwater resources (e.g. SADC, 2001). These include agreements entered into as a colony of Britain with various other colonial powers as well as those agreed recently with neighbouring states. Currently, there is no central repository of these agreements; some are housed at DWAF's offices and others at the Department of Foreign Affairs.

The objectives are to:

- Produce a complete list of all freshwater agreements to which the Government of South Africa (GoSA) is signatory
- Update the TFD database with the missing agreements
- Store the agreements digitally as a database in South Africa and make it available in CD Rom format
- Using the legal assessment model (LAM) of the International Water Law Institute (IWLI) determine how effective current agreements are

Estimated cost: *R270 000*
Expected term: *2004-2005*

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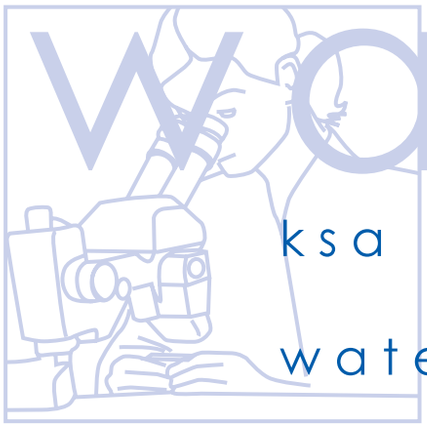

ksa 2

water-linked ecosystems

Scope

The National Water Resource Strategy (NWRS) focuses on resource protection as one of the components of the NWRS. The research undertaken in this KSA provides knowledge for protection of the resource, and is therefore central to this aspect of the NWRS.

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 primary objective is 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, utilise and rehabilitate the aquatic ecosystem.
- Transfer the knowledge to appropriate end-users.
- Build capacity in both research and management to sustainably manage aquatic ecosystems.

Thrusts and programmes

Thrust 1: Ecosystem Processes

Scope: This thrust includes research addressing the biophysical processes, form and function of ecosystems. The aim is to generate knowledge to inform policy and management. Current programmes are:

- Estuarine processes
- Riverine processes
- Wetland processes
- Groundwater-dependent ecosystems

Thrust 2: Ecosystem Management and utilisation

Scope: This thrust includes research which specifically addresses 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. Capacity will be built to implement the research findings. Current programmes are:

- Ecological Reserve
- Estuary management
- Ecosystem health
- Environmental water quality
- Endocrine disrupting compounds (EDC)

Thrust 3: Ecosystem Rehabilitation

Scope: This thrust addresses the rehabilitation of the aquatic environment (including both the abiotic and the

biotic components) which have been degraded through anthropogenic activities with the view to restoring, as far as possible, process, form and function. This will be done in terms of both relevant international conventions and national legislation. Capacity will be built to implement the research findings. Current programmes are:

- Wetland rehabilitation
- River rehabilitation
- Influence of instream-constructed barriers

Research portfolio for 2003/04

This KSA focuses on the protection and sustainable utilisation of the aquatic environment (abiotic and biotic). It addresses national research needs (strategic and shorter term) as well as those of international conventions on environmental management (e.g. wetland conservation [Ramsar] and biodiversity). Work done within this KSA has contributed to the development of the National Water Act (NWA) and associated policies, an example being the Ecological Reserve. This has meant that work within this field has not only addressed the strategic needs of the country which have increased in line with the increased global recognition of the importance of the role of sustainable environmental management, but also has addressed some of the immediate research needs related to the NWA and its implementation. What people require of the environment is an area of increasing importance, and the building of capacity amongst the country's citizens (managers and the various user groups) to manage the environment sustainably is of cardinal importance.

The proposed new projects will continue to develop knowledge to enhance the national capacity to ensure sustainable management and utilisation of ecosystems while maintaining diversity in the form and function of ecosystems.

Budget for 2003/04

The approved funding of the research portfolio for 2003/04 leads to a committed funding budget of R 9.2m.

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.

The research undertaken in this KSA provides knowledge for protection of the resource. The National Water Resource Strategy (NWRS) focuses on resource protection as one of the components of the NWRS, and this research is therefore central to this aspect of the NWRS.

The position of the WRC in funding research into ecosystems

Aquatic ecosystems comprise the resource in terms of the National Water Act of 1998. Even without this they are important for a number of reasons. They provide a barometer of ecosystem health, and hence environmental quality, which is responsive to change and easy to interpret. They also provide a number of goods and services which are used by all sectors of the population. Examples of this are water for domestic, agricultural and industrial use, basic food (fish, plants), traditional medicines and recreation opportunities to name a few. A stable ecosystem provides the necessary resilience to cope with extreme events such as floods and droughts (natural) and pollution events (anthropogenic). In the past, a proportion of the national cost for the treatment of wastes has been externalised to the environment and although the environment was degraded by this, by and large the load did not exceed the capacity of the environment to cope with it. However, recent developments indicate that it is more cost effective to maintain the resource in a good condition than to carry the costs associated with a poor-quality resource.

To this end the WRC has funded research on ecosystems for approximately a decade and a half. The work funded has been a balance between the generation of knowledge needed to support resource management and the generation of understanding of the ecosystem processes to guide future resource management direction. Some examples of this are the funding of research on instream flow requirements (now the basis of the

Ecological Reserve in the NWA), biomonitoring (now the River Health Programme), toxicology (now incorporated in policies for the implementation of source-directed control in the NWA) and strategic adaptive management (which now provides the basis for resource management within the Kruger National Park).

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 (the NRF has a thrust which overlaps to some extent with the field covered by this KSA) 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 more 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 lead for which may come from global trends not necessarily yet reflected as needs in South Africa. The need to implement legislation tends to distract attention from this long-term need, although this is 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. This was articulated at the recent World Summit on Sustainable Development (WSSD).

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.

In addition, 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 related to needs

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. Within this programme 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 inter-action 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. Research drivers include:

- 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.

- Groundwater-dependent ecosystems present a little-understood area where the over-use of resources can cause irreversible (on the time scale of a human life) change.
- Rehabilitation addresses the problems caused by people altering the 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 (almost an entire dairy herd at Kareedouw).

Key stakeholders

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 governments are also key stakeholders, and the anticipated needs of catchment management agencies (CMAs) 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 two main groups in this category. As 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. Important international players are IWMI (currently mainly through their Dialogue Programme), WWF, UNEP and the World Bank.

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 (Venda, The North, Witwatersrand, RAU, Potchefstroom, Free State, Zululand, Natal (both Pietermaritzburg and Durban), Transkei, Rhodes, Port Elizabeth, Stellenbosch, Western Cape and Cape Town), science councils (in this field predominantly the CSIR and the ARC) and within various consultancy firms.

Within these universities the researchers are often housed within specific research institutes or other units focused on specific aspects of research. The consultancy firms which do work in the field of ecological research and management normally focus on the more applied aspects which is a good way to rapidly implement research results and gett feedback into the research process at the same time.

Research portfolio for 2003/04

The primary objective of this research portfolio is 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, utilise and rehabilitate the aquatic ecosystem
- Transfer the knowledge to appropriate end-users
- Build capacity in both research and management to sustainably manage aquatic ecosystems

An overview of KSA 2 research thrusts and programmes is presented in **Table 1**.

TABLE 1
Overview and description of thrusts and programmes for the research funded within KSA 2

THRUST 1: ECOSYSTEM PROCESSES	
Scope: *: This thrust includes research addressing the biophysical processes, form and function of ecosystems. The aim is to generate knowledge to inform policy and management. Current programmes are:*	
Programme 1 **Estuarine processes**	**Scope:** Estuaries are fragile and highly productive ecosystems and are highly sought after as places to live. Projects in this programme address the ecological processes occurring in estuaries.
Programme 2 **Riverine processes**	**Scope:** Programmes to investigate the ecosystem functioning and processes of riparian zones, rivers and impoundments will be developed This is an area in which South Africa needs improved capability to manage, and in the case of riparian zones, this is a topic attracting international interest. (was previously in a separate paragraph)
Programme 3 **Wetland processes**	**Scope:** 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
Programme 4 **Groundwater-dependent ecosystems**	**Scope:** 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.

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION	
Scope: *This thrust includes research which specifically addresses 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. Capacity will be built to implement the research findings.*	
Programme 1 **Ecological Reserve**	**Scope:** 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.
Programme 2 **Estuary management**	**Scope:** 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 sustainability. This programme is managed in close association with Marine and Coastal Management, DEAT.
Programme 3 **Ecosystem health**	**Scope:** 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 bio-monitoring programme with well-defined indices. Much of the R+D is 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. This programme links with the cross-cutting domain `Water and Health' and includes the research being done on endocrine disrupting contaminants.

THRUST 2: WATER RESOURCE ASSESSMENT (continued)	
Programme 4 Environmental water quality	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 licenses 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 within the crosscutting domain `Water and Health'.
Programme 5 Endocrine disrupting compounds (EDC)	The overall objective is to characterise, and acquire information for assessing the EDC effects of various chemicals and compounds in water (singly or in combination), both those occurring naturally and those resulting from pollution which have the potential to cause detrimental health effects in humans, animals and the aquatic environment as a guide to develop and implement a cost-effective treatment and control strategy. Further emphasis is on the development of simple, rapid and cost- effective detection techniques. This programme will be done in three phases, of which the first phase is already completed.

THRUST 3: ECOSYSTEM REHABILITATION	
Scope: *This thrust addresses the rehabilitation of the aquatic environment (including both the abiotic and the biotic components) which have been degraded through anthropogenic activities with the view to restoring, as far as possible, process, form and function. This will be done in terms of both relevant international conventions and national legislation, and seeks to restore bio-diversity where possible. Capacity will be built to implement the research findings:*	
Programme 1 Wetland rehabilitation	**Scope:** Within this programme research will be conducted to develop methods to rehabilitate wetlands which will address both abiotic and biotic components, and seek to rehabilitate ecological processes and restore biodiversity as far as possible in degraded 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 link closely with each other, and are managed as a unit
Programme 2 River rehabilitation	**Scope:** The research conducted within this programme aims to provide protocols for the rehabilitation of rivers, with the emphasis on urban rivers, that have been degraded as a result of anthropogenic activities or invasive biota.
Programme 3 Influence of instream-constructed barriers	**Scope:** This programme investigates ways to ameliorate the effects of barriers such as weirs and impoundments on natural river systems.

COMPLETED

Thrust 1: Ecosystem Processes

Programme 2: Riverine processes

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

No 956

Water quality is complex, and its management is one of the major issues facing water managers in South Africa at the moment, especially as it is required in the context of the new legislation and policy. The main aim of this project was to address the relationship between water quality and quantity (discharge), particularly in relation to the instream flow recommended during the determination of the Ecological Reserve.

The approach used was two-fold. Firstly, methods were developed to predict the concentrations of given chemical components and values of physical variables that will result in a given reach from the flow regime that

is recommended by the specialists at the Instream Flow Requirement Workshop. Secondly, methods were developed to predict the effect that these changes in water quality would have on the abundance (or other measures) of key invertebrate taxa and thus on the ecological functioning of the aquatic resource.

No single method for modelling water quality will possess all the attributes required. Also, specific situations will not require all the attributes exhibited by the models. Therefore, a hierarchy of three tiers of complexity has been developed to cater for the requirements of different situations, as follows:

- A simple discharge – concentration (Q-C) method
- Mass – balance modelling (QUAL2E or spreadsheet-based)
- Catchment runoff model

Discharge – concentration (Q-C) modelling is a useful method for estimating the concentration of chemical constituents that will arise from the implementation of a particular discharge regime, and may be used as an initial screening process. However, this approach is empirical, and the limitations of this level of modelling should be clearly recognised.

Mass balance models may be used to examine the effects of different water management scenarios. QUAL2E particularly can provide a more mechanistic description of the processes affecting water quality in a given river reach. However, it does require additional data to those normally available. QUAL2E is suited where there is a complex situation of pollutant loading or nutrients, dissolved oxygen or temperature need to be modelled. The time series developed may be used for comparing (ranking) different flow scenarios as generated by the Water Resource Yield Model. These time series may than be used to predict the likely impacts on aquatic biota which in turn, when interpreted using the Biotic Protocol, may be used to identify taxa which may be lost or regained from a system.

This research has been done in close co-ordination with the resource directed measures (RDM) process to determine the Ecological Reserve, and through a number of iterations, it has been developed to provide results to inform the RDM process on the water quality implications of various management scenarios. The results will be equally applicable to situations where water quality needs to be predicted for other reasons.

Cost: R800 000
Term: 1998 - 2001

Incorporation of economic considerations into quantification, allocation and management of the environmental water Reserve
Institute for Natural Resources, University of Natal
No 978

The National Water Act, No. 36 of 1998 requires that an Ecological Reserve is determined and set aside to promote ecological integrity. Although the Reserve is provided for in the legislation, it will become increasingly difficult to justify the allocation of a scarce resource without showing the values and benefits provided to society through maintaining or enhancing the functioning of river ecosystems.

The aim of this project was to evaluate the utility of a resource economics approach in contributing to the determination of the Ecological Reserve, as described in the National Water Act.

It was expected that the findings of this research project would provide a basis for a rational decision on whether or not to apply resource economics to the determination and management of the Ecological Reserve. The project adopted ecological economics, with its focus on ecosystem goods and services, as a basis for economic analysis. Importantly, the project did not focus on the value of water abstraction as this has been the focus of numerous other studies.

The project researched and developed three approaches for using economics in the Reserve determination process:

- Firstly, the project identified where and how economics should be used in establishing the Ecological Reserve and its management,
- Secondly, a multicriteria decision analysis procedure was developed for integrating economic information into decision making regarding strategic adaptive management (SAM), and including the Ecological Reserve, management classes and resource quality objectives, and
- Thirdly, developed methods for valuing river ecosystem goods and services and tested these in the Crocodile River catchment, Mpumalanga Province.

The project integrated its activities with the resource-directed measures (RDM) process associated with national catchment management initiatives in South Africa.

A number of lessons emerged in applying resource economics within the context of strategic adaptive management including the Ecological Reserve, management classes and resource quality objectives. Generally individuals and organisations perceive the importance or the role of rivers in terms of their own experiences and needs. By using the concept of rivers as suppliers of goods and services (such as recreation, fishing, fibre source, etc.), stakeholders are able to develop a more complete picture of their relationship to the river and other user groups.

An assessment of the RDM process revealed that there was no clear mechanism for integrating economic information into the decision making process. There are a number of steps in the strategic adaptive management framework and RDM process which should include economic information. These include:

- Decisions on feasible options for supply and demand management (i.e. increasing efficiency of water use)
- Development of a catchment vision
- Decisions on allocation between river reaches or quaternary catchments
- Decisions on allocation of allocatable water resources within reaches

With each of these decisions, there are stakeholders that will benefit, while others may have costs. The MCDA process involves evaluating or "scoring" alternatives from different points of view (economic, ecological and social criteria) and combining these separate scores to obtain an overall ranking of alternatives which best reflects society's desires.

Many ecosystem services proved to be complex services requiring considerable primary research to establish predictable relationships between river functionality and the quantity and quality of ecosystem goods and services supplied. There are also considerable limitations in data availability. The intensive effort required to make such assessments is likely to constrain the widespread application of resource economics in the RDM and SAM activities.

Within the existing SAM framework, the RDM process is designed to take place at the level of a river reach. There are thus two possible options for making decisions at the level of individual resources (e.g. river reaches):

- Option 1 – The RDM is applied **sequentially** from mouth to source, and the constraints set at each reach. This gives automatic priority to lower reaches and estuaries, and the degree of flexibility afforded to higher reaches will be highly dependent on the natural augmentation of supplies via tributaries, etc.
- Option 2 – A **strategic assessment** is made whereby all resources within a catchment are assessed together. This would attempt to promote the optimal allocation of water and water quality objectives between its component resources. This will still require stepwise setting of constraints from mouth to source, but will not automatically give priority to lower reaches and estuaries. It means that one reach could be altered to service the needs of another reach.

Cost: *R488 000*
Term: *1998 – 2001*

Integration of water quality tools for the Ecological Reserve into a risk-based DSS
Institute for Water Research, Rhodes University
No 1108

The whole thrust developing methods for environmental water requirement determinations began with those to ascertain the flow (quantity) requirements of rivers. Methods for estimating water quality requirements were not addressed in the early stages of the overall development of the methods. When the need for this was first realised it quickly became apparent that there was no direct relationship, but rather a complex relationship which depended on a range of factors. By this stage the flow side of the methods development was in full swing and the quality side was in danger of missing the bus altogether.

With this in mind, the aim of this project was to develop a water quality module for the decision support system entitled `SPATSIM' (WRC **Project No K5/1160** – final report to be tabled soon), thus integrating water quality into the main stream of decision making around the Reserve determination. SPATSIM has been work-shopped through both DWAF personnel and the consulting community during its development, and so is known and used.

This was achieved through a combination of two processes: DWAF organised method development workshops and contracts and DWAF contracted Ecological Reserve assessments (Crocodile River, Mpumalanga; Olifants River, Mpumalanga and Breede River, Western Cape). Innovations made during this work were included in the methods.

This was followed up by a second contract (**K5/ 1312 - 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**) to finalise certain aspects.

Cost: R278 000
Term: 2000 - 2001

Programme 4: Groundwater processes

Impact of groundwater abstraction on ecosystems in the Kammanassie Nature Reserve and environs
Department of Applied Natural Sciences, Technikon of South Africa
No 1115

The effect of large-scale groundwater abstraction on the environment is largely unknown as very few studies in this field have been conducted in South Africa. The Klein Karoo Rural Water Supply Scheme (KKRWSS) abstracts water from the Table Mountain Group aquifers. This abstraction has been effected for seven years. A previous study funded by the WRC on the geohydrology of the western section of the Kammanassie Mountain recommended that the impact of water abstraction on the environment should be investigated. As a result WRC initiated this study to investigate the effects of large-scale groundwater abstraction of this scheme on the environment.

The objectives of the project were to determine the impact of groundwater abstraction on the riparian vegetation, terrestrial vegetation, springs, and the population of Cape Mountain Zebra.

The most important conclusions based on this research are as follows. The abstraction has impacted on the groundwater base flow discharging into the Vermaaks River. Superimposed on the abstraction effects, is a declining precipitation trend since commissioning the well field. Abstraction has dried up one of these "permanent water" localities (spring 009) causing a localised impact. The other spring (051) was temporarily affected and stopped flowing for 6 months. The combined effect of the negative rainfall trend over the past 13 years is, in the majority of cases, a major contributor to the springs drying up. There appears to be a lag period (7 years) between the start of abstraction and significant impact on surface flow in the Vermaaks River. Twenty-seven springs (50%) occurring on the Kammanassie Mountain clearly emanate from perched groundwater systems, which cannot be influenced by groundwater abstraction and are excluded from potential influence. Sixteen (30%) "water table" springs occur and are potentially vulnerable to the effects of abstraction if all the other hydrogeological parameters permit. In a further 10 cases (19%) there is a possibility that the springs emanate from perched systems but there is an element of doubt. Base-flow in the Huis River is likely to have been influenced by abstraction from the well field but the volume cannot be quantified. It has been long recognised that the Cedarberg shale plays a prominent role in the occurrence of springs. It has become clear that a large proportion of these springs emanate from perched groundwater tables, and are not vulnerable to influences of abstraction. This study has allowed a comprehensive plant species list to be completed for the Vermaaks, Marnewicks and Buffelsklip Valley sections of the Kammanassie Nature Reserve. The plant species list can now be included into the Kammanassie Nature Reserve Management Plan and will result in the plant species list for the Reserve being much more comprehensive.

A new *Erica* species was discovered, and the localities of rare and vulnerable plant species previously unknown were identified during this survey. The floristic account, together with the descriptions of the plant communities serves as a basis to develop a habitat management plan for the Kammanassie Mountains. If further springs dry up on the Kammanassie Mountain, plant communities at these springs will change over time and species diversity is expected to decrease. Important water-dependent plants will be lost and wet plant communities will be transformed into dry shrub and grass dominated areas. The Vermaaks River (abstraction) sites within the alluvium basin had higher plant water stress than at the control site at Marnewicks, which has similar rainfall. This indicated stress probably related to groundwater abstraction. Plant water stress tests only need to be carried out in the summer months as this proved to be the time when the most pronounced differences were found, since high groundwater abstraction and low rainfall put additional stress on the plants.

Without artificial watering points at strategic places on the Kammanassie Mountain the 38 endangered Cape Mountain Zebra risk extinction as a result of natural water sources (springs) drying up.

Cost: R200 000
Term: 2000 - 2001

Thrust 2: Ecosystem Management and Utilisation

Programme 2: Estuary management

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
No 1308

Procedures for the determination of the resource-directed measures of estuaries were developed as part of the DWAF project in 1999 – 2000. However, these stopped short of the development of monitoring procedures. These procedures should be in place during the initial RDM investigation to enable the experts who determine the RDM requirements to design the monitoring programme to ensure surveillance of key variables in the system. The aim of this project was to develop guidelines and procedures for the RDM process for estuaries. Congruence between the different phases of the process has been ensured by specifying methods for baseline studies (for both intermediate and comprehensive) as well as long-term monitoring procedures for systems. In recognition of the uniqueness of individual estuaries, the procedures developed are generic with recommendations provided for the spatial and temporal scales at which each abiotic or biotic component should be measured.

Abiotic factors covered are hydrology, sediment dynamics, hydrodynamics and water quality. Biotic components developed are micro-algae, macrophytes, invertebrates, fish and birds. A number of recommendations have been made, not all of which have research components but which are, nevertheless, important for a successful monitoring programme. The recommendations may be broadly categorised as follows: Co-operative governance, the establishment of monitoring programmes, implementation of monitoring programmes, data capture and storage, communicating information from programmes and key considerations for the way forwards.

The main aim of developing resource-monitoring procedures for the RDM process has been achieved. The second aim of including these in the RDM protocols for estuaries has been achieved in so far as these have been implemented during the course of the project. The final aim of involving a previously disadvantaged intern was achieved.

Cost: R195 500
Term: 2002 - 2003

Programme 3: Ecosystem health

Evaluating the environmental use of water-selected case studies in the Eastern and Southern Cape
Department of Economics, University of Port Elizabeth
No 1045

The bulk of water supplies in South Africa are generated in mountain catchments. They cover approximately 10 % of its surface area but yield in excess of 50 % of the total annual water runoff. One of the things that undermine this yield is the invasion of them by alien woody species. The *Working for Water Programme* (WWP) is a management strategy which entails the removal of water-consuming alien vegetation and restoring of low water-consuming indigenous vegetation.

The first objective of this study was to determine the net economic benefit of the WWP on six selected project sites in the Eastern and Southern Cape. The six project sites are those of the Tsitsikamma, Kouga, Port Elizabeth Driftsands, Albany, Kat River, and Pott River. These sites harbour a great diversity of plant spp., most notably, fynbos spp. and grasses, but they also have been invaded by alien trees such as *Pinus*, *Hakea* and *Acacia* spp. A second objective of this study was to value the freshwater inflow benefit to the Keurbooms Estuary in the Tsitsikamma catchment, in order to provide policy makers with insights into the scale of economic tradeoffs resulting from reduced freshwater supplies to this estuary.

The methodological approach to the study on the selected sites mentioned above entails the identification and estimation of the social costs and social benefits of the water resource conservation projects on these sites and the comparison thereof with those expected costs and benefits without the projects in question.

A distinct cost-benefit profile was generated for each site. From these profiles net benefits were calculated and discounted to present values for the purposes of establishing a standard of comparison. A social discount rate of 10.1 % was employed to derive present values. Three investment criteria, namely the internal rate of return (IRR), the net present value (NPV) and the benefit cost ratio (BCR) were generated.

The contingent valuation method was used to value the water benefit of the Keurbooms Estuary. This method

entails asking respondents how much they are willing to pay to prevent the loss of environmental services provided by the estuary due to reduced freshwater inflows.

The cost-benefit analysis results are shown in the table below:

Project	CBA criteria		
	NPV (R)	IRR (%)	BCR
Tsitsikamma (agricultural water value) (estuarine water value)	-31 757 404 -55 492 203	5.00 1.20	0.54 0.20
Kouga	-33 854 196	7.25	0.75
Port Elizabeth Driftsands	-14 674 240	0	0
Albany	-15 232 753	1.13	0.21
Kat River	-1 031 609	3.60	0.43
Pott River	-1 446 624	-3.14	0.03

The contingent valuation method was used to value the services yielded to recreation users through freshwater inflows into the Keurbooms Estuary. Through this valuation, it was concluded that the freshwater inflow had a value of R0.046/m^3.a.

The study concludes that the catchment management carried out under the WWP on the Tsitsikamma, Kouga, Port Elizabeth Driftsands, Albany, Kat River and Pott River sites is inefficient in terms of what benefits could be valued. This conclusion is subject to three qualifications. The first is that more work remains to be done on the evaluation of the non-water benefits. The second qualification is that at lower discount rates, for instance 5 %, the Kouga project is efficient. The third qualification is that if 30 % cost savings could be achieved, and a discount rate of 5 % was employed, that both the projects at the Tsitsikamma and Kouga sites would be efficient.

Based on the results of this report it is recommended that the managers of the WWP focus their future activities in areas where a high demand for water for consumptive use exists. This will ensure a high value for the water benefit and improve the economic rationale for the Programme.

Cost: R143 000
Term: 1999 - 2002

Geomorphological research for the conservation and management of Southern African rivers
Department of Geography, Rhodes University
No 849

The overall aim to implement geomorphological research as an integral component of multidisciplinary river system management for the conservation of their ecological integrity was met, both sections contributed to the understanding of the relationship between river flow and geomorphology. Six specific objectives were listed as follows:

- Further development of the hydraulic biotope concept. Little was done on this objective as the specialist researcher left Rhodes before the project started. The resources were mainly channelled into objectives 2 and 3.
- Refine the geomorphological component of the RDM methodology. The project leader and the 2 main research students participated in 11 RDM studies, and the experience gained refined the methods being developed.
- Develop geomorphological indices. This was done in conjunction with DWAF, ensuring that the products will be used in the future.
- Build capacity in fluvial geomorphology
- Continue research collaboration with aquatic SA ecologists. The project leader has worked in close association with scientists from Rhodes and UCT during the project.
- Collaborate internationally. This has happened through conferences.

The aims have been met, the science is good, and the results have been honed to address the needs of ecosystem conservation in the face of resource management.

The report has been published in 2 separate sections. The first examines the geomorphological impact of water

resources development through either impoundment of inter-basin transfers (IBT), and the second addresses the flows necessary for maintaining channel form, substratum characteristics and hydraulic habitat. Section 1 is one of very few studies internationally, which addresses the impact of flow increase through an IBT on the receiving river, in this case the Schoenmakers River receiving water from the Orange - Fish – Sundays scheme (the neighbouring Volkers River was studied as the control). The IBT changed a flood-dominated ephemeral stream into a baseflow-dominated perennial river. Considerable erosion occurred in the upper reaches (exposing bedrock), with sediment deposition in the lower reaches making the channel broader and shallower. Riparian vegetation was influenced (negatively in terms of natural biodiversity) through habitat loss resulting from erosion and change of species through stable flow. Section 2 addresses the debate around the magnitude and frequency of flows necessary to maintain geomorphological characteristics. In this section flows necessary for maintaining channel form, substratum characteristics and hydraulic habitat are investigated to develop a conceptual model of channel-forming discharge for selected rivers (Mhlatuze, Olifants and Mkomazi Rivers).

Cost: R738 000
Term: 1997 - 2001

Development of monitoring methods for the Ecological Reserve (quantity) for rivers
IWR, Rhodes University
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.

Cost: R538 000
Term: 1999 - 2001

Programme 4: Environmental water quality

Biomarker assays for the detection of chronic toxicity in the aquatic environment
Division of Water, Environment and Forestry Technology, CSIR
No 952

While there is a selection of aquatic toxicity tests available to detect acute toxicity, very little attention has been given to the establishment of techniques to detect chronic or sub-lethal toxicity. Chronic toxicity is traditionally measured in life-cycle tests taking 30 days or longer. This is sometimes shortened to 7 to 10 days, focusing on the most sensitive life-cycle stages. A new approach is the use of biomarker assays which provide rapid measures of the molecular mechanisms underlying toxicity. These assays have been derived from mammalian medicine and allow for rapid assessment of ecosystem health (usually hours to a few days). The aim of this project was to establish biomarker assays for the detection of chronic toxicity in the aquatic environment and to produce an operational manual on the established methodologies.

The project focused on using biomarkers as sub-lethal endpoints in a laboratory fish test employing tilapia (*Oreochromis mossambicus*), to complement the acute (lethality) tilapia test developed for local use. Since juveniles are much more sensitive than adult organisms, the researchers attempted to use the youngest possible juvenile fish in the laboratory test. Assays for the following biomarkers were established and optimised: protein; AChE; ethoxyresorufin-O-deethylase (EROD); glucose; glycogen; delta-aminovulinic acid dehydratase (ALA-D); LDH; glucose-6-phosphate-dehydrogenase (G-6-P-DH); pyruvate kinase (PK); heat shock protein (Hsp 70) and osmotic ion analyses. Published protocols were followed. Where possible, techniques were miniaturised (microplate assays) or test kits were used. Biomarker activity was evaluated by exposing 30 fish per container (single exposures) or 60 fish divided over 3 containers (triplicate exposures) to various concentrations of selected chemicals for exposure periods of 8, 24 and 96 h. Selected biomarker assays were carried out on the supernatant of the homogenised fish.

The control results showed that, although values were low, all the biomarkers were present at measurable levels in the fish homogenate. A considerable fluctuation was noticed in the control biomarker values (mean of triplicate assays) of different single exposures. When triplicate exposures were carried out, the fluctuation between the results of triplicate assays was much smaller, probably because the age of the fish used in these studies ranged between 21 and 24 days, reducing differences in weight and size.

The exposure studies showed that biomarkers were affected by the test chemicals. Biomarkers were induced or inhibited. Although large effects were observed in some instances, effects were not always significant because of the large variation between replicate results. The results of replicate experiments (PCP and cyanide) were often inconsistent. Test concentrations showing significant biomarker induction in one experiment did not affect the biomarkers in the other experiment or *vice versa*. This could be attributed to variability in the sensitivity of test fish or to large variations between replicate results, rendering test results not significantly different from control results. Results showed that concentrations of cadmium and zinc that exhibited significant biomarker responses during 8 and 24 h exposure, caused lethality during the 96 h exposure. The biomarkers thus acted as early warning signals for acute toxicity.

In field studies all the biomarkers, except the AChE in erythrocytes, showed positive results on one or more of the sampling occasions. The effects of test sites on G-6-P-DH could not be determined because of the large variability in results.

The limited number of offspring obtained for tilapia maintained in the laboratory and the inconsistency in reproduction was a major constraint. Consequently, the sub-lethal test using biomarkers as endpoints was not sufficiently validated to enable informed decisions on its potential as a routine laboratory test. However, in spite of the inconsistency in the results of laboratory exposure studies, sufficient evidence was obtained that biomarkers could be applied as sub-lethal measures of toxic activity in laboratory toxicity tests. At this stage the sub-lethal test protocols, outlined in the *Operational Manual* is only applicable for qualitative studies. Protocols were optimised, but extensive testing/evaluation is required before the methods can be standardised for specific applications.

Cost: R650 000
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
No 1029

Cyanobacterial blooms are ubiquitous, often associated with eutrophication and appear to be on the increase, also in South Africa. N, P and C are important nutrients for high growth rates and the ratios in the supply concentrations are often decisive in selecting for cyanobacterial dominance. *Microcystis* often dominates and this organism produces a vast number of peptides (microcystins), some of which are highly toxic. The toxicity varies not only within the same strain, but non-toxic strains also occur.

The aims of this project were to investigate the growth characteristics of different *Microcystis* strains and to relate these to potential toxicity. Also to elucidate the genetic control of microcystin synthesis and attempt to develop a molecular screening tool for the presence of toxicity or not. An attempt was also made to determine variations in toxicity under natural conditions.

Methodology entailed cultivation of many different strains of *Microcystis*, HPLC-analyses of different microcystins, growth analyses, chlorophyll fluorescence, DNA analyses, PCR and AFLP assays.

The molecular basis of toxin-production in *M. aeruginosa* was partially elucidated elsewhere and it was found that both toxin-producing and non toxin-producing strains of *M. aeruginosa* contained sequences that revealed a high degree of homology with several well-characterised peptide synthetases. In blotting experiments, a PCR fragment based on a portion of one of these peptide synthetases hybridised exclusively to restricted genomic DNA from toxin-producing strains indicating that this peptide synthetase was involved in toxin production.

Based on conserved motifs present in known sequences of the mcyB gene, four primer pairs were designed and used to identify strains with toxicity or not. Analysing the strains and using the insertions/deletions (indels) to discriminate between *M. aeruginosa* and *M. wesenbergii* in raw water samples it confirmed the value of PCR assays as an indicator of toxicity and taxonomical characteristics.

Many factors and combinations of factors influence bloom formation of cyanobacteria and the only conclusions that can be made from this study are that there is a high probability that cyanobacteria may form blooms, when eutrophic conditions are present, water temperature is high and water pHs are alkaline. Water temperature appeared to be the most important factor influencing bloom development in a eutrophic pond and little growth was seen at temperatures below 18°C. Once blooms develop, toxin measurements are the only means of determining the presence or not of these secondary metabolites and PCR assays should be used.

Cost: R372 000
Term: 1999 - 2001

Benthic diatoms in the rivers and estuaries of South Africa
Department of Botany and Institute for Coastal Resource Management, University of Port Elizabeth
No 1107

Internationally, diatoms are known to be sensitive indicators of water quality. This research aimed to define this relationship for South African inland and estuarine waters. Diatom taxonomy is very complex and to avoid the `noise' created by dealing with a large number of taxa that are difficult to identify, the decision was taken to deal only with dominant and sub-dominant taxa in each sample. A taxon was considered dominant if it was the most numerous taxon in the sample and was considered sub-dominant if it was not dominant but comprised more than 10% of the total sample. This reduced the number of taxa on which the index was built to approximately 1/3 of the estimated number of taxa present. Only epilithic (growing on rocks) and epipelic (growing on sediments) habitats were sampled as these were seen as sufficiently stable to allow the diatom flora to integrate the water quality at the site.

Samples were analysed from a total of 212 river sites, with samples being taken from the major rivers within each of the provinces, and a total of 289 estuarine sites were sampled from the Olifants River in the West to the Mhlatuze River in the East. River sites used were deliberately placed at DWAF water quality monitoring sites so that water quality data from the DWAF database could be used. There is no routine water quality monitoring in estuaries, so only salinity was considered, and this was measured at the time of collection.

Dominant diatom taxa in rivers correlated with TDS, although a few taxa tended to occur over a wide range of salinities. Dominant diatom taxa in estuaries could be correlated to high (24 to 35 g/ℓ), medium (13 to 23 g/ℓ) or low salinity (1 to12 g/ℓ), and so indicate freshwater inflow.

The third specific aim of the research was to produce an annotated guide to the dominant and sub-dominant diatom taxa. This has been done, and will be published as part of the report.

The Water Quality Index developed from the correlation between water quality and diatom taxa, combined with the illustrations of the dominant and sub-dominant taxa, will provide an accessible method for the use of diatoms in water quality monitoring. This is already in use within Umgeni Water.

Cost: R415 000
Term: 2000 - 2002

Thrust 3: Ecosystem Rehabilitation

Programme 1: Wetland rehabilitation

Guidelines for Integrating the Protection, Conservation and Management of Wetlands into Catchment Management Planning
Umgeni Water
No 1410

The legal framework that exists in South Africa provides every incentive to ensure that the water resources of this country, including its wetlands, are used sustainably. From the Constitution to legal acts such as the National Water Act, the National Environmental Management Act, the Conservation of Agricultural Resources Act and others, an environment is created whereby the protection, conservation and management of wetlands could and should happen in order to ensure the sustainable use of natural resources. Yet, all is not well with the wetland resources of this country. Already suffering from years of abuse and over-utilisation, wetlands remain under threat as part of the water resource.

So, what are the problems? Why are the water resource contributions of wetlands not appreciated by society? Why are procedures not in place to protect them to ensure the ongoing supply of benefits they provide? Essentially, there are three main problems:

- Protection of wetlands requires protection of both the land uses around and within wetlands, as well as the water that feeds them and maintains their essential character. Generally, these two critical aspects are the responsibilities of different agencies, resulting in a lack of alignment of objectives and priorities, which in turn leads to one or the other of the land or water aspects not being adequately addressed.
- The web of legal and institutional responsibilities is complex and confusing. Wetlands are an issue for so many legal instruments and government departments that there is a tendency to hand over the responsibility of dealing with them to someone else. The result is that wetlands tend to be ignored.
- The technical tools needed to protect, conserve and manage wetlands as an important water resource are generally deficient. So, while there may be a strong desire to manage wetlands, as well as adequate (albeit fragmented) legislative and policy support, the wherewithal to ensure that the efforts invested are well spent,

are inadequate.

This Guideline sets out to chart a way through the complexity that exists in the hope that the responsible agencies will incorporate wetlands into their catchment management planning processes.

The Guideline provides a template, or "Critical Path" on which CMAs and other agencies responsible for water management will be able to implement wetland management in their areas. The Critical Path intends to help agencies navigate from planning at catchment level for wetlands management and protection, to implementation of wetland protection, rehabilitation and management strategies at site level.

The Guideline provides these agencies with the following information:

- Summarised information of the International Conventions that give support to the protection of wetland resources.
- Summarised information of the laws within South Africa that create the environment necessary for effective wetland management, and that can be used to strengthen the implementation of plans and strategies.
- An introduction to social and technical issues such as:
  - Involving stakeholders in the process
  - The survey and inventorying of wetlands
  - Determination of the health of wetlands
  - Setting of objectives and priorities for wetlands.

The Guideline also provides template style *Terms of Reference* that CMAs and other agencies can use in order to direct teams to the necessary tasks.

The impact of these guidelines is expected to be significant, especially for professional staff and interested members of society working at ground level to protect and manage wetlands and the benefits that wetlands provide for people. In addition, the international impact will be wide: The project was supported by WWF International (with Dutch DGIS funding) with the intention of providing a working model, so far not achieved in the world, of integrating wetlands into "mainstream" water resource management. South Africa's policy and legal environment are so far supportive and provide the most advanced tools in this respect.

This project was initiated by the Mondi Wetlands Project in partnership with the World Wide Fund (WWF) for Nature's *Living Waters Programme*, WWF's South African office (WWF-SA) and the WRC. Funding has been provided by DGIS (Netherlands) through the *Living Waters Programme*, and by the WRC. The project was administered and managed by the WRC, according to standard WRC procedures.

Cost: R255 000
Term: 2003 - 2003

Programme 2: River rehabilitation

Decision-support system for rehabilitation and management of riparian systems
Institute for Natural Resources, University of Natal
No 1064

The field of river revitalisation has experienced considerable growth in the past decade. In SA, however, very little is done on the ground. This signifies lack of guidelines specific to SA.

An existing framework (from Australia) has been adopted, and modified, and used in this study as a basis for rehabilitation planning. Components of decision support system were locally developed for the planning of rehabilitation projects.

The project has modified an approach for mapping landscape scale assets; methodology for identifying and mapping wetland boundaries from satellite imagery, techniques for identifying riparian, stream bank and in-channel assets and problems and the scale of a river reach, G1S-based protocol for identifying priority river reaches for rehabilitation and buffer establishment for sediment control.

The study further evaluates the application and transferability of the procedures to other river systems as well as development and enhancement of capacity in rehabilitation and river management.

Lastly, effective conceptual and operational linkages are established between the *Land Care Pogramme* of the National Department of Agriculture, *River Health Programme* of DWAF and Decision Support System of the WRC.

Cost: R 600 000
Term: 1999 - 2001

Ecological and geomorphological principles for river rehabilitation
Department of Zoology, University of Cape Town
No 1161

Land and water have brought many benefits to humans, but also have led to some decline in the ecological form and functioning of rivers. Such decline involves costs, such as expensive water quality treatment, sedimentation of reservoirs, flood control measures, etc. Because of this, river rehabilitation is "shifting" from being "grey" science to a structured science with a rapid build-up of data and knowledge.

The project focused on physical aspects of river degradation and rehabilitation. Degradation of the river, however, could take many forms, and physical rehabilitation may not always be necessary or appropriate.

Physical degradation of aquatic ecosystems can be due to both physical disturbance and hydrological manipulations. Physical disturbance may result from human interventions either within the catchment or the channel. Hydrological manipulations occur when humans intervene in land-based parts of the hydrological cycle.

Successful rehabilitation is based on three main activities, namely the environmentally sensitive river maintenance actions, soil bioengineering and measures to mitigate the effects of hard engineering practices. Natural recovery of the river channel without interventions is an option where time and space allow, and where limitations, such as excessive water abstraction, are not present.

A range of off-channel rehabilitation activities can be part of rehabilitation, such as reconnection of floodplains to rivers, re-instatement of meanders, stabilisation of stream banks and rehabilitation of riparian zones. Five methods of stabilising stream banks are vegetation alone, vegetation with structural control, vegetation and structural control with bank shaping, structural control alone, and bioengineering methods.

Three river response studies have shown that:
- Channel morphology is largely determined by high flows
- Hydraulic biotopes change as discharges change
- Floods enhance the diversity of riparian and aquatic plants
- Channelisation is usually followed by an upstream mitigation of bank erosion, which in turn, is followed by bank collapse particularly during the wet season.

Cost: R1 190 000
Term: 2000 - 2002

CURRENT

Thrust 1: Ecosystem Processes

Programme 1: Estuarine processes

Assessment of the geomorphological reference condition: Application to resource-directed measures and the river health programme
Department of Geography, Rhodes University
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

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
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*

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
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*

Groundwater-dependent ecosystems
CSIR
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

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
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
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
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 management he Ecological Reserve of the estuaries to ensure the maintenance of a long term equilibrium.

Estimated cost: *R950 500*
Expected term: *2001 - 2003*

Valuation of changes to estuary services in South Africa as a result of reductions in freshwater inflows
Department of Economics, UPE
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
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 - 2004*

Programme 3: Ecosystem health

Evaluation of the fish assemblage integrity index to assess river health, and its refinement to ensure high levels of accuracy
Contractor: Ecosun
No 1256

Worldwide 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*

Development of DRIFT, a second generation methodology for instream flow assessment
Southern Water Research and Ecological Consulting cc
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
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
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
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 DWAF 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 DWAF, 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*

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
No 1303

Previous research (Report No 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
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.
No 1310

Many fish-ladder designs exist, some of which are more effective in certain situations than others. DWAF 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 **Project No 1270: Flow measurement at natural controls and the provision of fish-ways** in the KSA 1 thrust **Water Resource Assessment.**

Estimated cost: *R553 000*
Expected term: *2002 - 2005*

WRC Programme for endocrine disrupting contaminants (EDC)
Consortium Members: US; UFH; MEDUNSA; Techknikon Free State; Technikon Pretoria; SABS; CSIR Environmentek; ARC-PPRi; Consultant manager
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: Environmental water quality

Applied aquatic ecotoxicology: Sub-lethal methods: Whole effluent toxicity (WET) testing, course development and communication
Institute for Water Research, Rhodes University
No 1245

The release of harmful and potentially harmful substances into the environment has caused water quality problems worldwide. 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
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*

A programme for research into the application of aquatic toxicology to water resource management
Institute for Water Research, Rhodes University and Ecosun
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*

Programme 5: Endocrine disrupting compounds

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
No 1399

The aims of the project are to:

- Establish the levels of cadmium in the Umtata River.
- Identify the point and diffuse sources of cadmium in the river catchment
- Establish the health impact of chronic cadmium poisoning on the primary users of water from the river by use of epidemiological survey of cadmium-related diseases among them
- Produce a recommendation for the management options of cadmium pollution in the River.

An initial study of the water quality of the Umtata River (**WRC Project 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.

Cost: *R250 000*
Term: *2002 - 2003*

Thrust 3: Ecosystem Rehabilitation

Programme 1: Wetland 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
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

Programme 3: Influence of instream-constructed barriers

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
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
Estimated term: 2001 - 2003

NEW

Thrust 1: Ecosystem Processes

Programme 3: Wetlands processes

Integration of indigenous knowledge systems in the conservation and protection of wetlands in communal areas of South Africa
CN Magwa Consultant
No 1417

This project aims to identify and describe the indigenous knowledge systems contributing to the conservation of wetlands in communal areas, and to provide guidelines on how this knowledge can be integrated into current systems to enhance sustainable management.

Estimated cost: R300 000
Estimated term: 2003 - 2004

Thrust 2: Ecosystem Management and Utilisation

Programme 1: Ecological Reserve

The DRIFT Methodology: Development of a user's manual, and consolidation of DRIFT software
Southern Waters
No 1404

DRIFT, as a methodology, has reached the point where it is increasingly being used both within South Africa and elsewhere in the world. Currently, the knowledge lies with the developers of the method. During the course of this project the components will be consolidated so that the method will perform consistently when used by other people.

Estimated cost: *R287 500*
Expected term: *2003 - 2004*

Low-flow hydraulics in rivers for environmental applications
Dept of Civil Engineering, University of the Witwatersrand
No 1405

The science of hydraulics integrates the hydrology with the ecology. It has been shown that the conventional equations are unsuitable for the estimation of low flow, and it is critical that there are reliable methods for the estimation of low flows for use in the determination of environmental flows. This follow-on project will continue the development of appropriate methods for describing the hydraulic characteristics of South African rivers under conditions of low discharge, as well as the influence of vegetation on large bed roughness.

Estimated cost: *R1 224 200*
Expected term: *2003 - 2006*

The determination of substrate maintenance flows in cobble and boulder bed rivers: Ecological and hydraulic considerations
Dept of Civil Engineering, University of Stellenbosch
No 1411

The science of hydraulics integrates the hydrology with the ecology. It has been shown that the conventional equations are unsuitable for the estimation of low flow, and it is critical that there are reliable methods for the estimation of low flows for use in the determination of environmental flows. This project will define and quantify the flows causing ecologically significant disturbance of substrate in cobble- and boulder-bed rivers, develop models to address the relationship between discharge and substrate disturbance and develop guidelines for the specification of substrate-maintenance flow components in these rivers.

Estimated cost: *R904 000*
Expected term: *2003 – 2006*

Programme 2: Estuary management

Freshwater requirements of the marine environment: A proposed predictive approach to assessment of potential impacts
Environmentek, CSIR
No K8/509

The reduction in freshwater flows in river/estuarine systems is likely to have a significant effect on the offshore marine ecosystems, particularly along the East coast of Southern Africa. It is necessary to define and assess potential impacts on estuarine and offshore marine ecosystems

It is believed that nutrient-rich freshwater and sediment inputs into the coastal marine environment create habitats that sustain highly productive offshore ecosystems (e.g. Tugel prawn industry)

A methodology exists to assess the reduction of freshwater reduction in rivers, groundwater and estuarine environments, but not for offshore marine environments. It is the purpose of this project to provide a framework in support of rapid and intermediate Reserve Determination Assessment, particularly for offshore marine ecosystems.

It is necessary to:
- Determine where freshwater reduction would have significant offshore impact

- Determine the nature of the physico-chemical and ecological links between estuarine and the offshore marine environment
- Predict and quantify the extent of potential impacts of reduced freshwater with regard to ecosystem integrity and also with regard to regional economy
- Provide rapid and intermediate assessments that are accurate and cost-effective.

The aims are to:
- Provide a preliminary but robust framework for investigating the impact of freshwater reduction on the marine environment.
- Test the efficacy of a proposed low-cost assessment for application in Reserve Determination
- Recommend future research in this field
- Transfer knowledge
- Develop links with the "Catchment to Coast" research initiative between South Africa and Mozambique and EU partners

Thrust 3: Ecosystem Rehabilitation

Programme 1: Wetlands rehabilitation

Wetland rehabilitation
Consortium: University of Natal School of Life and Environmental Sciences (Lead agent)
No 1408

This programme, co-funded by *Working for Wetlands*, aims to establish national wetland rehabilitation procedures by establishing a framework within which wetlands requiring rehabilitation may be prioritised and continually assessed. It will develop a diagnostic framework for assessing the underlying causes of degradation and develop national guidelines for rehabilitation including a review of the methods available. It will also develop synergy with other research being done on wetlands, examine the institutional arrangements around wetland management, and develop a long- term monitoring system that will allow strategic adaptive management of wetlands.

Estimated cost: *R4 000 000*
Expected term: *2003 - 2006*

Programme 2: River rehabilitation

The nature and rehabilitation of alien-invaded riparian zones
Dept of Zoology, Freshwater Research Unit, University of Cape Town
No 1407

Riparian zones are important components of river ecosystems, but are particularly prone to invasion by aliens. The *Working for Water Programme* is putting a lot of effort into clearing the invasive aliens from riparian zones, and this project, which will be run in conjunction with *Working for Water*, will characterise the vegetation of undisturbed and invaded riparian zones as well as the parts of the riparian zone invaded by specific invaders. The impact of commonly used clearing methods will be investigated through monitoring early recovery and germination experiments on the existing seed banks.

Estimated cost: *R1 000 000*
Expected term: *2003 - 2006*

Programme 3: Influence of instream-constructed barriers

Facilitating the free passage of migratory aquatic biota in South African rivers
Consortium: Pulles Howard & de Lange (Lead agent)
No 1409

The need to manage water has led to the construction of barriers in rivers, effectively fragmenting the habitat and curtailing the passage of migratory biota. This project will develop protocols for assessing the extent of blockage to free passage, and so prioritising river systems for remedial measures, for the assessment of sites for use in the EIA and the RDM process. Understanding of the biological / hydraulic requirements of the relevant biota will be developed and this, together with data from existing fish-ways, will be used to develop cost-effective designs for local biota.

Estimated cost: *R2 000 000*
Expected term: *2003 - 2007*

r-linked ec

Contact person

Thrust 1: Ecosystem Management and Utilisation
Thrust 2: Ecosystem Protection
Thrust 3: Ecosystem Rehabilitation
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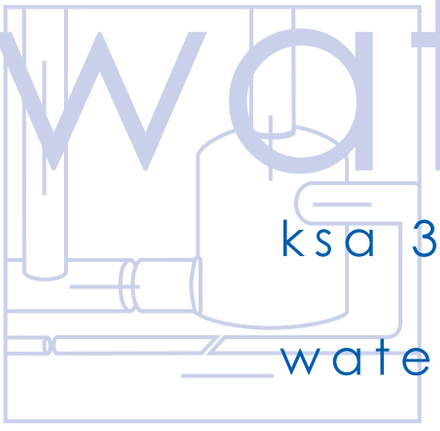

ksa 3

water use and waste management

Scope

The provision and supply of water of adequate quality and quantity for economic and public health purposes remains a continuous challenge. 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. A changing institutional environment and the need for strong institutional capacity add to this challenge.

The **Water Use and Waste Management** KSA focuses mainly on the domestic, industrial and mining water sectors. It aims to proactively and effectively lead and support the advancement of technology, science, management and policies relevant to water supply, waste and effluent management, for these sectors. This KSA also supports studies on institutional and management issues, with special emphasis on the efficient functioning of water service institutions and their viability. Research on infrastructure for both water supply and sanitation is included. A further focus is on water supply and treatment technology serving the domestic (urban, rural, large and small systems) as well as the industrial/commercial and mining sectors of our economy. This KSA also focuses on waste and effluent as well as reuse technologies that can support the municipal, mining and industrial sectors and improve management in these sectors with the aim of improving productivity and supporting economic growth while minimising negative effect on human and environmental health.

Objectives

The primary objective of this KSA is to provide knowledge that ensures reliable, affordable and efficient services to enhance the quality of life, and contribute to economic growth and improved public health.

The secondary objectives are to:

- Improve the management of water services in both rural and urban areas
- Develop appropriate technologies for improving the quality and quantity of our water supplies for both domestic use and industrial applications
- Develop new approaches to manage and enhance hygiene and sanitation practices
- Provide appropriate, innovative and integrated solutions to water and waste management in the industrial and mining sectors
- Develop applications for improved treatment of wastewater and effluent and improve processes for enabling increased reuse thereof
- Improve health, economic and environmental conditions while supporting the development of appropriate technologies and socially focused management practices related to water and effluent management

Thrusts and programmes

Thrust 1: Water Services - Institutional and Management Issues

Scope: The efficient functioning of water service 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 (storm water, sewerage and on-site sanitation), water-related competencies and capacity required for the strengthening of water institutions (Water Service Providers, Water Service Authorities, Water Boards, National Departments) in providing sustainable water services.

- 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

Scope: The provision and supply of affordable and reliable water of sufficient quality and quantity for 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 is the all-important aspect of the protection of human health. The objective of this thrust is to develop innovative technologies, processes and procedures that address aspects related to bulk water supply, water treatment technology, distribution and water quality.

- 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

Scope: With the continuous increase in wastewater and effluent flows, the challenge arises to better manage treatment, such 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.

- Biological sewage treatment processes
- Sludge characterisation, treatment, utilisation and disposal
- Treatment and recovery of organics from agro-industrial processing
- Treatment and recovery of inorganics (incl. sulphate and metals) in industrial and mining effluents
- Training in wastewater treatment plant operation.
- Biotechnological co-treatment of saline and sewage wastewaters.

Thrust 4: Industrial and Mine-Water Management

Scope: 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.

- Quantification of water use and waste production
- Regulatory mechanisms to improve industrial and mine-water management
- Minimising impact of waste on the water environment
- Minimising waste production
- Improved ability to predict and quantify effects.

Research portfolio for 2003/04

The strategic focus of this KSA is guided by the technical, environmental, social and institutional challenges posed in the supply of water and the treatment and disposal of wastes (including sewage, effluents, polluted drainage and solid waste) in the domestic, industrial, commercial and mining sectors. A key consideration is to achieve integrated and holistic solutions that aid sustainable development. In the domestic sector, greater emphasis has been placed over the past few years on supporting water services issues, in order to accelerate service delivery and implementation of water services legislation. The current priority in this very dynamic area is on assisting and capacitating local government in the delivery and acceleration of services, education around sanitation and hygiene issues, and promotion of sustainable solutions. In the industrial and mining sectors, the focus is on developing and promoting management systems, technology and process improvements which support greater efficiency in the use of material and energy resources and hence a reduction in pollution. While continuing to support the development and improvement of treatment systems for environmental and human protection, the emphasis is on getting all sectors to recognise wastes as a resource and the processes for recovery and reuse as commercial opportunities. The new portfolio of projects aims at providing solutions that support these directions in the following ways:

- Developing tools, guidelines and appropriate institutional models for accelerating sustainable delivery of water and sanitation services
- Providing information that supports the development and application of water services legislation
- Improving understanding and knowledge on sanitation and hygiene education;
- Extending the implementation of waste minimisation, cleaner production, cleaner consumption and clean technologies
- Investigating the potential and technologies required for recovery and reuse of water from industrial, mining

and domestic wastewaters (including grey-water and storm-water)
- Furthering the knowledge and technologies for recovery and reuse of material and energy resources in water and wastewater management
- Enhancing ways to predict pollutants and their impacts
- Addressing infrastructure security and sustainability
- Optimisation of water and wastewater treatment processes.

A key focus for the year 2003/04 will be on consolidating and strengthening the activities of the KSA related to strategic direction, technology transfer, project management and business processes. The results from the needs analysis under progress will be widely disseminated and discussed as one of the core activities for the year.

A number of workshops are planned to effect this, and also to test the outputs and provide finalisation for the strategic direction, programs and research issues to be addressed in the ensuing years. Linked to this is the critical issue of widening the capacity base and improving the involvement of previously disadvantaged individuals and institutions in the activities of this KSA. To achieve these objectives, strong internal processes are necessary. Changes introduced in the previous year provided for new processes and challenges that bring about greater efficiency and effectiveness in meeting these goals. Strengthening internal processes and capacity will therefore receive greater attention.

Budget for 2003/04

The approved funding of the research portfolio for 2003/04 leads to a committed funding budget of R 27.4 m. The focus of this portfolio will continue along the current trends.

Core Strategy

Strategic context

Water is an essential ingredient for economic development, the maintenance of natural life support systems and basic human existence. Urbanisation and industrialisation rates in developing countries have been dramatic over the past 20 to 30 years. Economic growth and development resulting in a greater demand for water and annual consumption continues to rise in most countries. Ensuring a reliable source of clean water and adequate treatment of wastes and wastewater for large urban populations and rural communities pose great challenges for many developing countries. South Africa is no exception to this situation and this has led the government to embark on major water-related infrastructure development projects and to introduce water conservation measures, the focus being on optimal utilisation of existing water resources; the upgrading of existing sources and conservation and protection of catchment areas.

As water consumption continues to rise, Government will face the huge challenge of meeting increasing water supply and wastewater treatment demands, together with overcoming a legacy of poor water resource management, the pollution of water sources and wastes. Only by developing long-term strategies to address these issues, including the introduction of water conservation measures and continued investment in water-related infrastructure, will access to clean water and treatment facilities be available to a greater proportion of the population in the future. It is clear that the cost of providing clean water to an expanding and growing population and growing economy will continue to grow.

Whereas the provision of water for human needs plays a cardinal socio-economic role in the upliftment of people and in promoting a healthy population, it is the industrial and mining sectors which play a primary role in the development of the South African economy and hence in development of the country in terms of wealth creation, employment creation and export earnings. Sanitation and wastewater treatment are essential elements of maintaining a healthy environment for our population. Environmentally, the mining and industrial sectors have common features such as an intensive demand on material and energy resources, a major impact on the landscape, a relatively small demand on the national water use and a proportionately much higher pollutant profile. This includes effluents of high concentration, contaminants that are difficult or expensive to remove, and with the potential to degrade large volumes of water, thereby rendering them less fit for other beneficial uses. Effluents from all of these sources arise both as point sources (e.g. piped effluents from factories or sewers) and as non-point sources (e.g. runoff from unserviced high-density settlements and seepage from mine slimes dumps or mine workings).

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 aspect in determining our future.
Although the water requirements for domestic and urban (11%), industrial and mining (6%) 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.

The policies of the previous Government had left a legacy which has resulted in at least half the population of South Africa not having access to safe and reliable water services. The Government has made this the focus of attention since 1994 and great strides have been made in improving this situation. The radical policies and strategies that have been introduced to accelerate and achieve the goal of complete coverage, has in itself generated and posed a number of new challenges on the issue of sustainability of water services.

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 storm water 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. New innovative and appropriate technologies will play a key role in the improved management and extension of our water resources.

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 wastewater released to the water environment is thus of paramount importance to ensure the sustainability of the resource and the activities relying on it.

With all the achievements and developments to date, 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:

- In a changing and dynamic legislative and strategic environment many solutions are required towards sustainable and affordable water services provision. Key focus over the next few years will be on strengthening the capacity of local government to function in this challenging environment, introduction of successful models of service delivery which enjoy the support of all stakeholders, tackling the issue of poverty and service provision (including affordability and cost-recovery), development of appropriate strategies, tools and policies to regulate water services and give effect to the Water Services Act and related legislation. The aspects of community participation and local economic development are central to these objectives.
- Since 1994, greater emphasis has been on improving water supply coverage resulting in sanitation coverage lagging behind. Recent incidences of cholera outbreaks have highlighted the importance of sanitation and hygiene. The provision of sanitation is more complex and provides greater challenges as the responsibility is spread across many Government departments. The short-, medium- and long-term goals are to find effective and efficient mechanisms to accelerate sanitation and hygiene education coverage. These two components are essential ingredients for sustainability and achieving public health objectives. Focus areas over the short term are to develop appropriate technical solutions, finding ways to cost-effectively provide high-impact hygiene education, finding acceptable and affordable service arrangements, models for sanitation delivery and O&M, improving the legislation and policies that contribute to an enabling environment and accelerating sanitation delivery.
- 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. 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, Giardia* and other pathogens; safe and efficient water fluoridation; improvement in the cost efficiency and sustainability 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. Medium- and long-term goals are to focus on infrastructure and asset management.
- 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. As urbanisation and industrialisation increase, more and more complex wastewater streams are introduced. It is imperative that solutions are generated to manage these negative impacts. Further, there is growing recognition for more innovative approaches such as cleaner production and waste minimisation. This 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 areas to be addressed include the process of acceleration of cleaner production and waste minimisation technology and the development of 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 gathering and knowledge generation and application are required in this area over a short period of time.

Overview of technological trends related to needs

At an international level there is a move towards new approaches as to the provision of water services. An emerging trend in developed countries is from a public management model towards private sector models, with the public authorities moving into a stronger regulatory environment. A similar shift is also seen to be occurring in large cities in developing countries; however, these models have not been completely successful in addressing the plight of the poor and indigent who make up a large portion of the customer base. Thus innovative institutional arrangements and partnership models between public/ private/ community are being investigated to provide optimum solutions. Specifically in Africa, the issue of capacity and competency requirements, technology choices, institutional arrangements and costs and affordability are key areas of activity. Outcomes from the WSSD have highlighted the slow pace of water and sanitation delivery, and specifically sanitation, which is lagging further behind. There is a new drive to accelerate sanitation and hygiene education delivery and radical new policies and strategies are being investigated to achieve the millennium goals. An example of some of the processes is that of the WASH campaign. It is essential that these concepts and ideas be translated at a local level thus requiring the need for developing improved strategies, policies and mechanisms that create a sustainable and enabling environment.

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 less and less 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 removal 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. There is a strong trend towards improving determination techniques of these new emerging contaminants. An area receiving considerable attention is in the use of molecular biology and genetic engineering techniques.

In both the municipal and industrial sectors, the most significant trend internationally, nationally and at local authority level has been the growing realisation of recognising effluent wastewater and wastes as a resource. The 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 cleaner 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 of mining-related non-point sources 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 this KSA in particular. They are divided into internal and external stakeholders.

The internal stakeholders are the WRC personnel, Executive Management and the Board.

The external stakeholders include:

- Government departments and the Ministers representing them (DWAF, DEAT, DPLG, DoH, Mineral and Energy, etc.)
- Advisory groups
- Beneficiaries (i.e. the users or potential users of research, development and knowledge products produced through WRC funding)
- Local government, provincial government units
- Development Bank of Southern Africa
- Water boards, water services providers, catchment management agencies, water user associations
- Industrial sectors and industry-representative bodies (mining, forestry, water services, etc.)
- NGOs, CBOs and international aid agencies
- Private consultants
- Tertiary institutions, primary and secondary education institutions, science councils, professional bodies (WISA, SAICE, IMESA etc.) media agencies, and
- Members of the public.

Providers

Providers are solicited or unsolicited individuals and organisations who generate research, development and knowledge products with WRC funding. The key providers are tertiary institutions, science councils, consultants, NGOs, water boards, research units within government departments and local government, private companies and individuals.

RESEARCH PORTFOLIO FOR 2003/04

The primary objective of this KSA is to provide knowledge that ensures reliable, affordable and efficient services to enhance the quality of life, and contribute to economic growth and improved public health. The new portfolio of projects aims at providing solutions that support these directions in the following ways:

- Developing tools, guidelines and appropriate institutional models for accelerating sustainable delivery of water and sanitation services
- Providing information that supports the development and application of Water Services legislation
- Improving understanding and knowledge on sanitation and hygiene education
- Extending the implementation of waste minimisation, cleaner production, cleaner consumption and clean technologies
- Investigating the potential and technologies required for recovery and reuse of water from industrial, mining and domestic wastewaters (including grey-water and storm-water)

- Furthering the knowledge and technologies for recovery and reuse of material and energy resources in water and wastewater management
- Enhancing ways to predict pollutants and their impacts
- Addressing infrastructure security and sustainability
- Optimisation of water and wastewater treatment processes.

To achieve these objectives, strong internal processes are necessary. Changes introduced in the previous year provided for new processes and challenges that bring about greater efficiency and effectiveness in meeting these goals. Strengthening internal processes and capacity will therefore receive greater attention.

Initiatives planned in 2003/04 around developing strategic research plans and needs, will definitely influence the future direction of the thrusts and KSA.

An overview of KSA 3 research thrusts and programmes is presented in **Table 1**.

TABLE 1
Overview and description of thrusts and programmes funded within KSA 3

THRUST 1: WATER SERVICES - INSTITUTIONAL AND MANAGEMENT ISSUES	
Scope: The efficient functioning of water service 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 (storm water, 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.	
Programme 1: Cost-recovery in water services	**Scope:** 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.
Programme 2: Institutional and management issues - Water services	**Scope:** Relationships and partnerships between service providers, both external and internal, are a key to sustainable water service delivery. This program's objective is 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.
Programme 3: Innovative management arrangements - Rural water supply	**Scope:** 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.
Programme 4: Rural sanitation and hygiene education	**Scope:** 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. This issue is also linked to the impact of HIV/AIDS and water-related diseases. 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.

THRUST 1: WATER SERVICES - INSTITUTIONAL AND MANAGEMENT ISSUES (continued)	
Programme 5: Peri-urban sanitation research	**Scope:** 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	
Scope: *The provision and supply of affordable and reliable water of quality and quantity for drinking (domestic) and economic (industrial/commercial and mining) activities, remains continuous challenges. Research support for these activities is the focus of this thrust. Linked to water supply and use is the requirement 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.*	
Programme 1: Drinking water treatment technology	**Scope:** The 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.
Programme 2: Water treatment for rural communities	**Scope:** 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 improved technologies, community involvement, cost-recovery, effective operation and maintenance, affordability and willingness to pay for water services.
Programme 3: Drinking water quality	**Scope:** The programme aims to protect human health by ensuring that water supplies are of acceptable quality and standards. Outcomes include improved analytical methodologies, treatment technologies and hygiene practices.
Programme 4: Water distribution and distribution systems	**Scope:** 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 the 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 is 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	
Scope: *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.*	
Programme 1: Biological sewage treatment processes	**Scope:** 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.
Programme 2: Sludge characterisation, treatment, utilisation and disposal	**Scope:** 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.

THRUST 3: WASTEWATER AND EFFLUENT TREATMENT AND REUSE TECHNOLOGY (continued)	
Programme 3: Treatment and recovery of organics from agro-industrial processing	**Scope:** 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.
Programme 4: Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents	**Scope:** 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.
Programme 5: Training in wastewater treatment plant operation	**Scope:** 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	
Scope: *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.*	
Programme 1: Quantification of water use and waste production	**Scope:** In order to prioritise those facets of industrial and mine-water management that need 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.
Programme 2: Regulatory mechanisms to improve industrial and mine-water management	**Scope:** The regulatory authorities are responsible for managing the impact of industrial and mining waste 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.
Programme 3: Minimising impact of waste on the water environment	**Scope:** 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 for 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.

THRUST 4: INDUSTRIAL AND MINE-WATER MANAGEMENT (continued)	
Programme 4: Minimising waste production	Scope: 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.
Programme 5: Improved ability to predict and quantify effects	Scope: 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.

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 2003 and 31 March 2004

COMPLETED

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
No 886

Over the past five years, a consensus has emerged on the principles to guide the provision of rural water supply. Internationally, policies call for treating water as an economic and social good managed at the lowest appropriate level. For the provision of water supply this requires that consumers be engaged in the process of selecting, financing and operating systems that meet their demands and willingness to pay.

Over 40 operational stand-alone type rural water projects were visited and surveyed in order to obtain a picture of the kinds of operation and maintenance costs which are being experienced in the field. The key observations from this field work were as follows:

- Although water consumption can in most cases only be estimated from the data gathered, the indications are that the median water consumption in rural areas is low, less than 4kℓ per month. Schemes with metered yard taps recorded relatively low consumptions, but those with un-metered yard taps recorded higher consumptions.

- The budgeted costs per family per month are low. The mean figures in 1999 rand were R9.15, R5.49 and R3.87 for KwaZulu-Natal, the Northern Province and the Eastern Cape respectively. However, the spread of figures is wide – the standard deviations of the mean in the provinces are R8.62, R6.81 and R2.80 respectively. In other words, the majority of projects are running on budgets of less than R15 per family per month and some much less.

- The mean budget cost per kilolitre is R4.96 in KwaZulu-Natal, with a standard deviation R3.58. In the Northern Province the mean is R1.78, with a standard deviation R1.35. In the Eastern Cape the figure is R1.61, with a standard deviation R0.90. The higher costs in KwaZulu-Natal are indicative of the greater use of water meters

or water vendors in that province.

A tariff model meeting specified criteria has been developed, and provisionally this model is called the WRC Rural Water Supply Cost and Tariff Model.

Cost: R378 000
Term: 1998 - 2001

Identifying examples of successful cost-recovery approaches in low-income, urban and peri-urban areas
Sigodi Marah Martin Development Consultants
No 1131

The purpose of the study was to identify the main determinants of successful cost-recovery for water services in South Africa and to use this information in the development of practical strategies to overcome obstacles to cost-recovery

The national survey of cost-recovery yields the most up-to-date available information about water services infrastructure, billing and payment, and cost-recovery outcomes in South Africa. The results highlight severe constraints on cost-recovery – especially for the provision of basic water services to the poor. Combining consumer poverty, low "RDP" service levels (e.g. public standpipes), and the associated inability to punish non-payment by selectively restricting services, is the surest recipe for failed cost-recovery. Although case studies have identified a few potentially instructive exceptions to this rule, the national survey data suggest that expectation of recovering the operation and maintenance costs of "RDP" water services through user fees is an unrealistic premise for national policy in the foreseeable future. There is a close fit between the empirical observations from the case study and the result of the simulations from the National Survey. Predictors of success are individual water meters (in whatever form), prompt and firm response to non-payment, progressive tariffs, good community relations and convenient payment facilities.

There can be no shortcut to successful cost-recovery. It must be a broad-brushed approach involving technical, financial and community aspects. It must be implemented with a unity of purpose between the political and administrative arms of the municipality. Finally it must be seen as a sustainable means by which the standard of service delivery to the public can be enhanced.

Cost: R438 000
Term: 2000 - 2001

A cost-recovery analysis of the trickle feed rural community water supply system
Lenehan Engineers and Environmental Consulting
No 1272

The study was initiated to find cost-effective solutions for providing sustainable water services to rural communities. The trickle feed system is a new technology that allows delivery of a set quantity of water per day to a storage tank at each household. This allows the application of a monthly pre-paid tariff with minimal administration. The implementation of the government policy of providing 6kℓ per month of free water to every household in 2000 created a major challenge for water services institutions. The trickle feed technology can provide municipalities with a cost-effective solution for providing free basic water to poor households. The specific objectives of this research were to assess the cost-recovery efficiency of the trickle feed system and to evaluate the effectiveness of the technology for application in the implementation of the free basic water policy in rural communities.

The study evaluated four case studies that are using technologies similar to the Trickle Feed System, which included both functional and non-functional water supply schemes. Evaluation included capturing of operation and maintenance data, liaison with role-players and visits to the projects. The findings indicate that the trickle feed system offers a viable option for implementing the free basic water policy in rural areas because of low operation and maintenance cost, simple administration and reduced water losses due to the low pressure in this system. The study concluded that the trickle feed system is a reliable water supply technology that delivers a higher level of service at a reduced cost. The challenge is to get community acceptance for this technology.

Cost: R176 500
Term: 2001

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
No 1384

The overall objective of the study has been to make an assessment of the level of cost-recovery as far as local government is concerned, and identify which measures are the most effective in increasing the rate of collection. This study highlights the substantive implications of the findings for municipal officials and national policy makers seeking to overcome obstacles to successful cost-recovery. An assessment is also made of the impact of the free basic water policy, and the issue of unaccounted-for water.

In analysing the data and the concepts of debt ratios and repayment rates as indicators of cost-recovery performance (debt ratio is the ratio of current debt to total debt. If payments are made on time, then the ratio will be one), it was found that, even though the free basic water policy removes a substantial proportion of households from the debtors list, the average ratio from the municipalities studied was about 0.5. One municipality received only 3% of the amount they billed in a quarter. The use of the repayment rate (proportion of households who pay on time) gave very similar results.

The study indicates that the reconfiguration of the municipalities, coupled with the implementation of the free basic water policy has had a marked influence on how recovery of costs can be enhanced. On the one hand initiatives geared towards the lower end of the market are increasingly overshadowed by the impact of the free basic water policy. On the other hand, the implementation of punitive sanctions against non-indigent consumers who fail to pay a progressive, volume-related tariff, takes on increasing importance. However, it must be noted that just as punitive sanctions become increasingly necessary, they also become more expensive to implement. Water services providers are no longer able to cut the flow of water to defaulters – the policy would suggest that they have to ensure that the free basic allowance remains available to all.

Cost: *R400 000*
Term: *2002 - 2004*

Programme 2: Institutional and management issues - Water services

The preparation of a guideline for water services providers dealing with customer services issues
Umgeni Water
No 1207

The concept of "customer service" has received little attention in South Africa, perhaps related to the historic situation where the water supply and sanitation services were provided on a monopolistic "take it or leave it" basis, provision is strongly associated with the application of good business principles. This implies a services orientation, with a primary focus on the customer. It also implies a mutually beneficial relationship between customer and service provider where the customer must fulfil their responsibility to pay for the service.

While there is increasing recognition of the conceptual importance of customer service, there are only a few services providers, which are putting this into practice. One reason for this is that there is insufficient understanding of what customer service involves. This is partly related to the lack of capacity to run services properly in the transitional period when coverage has to be increased rapidly in a situation of resource scarcity and partly it relates to lack of information on the topic.

The results of this study, presented in a discussion report, are aimed at improving the understanding of what customer service involves through providing information both in written form and through interaction with management of water services providers at workshops. Emphasis is placed on good business practice, drawing as much as possible from private sector marketing techniques which are grounded upon principles of good communication. However, it is recognised that there is much more to customer service than just marketing; the product also has to be good. But, while the issues associated with providing a good product, in a technical sense, will be briefly addressed, the emphasis has been on the softer elements of customer service.

Cost: *R370 000*
Term: *2001 – 2002*

Least-cost planning for the water services section in South Africa
Semenya Furumele Consulting
No 1274

South Africa has over the years, developed extensive infrastructure to meet the growing demand. Further

investment in infrastructure historically tended to favour certain sectors of society at the expense of others. The main challenges facing the country are water scarcity and access to basic waters services. It is therefore essential that the available resources be used equitably, efficiently and beneficially. In a scenario of growing demand, limited resources, financial constraints, environmental concerns, and increasing public scrutiny, a paradigm shift in the planning of water services is inevitable. Traditional planning approaches for water services can no longer be as effective as they were in the past.

The aims of the study were achieved through tracing the history of least cost planning (LCP) and adoption of a definition applicable to the water services of South Africa. Lessons were drawn from the various sectors. Although some experience from the energy sector is transferable to the water sector, certain aspects of water supply are dramatically different from energy supply, in particular the electricity utilities. The study developed an algorithm that demonstrates the effectiveness of LCP.

Cost: *R200 000*
Term: *2001 - 2002*

Economic regulation of water services models for South African municipalities
Palmer Development Group
No 1383

DWAF is currently engaged in a process of developing a water services regulatory framework for South Africa. 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.

The project sought to answer the following key research questions:

- How will a "regulator" (regulatory authority) determine if the average price level is appropriate?
- How will a regulator determine what level of investment is appropriate?
- How does the institutional/governance model affect the above two questions?

The scope of the study extended to both water and sanitation, to both bulk and retail water and sanitation, including on-site sanitation services and pit-emptying, water services for households, commerce, institutions and industry but not for agricultural use, focus on method (but take into account the policy and institutional context), focus on economic regulation of water services in the municipal context, focus on pricing and investments and not on price structures. The following were the key findings and recommendations emanating from the study:

- Building blocks for improved economic regulation:
  - National capacity needs to be strengthened to support the development of good contracts between water services authorities and water services providers (where these are external). There needs to be greater transparency in these contracts. A much greater understanding needs to be developed with respect to what constitutes best contracting practice (see capacity above). Greater clarity is needed on the enforcement of (especially public-public) contracts.
  - Proper financial ring-fencing of water services, including proper accounting for the assets is a necessary pre-requisite for economic regulation of water services in South Africa.
  - Establishing an appropriate rate of return on water services assets when used for "economic purposes" is a good starting point for economic regulation in South Africa.
  - A standard method for valuing water services assets in South Africa should be developed. A standard method for depreciation should be adopted and standard periods used for types of assets appropriately classified. This could be part of GAMAP.
  - A better understanding of how to measure operating efficiencies is needed. This also entails developing measures for quality of service provided.
  - Ways to strengthen consumer voice need to be found. The requirement of customer or consumer charters is an important step forward.
- Policy, legislative and institutional reform:
  - Wherever external contracts are entered into, these should be on a competitive basis. There are no good grounds for excluding public agencies from competitive tendering requirements.
  - As a first step towards improving economic regulation of water services in South Africa, the economic regulation of water boards could be considerably improved and strengthened. Water Board regulation should be moved to a rate of return, with clear ring-fencing of any community service obligations and retail operations.
  - It is not clear that adequate or appropriate incentives exist at present for institutional and regulatory reform in the water services sector.
  - The case for vertical integration of water services providers (even on a selective basis) in South Africa needs

to be examined more thoroughly.

Cost: R379 500
Term: 2002 - 2003

Programme 3: Innovative management arrangements – Rural water supply

Assessing the impact of gender in water and sanitation provision and maintenance
Networks for Development
No 1087

TERMINATED

Cost: R150 000
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
No 1130

A sustainability evaluation study conducted by the Mvula Trust and the Department of Water Affairs (1999) highlighted poor operation and maintenance (O&M) as a major cause of failure of most new water projects. The study showed this was caused by inappropriate O &M systems that were generally unresponsive to the needs of households. This project was initiated to investigate how local community capacity and experience was being used to operate and maintain water projects in a sustainable manner.

The study was conducted in four provinces, namely, Limpopo, Mpumalanga, North West and KwaZulu-Natal and found that communities that had good O&M systems shared the following features:

- Small communities with a sense of unity and cohesiveness
- Strong sense of ownership of the schemes
- Traditional leaders played an important role in all projects and had authority to enforce payment for water services
- Water committees were stable and united
- Women were involved in the O&M of projects on a voluntary basis
- Projects were initiated by local people (demand-driven approach)
- Good communication and consultation between water committees and village role-players.

These research findings were used to prepare a Handbook for municipalities and project agents. The title of the handbook is: *Making Water Work for Villages- Community Managed Water Service Provision*. The Handbook will assist municipalities and project implementing agents to understand how community management can be supported and implemented.

Cost: R546 000
Term: 2000 - 2001

Development of a strategy for effective public participation in rural water supply projects
Nemai Consulting
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 aimed at analysing 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.

Public participation refers to the ongoing process of interaction between service providers or project implementers and the community with the aim of improving decision making during the planning, design,

implementation and evaluation phases of the project. Six principles of public participation have been identified as underpinning public participation process. The principles are: Identifying and supporting effective local organisations, communication, empowerment, opportunities and effective involvement of traditional leaders. These principles would assist project implementers involved in rural water supply and sanitation projects to facilitate effective public participation. Further, any development project is characterised by the following phases: planning, implementation, construction, operation and maintenance phase and the evaluation phase. In all these phases the inclusion of community members in the project is of outmost importance.

The findings indicate that there are various tools and methods which can be used to facilitate public participation. Each method has its own characteristics, strengths and weaknesses. No method can therefore be regarded as appropriate to effective community participation. In other words, it is important to use a range of methods in public participation programmes since each method is unique. Public participation methods are: Public meetings, public hearings, open houses, workshops, citizen advisory committees, social surveys, focus groups, news-letters and reports. The involvement of all community members including women, youth and the poor is of critical importance in rural water supply and sanitation projects. Project implementers or service providers should consider the views, opinions and perspectives of the community in development projects. Thus, for the project to be sustainable in rural areas, it is imperative that the community is actively involved from the implementation phase of the project to the evaluation phase.

Cost: *R77 000*
Term: *2002*

Protocol Manual for the Transfer of Methodology Required to Link Ecosystem and Human Health
Pulles, Howard and de Lange
No 1400B

In South Africa the pollution of freshwater aquatic systems can be linked to point-source discharges (wastewater treatment works and industrial effluents) and diffuse surface runoff (agricultural, mining and urban). As a result of these anthropogenic activities, innocent people as well as other life forms may be exposed to harmful contaminants, which may be released without adequate consideration of human health and the environmental effects. Studies have shown that when people are exposed to surface water contaminants through contact recreation, drinking water and the consumption of contaminated food their health may be affected.

A review of the published literature revealed that several surveys were undertaken in South Africa to investigate chemical contaminants in freshwater fish, most of these studies were aimed at contributing to the assessment of the health of the aquatic ecosystem but the health risks to humans when consuming contaminated fish are seldom addressed.

To address this limitation a generic protocol has been developed that would give guidance in the undertaking of fish contaminant surveys to provide information regarding the possible health risk if the fish are consumed by recreational and subsistence fishermen. As well as to give guidance to surveys investigating the chemical contamination of fish for ecosystem health assessment programmes.

The fundamentals of the protocol are based on catchment information (possible anthropogenic activities that can result in chemical pollution), socio-demographic information of consumers of freshwater fish in the catchment, bioaccumulation potential and health risks of analytes, sound sampling design, risk assessment procedures and performing monitoring at different scales and depth. The methodology identifies 10 major steps, namely:

- Selection of scale and depth of survey
- Assessment of the water-body catchment
- Monitoring system design
- Field collection
- Laboratory sample processing and analysis
- Analysis of and reporting of results
- Risk assessment
- Risk management
- Risk communication
- Evaluation and review of the programme to provide guidance to government authorities at national or provincial level and project managers.

The basic requirements of each step are highlighted as limited resources (financial, infrastructure and skilled personnel) in South Africa would limit the possibility of undertaking detailed assessments as undertaken by the US EPA. Nevertheless, by applying the proposed protocol, sound comparable assessments, based on risk assessment methodology, can be made regarding the human health risk associated with the consumption of freshwater fish

in South Africa.

Two documents were produced during this project namely an *Overview Guide* and a *Reference Guide*. The *Overview Guide* is written for a wide variety of potential users such as regulators (government, conservation organisations and health authorities), practitioners (consultants and researchers), water resource managers, polluters (agriculture, mines and industry) and educational facilities. This Guide has been developed to give an overview of a South African developed process to determine whether fish are safe to eat. This *Overview Guide* will enable potential practitioners to have a standardised scientifically repeatable process that can be used to determine the health risks associated with consuming fish, what levels of contaminants occur in the fish and can the fish be eaten with minimal risks to humans.

The *Reference Guide* is written for practitioners and spells out the precise methods to be applied as well as supplying a set of standardised data sheets for field and laboratory assessments.

Cost: R196 450
Term: 2002-2003

Programme 4: Water distribution and distribution systems

Development of a marketing plan for sanitation promotion: A participatory approach
Limakhozu Development Agency
No 1382

This study aimed to use participatory approaches to identify factors that motivate people to adopt safe hygiene practices. The identified factors were used to develop a social marketing plan for sanitation and hygiene promotion in rural areas. The research output will assist in encouraging households to invest their own financial resources in the improvement of their sanitation facilities.

The study found that in order to plan an effective marketing plan for sanitation promotion, the problem and its underlying causes have to be understood. Solutions must be informed by research and not based on assumption. Only when the problem has been quantified and qualified can appropriate measures be taken to improve the situation. Since poor sanitation does not exist in isolation, the starting point is to identify and understand the environmental conditions, religious, social and cultural factors (i.e. traditional beliefs, perceptions, customary sanitation practices, habits, priorities) within a particular household and community. Based on these, recommendations have been made on the development of a marketing plan for sanitation promotion. While the findings implicitly highlighted the factors that played a role in the communities' inability to adopt safe hygienic practices, it showed that the motivating factors for adoption of safe hygienic practices are varied and complex. Though not mutually exclusive and for the purposes of simplicity these factors can be grouped into four linked and overlapping categories, namely: social factors, educational factors, environmental factors and economic factors.

Cost: R300 000
Term: 2002

Programme 5: Peri-urban sanitation research

Pilot initiative to implement shallow sewerage technology in Durban
Durban Metro Service
No 1146

The shallow sewer concept has been successfully implemented in Brazil, Greece, Australia, USA, Bolivia, India and has become the norm in Pakistan, and has proven to be an extremely practical, low-cost solution for installing water-borne sewage systems within highly dense, informal communities. The technology is intended to develop and uplift communities while enabling governments and service providers to provide greater coverage of sanitation services. This is done through the relaxation of several design characteristics of conventional sewerage and in the process allows for shallower depths, smaller diameter pipes, flatter gradients and community-based construction, operation and management. Besides offering the convenience and health benefits of water-borne sanitation, the methodology with its intensive social programme, is intended to provide people living in communities with the skills to pull themselves out of poverty and to better organise themselves to use their social, intellectual and other capital for their own upliftment, while at the same time reducing the operational load of the service provider.

Ethekwini Water Services (EWS), in a joint venture with Water and Sanitation Services (South Africa) (WSSA) and the WRC, investigated, through a pilot project, whether shallow sewers would provide a viable alternative water-borne sanitation system to the urban poor in dense settlements. The practical applications of the shallow sewer

methodology were evaluated in two Ethekwini communities, Emmaus and Briardale. The research objectives were to assess the financial, social acceptance, quality of life, technical, legal and institutional management aspects of shallow sewers in Ethekwini. In addition, this initiative evaluated the methodology and how it was applied to the La Pas model imported from Bolivia, and discussed the suitability and relevance of such interventions to the South African environment. Undertaking this research in South Africa through the Ethekwini Shallow Sewer Pilot Study has revealed considerable insight into the sanitation environment in general, with particular reference to shallow sewers. It has also provided an opportunity to guide the development of a range of similar technologies that would be applicable in the South African context.

The following were the key lessons emanating from the pilot study:

- Of the mismatches between communities' expectation that the "government will provide" and the self-help tenet of the shallow sewers
- Governments assume that rapid infrastructure development and community social upliftment are concordant
- Legal conflict between the private land tenure and communal ownership of fixed property on that land
- Institutional arrangements at local government are not structured for interdisciplinary community development
- Potential capital saving provided by a reduced depth sewer is enormous, and technically it should not be difficult to develop a reduced depth, conventionally owned and operated, sewer from the lessons learned from the shallow sewer pilot plant
- Research has provided some understanding of the urban poor market, and some of the lessons learnt from the shallow sewer pilot study could be applied to improve the success of other community development projects. In this regard, should it still be the government's intention that infrastructure development should encompass community social development, the shallow sewer methodology could form the basis of a "South Africanised" community development methodology.

Cost: R600 000
Term: 2000 - 2001

Towards policy, strategy and detailed procedures for the provision of sanitation to low-income settlements in Johannesburg
Johannesburg Water (Pty) Ltd
No 1192

The aim of this research project has been to review the Sanitation Policy and Protocol of the City of Johannesburg (CoJ) 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 was extended to take in a range of other policy and protocol documents that have been developed during 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.

The study found that with respect to sanitation policy for Johannesburg, current initiatives based on the White Paper on Basic Household Sanitation appear sound. With respect to more detailed procedures, current pilot studies by Johannesburg Water have sought to gain an understanding of technical requirements and community dynamics as a first step. While sensibly following a pilot-and programme approach and gaining essential experience in low-income settlements in Johannesburg, this initiative does need to be aware of possible dangers. With respect to the apparent difference in approach between housing/planning and water services, it is recommended that mechanisms be explicitly set up to develop a clear and detailed vision for how spatial development, infrastructure development and economic development are going to take place in CoJ - translated into clear step-by-step strategy. On the matter of overlapping responsibilities over pollution from sanitation systems, it is recommended that this be resolved through multilateral discussions between the three departments (DWAF, DEAT and DTI and their provincial equivalents). Crucially, it is recommended that the service provider takes formal steps to assess customer demand for services, which may include the use of tools such as contingent valuation studies.

Cost: R150 000
Term: 2000 - 2002

Sanitation demand and delivery in informal settlements
Peninsula Technikon
No 1280

This research is the culmination of the first phase of developing a framework for sanitation delivery to informal areas. The framework is intended for application in planning and to improve the efficiency and effectiveness of

delivery by facilitating the development of implementation guidelines. It uses current approaches of sanitation delivery, while drawing from local case studies to inform the City of Cape Town. This would be of relevance to the rest of the country. The framework does not propose a "quick fix" for the suggested change of paradigm that is needed for approaching delivery strategically. Accepting that there are financial and legal constraints to be addressed, the focus of the framework is to facilitate the building of capacity and changing of roles, including the recognition that communities are key activists in sanitation improvements and sustainability. The challenge for strategic approaches to sanitation provision is to move forward in ways that are appropriate to the task in hand, and that respect the way in which knowledge and skills are distributed amongst the stakeholders. Strategic sanitation planning is based on three strategic elements, suggesting that the development of three strategic programmes require planning within, and across, the relevant local authority departments. The associated key programme elements are those that have emerged from the research of current approaches in the City of Cape Town.

Cost: *R250 000*
Term: *2002*

Thrust 2: Water Supply and Treatment Technology

Programme 1: Drinking water treatment technology

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
No 919

The circumstances under which rural water treatment plants are operated place restrictions on the designers of rural water supply schemes to provide low-cost, low-maintenance plants without compromising the quality of water produced. Processes that are inherently self-regulating and simple have an obvious advantage in that they will require fewer skilled operator visits. Examples of these processes include roughing filters, slow-sand filters and autonomous valve-less gravity filters (AVGF) which backwash automatically by siphoning. The objectives of the project were to:

- Assess the suitability of a proprietary autonomous valve-less gravity filter for potable water production from surface waters
- Propose where necessary, design modifications aimed at improving the reliability and reducing the capital cost of a proprietary backwash filter
- Propose specific operating rules by which the unit should be operated and maintained and to prescribe minimum levels of operator supervision.

After analysing the components and dimensions of the AVGF and monitoring the filtration process under controlled conditions on a pilot-plant scale and full-scale AVGF, some modification to the design and other considerations for design were suggested. Implementation of these suggestions will be influenced by cost and other factors like raw water variability, infrastructure, and readily available and technically competent operators. The application of the AVGF for the supply of drinking water in the rural areas, considering the lack of resources and infrastructure and the level of readily available technical expertise, is a challenging prospect. Experience has shown that the AVGF cannot operate efficiently without operator intervention.

Cost: *R138 000*
Term: *1998 - 1999*

Evaluation of a filter wash-water recovery plant to establish guidelines for design and future operation
Scientific Services, Rand Water
No 920

The aims of the project were to establish guidelines for the design and future operation of filter wash-water recovery plants with emphasis on the following:

- Removal of suspended matter, pathogenic bacteria, protozoa, taste-and odour-causing compounds and algae
- Establish design, treatment requirements and operational procedures to produce water of potable quality

A filter backwash recovery plant (FWWRP) was constructed at Rand Water's Zuikerbosch Pumping Station to treat spent filter backwash to potable standard. The technology included a conventional treatment plant, consisting of pretreatment, coagulation, flocculation, high-rate clarification, sand filtration and tertiary experimental treatment units such as ozone, granular activated carbon (GAC) and membrane filtration treatment.

The suspended solids in the spent filter backwash were effectively reduced from 352 NTU to 0.18 NTU in the filtered

water. Water with turbidity of between 5 and 10 NTU was fed onto filters and a filtered water turbidity of less than 0.3 NTU was consistently produced. The standard plate count of the filtered water was slightly higher than counts observed in the filtered water of the main treatment process at Rand Water. Very high invertebrate numbers were detected in the spent filter backwash at times. The chlorine demand of the filtered water was the same as in filtered water from the main treatment process. The average total organic carbon concentration of the filtered water was determined to be 3.7 mg/ℓ.

Cost: R214 000
Term: 1998 - 1999

Characterisation and chemical removal of organic matter in South African coloured surface waters
Chris Swartz Engineering
No 924

By far the highest priority for further research on the treatment of coloured water in South Africa was found to be the need for characterisation and removal of unwanted organic compounds in these waters. Little information is available on the true character and properties of the local coloured waters, and more specifically of its high variability in locality and time (spatial and temporal), as well as the many complexes that it forms with other substances, notably metals. There is also a lack of knowledge on the effect of treatment processes, and in particular coagulation, on the removal of the different constituents of the coloured water. There was, therefore, a need for a more fundamental characterisation of natural organic matter (NOM) in South African coloured waters and classifying the coloured surface water sources, and to use this for establishing the treatability of the different classes of coloured water. The aims of the project were as follows:
- Establishment of a coloured water characterisation and classification approach
- Characterisation of the natural organic matter
- Classification of coloured waters into main types
- Application of characterisation data and coagulation diagrams to assess treatability of each of the main coloured water types
- Drawing up a manual on the treatment of South African coloured surface waters.

It was found that:
- Differences between the waters, apart from turbidity, lie in the amount rather than the nature of the organic content
- Most of the organic matter has a high UV absorbance, indicating a high aromatic content
- DOC, UV absorbance, COD and, less accurately, colour, may all be used to estimate the amount of humic materials present in the water
- Optimum coagulation pH values are 4.6 for ferric salts and 5.6 to 5.8 for aluminium sulphate.

Cost: R317 000
Term: 1998 - 2001

Modelling of flocculation, thickening and sedimentation in water treatment
School for Mechanical and Materials Engineering, Potchefstroom University for CHE
No 998

Computational fluid dynamics (CFD) is the analysis of systems involving fluid flow (gases or liquids) by means of computer-based simulation. It is a research tool and a design tool and it is complementary to theory and experiments. The objectives of this specific study were to:
- Evaluate the suitability of CFD as a technique for design and research of rectangular sedimentation tanks
- Design CFD models for simulation of sedimentation tanks, i.e. grids and numerical descriptions
- Validate the models with experimental data
- Use CFD to investigate the effects of design parameters and operational parameters
- Make recommendations for improved design and operation of sedimentation tanks.

The study showed that CFD does indeed provide a useful tool for modelling of sedimentation tanks. It can, however, not be used as a routine tool by simply any operator. In order to construct a realistic model, the operator must be educated in CFD in general, skilled in constructing computational grids and experienced and knowledgeable about the aspect to be modelled in practice. At present CFD is still a qualitative rather than quantitative tool for this specific application. The major limitation lies in modelling two-phase flow where the solid phases (flocs) are non-homogeneous in the critical computational parameters of size, density and shape. It is necessary to develop better mathematical descriptions or measurements of these parameters and incorporate them in the CFD models in order to obtain better quantitative results.

Cost: *R269 000*
Term: *1999 - 2001*

Microbiological assessment of membrane technology in water treatment
Biological Sciences, ML Sultan Technikon
No 1034

The degree of integrity (being leak-free to micro-organisms) is very important when potable water is being supplied by membrane systems. Standard turbidity measurements have been shown to be ineffective in detecting numbers of micro-organisms already posing a health risk. Protocols for testing membrane performance based on removal of micro-organisms (spiked into the water or naturally-occurring) are, therefore, called for. Passing such tests successfully, will ensure proper functioning of the ultra-filtration system and reduce risks of infection by contamination of drinking water.

The primary aim of the research was to evaluate membrane efficiency in removing micro-organisms and subsequently to set up protocols for guiding membrane users for evaluating membrane performance in potable water treatment. Locally developed polysulphone ultrafiltration capillary membranes were used in bench and pilot scale studies. Bacteria, bacteriophages (to simulate virus removal), yeast cells, *Giardia* cysts and *Cryptosporidium* oocysts were used to determine the permeability of the membranes under different conditions. From these studies, it was possible to draft general protocols for microbiological testing of membrane integrity.

Cost: *R683 00*
Term: *1999 - 2001*

Support, maintenance and debugging of WATREX - Expert system for water treatment plant design
Sutherland Associates
No 1041

The WATREX program, or Expert System for Water Treatment Plant Design, is an intelligent software program for the selection and design of conventional drinking water treatment plants. From a set of raw water parameters and their variation, the program is able to:

- Assist in the selection of processes, using various weighted criteria
- Design each unit process required; provide the water quality after each unit process; and calculate a relative cost for each plant design. The program is very helpful in assisting students and design engineers to investigate various "what-if" scenarios of process selection and design.

The project at question had as overall aim to improve on the existing program, both regarding the technical capabilities as well as the computer programming itself and "user-friendliness" of the program. The aims of the project were the following:

- Compilation and distribution of WATREX (The Expert System) to interested users
- Continued improvement of the operation and integrity of WATREX (technical and computing related 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 feed-back.

These objectives were carried out and met successfully. Comments received from test users of the program were incorporated into the program, thereby contributing substantially to the credibility and "user-friendliness" thereof. Following the "polishing" improvements made under this project, the program can be of assistance to the consulting engineering fraternity because of the ease of plant selection and design when using this program. Built-in formulae can be adapted or changed to suit the specific designs and methodology used by the specific consulting company. "What-if" scenarios, varying any parameter of water quality or process configuration, can be performed. The program is also very educational and students will find the program very good in understanding drinking water plant design and the formulae and design rationale on which the designs are based.

Cost: *R84 000*
Term: *1999*

Reduction of urban litter in drainage systems through integrated catchment management
Department of Civil Engineering, University of Cape Town
No 1051

Few data are available on the nature and quantity of the litter that finds its way into stormwater systems. Previous South African studies have concentrated on removing litter from drainage systems once it is already there rather

than reducing the amount of litter entering them in the first place. Litter management in South Africa has been hindered by the shortage of scientifically verified data indicating the likely effectiveness of any of these options. To address this lack of data, a two-year monitoring programme was conducted in nine pilot catchments (covering a range of different land uses, socio-economic levels and densities) in the Cape Metropolitan Area. The monitoring programme had two objectives:

- To improve the knowledge of the source, type and amount of litter reaching the drainage systems from different types of urban catchments
- To measure the effectiveness of different catchment based litter management options.

The principal findings were the following:

- There appears to be an inverse relationship between income and litter loadings in residential areas when garden refuse is excluded. This is largely due to the more effective and reliable household refuse removal service enjoyed by affluent areas.
- The installation of grids over catch-pit openings resulted in a significant decrease in the amount of litter trapped in catch-pits in Summer Greens and Montague Gardens.
- There was a significant reduction in litter loads in Ocean View during the monitoring period. The sensitizing of the community to littering issues from the end of 2000 and a more frequent and comprehensive litter removal service by the local authority are plausible reasons for this improvement.
- Sand entering the catch-pits is a major problem in many catchments as it tends to become entrained in other litter such as plastic bags resulting in blockages and flooding of the stormwater system.
- Street sweeping is an extremely effective method of reducing the quantity of litter reaching the stormwater system as was demonstrated in the Cape Town Central Business District.
- Construction rubble is a significant contributor to the waste stream. Catch-pit grids are an effective way of reducing the amount of rubble entering the stormwater drainage system.
- Plastic items contributed between 19% and 50% of the litter stream by mass when sand, stones, vegetation and rubble were excluded. Plastic was the largest major litter category in all the catchments except for the formal residential areas of Summer Greens and Welgemoed.

Cost: *R690 000*
Term: *1999 - 2002*

Coagulation and cationic polymers
Umgeni Water
No 1225

Coagulation is one of the most important aspects of potable water treatment, being essential in the separation of solids and providing a primary barrier against waterborne diseases. Anomalies have been observed in Umgeni Water's operational area, which complicate coagulant selection and dose optimisation. A better understanding of the factors affecting coagulation with organic polyelectrolytes would allow for more rapid and accurate selection of the correct type of polyelectrolyte and dose. The objectives of this project were as follows:

- Elucidate the chemical reactions that occur during coagulation using polyelectrolytes
- Characterise Southern African waters in order to determine the effect of natural organic matter on polyelectrolyte coagulants
- Produce procedures and tests to enable accurate and easy selection of polyelectrolyte coagulant type and dose for a particular water type.

In conjunction with the laboratory tests conducted for this project, an in-depth data analysis was conducted on a large database of historical data, including both water quality and operational data. The objectives of this data analysis and interpretation were to assess:

- Differences in land cover and water quality in the upper Mooi and upper Mngeni catchments that will provide an indication of the cause of the waterworks (WW) coagulant dose during transfer periods
- Historical WW coagulant doses during transfer and non-transfer periods
- The relationship between coagulant dose and selected water quality constituents to assist in predicting changes in coagulant dose during transfer periods. Standard jar tests were performed on each raw water source and, where relevant, any blends of these waters, using a range of polyelectrolytes and aluminium sulphate. Tests to assess variations in coagulant demand were conducted using polyelectrolytes which were chosen to cover the variety currently available on the Southern African market.

The general conclusion from all the work carried out in this investigation is that the tools used to measure differences in water quality for correlation with coagulant demand are not significant in their effects as far as predicting the coagulant demand is concerned. Even measuring of the organic species or the zeta potential and streaming current did not yield a reason why the coagulant demands varied. More detailed work would need to be carried out into fundamental characteristics of the particles in suspension to possibly account for the differences noted in coagulant demand.

Cost: *R 204 000*
Term: *2001 - 2002*

Programme 2: Water treatment for rural communities

Designed functionalised polymers by anionic macromolecular engineering for membrane development
Department of Chemistry, Vista University (Port Elizabeth Campus)
No 723

The hydrophobic nature of polysulphone membranes makes these susceptible to fouling - that effectively inhibits its potential application in water and effluent treatment. Thus, the project aimed to synthesize new, reactive functionalized polymers and attach these polymers to the membrane surfaces in order to render the surfaces more hydrophilic and therefore, less susceptible to fouling. Various hydrophilic groups were grafted onto the surface using a novel (patented) chemical reaction technique. Two methods, namely a lithiation process and a controlled free radical process were employed to attach the hydrophilic groups to the membrane surface. Initial successes were achieved with both of these processes. These successes will pave the way to develop separation membranes with high chemical resistance, increased hydrophilicity, good permeability and controlled selectivity. This will result in improved and more cost-effective membranes for the purification of water and effluents in future.

Cost: *R476 335*
Term: *1995 - 2001*

Development and implementation of gas and liquid chromatographic organic water profiles as a management tool
Scientific Services, Rand Water
No 831

It is normal for many drinking water supplies to contain several hundred milligrams per litre of inorganic constituents, but the concentration of organic compounds rarely exceeds 20 mg/ℓ. This small quantity of material is a very complex mixture containing hundreds of different compounds, some of natural and some of synthetic origin. Its analysis is difficult, and even the most advanced analytical techniques cannot yet identify more than 10 to 20% of the organic material present. Progress has been made, however, and in this report the current state of knowledge is summarised. Much more difficult is the question of the significance to public health of these organic substances. Information on this is either totally lacking or highly controversial, and it is clear that considerably more research is required in this field. The aims of the research programme were:

- Setting up of gas and liquid chromatographic methods to determine profiles of organic compounds in water and establish fingerprints of volatile and non-volatile fractions
- To compile a database of the profiles from different regions
- To implement these profiles as a management tool.

Sample profile differences were monitored on the basis of mass spectra and sensory characteristics. The removal efficiency of a treatment process for a particular profile in a specific region was examined. Methodology for both gas and liquid chromatography were subsequently developed to satisfy these objectives. Mass spectrometry was used extensively in the development of these methods to facilitate the identification of unknown compounds in the water samples investigated. It was found that values for drinking waters were normally in the range of 3 to 5 mg/ℓ while source waters can vary between about 8 and 10 mg/ℓ.

Cost: *R551 000*
Term: *1997 - 1999*

Development of small-scale ultrafiltration systems for the provision of potable water at point source
Department of Chemical Engineering, ML Sultan Technikon
No 1070

The project addressed the development of a small-scale potable water treatment system for rural and peri-urban areas. The major focus of the project was to develop a system that would be sustainable in these applications. Field trials were performed to increase technical knowledge of the process, using criteria gathered from various sources on what needs to be fulfilled for a system to be sustainable. The various sources of information for sustainable water treatment systems in SA included farmers, water authorities, other membrane vendors, funding agencies, e.g. Development Bank, CMIP. Periodically, the information from the technical evaluations was combined with the information of sustainability needs. From this, proposals for the improvement of the unit design were developed. These were implemented either by modifying the existing unit, or by constructing a new unit. Criteria used include water quality aspects, cost factors, control strategy and operator requirements, reliability

and robustness, local construction and ongoing technical support.

A design and a strategy for operation and maintenance have been developed to provide tools for improved sustainability of these systems. The system design is very simple, and uses locally produced capillary ultrafiltration membranes. The other hardware components are also easily available locally. The strategy for operation and maintenance combines onsite monitoring by the user community with a regional approach to membrane cleaning and mechanical maintenance. This reduces the requirements for high technical skills, while still promoting community ownership of the units. The capital cost of the system is regarded as quite competitive and economically feasible, and demonstrates economies of scale. The operating costs, which must eventually be met by the user, are regarded as highly attractive, mainly due to the regional approach to operation and maintenance.

Cost: R630 000
Term: 1999 - 2001

Small water treatment systems: A case for development of an approval/certification system
Options to Solutions cc
No 1125

In early 1999 the Water Research Commission (WRC) commissioned Options to Solutions cc to broadly establish whether the prior use of an approval/certification system would have ensured sustainability of small water treatment systems. In testing out the hypothesis, the project team were to develop such a system with a suggested reference using the American - USA National Science Foundation (NSF) Standards. This prototype standard would subsequently be tested at a randomly selected number of waterworks around the country for validation. The aims of the project were as follows:

- To establish whether the prior use of an approval/certification system could result in better sustainability of small water treatment systems
- To develop a standard, with reference to NSF standards (e.g. Standard #61) which can be used in South Africa for small water treatment systems.

An exhaustive review was carried out on the library of NSF standards (via the internet). Out of the 49 standards currently published, two (NSF 52, NSF 92) were deemed as relevant to the objectives of the project. These were then duly bought and scrutinized with a view to adapt to local considerations. Whilst working with these standards, it became increasingly clear that they were completely inappropriate for application within the South African rural water treatment scenario as they tended to deal with advanced treatment processes such as activated carbon as well as the removal of "trace" chemical constituents such as organics and heavy metals. These are a concern in industrialized countries such as the USA but are hardly a problem in South Africa, save for isolated cases. A questionnaire on the state of small systems was sent to 22 water supply projects. In virtually all cases the treatment systems were in some sort of functional state - although barely so in certain instances. The fact that the schemes were still functional could not be attributed to either good design or good practices in management, but rather to continued support from government structures. A questionnaire such as this can prove to be an invaluable component in the approval process for a new water system to be built. What has been developed is a basic and practical tool which, no doubt, can be refined further with increased application in the field.

Cost: R 290 000
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
No 1139

Local governments in South Africa face the critical challenge of delivering services to the poor while facing severe financial and capacity constraints. There is a changing politico-institutional framework in which there are high expectations of delivery from the poor. The KwaZulu-Natal BPD was launched as a trisectoral model involving local government, civil society and business. The KZN-BPD formed a component of an international exercise to test new and innovative approaches for partnership. Eight international projects formed the cluster under the auspices of the World Bank. The problem of social delivery is a global question. And the vision was to bring together the strengths and abilities of local government, business and civil society in providing services to the poor. At one level it was the engagement of fairly equal partners in the mutual exploration of what is possible. It was flexible and innovative. It did not take the form of a legal instrument between local government and business, but worked through mutual understanding to develop a new outlook on working with poor communities.

Although firmly rooted in actual on-the-ground projects, the partnership was fundamentally a learning (or research) experience (though never an academic exercise). A better understanding of how to achieve service delivery through democratic participation was being generated by each of the partners. There are no formulae, only learning from successes and failures. To give a few examples of the wide learning involved:

- Local government management benefited particularly by learning the need for close communication with poor communities through experience with the NGO. It also accessed the knowledge of a multinational firm (working in many socio-economic environments in many countries), and developed a better understanding of private sector operations (with particular lessons in resource management and planning and the use of GIS);
- The private sector learnt about the working as a team with the NGO particularly in education and awareness.
- The NGO, which has extensive knowledge of rural conditions, gained an understanding of the issues in operating water services in poor urban communities.

Altogether the partnership completed 16 projects in Pietermaritzburg and 14 in Durban on a fairly modest budget, a key element was the research component which captured the lessons and experience of this initiative.

Cost: R880 000
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
No 1185

A large number of small water treatment systems installed in South Africa are subject to failure during its life, some even right from the planning stages of the project. This implies first and foremost that these communities for whom the plants are installed are still not involved and their support and participation obtained during the initial phases of a water supply project. While the various manuals have proven to be valuable in allowing engineers, authorities and communities to plan and design small water treatment systems for rural communities, they do not specifically address the very important aspect of community involvement in the planning stages of a project. There was, therefore, a need for guidelines for planning and design of small rural water treatment plants, that specifically identify those aspects and pitfalls which should be avoided in the design of these plants and guidelines on how to obtain community support and participation in the project. There was also a need to provide information on "simpler" and indigenous technologies can be used to ensure community participation and cost-reduction of the systems. The project aimed to:

- Understand why small water treatment systems for rural communities often fail
- Provide design guidelines for rural water treatment technologies
- Create an understanding of the unit processes employed in small rural water treatment plants
- Provide practical and useful guidelines on how to obtain full involvement and participation from the communities when a new treatment system is planned or an existing treatment system is to be upgraded
- Provide information on indigenous water treatment technologies.

A major input towards the compilation of these guidelines for planning water treatment systems for rural communities was the presenting of a national workshop on small water systems during August 2002. The workshop attempted to bring together all the role players in die field of small water systems in Southern Africa to discuss the important issues regarding failure of small treatment systems that are installed across the country, and problems that are experienced with ensuring the sustainability of the systems. Recognized experts and role players in the field of small water systems (either on institutional or technological level or both) were invited to do presentations at the workshop to present current viewpoints and their experiences, and to stimulate discussion.

Cost: R95 000
Term: 2000

Guidebook for alternative small-scale desalination technologies for potable household water augmentation in South Africa
Institute for Polymer Science, University of Stellenbosch
No 1228

Saline water sources, such as brackish groundwater, are often available to small and rural communities, but desalination technologies are still regarded as too expensive or sophisticated for implementation and maintenance at such communities. However, some economically feasible and community-acceptable water supply options may exist, but the relevant role-players may not be aware thereof or do not have adequate information regarding these options at the point of decision-making. The aim of the project was to produce a

guidebook to serve as a decision-making aid to individuals and organisations for the identification and selection of suitable options for water supply from saline sources. The content of this guidebook was developed through theoretical research into relevant water supply options, consultations with researchers active in the field of desalination technology, meetings and correspondence with water authorities and field visits to typical target communities where selected water supply options are currently in use.

A number of relevant water supply options, ranging from sophisticated desalination technologies to simple household water augmentation methods, such as rainwater collection, were identified as part of the above research study. Those options that were considered of most importance in terms of actual or potential use (locally and internationally) were listed. Key technical aspects of each of these options were then identified, and then included in the database of water supply options. A socio-economic study was performed to take into account demography, housing structure, waters source, water quality, community involvement, participation and willingness to pay. The guidebook, therefore, provides guidance on the selection of suitable water treatment options from both a technical and social point of view and will be a very useful tool in the provision of safe and economical water to the rural communities depending on saline sources for their water supply.

Cost: R215 000
Term: 2001 - 2003

Treatment of rural groundwater for potable use
Department of Chemistry, Potchefstroom University for CHE
No 1230

Many groundwater sources in the North-West Province cannot be used for potable purposes because of the saline quality of these sources – especially regarding nitrates, fluorides, sulphates, calcium and chloride. High nitrates in water used for potable purposes cause health problems, such as methaemoglobinemia (blue babies). The project aimed to evaluate different nanofiltration membranes at a laboratory scale in the removal of these compounds. The water from a number of boreholes in the North-West Province was evaluated, using a few commercially-available membrane makes. The studies showed that divalent compounds could be removed with varying success by the use of these membranes, but that the monovalent ions, such as fluoride and nitrate, could not be adequately removed. These results are significant in that they point the way forward to the niche areas where nanofiltration could be implemented with success – and which applications to avoid.

Cost: R178 000
Term: 2001 - 2002

Removal of fluoride from drinking water
Department of Civil Engineering, Rand Afrikaans University
No 1289

Fluoride is universally recognised as a necessary compound to grow strong, attractive teeth. At the same time, it is also recognised that an excess of fluoride leads to dental fluorosis and even to skeletal fluorosis at higher levels of exposure. In South Africa, there are regions where natural waters lack the required fluoride concentration required for healthy teeth, which is the drive behind the recent legislation for the enforcement of water fluoridation. Similarly, there are regions in South Africa where the natural fluoride concentration in water exceeds the concentrations generally recognised to be acceptable to the health of the general public. The anticipated research products of this contract were originally stated as:

- Provide a physical explanation of how fluoride adsorption onto baked clay works
- Produce a prototype of a domestic unit for the removal of fluoride from drinking water.

It was further anticipated that a prototype would be field-tested in a rural village. When the laboratory efficiency of the unit was found to be only 50% it was deemed to be inadvisable to move a relatively inefficient unit to site. The team was requested to rather divert the resources for the final part of the project towards attaining higher efficiency.

It as found that the use of discarded brick fragments as piloted in Sri Lanka, is a promising technology with a proven track record at hundreds of households. The adsorption of fluoride onto clay was modelled successfully in this project and a rational basis for this technology therefore exists. Clay deposits in South Africa could potentially be just as successful, but great variations exist even within the same deposits. Careful mining of the deposits is an important prerequisite. A practical, simple method of compression and baking was developed which will effectively immobilise the clay as pellets to ensure good water quality, while still attaining good defluoridation efficiency. The initial defluoridation efficiency of domestic units using these pellets was measured at about 70%.

The ground work had therefore been done to expand this project to future field-scale testing, with adequate demonstration of its potential to warrant further attention.

Cost: *R 495 000*
Term: *2001 - 2003*

Research on the application of *in situ* groundwater treatment as robust low-cost rural water supply treatment option
Environmentek, CSIR
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. 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 were 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).

Research into methods of groundwater clean-up or remediation has increased and various techniques have been developed and applied. As an alternative to pump-and-treat systems, in situ treatment techniques are an alternative, which remove contaminants while the groundwater residues in the aquifer are being developed. This report presents information gained from literature and contacts with researchers abroad. The literature review shows that in situ groundwater treatment has significant potential for application in South Africa. Recommended systems for South African application include:

- Permeable reactive barriers (or "treatment walls")
- *In situ* biological denitrification
- Electrokinetics
- Nitredox

Estimated cost: *R250 000*
Expected term: *2002 - 2003*

A sustainable colloidal silver-impregnated ceramic water filter for household potable water treatment
Envi-Sabi Scientific
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 were 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.

Cost: *R350 000*
Term: *2002 - 2003*

Programme 3: Drinking water quality

Determination of cytotoxicity and invasiveness of heterotrophic plate-count bacteria isolated from drinking water
Scientific Services, Rand Water
No 1069

Heterotrophic plate counts (HPCs) are commonly used to assess the general microbiological quality of drinking water. The South African Bureau of Standards (SABS) specifies a limit of 100cfu/ml of these organisms for drinking water. However HPCs limits are often disregarded due partly to difficulties to produce drinking water within the limits and also because of the perception that these commonly used indicator bacteria are harmless. Recent studies, however, indicated that some of these heterotrophic bacteria are indeed opportunistic pathogens. These findings have raised concerns worldwide because of the health implications this might have for consumers. Many of these potentially pathogenic bacteria are associated with primary and secondary infections in immuno-compromised individuals. The concern arises with the increasing immuno-compromised component of the consumer population who will be at risk if the drinking water does not comply with the standard.

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. At first a screening was done to determine whether these bacteria are potentially pathogenic. Haemolytic analyses followed by examining the production of extra-cellular enzymes associated with pathogenicity by the HPC isolates were done. Antibiotic analyses were also done to determine whether HPC bacteria isolated from drinking water displayed resistance to various antibiotics commonly occurring in the environment because environmental isolates carrying the resistance could pass it on to opportunistic pathogens. The cytotoxicity, adherence and invasiveness of HPC bacteria were also determined.

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, especially those with compromised immune systems. Cost estimates for the various analyses used in the study were done for use in routine monitoring by water utilities. The cost of the specialized analyses implicated that it is not feasible to do the analyses on a routine basis. The facilities to do these analyses if needed are, however, established at the University and are available to water utilities

Cost: R500 00
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
No 1124

Eutrophication as a result of organic pollution of the water in impoundments leads to the establishment and proliferation of organisms which may release toxins and taste and odour forming substances into the water. Two of the most common taste and odour compounds are geosmin and 2-methylisoborneol (2-MIB). The most commonly used method of removal of geosmin or 2-MIB from water is the use of activated carbon. This is achieved either by the use of granular activated carbon (GAC) in fixed beds on a continuous basis, or by dosing powdered activated carbon (PAC) into the water on an intermittent basis whenever there is a taste and odour problem at the works. Unfortunately experience has shown that the commonly used adsorption numbers do not predict the ability of a carbon to adsorb geosmin or 2-MIB. This project was initiated with the following objectives in mind:

- To establish the relationship between the physico-chemical properties of PAC for the removal efficiency of taste and odour causing compounds from water
- To determine what effect water quality and the chemical composition has on the removal of taste and odour by adsorption onto PAC
- To determine if the same PAC product could be used effectively in all regions throughout South Africa with the aim of setting up a centralised stock to serve more than one water treatment authority
- To try to establish whether compounds exist which have similar adsorption behaviour by PAC as geosmin, but which are cheaper and easier to evaluate
- To set guidelines for the evaluation of PAC for the removal of taste and odour-causing compounds like geosmin and 2MIB.

Ten samples of PAC from various suppliers in South Africa were selected for testing. The physico-chemical

properties of the 10 PAC samples used in the evaluation were characterised as moisture content, ash content, bulk density, particle size analysis, nitrogen intrusion determinations, mercury intrusion determinations, tannin number determination, iodine number determinations, methylene blue number determinations, geosmin adsoption determinations and 2-MIB adsorption determinations. The ability of the various PAC samples to adsorb geosmin and 2-MIB were then compared against the physical characteristics as well as other factors such as the quality of the water and the treatment process employed at the relevant waterworks in an attempt to find good correlations or even the ability to predict a carbon's performance.

It was found that water quality does affect the ability of PAC to adsorb geosmin and 2-MIB with best results being obtained for deionised water and worst results for water containing a relatively high concentration of suspended solids. Similarly the water treatment process also affected adsorption - with lime having little effect, polyelectrolyte having a relatively minor effect, and sodium silicate being significantly inhibitory to geosmin and 2-MIB adsorption.

Cost: R400 000
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
No 1164

Viral infections feature prominently among water-borne diseases which have a major public health impact world-wide. Information on viruses in drinking water is restricted because the detection of viruses in water is expensive and requires special skills. In this project the latest technology and expertise has been applied to obtain the most comprehensive data on viruses in a representative selection of South African drinking water supplies on record. The aims were 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.

A statistical model designed by the World Health Organization (WHO) was used to assess the risk of infection constituted by the viruses detected. Mainly due to sensitive techniques not previously applied, viruses were detected in drinking water supplies which were prepared according to international specifications for treatment and disinfection, and which conform to specifications for indicators of water quality such as faecal and heterotrophic bacteria. In addition, the results revealed that the risk of infection constituted by the viruses exceeded an acceptable risk of one infection per 10 000 consumers per year recommended for drinking water in the USA. The detection of viruses in drinking water supplies and risk of infection which exceeds recommended levels have been reported previously in South Africa, as well as other parts of the world where studies of this kind have been carried out, notably the USA. The results of this project do not necessarily imply unacceptable drinking water quality. However, they disclose controversies regarding guidelines for drinking water quality which confuse the water industry and public health authorities. Solutions would require a revision of strategies to ensure drinking water of acceptable quality in South Africa.

Cost: R1 000 000
Term: 2000 - 2002

The establishment of a water purification demonstration plant for the Star Galaxy Technology Showcase
IWS (Pty) Ltd
No 1293

A very ambitious (but failed) scheme, "Star Galaxy", was planned by a consortium of companies to build a science park and technology exhibition and educational centre across the N1 highway in Centurion. Part of the science park would have entailed an outside environmental park, demonstrating environmental technology. In turn, part of this park would have consisted of a water and effluent section, depicting the purification of wastewater to drinking water and the environmentally-friendly handling of all wastes generated in the process. The objective of the project was to select the various treatment processes for the environmental park and design a feasible process flow diagram around these processes.

The project succeeded in its aims and provided the process design basis, design philosophy and process description for ten main water treatment unit processes. These processes are the following: Anaerobic reactor,

aerobic reactor, wetlands, clarification (settling and/or dissolved air flotation), filtration, oxidation, disinfection (UV), reverse osmosis, evaporation and crystallisation. Maintenance requirements, health and occupational safety and environmental issues were further incorporated into the report. It was recommended that a full process design be made and that financial issues pertaining to the demonstration plant be resolved before progressing further with project implementation. The report is internal and was not published.

Cost: R98 000
Term: 2001

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.
No 1177

The geographical mismatch of the water-demand centres and the water resources in South Africa necessitate the transport of water over long distances and high elevation differences. On average water is transported about 350km in South Africa. To ensure operational effectiveness of pipelines, one of the elements is that they must be effectively de-aerated. Thus the objective of this study was to conduct experimental and field work to establish the influence of air in pipelines and strategies to effectively manage and de-aerate pipelines. Through the experimental work different air bubble sizes at different velocities and different pipe angles were tested to evaluate the available relationships predicting the required flow velocity to hydraulically transport air. New relationships were determined for different bubble sizes and operational conditions that can be used to determine the required positions where mechanical removal of air is required. The findings emanated in a simple relationship with respect to the pipe diameter and pipe slope that can be used to determine if air will be transported. Due to the erratic flow path of air bubbles that are transported along a pipeline it was necessary to derive a relationship for the required discontinuity that should be created to capture the air for mechanical removal from the pipeline. Experimental work and numerical analyses (CFD Modelling) were used to compare the effectiveness of a specific size of discontinuity to capture the air that is transported along the pipe. It was found that the required size for effective de-aeration is dependent on the flow velocity, size of air bubble and the pipe slope. This is an important finding because it has been reported that although systems have been equipped with sufficient air valves air was still trapped in the pipeline. These experimental results reflected that to effectively de-aerate a pipeline the size of the discontinuity should be at least 35% of the pipe diameter.

Cost: R750 000
Term: 2000 - 2002

Thrust 3: Wastewater and Effluent Treatment and Reuse Technology

Programme 2: Sludge characterisation, treatment, utilisation and disposal

Enzymology of accelerated primary sewage sludge solubilisation and digestion in sulphate-reducing systems
Department of Biochemistry, Microbiology and Biotechnology, Rhodes University
No 1170

Wastewater sludges, generated as by-products of the physical, chemical and biological processes during the treatment of municipal wastewater, require further treatment for safe and acceptable disposal. Anaerobic treatment processes are widely used as the most broadly-beneficial stabilisation route. In the presence of sulphate, sulphate-reducing bacteria (SRB) compete with methanogenic and acetogenic bacteria for the substrates available and have been shown to stimulate the rate of primary sewage hydrolysis and solubilisation. Sulphidogenic bioreactors are thus a promising alternative to conventional methanogenic sludge digestion. The aim of this project was to experimentally investigate and characterise the enzymology of primary sewage sludge solubilisation and disposal in such sulphidogenic systems.

The report presents an enzymological depth-profile of enhanced solubilisation of primary sewage sludge within a sulphidogenic recycling sludge bed reactor (RSBR). The activities determined for key enzymes (glucosidases, proteases and lipases) reflect the enzymatic processes occurring, and were found to be affected by changes in treatment plant operating parameters such as pH, alkalinity, temperature, COD, sulphate and sulphide concentrations, as well as by specific enzyme inhibitors when these were introduced The mechanisms involved in floc formation, size distribution and fragmentation were elucidated and integrated into a model interrelating bioreactor operating conditions, physiochemical parameters, environmental factors (e.g. sulphide, sulphate and alkalinity/pH levels) and the functioning of enzymes in the sulphidogenic mineralisation of complex particulate organics. The rate of hydrolysis was found to be best described by first order kinetics, strongly influenced by

environmental and operational parameters such as pH, temperature, biomass, particle/floc size, type and concentration of particulate substrate and product concentration. The work carried out contributes significantly to better understanding of the biosulphidogenic hydrolysis of primary sewage sludge and will aid in improving the overall design and performance of sludge digestion systems.

Cost: *R707 000*
Term: *2000 – 2002*

Technical and financial review of sludge treatment technologies
Africon
No 1240

In this project an authoritative reference document was developed, which reviews and evaluates the applicability and cost implications under South African conditions of sludge management technologies that are available both locally and internationally. It therefore fills a gap experienced by local sludge handling agencies which previously did not have access to a reference standard that could guide them in making decisions regarding technical performance and relative costs of alternative sludge treatment and management options. As background to the presentation of available sludge management technologies, the report gives an overview of current sludge management practices in South Africa, an estimate of sludge quantities and qualities and a brief description of commonly used sludge treatment and disposal methods. The report also describes the status quo of South African legislation regarding sludge management and describes the possible utilisation and disposal routes available within the South African legal framework. The sludge treatment requirements and available technologies for each of the utilisation or disposal routes are listed in matrix form for easy reference and use. The processes are classified in different categories (embryonic, innovative and established) according to their South African application. Established processes are described in technology sheets that can be easily updated. These sheets provide a brief description of each process; assess its applicability under South African conditions, list advantages and disadvantages as well as references to existing installations and typical literature references. First-order cost estimates are given for the established processes considered most applicable to South African circumstances. Cost estimates are presented in cost sheets and include estimates of capital costs, annual costs of the capital expenditure, operating costs, and maintenance costs. Typical case studies are presented to illustrate the use of the Sludge Management Decision Matrix and the cost sheets.

Cost: *R275 000*
Term: *2001*

Programme 3: Treatment and recovery of organics from agro-industrial processing

The regional treatment of textile and industrial effluents
Department of Chemical Engineering, University of Natal
No 456

Colour and auxiliary chemicals from the processing of textiles persist through conventional wastewater treatment plants and enter receiving water bodies. Despite considerable progress in the in-house management of textile effluents (mainly recycling of water, chemicals and energy), colour removal and concentrate disposal remain problematic, particularly in the RSA due to the limited dilution generally available at discharge, causing aesthetic and other water quality problems and potentially limiting some further downstream uses of the water. The objectives of this project were to determine experimentally the fate of textile and specific industrial effluents through conventional sewage treatment processes and their effect thereon, to investigate the addition of processes within a sewage works to improve the removal of specific pollutants; and to investigate the treatment of specific concentrates which had been segregated at source and transported to the sewage works.

Anaerobic studies conducted at laboratory-scale, pilot-scale and full-scale on reactive dyes and dye effluents showed that reactive dye concentrates could be treated by conventional anaerobic digestion to reduce colour and COD (chemical oxygen demand). Prior exposure of the biomass to the dye did not increase the rate of decolourisation but did render the micro-organisms resistant to previously inhibitory concentrations of the dye. The rate of decolourisation was first order with respect to dye concentration and an additional carbon source (e.g. glucose) was found to be necessary to maintain the microbial metabolic state. The presence of nitrate inhibited decolourisation whereas sulphate had no effect on the decolourisation rate. Decolourisation only occurred once all the nitrate in the system had been reduced and a potential of less than -450 mV (SCE, saturated calomel electrode) was conducive to rapid decolourisation. Adsorption of the dye to the biomass played a role in the initial stages of decolourisation, but the adsorbed dye was subsequently decolourised and therefore no distinction was made in the study between abiotic and biological decolourisation. The refractory degradation products of the dye after anaerobic digestion were isolated and identified and found to be consistent with reduction of the azo-bond. Laboratory-scale investigations using chemical reducing agents to decolourise azo dyes found that

specific chemical agents were effective but that this was an expensive method of treatment. Preliminary waste minimisation surveys carried out at four textile factories in KwaZulu-Natal showed that waste reduction and pollution prevention should be implemented at source throughout the textile industry, to alleviate effluent treatment requirements.

Cost: R490 000
Term: 1992 –1995

Purification of abattoir effluents by means of the protein reclamation process
Abakor Ltd.
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 was to transfer single-cell protein technology to a full-scale plant at the Johannesburg Abattoir.

Cost: R300 000
Term: 1994

Programme 4: Treatment and recovery of inorganics (including sulphate and metals) in industrial and mining effluents

Caustic management and reuse in the beverage bottling industry
Department of Chemical Engineering, ML Sultan Technikon
No 1033

Internationally membrane-based systems for the clean-up and reuse of spent caustic solutions are available from various commercial vendors. In South Africa, however, clean-up of spent caustic solutions and their subsequent reuse or recycling is rarely practiced. Possible reasons for this include the high cost of imported caustic clean-up systems, the high cost of obtaining spares and new membranes for imported systems, as well as the perception that membranes are a very "high tech" technology that requires very high skills levels to operate and maintain. There could be considerable benefit to the South African food and beverage industry and the broader aspect of environmental protection, therefore, if a locally developed caustic clean-up system was available which addressed the above concerns. The evaluation of locally available ultrafiltration and (woven fibre) microfiltration membranes, as well as an imported nanofiltration membrane to address these concerns, forms the overall objective of the project. These membranes were evaluated on a bench-scale system, on both high strength and low strength caustic wash residue used for container cleaning by the sugar and bottling industries.

It was found that the woven-fibre membrane was not suitable for the services required. The ultrafiltration and nanofiltration membranes, on the other hand, both performed very well. Both the capital and operating costs of the ultrafiltration are likely to be lower than that of the nanofiltration membrane system. In view of the fact that the separation efficiency of the nanofiltration system is only marginally better than the ultrafiltration system, it may be concluded that the ultrafiltration system would be more economically attractive for caustic clean-up. This will not only impact positively on caustic reuse and cleaner production, but will also benefit the local membrane manufacturing industry.

Cost: R370 000
Term: 1999 – 2001

Mechanism and kinetics of biological treatment of metal sulphate containing effluent
Department of Chemical Engineering, University of Cape Town
No 1080

Mining, mineral and chemical processing, electricity generation and several other industries produce wastewater that is acidic, has high sulphate (and other salt) concentrations and (frequently) high concentrations of dissolved metals. To exploit the potential technical, cost and operating advantages of bioprocesses for treating acid mine drainage (AMD) and other such acidic high-sulphate wastewaters, this project aimed at obtaining fundamental information for developing and optimising bioprocesses for treatment of these wastewaters, both to produce clean water and to recover metals. Descriptions of the transformation pathways of the breakdown of complex

organics, sulphate reduction and methane formation were obtained from the literature, but these were mainly limited to sulphide inhibition at relatively low levels of sulphide, rather than the effect of elevated sulphate or sulphide levels and low pH on the rates of organic hydrolysis as applying in sulphate bio-reduction. In the project therefore the kinetics of bacterial sulphate reduction using acetate (chemostat culture in well-mixed stirred tanks) and using ethanol (preliminary study only) were experimentally determined. The kinetics were found to be inhibited by sulphide and possibly by sulphate. For acetate-based sulphate reduction, the effects of sulphate concentration and temperature were determined and a rate equation describing the kinetics was proposed and used in two simulation models for predicting the performance of the falling sludge bed bioreactor pilot plant developed by Prof P. Rose (Rhodes University). The simulations were reasonably successful although the models could not be tested exhaustively due to insufficient steady-state operating data from the pilot plant. Neither simulation model was complete and the work will be continued in the follow-up project (**No. 1251**), both to refine and extend the model in terms of newly available information and to inform further experimental investigation.

Cost: R574 000
Term: 1999 - 2000

Development of a novel membrane photobioreactor for the production of algal toxins
Department of Biochemistry and Microbiology, Rhodes University
No 1103

The phenomenon of algal toxins in surface waters, leading to both acute and chronic algal toxicity, is a serious problem to human health. This research group at Rhodes University previously developed and patented the concept of a "gradostat" reactor, which ensures a nutrient gradient across a layer of fungal micro-organisms, thereby pressurising the organisms in the nutrient-deficient region into the production of enzymes as a survival mechanism. The same principle was applied in this research, only in this instance algae were put under nutrient and light-gradient stress to force them into the production of scarce and expensive algal toxins - which are normally very difficult to culture under laboratory conditions. An abundant and inexpensive source of algal toxins will greatly facilitate research on the effects and prevention of algal toxicity. The aims of the project therefore included:

- The development of a membrane photobioreactor for the generation of algal mats across which a nutrient- and light-gradient can be established
- Application of the membrane photobioreactor to algal and cyanobacterial toxin production
- Application of the membrane photobioreactor to the study of the metabolism of the algal/cyanobacterial mats
- Evaluation of the potential of this system for nutrient removal from contaminated surface or groundwater

It was found that algal toxins could be successfully produced with this system, but the yields obtained were rather low. Considerable new information was obtained on the physiology of the *Microcystin* toxin production using the gradostat membrane bioreactor. However, further optimisation of the process will be required to obtain a better understanding of the physiology of the biofilm and toxin production.

Cost: R81 000
Term: 2000

Visualising the effects of electro-magnetic and turbulence defouling techniques in membrane modules
Institute for Polymer Science, University of Stellenbosch
No 1166

Membrane fouling is the single most critical problem limiting the wider application of water and effluent treatment by membrane filtration. The project aimed, through laboratory studies, to "visualise" the growth of a fouling layer on a membrane surface using advanced ultrasonic wave technology. A novel method for the detection, measurement and characterization of fouling layers on membranes, while located within their modules, has been developed. The method is based on the use of differential ultrasonic waves. It enables the detection of fouling on a (membrane) surface within half a minute of initiation thereof. This project highlights the growth in sophistication of the ultrasonic technique to enable the non-invasive measurement of fouling on membranes *in situ* before there is even a trace of flux decline. In conjunction with a German firm, a commercial monitoring unit based on the method is being developed for use on any membrane plant as a simple way to monitor the condition of membranes in practice.

Cost: R992 000
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
No 1173

Evaporators or reverse osmosis units are currently mostly used to remove and concentrate salt and heavy metals containing effluents. Available options for treatment of the resultant concentrated brines are limited (mostly storage in sludge dams or brine distillation). The dilute treated effluents are conversely also difficult to further polish cost-effectively because of their high volume / low concentration nature. The technology proposed aimed to develop a ligand system consisting of crown ethers which can be tailored to be capable of selectively trapping the contaminant ions in both high concentration/low volume as well as low concentration/high volume effluents. The ligands are anchored on a mobile polymer support which allows the contaminants and the ligands to be brought into contact for trapping of contaminants, and the release of contaminants (regeneration of the ligands) for subsequent recovery, sale or recycling for industrial use. Laboratory studies were conducted, during which a number of possible crown ether ligands were evaluated for their sodium removing capabilities and their attachment to plastic surfaces for use as a "conveyer belt" system for the removal of sodium from brines and effluents. In the research programme more than 90% of the available sodium cations were successfully transferred from a 200 mg/ℓ Na+ solution, and then half of this amount was released again in a previously determined reservoir in a single cycle. The ligands were also successfully attached to a "conveyer belt" surface, although the density of Na+ cations on the solid support was still low: only approximately 1.5 g/m^2. The present technology only supports Na+ removal from water and effluents. Further research will be required to improve attachment of the ligands to a feasible solid support and to expand the work to other contaminants in a more realistic and practical environment.

Cost: R702 000
Term: 2000 - 2002

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
No 1244

Acid mine drainage (AMD) waters are generally characterized by low pH, very high iron concentrations, significantly high concentrations of non-ferrous (mainly heavy) metals, and very high salinity. At present, metal ions are commonly removed from AMD water by first oxidizing ferrous ions to ferric (using oxygen) and then precipitating ferric hydroxide at around pH 6, but this process has a number of technical, cost and operating drawbacks. This project aimed at developing a novel low-cost system for metal ion removal without using oxygen-oxidation, namely an ambient-temperature ferrite process which would proceed at adequate reaction and settling rates in the presence of calcium, which is known to inhibit ferrite formation. The approach adopted was a systematic laboratory investigation informed by theory: sequential batch tests were first carried out on simulated AMD waters in an oxygen-free environment, to determine the independent effects of seed concentration, air flow rate, pH and temperature on ferrite formation, and a continuous-flow process with sequential back-mix reactors was then developed and investigated, first on simulated and then on various actual AMD waters.

Some significant features of the process developed are:
- All (>99.9%) of the dissolved iron is removed in a single step
- A high proportion of the non-ferrous metals present in AMD are simultaneously removed by cation substitution into the magnetite crystal lattice during magnetite formation
- Magnetite settles extremely well, has an economic value for use in many industries and is extremely stable in the environment
- The precipitation-settling sequence in the process configuration decouples the bulk AMD flow from the metals removal process, resulting in greatly reduced hydraulic retention times and correspondingly reduced capital and operating cost
- Calcium interference, arising from the use of lime for pH elevation, is eliminated by the novel way in which the ferrous : calcium ratio is increased in the oxidation reactor
- No chemical additives are required apart from air, a pH-elevating agent and an initial amount of magnetite seed

The "Steady State - Continuous Flow - Ambient Temperature Ferrite Process" developed in the project has been patented jointly by WRC and UCT. In a follow-up project (**No. 1454**), research aspects receiving attention are to quantify the efficiency of non-ferrous metals removal and to characterise, quantify and solve various potential fouling and interferences.

Cost: *R 520 00*
Term: *2001 - 2002*

Evaluation of microfiltration, ultrafiltration and nanofiltration for salt and chromium recovery from spent pickling and tanning effluents
Environmentek, CSIR
No 1370

Membrane processes including microfiltration, ultrafiltration, nanofiltration and reverse osmosis should function effectively for chromium and salt recovery from neutralized spent pickling/tanning effluent. However, insufficient information is available on a number of critical technical and cost/operating issues, the acceptability of chemical and water recycling to the tannery industry, the economics of such an approach, and current international practice. This desk study was therefore performed with the main aim of carrying out a techno-economic feasibility study on microfiltration/ultrafiltration/nanofiltration process technology for recovering chromium and salt from spent pickling/tanning effluent for reuse in the processes. The secondary aim was to establish the viability of developing ultrafiltration/reverse osmosis technology for the desalination of the final effluent produced by tanneries. The techno-economic feasibility of the processes was determined from literature information, and from discussions with experts in the leather industry. The acceptability of the use of membrane technology in the leather industry was also determined from discussions with experts in the South African and overseas leather industries.
The report concludes that:

- A combination of ultrafiltration, nanofiltration/reverse osmosis should be effective for treatment of various streams in the tanning industry and recovery of water and chemicals, such as chromium, for reuse in the tanning process
- At present, membrane technology does not appear to be economically feasible for the treatment of tannery effluent in South Africa, due to the low charges for effluent disposal
- It is foreseen that membrane technology will in future play a role in the treatment of tannery effluent for pollution control and for water and chemical recovery for reuse.

The report also lists possible further studies and an economic evaluation of various membrane types.

Cost: *R150 000*
Term: *2002 - 2003*

Thrust 4: Industrial and Mine-Water Management

Programme 1: Quantification of water use and waste production

An investigation of water usage at gold- and platinum-mine flotation plants
Department of Environmental Engineering, Technikon Pretoria
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.

Cost: *R224 000*
Term: *1999 – 2000*

Programme 3: Minimising the impact of waste on the water environment

A quantitative evaluation of water utilisation in different rehabilitation methods for slimes dams
Envirogreen and Freegold
No 899

Mainly two approaches are being used to ameliorate gold tailings deposits and create a medium that would support a vegetative cover, namely a leaching method whereby acidity and salinity is leached with the aid of heavy water applications and a chemical amelioration method where lime is applied to neutralise the active and

reserve acidity. Although they use different recipes, both approaches apply plant nutrients and a seed mixture to establish a vegetative cover. Once established the vegetative cover is actively managed through fertilisation and water applications, which is gradually reduced until a stable cover is established. A project was undertaken to establish which of these approaches and their variations produced the most sustainable vegetation cover at the end of the rehabilitation period and to quantify their water requirements. Although significant chemical and other differences between the plots were found immediately after the initial application of chemical and other amendments, these differences largely disappeared by the end of the three year re-vegetation period. Both approaches succeeded in producing a suitable environment for establishing vegetation. A total of 39 plant species were identified at the end of the experiment and out of the 19 species initially seeded, only 8 remained. Three species dominated on the experimental plots of both approaches at the end of the period, although not in the same ratios. Further natural colonising of the plots by grass species from the surrounding veld is foreseen. Three years after rehabilitation started, no conclusive statement could be made regarding the sustainability of the vegetation cover. However, results from tailings dams rehabilitated according to the different methods in the past, indicate that stable plant communities can be obtained. About half as much water was used in the chemical amelioration method compared to the leaching method, when using a micro-jet irrigation system.

Cost: R135 190
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
No 1002

A long-term experiment in which 10 experimental cells, filled with fine coal discard, on top of which a range of soil covers were placed, provided a great deal of insight about the role soil covers can play in controlling the formation of acid mine drainage following the rehabilitation of coal mines. It was found that for soil covers to be effective in reducing infiltration and oxygen ingress to acceptable limits, they had to be at least 1 m thick. While double-layer covers were found to be ineffective, store and release covers were effective in limiting rainfall infiltration to acceptable limits. Compaction and treatment of coal discard prolonged the onset of acid drainage, but acid breakthrough occurred in the leachate of all uncovered cells as well as cells with a 0.3 m cover. Although acid drainage has not yet been observed for the cell with a 0.5m cover, the increase in sulphate concentrations in its leachate indicates increased sulphide oxidation rates. Acid drainage was not observed from any of the 1 m thick cells and actually showed a slight decrease in sulphate concentrations, indicating a decrease in sulphide oxidation rates. Outflow rates were related to rainfall. High outflows occurred in above-average rainfall years and vice versa. Outflow rates were also related to cover thickness. The thicker the cover the lower the outflow. The implications for industry are that a distinct relationship was found between oxygen ingress rates and leachate quality. While the quality of leachate can be improved by restricting oxygen ingress, oxygen diffusion is not significantly restricted by covers of less than 1.0 m thickness. This is considerably thicker than current practice.

Cost: R247 000
Term: 1999 - 2000

Assessment of procedures used in Southern Africa to evaluate chemicals used in water and wastewater treatment
Department of Process Services, Umgeni Water
No 1184

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. Although wastewater is generally treated through biological processes, chemicals are often used for specific purposes. For example, coagulants are for sludge conditioning, lime for pH adjustment and to increase alkalinity, and aluminium and iron salts for phosphate removal. In spite of their general use, there is a serious lack in South Africa of standardised testing procedures for assessing these process chemicals. While recommended tests are available for some of these chemicals, such as the South African Bureau of Standards 459-1955 Standard Specification for Lime for Metallurgical Purposes, these tests mostly use time-consuming and outdated gravimetric procedures. This project conducted a literature survey to gather information on available test procedures for an identified list of water and wastewater treatment chemicals. This was followed by consultations with a number of the main role players in the water and wastewater industry regarding the test procedures they use. These activities culminated in the compilation of a manual that describes testing procedures for most of the chemicals used in water and wastewater treatment in Southern Africa. The methods are generally fairly simple to conduct, reliable and repeatable. This manual represents the first step

towards standardized procedures for the evaluation of water and wastewater treatment chemicals and should provide technical background for future legislation governing the use of these chemicals.

Cost: *R89 000*
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
No 851

The chemical processing industry is characterised by relatively low water use but the production of effluents that are often concentrated and which can contain toxic or inhibitory contaminants. This project aimed to apply and assess water pinch technology as an approach that can be used in South Africa to minimise water use and effluent generation in a chemical complex, to refine the technique as necessary, and to transfer expertise in the technology to industry, regulators and academics. The initial case study targeted the AECI Umbogintwini industrial complex consisting of 13 individual factories. Due to interest expressed by industry, investigations were also conducted at Sanachem, Eskom Lethabo and Mondi Merebank. At the Sasol Polymers Chlor-Alkali Plant, one of the three largest water users in the AECI complex, the study identified potential savings of 72% in water use and 45% in effluent generation. At Sanachem the investigation identified measures to reduce water use by around 40%, proportionate reductions in the generation of toxic and other effluents, and simultaneously a 25% increase in production capacity due to reduced batch times. At Lethabo Power Station, the pinch analysis quantified the balance to be struck between the quantities of river water, mine water and regeneration chemicals used and the volume and quality of the net effluent generated. One scenario showed that it was technically feasible to use the RO plant to operate the combined mine and power station together on a zero-liquid effluent basis with identifiable cost considerations. In general it was concluded that water pinch analysis provides a clear and systematic picture of the water requirements of a system of processes, highlights areas in which water efficiency could most beneficially be improved and provides a rational tool for negotiation on water use targets amongst industry, regulators and other role players.

Cost: *R907 000*
Term: *1998 - 2001*

CURRENT

Thrust 1: Water Services – Institutional and Management Issues

Programme 1: Cost-recovery in water services

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
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*

Payment strategies and price elasticity of demand for water in different income groups at three selected areas
Marketing Surveys and Statistical Analysis
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*

Programme 2: Institutional and management issues - Water services

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
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*

Programme 3: Innovative management arrangements - Rural water supply

Development of models to facilitate the provision of free basic water in rural areas
Mvula Trust
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 stand-pipes, 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*

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
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)*
- *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
1400 A

Sub-project: The development of a child-centred course for teachers to promote basic health and hygiene awareness in rural communities
Lenehan Engineering and Environmental Consulting
1400 C

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
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
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
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

Strategies to ensure sustainable effective disinfection in small municipal water distribution systems
Department of Biochemistry and Microbiology, University of Fort Hare
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 storm-water and groundwater ingress on municipal sanitation services
Water Systems Research Group, University of the Witwatersrand
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 storm-water and groundwater ingress.

The effects of urban developments on storm-water quality and quantity as well as groundwater infiltration into the sewer facilities cannot be left anymore to ad hoc solutions and there is 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

Development and evaluation of new South African ozoniser technology for removal of pathogenic organisms, possible enteritic viruses indicated by bacteriophages, and tastes and odours present in Hartbeespoort Dam water
PARC Scientific
No 1127

Ozone is recognised as very effective in the removal of pathogenic organisms, enteritic 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
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
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 cavitational flow
Rand Water
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*

Nanoporous polymers for the removal of organic contaminants in water
Envi Sabi Scientific
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
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

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
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*

Durability and performance testing of operational basin solar stills, including microbiological water quality characterisation
McCracken Solar Stills (Pty) Ltd
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*

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
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 3: Drinking water quality

Systems for the abstraction of surface water through river sand-beds
Chunnett, Fourie and Partners (CE)
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
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*

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
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

Investigation of the performance of domestic copper pipe in coastal areas
Pipeline Performance Technologies
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: *2001-2004*

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
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 – 2004*

The optimisation of water and wastewater treatment and supply systems using advanced process control techniques
Pollution Research Group, University of Natal
No 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
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 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

Development and monitoring of integrated algal high-rate oxidation pond (AHROP) technology for low-cost treatment of sewage and industrial effluent
Department of Biochemistry, Microbiology and Biotechnology, Rhodes University
No 799

This project is undertaking comprehensive monitoring of integrated algal high-rate oxidation pond (AHROP) 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
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
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
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
No 1178

This is one of three projects (WRC **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 characterizing 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
No 1179

This is one of three projects (WRC **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
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
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
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*

Material mass balances over and modelling of wastewater treatment plants
Department of Civil Engineering, University of Cape Town
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
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
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
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

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
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*

An evaluation of dedicated land disposal practices for sewage sludge
Institute for Soil, Climate and Water, ARC
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
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*

A detailed metal content survey of South African sewage sludges and an evaluation of analytical methods for metal determination
Research and Development, ERWAT
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*

Scale-up development of the Rhodes BioSURE® process for sewage sludge solubilisation and disposal
Department of Biochemistry, Microbiology and Biotechnology, Rhodes University
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 optimised, 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
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 LC_{50} 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
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 utilization 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

Assessment of a baffled (compartmentalised) anaerobic digester for the treatment of high-strength and toxic organic industrial effluents
Pollution Research Group, University of Natal
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
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.
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
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
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
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
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 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
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
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
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
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
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*

Monitoring, evaluation and verification of long-term performance of passive treatment plants at Vryheid Coronation Colliery
Pulles, Howard & de Lange Inc.
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
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 resveratrole) 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
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
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
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
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
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
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/pretreatment 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

Solids stabilisation of soluble wastes generated in the South African ferrochrome industry
Council for Mineral Technology (Mintek), Mineralogy & Process Chemistry Division
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
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 Mℓ/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
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
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 (neutralization 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
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_2S), 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*

Effective design of woven fabric microfiltration and tubular filter press technologies for different process applications in South Africa
Umgeni Water
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*

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
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 neutralized two highly corrosive waste streams. The resultant effluent was approximately neutral and could be further treated by ion exchange and electrodialysis 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*

An investigation of the mechanism and kinetics of bacterial sulphate reduction
Department of Chemical Engineering, University of Cape Town
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
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*

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 BioSURER process
Pulles, Howard & de Lange Inc.
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*

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
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
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

Electrochemical treatment removal of phosphates and sulphates from sewage and acid mine drainage respectively
Anglo Coal, Anglo Operations Ltd.
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 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
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

Development of an appropriate procedure for the closure of deep underground gold-mines
Pulles, Howard & de Lange
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*

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.
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
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

Practical application of special waste co-disposal with municipal refuse at the Coastal Park landfill bioreactor
Cape Metropolitan Council
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*

Improving the performance of covers for the rehabilitation of coal-mine residues
Golder Associates Africa (Pty) Ltd
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

Further application and development of pinch analysis for water and effluent management
School of Chemical Engineering, Pollution Research Group, University of Natal
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
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
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
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*

Promotion of biodegradable chemicals in the textile industry using the Score system: Phase 1 – Pilot study
School of Chemical Engineering, University of Natal
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
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
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

Investigation into the long-term impact of inter-mine flow in the Mpumalanga collieries
Institute for Groundwater Studies, University of the Free State
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
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 the Free State, with special emphasis on predictive tools and long-term water quality management
Institute for Groundwater Studies, University of the Free State
No 1263

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 and1264** will investigate the management of under-groundwater flow in collieries at various stages of closure with an aim to minimize 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
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 project 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*

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
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
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^2. 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*

NEW

Thrust 1: Water Services – Institutional and Management Issues

Programme 2: Institutional and management issues - Water services

Pilot initiative on setting up a benchmarking process for the water services sector
Phillip Pybus Consulting Engineers
No 1435

Water institutions in South Africa need information about the performance of their organizations as well as that of other similar organisations in order to compare performance. Such information is not readily and routinely available due mainly to a lack of a common framework within which to communicate and share the information effectively. Benchmarking is a process for continuous improvement that involves the measurement of performance. It is a continuous, systematic process for evaluating the products, services and work processes of organisations for the purposes of organisational improvement. It is a process where organisations exchange ideas and methods of working amongst themselves, with a view towards improving their own performances and striving towards best practice. The benchmarking process enables an organisation to compare and improve performance in a number of areas, both within the organisation and across organisations. This study is a follow-up on a completed study to put to affect the guidelines and principles of benchmarking of water services through a pilot initiative. This priority study will result in developing a fully functional methodology and support system to facilitate benchmarking in the sector.

Estimated cost: *R 1 600 000*
Expected term: *2003 to 2006*

Programme 3: Innovative management arrangements - Rural water supply

An identification and review of the factors in rural water services that facilitate and impact on local economic development in the Eastern Cape
Rural Support Services
No 1437

There has been ongoing debate in the water and sanitation sector regarding the importance of viewing water

services projects as part of an integrated development programme rather than as one-off projects that are seen as an end in themselves. One of the main issues related to this is the importance of, and ongoing need for local economic development in rural areas. This is an issue that should be addressed in both the planning and implementation stages of any project with the full participation of community members. However, the current framework for delivery does not allow for the facilitation and promotion of economic development. This is particularly problematic given the current context of unemployment and poverty in rural areas.Water supply and sanitation are considered to be very good catalysts which can stimulate local economic development in poor areas. Yet many initiatives both locally and internationally tend to obviate this opportunity. This study aims to investigate the factors which would influence LED and the outputs will be guidelines that would influence LED during implementation of WSS projects.

Estimated cost: *R 300 000*
Expected term: *2003 - 2005*

Programme 5: Peri-urban sanitation research

Guidelines for basic sanitation to informal settlements- promotion, institutional arrangements and capacity building
Peninsula Technikon
No 1438

Rapid urbanisation is a critical challenge to those charged with service provision to urban centres in developing countries. Unable to keep up with the rapid pace of population growth many urban centres have experienced a substantial increase in the number of people living below the poverty line in informal or unplanned settlements, many of which are illegal. Most informal settlements lack access to adequate and affordable basic services such as water supply and sanitation. Until recently improvements were considered a "pull factor" that would attract additional immigrants into informal settlements that were temporary in nature. National policies and regulations therefore discouraged or prohibited local authorities from providing adequate services within these settlements. Where lack of adequate policies is not a factor, difficult terrain and working conditions and poor cost-recovery inhibit action by utilities and local authorities. There is a lack of guidelines that take cognizance of local conditions and challenges in the provision of sanitation to informal areas. This research project builds on an initial study of sanitation demand and delivery in informal settlements in the City of Cape Town and focuses on three key components for a sanitation delivery programme to informal settlements. This study aims through an action-orientated process of evaluation, monitoring and pilot studies to develop guidelines relevant for the sector. It aims to cover the key areas of institutional models for service delivery, marketing and communication, sanitation and capacity requirements.

Estimated cost: *R 550 000*
Expected term: *2003 - 2005*

Strategy for the furtherance of knowledge and good practice of ecological sanitation (ecosan) technology in South Africa
Boutek, CSIR
No 1439

VIP toilets, correctly engineered and implemented, are a good means of providing a dry sanitation service, but these systems are not without their problems. If a dry toilet (i.e. not requiring water for its operation) is designed and constructed in such a way that the faeces vault can be quickly, easily and safely emptied, then one of the biggest maintenance problems will be obviated. If the processed excreta can also be productively and safely used for agriculture, the technology will become even more attractive. In South Africa, where many rural communities rely on subsistence agriculture, often in poor soils, and with urban agriculture becoming more common, this is an important aspect.

Urine-diversion ecological sanitation (ecosan) systems address the above problems. They have been successfully implemented in many countries, including South Africa where about 3 000 of these toilets are already in existence. However, despite much research having been carried out internationally and locally, various questions still remain, particularly on the health aspects of operation, maintenance, and excreta reuse or disposal. Not enough is currently understood about the processes taking place inside the faeces vault, and there is still disagreement on safe retention periods and stability of the final product. The roles of dryness, pH, temperature and time in pathogen destruction need to be further clarified. Furthermore, institutional aspects associated with widespread implementation and management of ecosan are largely unresearched in South Africa, and this will be a handicap to large-scale implementation unless efforts are made to address the matter.

A need has thus been identified to create further competence in this area of sanitation in South Africa, and to

increase knowledge concerning the technology.Ecosan technology is still at a conceptual and development stage, yet all indications are that it has the potential to provide benefits in the provision of sanitation. The technology is increasingly being introduced in a manner which consists of faulty design, poor implementation and improper use. This study aims to develop strategies and guidelines, through monitoring and evaluating existing schemes, which would provide fundamental answers in the sustainable management of this technology.

Estimated cost: *R 820 000*
Expected term: *2003 - 2006*

Drainage in rural and peri-urban townships
Water Systems Research Group, University of the Witwatersrand
No 1440

It is well known that drainage in low-income areas is lacking, leading to increased risks of flooding and environmental health. South Africa suffers from a backlog and inadequacy in drainage services, particularly in peri-urban and rural areas. The differentiation between sewage, grey water or sullage and stormwater is often unclear. In fact, in low-income areas, the paths are often merged. Sewage and solid waste enter surface drains, and pose health threats, are unaesthetic and degrade the environment. In high density, informal settlements, these services are often non-existent or at the most are inadequate and dangerous. Stormwater runoff from low cost townships is polluted by waste and overflows from toilets and goes untreated to watercourses. In some cases, the water is reused posing a health hazard. There is no separate disposal mechanism for sullage. Even where pit latrines or chemical closets are provided, the sullage is discharged onto the surface. This study aims to investigate and pilot alternative methods of drainage systems for low-income areas. The output will be a user guide and software that would assist decision makers in the field.

Estimated cost: *R 520 000*
Expected term: *2003 - 2005*

Thrust 2: Water Supply and Treatment Technology

Programme 1: Drinking water treatment technology

Membrane fouling and visualisation studies
Dept of Polymer Science, University of Stellenbosch
No 1441

Fouling of membrane plants is the main factor which is limiting the extent of their application in water and effluent treatment. The project aims to develop and refine sonic methods to measure the thickness and other important characteristics of the fouling layer in real time without interfering with the module in any way. This technique will also provide an indication of the relative efficiencies of pretreatment methods and cleaning protocols. The use of ultrasound and infrasound will further be investigated for the non-interfering and non-chemical cleaning of fouled membranes. Success in this regard will open the door to a much wider use of this, highly efficient, treatment technology.

Estimated cost: *R 1 500 000*
Expected term: *2003 - 2006*

Programme 2: Water treatment for rural communities

Development of appropriate brine electrolysers for disinfection of rural water supplies
Dept of Chemistry, University of the Western Cape
No 1442

Chlorine disinfection is required for rural water treatment since it has residual disinfecting powers after water has been carried into the homes. This project will further develop a novel system for the generation of chlorine from common table salt. The unit to be developed will not produce toxic chlorates as side-products – as can easily happen when employing currently available salt chlorinators. The unit will further allow pH control of the dosed chlorine liquid, allowing much more efficient disinfection and is a main advantage over the current systems.

Estimated cost: *R 480 000*
Expected term: *2003 - 2005*

The evaluation and selection of small water treatment systems for potable water supply
Chris Swartz Water Utilisation Engineers
No 1443

A large number of small water treatment systems supply water to small and rural communities from surface- and groundwater sources. The decision maker selecting a small water treatment plant has a large number of local and international designs and systems to choose from. The project aims are to identify new and suitable small water treatment systems being marketed for application to small communities and to provide technical and socio-economic guidelines to assist with the selection of such small systems. Promising new systems which have not been used locally yet will be evaluated on pilot scale if required. The guidelines document will incorporate a database on technical and economic information on these small systems, as well as an operation manual for each system.

Estimated cost: *R 1 200 000*
Expected term: *2003 - 2006*

Programme 3: Drinking water quality

Treatment and recovery of organics from agro-industrial processing
Technikon Witwatersrand
No 1444

Diarrhoeal disease accounts for a high proportion of the preventable deaths and illness in South Africa, especially in deep rural areas. The study aims to apply an innovative water quality screening approach to find a link between water quality and diarrhoea since current assays fail to indicate the presence or effects of metabolites of micro-organisms on human health. Current bio-assay methods for testing these inflammatory effects of pathogen metabolites will be adapted for water quality assessment and application to these communities at risk.

Estimated cost: *R 424 400*
Expected term: *2003*

Generic incident management framework for toxic blue-green algal blooms, for application by potable water suppliers
Rand Water
No 1445

An increase in the eutrophication of surface water resources is leading to increased incidence of toxic blue-green algae growth – thereby increasing health risks when drinking water from a treatment plant which does not use activated carbon adsorption in its process train. No structured framework yet exists in South Africa to manage the supply of safe drinking water during a persistent blue-green algae bloom in the source water. The project aims to establish such a pro-active approach by means of a generic algal bloom incident management framework to effectively manage potable water supply when toxic algal blooms are present. Such a system will be widely applicable to water services providers and will reduce the risk of human incidents related to blue-green algae toxins by providing this framework for informed and appropriate pro-active management measures.

Estimated cost: *R 236 300*
Expected term: *2003 - 2004*

On-line real-time enzyme diagnostic system for the detection and monitoring of sewage levels in drinking water
Dept of Biochemistry and Microbiology/ Rhodes University
No 1446

Surface water sources are increasingly becoming contaminated with sewage effluent, with a concomitant increase in human and animal health risks. This project intends developing a novel enzymatic diagnostic assay for the detection of the presence of sewage waste in water. Potential enzymatic markers will be identified for the identification of sewage waste material and to implement these markers for the rapid detection of sewage in water. It is suggested to produce the markers in the form of a rapid-detection test strip containing the enzyme and make it available as a test kit, which unskilled operators will be able to use. This will provide a simple, rapid way of determining any faecal pollution and thereby enable a timely warning of impending health risk

Estimated cost: *R 500 000*
Expected term: *2003 - 2006*

Programme 4: Water distribution and distribution systems

Benchmarking leakage
WRP Consulting Engineers
No 1447

The BENCHLEAK software was developed through the WRC to provide a simple yet pragmatic approach to leakage benchmarking throughout SA. The work undertaken in SA has been recognised as one of the key factors leading to the recent activity in this field and the BENCHLEAK Model is clearly the basis on which many new models have recently been developed around the world. This study aims to apply the Benchleak Index and software developed through the WRC in the water services sector. Outputs from this exercise will demonstrate how water suppliers are performing regarding UAW or water losses, and also be able to compare themselves in an equitable and fair manner with another supplier.

Estimated cost: *R 250 000*
Expected term: *2003 - 2004*

Grouted lining systems for the renovation of old steel pipelines and the design of new pipelines
Rand Water
No 1448

Steel pipes are used extensively in SA and need to be protected against corrosion, hence the need for internal linings and external coatings. In pressure pipes there are many problems associated with the use of grouted-viscous-elastic linings at joints, bends and fittings, etc. This study aims, through laboratory trials and investigations, to provide solutions to this unresolved problem experienced by water suppliers, which costs them large sums of money due to failures.

Estimated cost: *R 736 300*
Expected term: *2003 - 2006*

Thrust 3: Wastewater and Effluent Treatment and Reuse Technology

Programme 1: Biological sewage treatment processes

Characterisation of wastewater from low income - high density housing schemes with full water-borne sewerage and off-site disposal into conventional wastewater treatment works
Ninham Shand
No 1449

The provision of water and sanitation to low-income – high-density (LIHD) communities, many of whom were until recently not serviced, brings with it the need to characterise the diurnal, weekly, monthly and seasonal water use and wastewater discharge patterns, the latter in terms of both quantity and quality. Such characterisation is necessary to provide the same or equivalent level of information available in historically-serviced areas, so that new or extended water supply and wastewater treatment / disposal facilities can be properly designed and operated for optimal technical efficiency and cost effectiveness. The study will be a comparative assessment based on two adjacent LIHD catchments in the Cape Metropolitan area, with differing water, sanitation and demographic profiles. The research focuses on the wastewater aspect but uses water supply and population data to derive specific load parameters which can be compared or applied to other catchments nationally to build up a national database of such information.

Estimated cost: *R 500 000*
Expected term: *2003 - 2005*

Nitrification inhibition assessment of industrial effluents and influent to wastewater treatment works
Pollution Research Group, University of Natal
No 1450

The proposal comprises four parts, viz. nitrification inhibition screening tests of sewage treatment plant influent, branch sewer flow and specific industrial effluent discharges; determination of inhibition kinetic constants using a titrimetric biosensor; combining the WEST computer simulation package with the UCT BNR models to model the effect of inhibitory substances on WWTP performance (part of a larger programme to investigate and promote the modelling, simulation, control and optimisation of South African WWTPs); and providing information to the authorities for better regulation of industrial effluent discharges to sewer. The project will provide linkage with other

municipal/industrial management initiatives such as waste minimisation, the "Score" system, and process improvement, modelling and control. Leverage provided includes free access to WEST software and support (value USD 38 000) and in-kind technical and logistic support from other collaborators.

Estimated cost: *R 800 000*
Expected term: *2003 - 2006*

The production of aerobic granular activated sludge for enhanced settling in sewage treatment
BKS (Pty) Ltd
No 1451

Building on previous work carried out by the group on a synthetic (acetate) substrate, this project aims at the systematic selection of granulated aerobic sludge in a sequencing batch reactor process treating sewage. If successful, the overall process efficiency would be significantly enhanced by improving the sludge settleability. Some similar work has been carried out overseas and the innovation level is relatively modest but equally the risk is reduced.

Estimated cost: *R 327 800*
Expected term: *2003 - 2006*

Programme 2: Sludge characterisation, treatment, utilisation and disposal

Permissible utilisation and disposal of sewage sludge, Edition 2
ERWAT
No 1453

This work implements the major recommendation arising from the comprehensive multi-stakeholder WISA Sludge Management Group in the consultative process co-ordinated by the WRC to review and update the current published sludge management guidelines.

Estimated cost: *R 326 400*
Expected term: *2003 - 2005*

Programme 4: Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents

Modelling of metal ion removal from AMD
Dept of Civil Engineering, University of Cape Town
No 1454

The further development and modelling of a novel chemical process for precipitating ferrous (and other metal) ions will be investigated. Key features of the process are significantly lower capital costs (due to reduced hydraulic retention time and hence smaller reactors), lower operating costs (lower oxidation demand permitting the use of air rather than pure oxygen), the capacity for non-ferrous metal ion removal (by cation substitution) and the formation of a stable, high-density magnetite sludge which is rapidly dewaterable and moreover has a commercial recovery potential

Estimated cost: *R 360 000*
Expected term: *2003 - 2005*

Programme 5: Training in wastewater treatment plant operation

Assessment of wastewater treatment plants to prioritise and implement appropriate actions to ensure operational effectiveness and efficiency
Rand Water
No 1455

The project focuses on the correct maintenance and operation of treatment plants as capital assets that have already been financed. The approach adopted is to audit a range of plants and to systematize the data obtained using established benchmarking procedures. An existing database of information on 85 wastewater treatment plants in the RWB area will be augmented. An "options matrix" will be developed and then tested and applied to achieve cost-effective improvements in a range of performance areas. The proposed budget cost to the WRC (R139 131 over 2 years) is very reasonable and the project is expected to deliver value-for-money

benefits.

Estimated cost: *R 139 131*
Expected term: *2003 - 2005*

Programme 6: Biotechnological co-treatment of saline and sewage wastewaters

Biotechnological co-treatment of saline and sewage wastewaters with integrated recovery and reuse of water and organic and inorganic components for sustainable development.
Part 1: Saline sewage treatment
Part 2: Biosulphidogenic sewage treatment
Part 3: Hybrid systems for treating acid mine drainage
Part 4: Integrated community benefit
Dept of Biochemistry and Microbiology, Rhodes University
No 1456

The overall objective is to exploit and further develop beneficial applications of biotechnological processes for co-treating saline and sewage wastewaters in the sustainable and integrated management of various water-related community, industrial, agricultural and environmental needs. The specific research objectives are to determine the economic, social, technical and technological feasibility of a biological process for treating sewage reticulated in saline water, including nutrient removal and disinfection, for urban and rural communities (the "Saline Sewage Treatment" component); develop, test and demonstrate processes for biological treatment of effluents from the bio-sulphidogenic co-treatment of mine water and sewage sludge to standards suitable for a range of subsequent beneficial uses, and biotechnological oxidation and recovery of sulphur from such systems (the "Bio-sulphidogenic Sewage Treatment" component); develop, test and demonstrate hybrid active-passive systems for sustainable treatment of acid mine drainage before and after mine closure (the "Hybrid Systems for Treating Acid Mine Drainage" component) and develop integrated social responsibility / community components for employment opportunities, job creation, and other community upliftment benefits derived from the biotechnological applications envisaged (the "Integrated Community Benefit" component).

Estimated cost: *R 3 000 000*
Expected term: *2003 - 2005*

Thrust 4: Industrial and Mine-Water Management

Programme 3: Minimising the impact of waste on the water environment

An investigation into the use of permeable reactive barriers (PRBs) for the treatment and control of radionuclide and trace element contamination of water resources in South African mining lands
Ninham Shand
No 1457

It is very difficult to contain pollution plumes that originate from sources such as gold-mine tailings dams, and curtail the further contamination of groundwater. This project aims to introduce the local use of permeable reactive membranes for this purpose. Internationally, this technology has been applied successfully to shallow, porous (i.e. primary) aquifers to remove targeted contaminants. This project will investigate the feasibility and application potential of permeable reactive membranes under SA conditions, where groundwater mostly occurs in fractured aquifers that occur relatively deep below the surface.

Estimated cost: *R 1900 000*
Expected term: *2003 - 2004*

Stability and neutralisation capacity of potential mine backfill material formed by co-disposal of fly and acid mine drainage
Coaltech 2020
No 1458

The disposal of both fly-ash and acid mine drainage (AMD) present major problems in SA because of their magnitude and potential impact on water resource quality. This project follows on current WRC **Project No 1242**. The initial project demonstrated the feasibility of using fly-ash to neutralise AMD and produce zeolites. The zeolites are produced at very competitive prices and lock heavy metals in. This has the major advantage that heavy metals present in AMD are removed at the same time as it is neutralised. The metals locked within the zeolites may provide an added advantage where zeolites are used as catalysts in industrial applications. The new project aims

to test the initial results under larger scale, practical, field conditions, while continuing with more basic laboratory work.

Estimated cost: *R 420 000*
Expected term: *2003 - 2005*

Programme 4: Minimising waste production

Characterisation of microbial populations and identification of dominant microorganisms in different paper mill water systems
Dept of Microbial, Biochemical and Food Biotechnology, University of the Free State
No 1459

The water quality in a paper mill deteriorates as the overall water consumption of the mill decreases. This is due to an increasing amount of recycling of the water and less purging of contaminants. The water quality can deteriorate to the extent that paper-making becomes ineffective and paper quality suffers. Odours can also develop and the water can become threatening to the health of workers. Management of the water system thus becomes one of the most important constraints to reducing water consumption in a paper mill. This project aims to develop understanding of which organisms develop under different conditions in a paper machine water system that will play a major role in the development of better management systems and, thereby, enable a reduction in water consumption and the release of waste products.

Estimated cost: *R 686 050*
Expected term: *2003 - 2006*

Development of water balances for operational and post-closure situations for gold mine residue deposits to be used as input to pollution prediction studies for such facilities
Pulles Howard and de Lange
No 1460

The area covered by slimes dams is in the order of 400 km^2. Previous research has indicated a varying but significant potential for pollution underneath these dumps. The overall water balance of a dump is the main driving force behind this pollution. The water balance of tailings and rock dump facilities is not very well understood at present, both locally and internationally. This seriously limits our ability to make reliable predictions of post-closure pollution potential and to properly evaluate environmental management / rehabilitation strategies. This project aims to develop a procedure and methodology that can be used in developing water balances for gold-mine waste residue deposits. These water balances play a critical role in geochemical modelling of such deposits.

Estimated cost: *R 913 500*
Expected term: *2003 - 2006*

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ksa 4

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
- 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.

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.

Portfolios of current projects have 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

Scope: 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. 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. 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.

- 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

Scope: 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. 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.

- Water-efficient production methods and systems in agro-forestry, woodlands and forestry plantations

Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture

Scope: 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. 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. 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.

- Sustainable water-based agricultural activities in rural communities
- Integrated water management for profitable farming systems

Thrust 4: Water Resource Protection and Reclamation in Agriculture

Scope: 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. 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. Agricultural decisions to cultivate land and to conserve rainfall or to withdraw water from rivers, dams and boreholes, has 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.

- Sustainable water resource use on irrigation schemes and within river catchments
- Impact assessment and environmental management of agricultural production

Budget for research portfolio in 2003/04

The approved funding of the research portfolio of current projects and projects commencing in 2003/04 leads to committed funding of R9.9m in 2003/04.

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 dryland cropping and by

natural grasslands, woodlands and forests. Rainwater runoff and deep percolation become available as surface- and groundwater of which approximately 59% 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 13.8 million 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 10.5 million people are poor and are living below the breadline 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. Expansion of agricultural production on land suitable for cultivation will be constrained by the availability of water. At the same time there is a high ratio of people to cultivated land and a dependence on agriculture in rural areas, particularly of the poor. All of this will 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 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)

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 which are discussed 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.

Overview of technological trends related to needs

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 irrigation 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.

In particular, attention will have to be given to rain-fed agriculture and the existing technologies which have been developed for water harvesting in Sub-Saharan Africa. The impending challenge for research is therefore to adapt or 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, locally 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 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. Current activities of

relevance to the WRC are:

- 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 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 Integrated Development NPA 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, livelihood 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, Natal, 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.

Most of the research supported by this KSA is conducted by universities (50.1%). The ARC and the CSIR are responsible for approximately 29.6% of the research and 20.30% of the research is carried out by private consultants.

Research portfolio for 2003/04

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.

Expected outcomes

In the KSA: **Water Utilisation in Agriculture**, a holistic approach is followed to enable people to utilise water in a sustainable way for food production. This contributes towards improved living conditions, maintenance of the productive capacity of water resources and availability of food and fibre products from rain-fed and irrigated cultivation. The participation of end-users in research projects and the application of knowledge generated

through research are considered to be key success factors.

A description of the research thrusts and programmes is given in **Table 1**.

TABLE 1
Overview and description of thrusts and programmes funded within KSA 4

THRUST 1: WATER UTILISATION FOR FOOD AND FIBRE PRODUCTION	
Scope: *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 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture	**Scope:** 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.
Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture	**Scope:** 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	
Scope: *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.*	
Programme 1: Water-efficient production methods and systems in agro-forestry, woodlands and forestry plantations	**Scope:** 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	
Scope: *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.*	
Programme 1: Sustainable water-based agricultural activities in rural communities	**Scope:** 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.
Programme 2: Integrated water management for profitable farming systems	**Scope:** 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.

THRUST 4: WATER RESOURCE PROTECTION AND RECLAMATION IN AGRICULTURE	
Scope: *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 1: Sustainable water-based agricultural activities in rural communities	**Scope: I**ntensification 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.
Programme 2: Impact assessment and environmental management of agricultural production	**Scope:** 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 2003 and 31 March 2004

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 irrigated agriculture

Evaluation of a model for water use in deciduous fruit orchards and scheduling of irrigation with the aid of meteorological data
ARC
No 892

Water is the most limiting natural resource in terms of agricultural development in South Africa. However, fruit production, particularly in the Western Cape, is only possible under irrigation. Any restrictions on water use will have detrimental effect on the fruit industry.

In the Western Cape, 80 % of the farmers do not use scientific irrigation tools or programmes. This usually leads to over-irrigation. Improved irrigation scheduling could reduce the wastage. Scheduling requires water budgeting. Water budgeting requires, among others, evapotranspiration (ET) estimation, which is estimated by mathematical models from meteorological, soil and crop-related data.

Several ET models being used in SA were developed for annual crops. They are therefore not applicable to fruit trees where partial or total wetting of the soil surface under irrigation occurs and tree frame makes estimation of water use from meteorological data more difficult. The project was aimed at validating a model and its reliability in irrigation scheduling for fruit trees when linked to a weather station.

Output parameters indicated reasonable agreement of predicted Soil Water Balance (SWB) to measured soil water deficit. It was also noted that the model could under estimate evaporation grossly for warmer areas where the canopy cover fraction exceeds the irrigated fraction of the soil.

The use of an irrigation scheduling model such as SWB, that utilises the dual crop co-efficient approach, has the potential to improve irrigation water management of orchards based on meteorological data. Furthermore, development of separate water balances for trees and cover crop under full surface irrigation in the SWB model could enable more realistic simulations.

Cost: R561 500
Term: 1998 - 2003

Contribution of root-accessible water tables towards the irrigation requirements of crops
Department Soil Science, University of the Free State
No 1089

Approximately 260 000 ha of irrigated arable land in South Africa has shallow water tables, in or just below the potential rooting depth of annual crops. Proper utilisation of shallow water tables can contribute towards water requirements of crops, and is recognised as an important water resource in agriculture. When utilised improperly, however, shallow water tables can result in severe crop and soil losses due to salinisation of the top soil.

Understanding the capillary contribution from shallow water table towards crop water requirement is considered to be an important management tool to ensure conservation of natural resources. The project, therefore, quantifies the contribution from shallow water tables in different textured soils, formulates decision support system for the optimal use of irrigation water under shallow water table conditions and identifies future research needs.

Lysimeter experiments were conducted over three years, using dominant soils in the Free State province. Various crops were used. Treatments included various levels of constant and falling water tables between 1 m and 1.8 m depths.

Wheat used more water from the water tables compared to maize, peas and groundnuts – whilst groundnuts used the least. The cumulative uptake from the water tables over the growing season ranged between 38 and 63 % for wheat, 25 and 53 % for maize, 30 and 55 % for peas, and 21 and 45 % for groundnuts. During peak water uptake, the constant water table at 1 m contributed up to 90 % of the daily evapotranspiration for all the crops. The height of capillary rise from the water table is therefore important. This is usually high in soils with high silt and clay contents.

Both SWB and SWAMP models were used to simulate the uptake from shallow water tables and the estimated values were comparable to the measured values.

In this study, it is evident that crop irrigation requirements can be reduced with an amount of water taken up from a water table. Procedures were also developed to modify irrigation scheduling methods for such conditions.

Cost: R498 000
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
No 1136

The production of subtropical fruits and their quality are influenced by the amount of water received at specific production stages. Since plant water requirements are usually satisfied through irrigation, maximum water use efficiencies can be achieved by irrigating only during those critical stages of production. The goal of modern agriculture is to use less water for irrigation without compromising on fruit quality or yield.

The project was aimed at:
- Determining vegetative and reproductive growth habits of trees which are critical for the application of regulated deficit irrigation. This could also improve fruit quality.
- Improving shelf-life of produce by manipulating water supply to trees.
- Adapting the existing PEACH growth model for mangos.

A five- to- eight-year-old mango orchard was identified in Hoedspruit. Five irrigation treatments of RDI (reduce deficit irrigation) were applied. Transpiration and leaf conductance were measured. Seasonal crop yields and fruit quality were determined

The study reveals that deficit irrigation represents a suitable irrigation method to save water and simultaneously achieve optimum yield, particularly under water scarce conditions. Reduced deficit irrigation, however, requires regular monitoring of soil water status, preferably on a daily basis. Water savings, up to 24 %, were achieved with reduced irrigation deficit, compared to control treatment. The period of water reduction before flowering in the RDI treatment could be optimised further by bringing it forward. In that way, negative effects of reduced irrigation will be avoided while additional savings on irrigation water are achieved.

The current irrigation management practice on the farm (Hoedspruit) indicates that there is over-irrigation. This leads to water and nutrient losses, mainly on coarse sandy soils that are used. Furthermore, the Co-F (farm control) treatment had relatively low WUE values, indicating that too much water used does not lead to equally good

yield.

Reduced deficit irrigation will, if adopted, lead to savings in the amount of water used for irrigation, as well as savings in pumping and other costs. It is also possible that this treatment will improve fruit quality, and therefore, income.

Cost: R984 000
Term: 2000 - 2003

Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture

Health risk assessment In connection with the use of microbiologically contaminated source waters for irrigation
University of Stellenbosch and University of Pretoria with collaborator: Department of Community Health, University of Stellenbosch and Department of Medical Virology, University of Pretoria
No 1226

The presence of dense settlements on the river banks in the Western Cape give rise to water pollution of nearby rivers and severely affect the water quality downstream. Most of the water pollution can be attributed to inadequate sanitation in these settlements, severe overcrowding, as well as failing sewerage systems.

The study was done in two phases. In Phase A of the project a general overview of sanitation problems associated with dense settlements and background to the study site selection and environment gave an indication of the problems that could cause pollution of the nearby watercourse. *Esherichia coli* was used to quantify the faecal pollution in the river.

The results from the study revealed the high incidence of diarrhoea in the area and faecal pollution in the river over four years. Pathogens carrying considerable health risks were identified in the water. A number of the organisms in the water and in the biofilms on the stones in the water exhibited signs of antibiotic resistance and also resistance to chlorination. A further complication was that some of the organisms surviving the chlorination experiments showed enhanced antibiotic resistance. Several viruses were also detected in the water and the biofilms.

Recommendations were made to the prevention of the pollution, such as ongoing education campaigns that proved to be successful, and remedial actions such as interventions in sanitation and services rendered were proposed. The risks to health, environmental damage and the problems foreseen with economic activities downstream a faecal polluted river set the scope for Phase B of the project which investigated the microbiological quality of irrigation waters and contamination of foods crops.

Food-borne illnesses remain a widespread and growing public health problem in the developed and developing world and the burden of infection is grossly underestimated. Minimally processed foods such as salads, vegetables, fruits and other fresh produce that required minimal processing before consumption are usually contaminated through human contact during harvesting or processing, but contamination via waste water and sludge used for crop irrigation and fertilization, has also been documented. Increased faecal pollution due to the lack of sanitation or waste water plants not complied with standards may elevate risks of food- and water-borne disease in SA.

The isolation and detection of enteroviruses, human adenoviruses, HRVs and HAstVs from a river used for domestic purposes and as irrigation water suggests that the water could pose a potential health risk, but more data are required to quantify the risk. Pathogenic bacteria such as *Salmonella*, *Shigella* and *E. coli* were detected in a number of irrigation water and minimally processed foods samples.

Cost: R100 000
Term: 2001 - 2003

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 unguilata, Vigna subterranean* and *Amaranthus* spp.
ARC
No 944

Drought is a very common abiotic stress condition, thus economically important crops with high levels of drought

tolerance are of great value. The unpredictable and variable forms in which drought stress manifests itself, complicates the selection of superior plant material as well as breeding programmes.

The main objective of this study was to evaluate the drought tolerance of vegetable crops grown in environments where the crop yields are influenced by limited water supply. Germ-plasm of the cowpea (*Vigna unguilata*), Bambara groundnut (*Vigna subterranean*) and *Amaranthus* was collected by personnel of the University of Zululand and the Sustainable Rural Livelihood (SRL) unit of ARC-Roodeplaat.

A multidisciplinary approach was followed to measure the effect of drought stress on the physiology, biochemical and morphology of these plants, and to identify mechanisms that allow the plants to survive severe drought stress. Selected lines/ species as well as plant material collected from the communities were cultivated under optimum greenhouse conditions until the plants were subjected to drought stress by withholding water after which various screening methods were used to determine the levels of drought tolerance.

Demonstration trials of *Amaranthus*, Bambara groundnut and cowpeas were established in Soshanguve and Bronkhorstspruit in co-operation with farmers in order to introduce the crops to community members and to encourage them to be willing to evaluate them for acceptability and potential income generation. Eleven families from KwaZulu-Natal and Gauteng were involved in the first community trials.

It was found that *Amaranthus* appears to tolerate water stress by means of mechanisms of osmotic, metabolic and photosynthetic adjustment. From these results it can be concluded that some of the most important physiological factors which effect drought tolerance in amaranth seems to be:

- Limitation of water loss by reduction of leaf area
- Ability to maintain a high water potential during water deficit
- Efficient rooting ability and root/shoot ratio to exploit all available soil moisture
- Maintenance of water status through osmotic adjustment.

The most suitable methods for screening large numbers of cowpea plants for drought resistance are:

- Chlorophyll fluorescence (JIP-test)
- Free proline levels
- Wooden-box screening for drought resistance at the seedling stage
- Relative water content.

One of the strategies used by cowpeas to survive unfavourable conditions is very sensitive stomatal control to minimise water loss.

The most suitable screening methods for Bambara groundnut selection are:

- Chlorophyll fluorescence
- Free proline
- Wooden-box screening
- Yield

These all form an important part of the plant's survival.

The communities targeted to participate in this project were generally very enthusiastic about the new crops. The cultivation of the crops was well accepted by the eleven farmers in the test trial and they were all able to find suitable markets for the crops. The initial farmer participation was extended to 20 other farmers, who were generally very enthusiastic about the new crops and willing to grow them. They indicated that they learned a lot during the trials regarding cultivation, utilisation and general nutritional value. Valuable information was gathered on community preferences regarding these crops.

The information obtained through this study contributes towards a better understanding of the physiological and morphological basis of drought tolerance in indigenous crops. The techniques selected were able to distinguish between drought tolerance in the different genotypes tested. It was also noticed that the different species reacted differently to a drought stress. Some of the selections out performed the control drought tolerant lines, indicating the successful identification of increased drought tolerance in the germ-plasm screened in this study.
Cost: R735 000
Term: 1998 - 2003

Cheap and simple irrigation scheduling using wetting front detectors
Department of Soil Science and Plant Production, University of Pretoria
No 1135

Soil-water monitoring has improved irrigation, compared to other methods of irrigation scheduling. However,

studies have shown that farmers who use irrigation scheduling methods invariably save water and/or increase yields. At the same time, surveys show that very few farmers make use of scientific tools to schedule irrigation. The gap between advances in irrigation science and the practice of irrigation scheduling is traditionally seen as a failure in adoption that should be addressed by extension services.

The wetting front detector (WFD) follows a model that pursues "learning-based" approaches. It starts from the simplest requirement of the user – whether irrigation water penetrates to the desired depth. This assumes that farmers want to replenish the water in the root zone that had been used by the plants. Detectors are placed in a pair, a shallow one about half-way down the managed root zone and a deeper one towards the bottom of the managed root zone.

If detectors are rarely activated, the crop is likely to be under-irrigated. If both detectors regularly respond to irrigation, the crop is likely to be over-irrigated. Ideally, irrigation should fall between the two extremes. This project evaluated both the acceptance of WFD by farmers and a test of accuracy.

The learning-based approach taken as starting point is the farmer's current practice, implicitly valuing the farmer's existing skill level. The farmer watches the response of the WFD and decides what it means. For this project to achieve its objective, the WFD must achieve two tests. Firstly, the device must make intuitive sense to farmers. It should be easy to install and give results that the farmers believe in. Secondly, the WFD must pass the scientific test – crops irrigated on the basis of the device must perform adequately against other scientific procedures.

Wetting front detectors were installed on a number of farms throughout the country – among commercial and small-scale farms, annual and perennial crops, different soil types and irrigation systems. Experience from these users form the basis of the farmer evaluation of the WFD technology. A research trial at Hatfield research station, where various ways of using the detector were compared with standard irrigation scheduling practices, formed the basis of the accuracy test. The third aspect was intensive monitoring of wetting front detectors on farms.

Farmers' perceptions changed after the introduction to the WFD. For some farmers, this change was relatively quick to accept WFD as decision support tool. Farmers in general indicated their willingness to trial/test the WFD in their farming systems, and that served as a clear indicator that farmers were prepared to enter into a constructive learning approach. The direct experience on the farm helped farmers to build confidence in the use of the WFD and the fact that they could actually monitor the movement of the wetting front. The freedom of understanding how the WFD works and integration of the knowledge with important biophysical aspects involved in the operation of the device is a very important factor in terms of the learning experience by the farmer.

Cost: R961 000
Term: 2000 - 2003

Investigation into the potential of sustainable irrigation in Black developing communities of two subcatchments of the Pongola and Thukela Rivers
Sineke Developments (Pty) Ltd
No 1138

South Africa has various initiatives that support irrigation as a means of social and economic development. The national water policy aims at, among others, increasing access to water for economic development.

Emerging irrigation farmers, however, need new farming systems which should be developed on the basis of understanding of local social and economic circumstances of developing communities where the irrigation scheme is to be established. The history of irrigation development in black communities shows that the socio-economic realities to sustain irrigation are inadequately incorporated in the irrigation development process. During establishment of irrigation schemes, clear actions to address the circumstances of such communities are seldom taken.

The aim of this project was to determine community circumstances that, if overlooked, will impact negatively on established irrigation schemes, leading to failures of development initiatives. Two small-scale irrigation schemes, Keat's Drift and Esiphongweni, both located in KZN, were analysed for the purposes of this study. The study shows that irrigated agriculture among Black communities has mainly consisted of government controlled schemes. Post 1994, financial and in-kind assistance has been growing towards promoting local/community management of these schemes as most of them had been controlled by government.

In most cases, other livelihoods that the communities are engaged in, were not actively encouraged during irrigation scheme establishment. This often hindered the economic strengths of the schemes or traditional practices of survival.

Technological constraints still exist. In most cases, training on irrigation infrastructure has mainly been conducted on maintenance and not on the effective use of the irrigation system(s). Technologies are not always planned (and implemented) to suit the needs of small-scale farmers.

Gender biases experienced in most development initiatives have ignored women in most irrigation scheme development stages. Full participation of women, in particular the pre-design stages, is critical but difficult to achieve. In cases where there has been a balance in crafting local irrigation institution, that are sensitive to women needs, performance has increased. The study further indicates that women are involved in the most laborious work within irrigation schemes, while men are only involved in opening and closing pump and controlling pests using pesticides. There is a need to find an appropriate balance between the productive roles of the members of the scheme.

Given the socio-economic circumstances of Black communities in SA, irrigation development will continue to be supported by funding agencies. It is these agencies that must be sensitive to issues/factors that may or may not be quantifiable – which ultimately lead to success or failure of the irrigation scheme.

Cost: R995 000
Term: 2000 - 2003

Water conservation techniques on small plots in semi-arid areas to enhance rainfall use efficiency, food security and sustainable crop production
ARC
No 1176

The project had three main objectives:
- To study quantitatively within the in-field rain water harvesting (IRWH) system, different combinations of mulching techniques aimed primarily at reducing evaporation from the soil surface, soil fertility aspects with the focus on nitrogen, and the sustainability of the system
- To develop the capacity of three previously disadvantaged technical assistants
- To transfer the technology to the developing farmers and to the Department of Agriculture.

The first and second objectives were achieved concurrently by means of field experiments at Glen and on farmers' fields near Thaba Nchu, the technical assistants gaining invaluable skills and experience by being intensively involved in all the relevant activities. The crops grown were maize, sunflower and beans. The third objective was achieved by means of the demonstration plots on farmers' fields, and by numerous information days, lectures and demonstrations in the villages, all held in close cooperation with officials of the Department of Agriculture.

Four different IRWH systems and conventional (CON) tillage were compared in field experiments at Glen and on farmers' fields near Thaba Nchu. The four IRWH treatments were: organic mulch in the basins with a bare runoff area (ObBr); organic mulch in the basins with organic mulch on the runoff area (ObOr); organic mulch in the basins with stones on the runoff area (ObSr); stones in the basins with organic mulch on the runoff area (SbOr). An empirical stress model termed "Crop Yield Prediction for Semi-Arid Areas" (CYP-SA) was developed to enable long-term yield predictions to be made. The composition of the model for each crop is described in detail, together with validation results. Measured yields over three seasons in the field experiments, and predicted long-term yields using the model, showed the following: For all the crops on all the ecotopes the ObSr treatment was the best IRWH treatment, but generally only statistically significantly better than ObBr. These results are strongly supported and eloquently described by the long-term, yield cumulative probability functions (CPFs) obtained with CYP-SA.

Measurements on the experimental plots showed that water losses by deep drainage were negligible during the three growing seasons. Since runoff losses were also zero on all the IRWH plots, the only cause of water loss was evaporation from the soil surface (Es). This was shown on the maize plots to be highest on the ObBr treatment, and similar on the other three treatments, amounting to 79 % and 74 % of the annual rainfall, respectively. The equivalent value for the sunflower plots was approximately 70 % for all the treatments. It is clear that in order to further improve precipitation use efficiency (PUE) above the current best values of 7.4 and 4.8 kg ha^{-1} mm^{-1} for maize and sunflower respectively, it will be necessary to find ways of suppressing Es still further.

Short-term data indicate that the IRWH technique is far more sustainable than CON for this specific study area. Of all the IRWH techniques tested, ObSr has been shown to be the best, followed by SbSr, ObOr, SbOr and ObBr. In general, evaluation of the project in terms of the different sustainability criteria (agronomic productivity, risk - security, conservation techniques, economic viability and social acceptability) really needs to be done in the long-term. Only then could it be properly judged whether or not the project has succeeded in implementing sustainable land management practices (or best practice components thereof) among an acceptable

percentage of the farmers. However, there are sufficient indications that they are moving towards the goals, objectives and outcomes of sustainable agriculture. If the ARC-ISCW perseveres with the approach of 'true participation' for a critical period of at least 5 to 10 years, there is no doubt that sustainability can be achieved.

Taking all the above mentioned results into consideration it can be concluded that IRWH will enhance PUE, promote food security and ensure sustainability. The ObSr treatment was overall the best treatment, followed by SbSr, ObOr, SbOr, ObBr and a bare basin with a bare runoff area (BbBr).

Cost: R1 000 000
Term: 2000 - 2003

Contribution of aquaculture to rural livelihoods: A baseline study
Ichthyology and Fisheries Sciences, Rhodes University
No 1466

Fresh water aquaculture can contribute to economic development and food security in rural areas of South Africa. Policies that support aquaculture development in this country are being developed by the National Departments of Agriculture and Water Affairs and Forestry. However, the major constraint in formulating policy is the lack of information on the status and the potential contribution of aquaculture in rural areas. This was recognised during an aquaculture workshop organised by the Water Research Commission (WRC). Representatives of different stakeholders agreed that a baseline and scoping study was required to determine the contribution of aquaculture to rural livelihoods and to identify priorities for further research.

During the personal survey, stakeholders and participants in rural aquaculture projects were visited and interviewed in five provinces, namely the Limpopo, Mpumalanga, KwaZulu-Natal, Eastern Cape and Western Cape Provinces.

The contribution of aquaculture to the livelihoods of rural communities was found to be negligible. Of the five provinces surveyed, only two (the Western Cape and the Limpopo Province) had functioning projects. In the Limpopo Province, the 10 farms surveyed collectively produced between 5 and 10t of fish per year (carp, tilapia and catfish). The estimated profit made was approximately R50 000. Fifty farmers were associated with these 10 projects. Therefore, on average, each farmer earned R1 000 per year. In the Western Cape, the three trout cage-culture projects that were surveyed collectively produced a total of 16 to 18t of trout per year. The estimated profit that the farmers earned per year was between R64 000 and R68 000. The total numbers of fish farmers associated with the three projects was 30; therefore, on average each farmer made about R2 200 per year. Despite a fairly long history of public sector initiatives to establish rural aquaculture, no organic growth occurred in the sector.

The results of the survey suggest that the establishment of a rural aquaculture sector, which can utilise the potential aquatic resources in a sustainable way for the benefit of rural communities, will be entirely dependent on sustained public sector-led intervention. The failure of "food security" type aquaculture projects, initiated in the past by the public sector, and the decline of public aquaculture facilities should receive careful consideration in the drafting of new aquaculture policy and sector plans. Given the poor track record of the public sector in sustaining support to aquaculture projects, and the relative success of small-scale commercial projects, future policy should emphasise linkages to the existing private aquaculture sector by means of community-public-private partnerships. Misguided development policies of the past and the lack of direction of many of the government facilities highlight the need for an aquaculture policy, appropriate sector plans and the allocation of appropriate resources.

On the basis of the findings of the study, five possible research projects have been identified:
- GIS database of suitable areas for rural aquaculture including small water bodies and environmentally sensitive exclusion zones.
- Supplementary species for cage culture for trout farmers in the Western Cape Province.
- Culture based fisheries in small and large dams
- Recreational fishery development in rural areas
- Evaluation of the role of provincial fish hatcheries and training facilities.

Cost: R 347 100
Term: 2003 - 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

No 1043

Due to the unique characteristics of agricultural non-point source (NPS) pollution, it is not straightforward to quantify exactly who has caused the pollution and how much of it. In part this is due to the complex relationship between agricultural production and damages from water pollution involving physical, biological and economic links. How well NPS pollution control policy performed often depends on how well these links are understood.

The main objective of this research was to develop a spatial decision-support system capable of quantifying economic environmental tradeoffs of alternative NPS pollution abatement instruments.

Specific objectives included:

- Development of procedures to integrate a catchment level NPS pollution simulation model with an economic optimisation model.
- Development of a spatial economic optimisation model capable of linking the spatial use of alternative management practices to a total catchment outlet water quality standard.
- Evaluation of the cost-effectiveness of alternative NPS pollution abatement instruments through the quantification of economic environmental trade-off curves.

The research was conducted in the Gamtoos River catchment. The drainage area of the 70km long Gamtoos River, which is surrounded by the Baviaanskloof Mountains, constitutes an area of 1 357 km^2. About 7 400 ha were utilised to produce citrus, potatoes and other vegetable crops by 242 irrigators using micro-, drip- and centre-pivot irrigation. The Soil and Water Assessment Tool (SWAT) was selected to simulate inputs for the spatial optimisation models that were used to quantify the economic and environmental tradeoffs. Spatial variability in the Gamtoos catchment was taken into account by delineating 22 subcatchments and 129 hydrological response units of which 53 were used for irrigation purposes. The effects of 229 alternative crop, water and fertiliser input combinations on nitrate pollution parameters were thereafter simulated with SWAT.

Results from the baseline analysis indicated that significant variability exists between different subcatchments with respect to gross margins per unit emitted nitrate. However, it could not be concluded that subcatchments with relatively high values would have higher pollution abatement costs when the aim was to abate pollution at the catchment outlet, because each of the subcatchments was contributing differently to the pollution problem at the catchment outlet.

The ability of the non-linear spatial programming model to determine cost-effective economic environmental tradeoffs was clearly demonstrated. Significant tradeoffs were modelled at the subcatchment level due to the existence of both positive and negative tradeoffs, while little trade-off was modelled at the catchment level up to a 20% pollution abatement level. Thus, choice of pollution abatement levels based on catchment level tradeoffs may not be socially acceptable since it may make profitable farming for some farmers impossible.

Controlling the spatial use of alternative management options (crop, planting date, soil and input use) and a pollution tax were proposed as methods to achieve cost-effective pollution abatement. However, these options were very difficult to implement due to the large number of entities that needed to be controlled and the additional cost of obtaining the necessary water quality data at the sub-catchment level.

Another important result was that increasing water cost would not necessarily improve water quality, especially if farmers were using water more efficiently without decreasing the areas irrigated. Increasing water use efficiency would reduce streamflow via reduced return flows. Reducing the amount of water available to dilute the pollution emissions would increase the concentration of the pollutants, thereby decreasing the quality of the water.

Results from the research not only showed that the developed procedures were suitable to quantify economic environmental tradeoffs necessary for NPS pollution abatement policy, but also suggest important policy implications:

- To improve the cost-effectiveness of pollution taxes, taxes should be based on the pollution contribution of each source to the pollution problem at a specific location and not on reduced emissions loads or pollution concentrations at the source
- The cost-effectiveness of taxes on input use was very low

- Water conservation policies with the aim of increasing water application efficiencies would increase water quality problems if farmers were allowed to increase areas irrigated using conserved water

Only through the application of the decision-support system developed in this research would policy makers be convinced about the relative effectiveness of alternative policy instruments to control NPS pollution. Application of these models would further enhance the understanding of the interaction between water legislation, water policy administration, technology, hydrology, NPS pollution and human value systems necessary to advance water policy.

Cost: R683 000
Term: 1999 - 2002

Determining accuracy whereby flow rate of electric pumps can be calculated
MBB (CE) Inc / Agricultural Water
No 1190

Increasing demands on the water resources of Southern Africa require improved management of this commodity. Water metering is generally accepted as one of the most important vehicles in appropriate management of water, and is widely applied in practice, usually by means of mechanical flow meters.

The objective of this project was to develop a procedure, or method, by which water pumped with an electrically driven pump, can be metered indirectly.

Although policies that give guidelines for water measurement have been developed, limited implementation was seen since the proclamation of the National Water Act in 1998. Except for the efforts at the water management pilot study sites, very few irrigation boards (or WUAs) are making a concerted effort to implement measurement, and then usually because they have encountered management problems that cannot be overcome by any alternative other than direct measurement.

Various alternative procedures were tried at the beginning of this project. Existing testing facilities were also visited. Eventually most of the work for the testing phase was done in the laboratory of the Cape Technikon, using pumping equipment made available by the Department of Agriculture, Western Cape. Five test sites were identified for field tests. These were done in conjunction with the project team of WRC **Project 1265**, who are researching the application of flow-meters in irrigation water management. The proto-type meters were installed, calibrated and monitored at these five sites. Without compromising on the accuracy and usefulness of the results, calibration procedures were altered and made simpler during the course of the project.

The research calibration procedure started off with a very broad approach. The procedure was refined to become much simpler during the monitoring process, without losing accuracy of the readings. From the readings of all the tests done (laboratory and field tests) it is evident that there is a good correlation between power used by the pump and the flow-rate of the pump. What is more important is that this correlation is measurable and also that repetitive measurements give similar results. These findings enabled the project team to design the first proto-type meter. The monitoring done with the proto-type meter proved that the design meets the basic requirements for its application.

The results show that this procedure of indirect metering can be accepted as a practical method to measure the volume of water used with an acceptable level of accuracy.

The fact that the meter must be recalibrated periodically is not necessarily a disadvantage, since these actions serve as a useful preventative pump maintenance operation, which would otherwise probably be neglected by management.

Cost: R600 000
Term: 2000 - 2003

Thrust 4: Water Resource Protection and Reclamation in Agriculture

Programme 2: Impact assessment and environmental management of agricultural production

An investigation into the use of pathogenic organisms for the biological control of the troublesome alga Cladophora glomerata
ARC
No 918

Present control methods of *Cladophora glomerata* in irrigation canals in South Africa include mechanical removal or dosing with copper sulphate in reaction to large blooms of the alga. Both are expensive options with high labour or material costs. Neither option leads to long-term control. Because of these problems, two different biological control options are in the process of being investigated, namely the use of sterile triploid Grass Carp, and use of pathogens.

The aims of the project were:
- Investigate the efficacy of selected organisms to control *Cladophora glomerata* under laboratory and field conditions.
- Investigate the mass production, viable and practical formulations for application of, and the optimal dosage rates of the selected organisms.
- Determine the host range of the selected organisms to ensure crop safety.

The first and third aim were achieved; however, as no *Pythium* isolate proved to be highly pathogenic in laboratory conditions, testing under field conditions was not investigated. The second aim was therefore also not pursued.

Further studies were done on the effect of temperature, pH and copper on the growth, zoospore production and zoospore mobility of *Pythium* isolates. Lastly, preliminary studies on the use of *Acacia mearnsii* (black wattle) bark for control of algal growth were carried out. Factors influencing the integration of the use of *Pythium* with other existing or potential control methods were also investigated.

Conclusions reached were:
- The Pythium isolates tested are adapted to the conditions from which they were isolated.
- Copper treatment at 0.5 mg/ℓ Cu+ is unlikely to kill all the *Pythium* mycelium present in a system, but it will reduce the potential inoculum and in particular all zoospores will be eliminated.
- The *Pythium* species tested proved to be incapable of penetrating healthy algal cells, and therefore can't be considered as pathogens with the potential to be developed as a bioherbicide. The fungi are therefore not the causal organism of diseased *Cladophora glomerata* observed previously, and the use of *Pythium* species as biocontrol agents against *Cladophora glomerata* will not be pursued further.
- A few isolates of *Pythium* proved to have a high potential pathogenicity against certain of the crop plants tested.
- *Acacia mearnsii* bark proved to be algicidal (at high concentrations) or to inhibit growth (at low concentrations) of *Cladophora glomerata*.
- Fungal pathogens other than *Pythium* are present in the irrigation schemes, and may yet prove to be valuable biocontrol agents against *Cladophora glomerata*.

Integration with copper treatment would be problematical due to the general toxicity of the chemical to organisms. However the indirect use of pathogens present in the irrigation schemes, after treatments such as water level fluctuation or dosing with low concentrations of *A. mearnsii* bark, or possibly even low concentrations of copper (<0.2 mg/ℓ), may still prove to be valuable within an integrated management programme.

Cost: R279 400
Term: 1998 - 2000

Predicting the impact of farming systems on sediment yields in the context of integrated catchment management
ISCW, ARC
No 1059

Sedimentation is a major threat to water quality, its storage and how it is distributed. The use of computer simulations to predict impacts of farming practices and management on sediment yield in small catchments has had limited application in South Africa. In this project modelling tools, WEPP and ACRU were used in predicting the impacts of farming practices and management on sediment yield.

The study sought to improve methodologies used to predict the impact of selected land uses on sediment yield in South Africa. The improvements in methodologies also involved an assessment of the quality, availability and the spatial distribution of input data for the two models used in the study.

The study considered that integrated catchment management involved three phases which are identification of system characteristics, prediction of the behaviour of the system and management of the system. The study focussed on the behaviour and ways of managing agricultural lands through the use of modelling tools. Three study areas were selected: Weatherly, Zululand and Kokstad. These areas were selected on the basis of a number of factors which included land uses, soil types and patterns, topography, rainfall and availability of data.

Simulations were done in the study catchments for varying land use practices. Both models were applied in each catchment. The results from the models were analysed and compared on the basis of model outputs which included the following:

- Evapotranspiration
- Soil water content
- Runoff
- Sediment yield.

The findings showed that the WEPP Model generated better results on the impact of agricultural practice. The data collection for the WEPP model was however noted to be very challenging as it required very detailed inputs which were not readily available. The ACRU model had the advantage of having readily available datasets for the selected catchments. This study also identified the need to develop approaches which integrate the biophysical environment and the socio-economic environment.

Cost: R843 000
Term: 1999 - 2004

Laboratory- and field-scale evaluation of agricultural use of sewage sludge
ERWAT, ARC and the University of Pretoria
No 1210

While the agricultural use of sewage sludge is a promising alternative use / disposal route for this product over the short to medium term, several concerns restrict large-scale implementation. This project was carried out by a multidisciplinary team comprising researchers from ERWAT, ARC and the University of Pretoria, that conducted laboratory- and field-scale evaluations to investigate some of the concerns and benefits related to its agricultural use. As expected, high levels of extractable metals were found on lands where sludge with a high metal content was applied over extended periods. It was of concern that the extractable levels, contrary to expectations, increased when soils were limed with the intention to reduce plant available metal levels. Even so, no phytotoxic metal levels were observed in pot experiments at the highest loading rates. While conclusive yield increases were observed in pot experiments with sludge addition, in comparison to fertiliser addition, variable environmental effects caused field results to be inconclusive. Incubation studies showed fertiliser-N to be immediately available, while sludge-N was released slowly, reaching a peak after a month, and a third of the total N being mineralised after two months. A limited survey of public perception indicated a generally favourable perception of food produced with sewage sludge.

Cost: R570 900
Term: 2001 - 2003

The use of isotope (13C) techniques to define the riparian zone in commercially afforestated catchments
Environmentek, CSIR
No 1218

The riparian habitat is a physical structure and associated vegetation of the areas associated with a watercourse, characterised by alluvial soils, and inundated to an extent, with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.

The relative abundance of water in the habitat makes it an attractive prospect for commercial exploitation by the forestry and agricultural industry. However, increased riparian tree biomass leads to decreased riparian functioning – which led to the forestry industry deciding to protect the riparian zone.

Forestry is often classified as SFRA (streamflow reduction activity) based on the ability of trees to intercept rainwater and to transpire water that has already entered the soil. Whether the water tapped by the trees is

pyretic (retained in the soil above the saturated zone) or vadose (from, at or below the saturation zone), it remains relevant in the policy framework as the Act considers a holistic concept of the "water reserve".

The policy requires commercial forest owners to pay for the water that their trees use, and to protect the riparian habitat. In both instances the precise delimitation of the riparian area is required. The study used trees as integrators of the edaphic conditions in the vicinity of their roots. Using this approach, the objective was to explore the physical and chemical characteristics of wood that relate to water uptake of the trees and to use these to demonstrate reduced water stress associated with riparian water access. The spatial differentiation of characteristics that proxy water use was combined with the established criteria for defining the riparian habitat to give a more precise measure of the water-use or savings associated with the protection of the riparian habitat. This study is a pilot work focusing into the use of isotope and related techniques to determine water-use strategies of trees.

Cost: R200 000
Term: 2001-2003

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

Quantification of the water use of four tree crops in the Lowveld of Mpumalanga
ARC
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 - 2004

Surface drip irrigation
ARC
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 by-passing evaporation problems. However, subsurface drip irrigation is very "sensitive" to clogging of drip-lines. Crop types, 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

Evaluation of the filtering and back-flushing efficiency of different irrigation filters
IAE, ARC
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 system. 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

Application of risk assessment modelling in groundwater for humans and livestock in rural communal systems
NCE cc
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*

The effect of deteriorating irrigation water quality on the growth and water use of selected crops
Department Soil Science, University of the Free State
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: *2003 - 2006*

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
No 1047

Multi-cropping 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 multi-cropping 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 151 000*
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

Socio-economic impact study on water conservation cultivation techniques in semi-arid areas
Departments of Agricultural Economics & Sociology, University of the Free State
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*

Integrating flood-plain agriculture into a diverse rural economy by enhancing co-operative management: A case study of the Pongola
Institute for Natural Resources
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;

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
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
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 - 2004*

Implementing and testing the WRC guidelines on developing sustainable small-scale farmer irrigation in poor rural communities
IWMI, ARC
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 - 2005*

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
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.

Cost: *R750 000*
Term: *1998 - 2002*

Sustainable local management of smallholder irrigation
Department of Agricultural & Environmental Sciences, University of the North
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 - 2004*

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
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
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 - 2004*

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
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 proposed 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 333 729*
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
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 - 2005*

Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers
Tlou Water Management
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 this 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
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
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 - 2005*

Thrust 4: Water Resource Protection and Reclamation in Agriculture

Programme 1: Sustainable water resource use on irrigation schemes and within river catchments

Irrigation water measurement: The application of flow meters in irrigation water management
Department of Agricultural Food Engineering, University of Pretoria
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

Estimated cost: *R1 234 300*
Expected term: *2001- - 2005*

Can effective management of riparian zone vegetation significantly reduce the cost of catchment management and enable greater productivity of land resources?
Environmentek, CSIR
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 - 2006*

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
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
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 and 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 groundwater, 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 397 950*
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
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 - 2005*

Programme 2: Impact assessment and environmental management of agricultural production

Predicting the environmental impact and sustainability of irrigation with gypsiferous mine- water
Coaltech 2020
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 - 2005*

Development of guidelines for treatment of scale in assessing the streamflow reduction impacts of alien infestations
Ninham Shand (Pty) Ltd
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 2: Fitness-for-use of water for crop production, livestock watering and aquaculture

Assessment of the interaction between aquaculture and water quality in on-farm irrigation dams
Dept of Aquaculture, University of Stellenbosch
No 1461

Most irrigation areas make use of on-farm storage dams to store water until it is required for the irrigation of crops. The existence of these dams presents an opportunity to utilise them also for fish production. Benefits associated with this dual use of farm dams include the additional income associated with such an enterprise, the supply of fresh fish as protein source for local communities, the creation of additional employment opportunities and a potential reduction in fertiliser requirements for crop production, as a result of the enrichment of the irrigation water by fish food and excrement. Potential disadvantages of such an integrated water use system, are the operational restrictions the one use will place on the other (e.g. the dam cannot be completely emptied), concerns about the fitness of irrigation water for fish production and the fitness of aquaculture water for crop production and some irrigation systems. Although dual use is practiced in many countries, it is not common in South Africa. In the light of the potential benefits associated with the integration of aquacultural production with irrigation practice, it is proposed that the interaction between these two practices, the benefits and disadvantages associated with such integration and ways to maximise the benefits, be investigated for two case studies. Specific attention should be given to water quality effects and the precautionary measures that are required in order to maintain fitness-for-use, need to be identified.

Estimated cost *R 1 000 000*
Estimated term: *2003 - 2007*

Thrust 2: Water Utilisation for Fuelwood and Timber Production

Programme 1: Water-efficient production methods and systems in agro-forestry, woodlands and forestry plantations

Water use in relation to biomass of indigenous tree species in woodland, forest and /or plantation conditions
CSIR
No 1462

Information on the water use of trees is essential in order to manage different land-use activities. Currently no information is available on the water use of indigenous trees in relation to biomass production. The central question that must therefore be answered is the following: What is the net benefit of water used by indigenous woodlands compared to commercial forest plantations? For this project it will be important to consider a limited number of species for stands of indigenous trees. Since the emphasis is on water-use efficiency, the water use for the harvestable above-ground biomass production for different end uses should be quantified. The focus should be on slow-growing and initially fast-growing indigenous trees in defined catchments or bio-climatic zones. The following climatic conditions and regions should be considered: Cold-tolerant (Highveld, Piet Retief); subtropical (coastal and Mpumalanga Lowveld); and temperate (KwaZulu-Natal midlands, Mpumalanga escarpment and Transkei in the Eastern Cape). The water use/biomass relationship of indigenous trees and comparison with existing

information for trees in commercial forests must enable future comparisons of the productivity and value of water used under different tree production systems.

Estimated cost: *R 2 249 616*
Estimated term: *2003 - 2008*

Thrust 3: Water Utilisation for Poverty Reduction and Wealth Creation in Agriculture

Programme 1: Sustainable water-based agricultural activities in rural communities

Principles, approaches and guidelines for participatory revitalisation of smallholder irrigation schemes
ARCUSS GIBB
No 1463

Revitalisation of irrigation schemes is receiving priority attention in many provinces. Of particular importance are those irrigation schemes where the majority of participants are in the category of rural poor. No generally applicable guidelines are presently available in South Africa. The need exists, therefore, to develop an adaptable, generic approach to participatory revitalisation of irrigation schemes. In contrast to rehabilitation – which tends to be interpreted in the narrow technical sense – revitalisation is a broader concept referring to institutional and social development, involvement of management in the process and empowerment of all participants on the irrigation scheme. These participants include farmers and providers of support services. The process of revitalisation must enable farmers, who are mainly women, to obtain food security and develop further, i.e. progress from subsistence to commercial farming by own choice. This means that revitalisation must also be technically appropriate, economically viable and lead to transfer of management responsibilities to local water users. The research to draw up practically useful approaches and guidelines, should not be only a desk-top study, but should include field visits and on-site evaluations. The maximum possible involvement of community members should be achieved to ensure that the process which is described is community driven.

Estimated cost: *R 1 195 000*
Estimated term: *2003 - 2006*

Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research
Pretoria Technikon
No 1464

Most agricultural research is often not packaged according to the requirements of subsistence farming. In some instances research results are not adapted and therefore not directly useful for small-scale farming operations. As a result, extension, technology transfer and adoption need to receive more attention. In the past, extension services normally did not participate in the research projects, resulting in limited or no support for the intervention after the research was completed. The need for early involvement of both farmers and extension services in this research project cannot be overemphasised as this leads to better diffusion of knowledge, thus making the intervention more sustainable. The benefits of the research intervention should be apparent to the farmers as early as possible. Motivation and promotion of awareness among the end-users with regard to the objectives of the intervention and the ways to achieve them are essential. The research project on "best management practices for small-scale subsistence farming" requires commitment and co-operation amongst researchers, farmers and the community. It is acknowledged that research results available for water management in commercial farming are applicable to subsistence farming, and need not be repeated. However, the intention is to make existing knowledge, indigenous and new technologies, useful for the particular circumstances of subsistence farming. This should be done through participatory action research which combines research, education and action to the direct benefit of farmers and surrounding communities.

Estimated cost: *R 1 200 000*
Estimated term: *2003 - 2007*

Sustainable techniques and practices for water harvesting and conservation and their effective application in resource-poor agricultural production
Zakhe Agricultural College
No 1465

Approximately 74% of South Africa's rainwater is used by dry-land cropping, natural grassland, woodlands and forests. It is therefore clear that the biggest share of rainwater is used for extensive agricultural production. The

critical issue in the near future will be the increasing pressure on agriculture, in particular food and fuel-wood production, due to population growth. At the same time, there is increasing dependence on agriculture in rural areas, which exerts even more pressure on the rainwater resource base, particularly among the poor. The productivity of land and water in rain-fed agricultural areas can be greatly enhanced through water harvesting and conservation. Rainwater harvesting is defined as the process of concentrating rainfall as runoff from a larger area for use in a target area. Water harvesting and conservation techniques have had limited impact elsewhere, and in some cases failed, despite good techniques and design. This is due to social, economic and management factors that are often overlooked, or inadequately integrated into the development of the system. The research project on "water harvesting and conservation" promotes techniques and knowledge that improve the agricultural productivity of water at farming level. Attention should be given to production methods for crop cultivation in combination with livestock husbandry (and where possible utilising indigenous products). The intervention should also take into account social, economic and environmental factors. The perceptions of rural households and possible adjustments to water harvesting and conservation practices in order to improve food security and rural livelihoods should be analysed.

Estimated cost: *R 3 000 000*
Expected term: *2003 - 2008*

Thrust 4: Water Resource Protection and Reclamation in Agriculture

Programme 2: Impact assessment and environmental management of agricultural production

Modelling non-point source pollution in agriculture from field to catchment scale – A scoping study
Sigma Beta Consultants
No 1467

It is increasingly recognised that non-point source (NPS), or diffuse pollution, plays a major role in the degradation of water quality; specifically with respect to salinity, eutrophication (nutrient enrichment), sediments, pathogens, pesticides and some heavy metals. It is furthermore increasingly accepted that it is unfeasible to properly manage water quality without addressing the contribution from non-point-sources. Consequently, attention is increasingly devoted to the quantification of NPS pollution and to identify means to control it cost-effectively at source. Since most of the land area is utilised for agricultural activities, agriculture has both locally and internationally been implicated as a major source of NPS pollution. It is thus necessary to assess the contribution that the different agricultural activities make to the different manifestations of NPS pollution, to devise the means through which these can be controlled and to determine and predict the effect that control measures will have on reducing NPS pollution. During 2001 the WRC published the document *A Guide to Non-Point Source Assessment* (**Report TT 142/01**, by GC Pegram and AHM Görgens), which aims to assist users in understanding their NPS assessment needs in a particular situation, and thereby to enable them to identify and apply appropriate NPS assessment techniques. This Guide development process was generic and did not include any direct model development and testing, nor did it deal with the agricultural sector specifically. Understanding the production, delivery, transport and use components of agriculture-derived NPS loadings of water resources and having a predictive ability about the fate of agriculture-related NPS constituents are discrete research themes that would enhance the usefulness of the Guide in the agricultural domain. The contribution of irrigation activities towards the salinisation of water resources has been studied for quite some time and is currently still receiving attention.

Other water quality issues of concern that are potentially aggravated by agricultural activities are eutrophication (through fertiliser leaching and wash-off from human settlements), sediments (as a result of erosion), pathogens (from intensive animal production units), pesticides (through the application of insecticides, fungicides and herbicides) and some heavy metals. Although agricultural activities that give rise to the latter water quality issues have been the subject of previous studies, our present level of knowledge concerning them is not as advanced as for irrigation-induced salinisation of water resources. In order to plan future research activities and, specifically, a project that will address those issues that require priority attention, it is necessary to take stock of the present situation with regard to NPS pollution and the existing knowledge base. The process of developing and scoping such a project should involve the major researchers, academics and professional practitioners in these fields in South Africa

Estimated cost: *R 644 400*
Expected term: *2003 - 2004*

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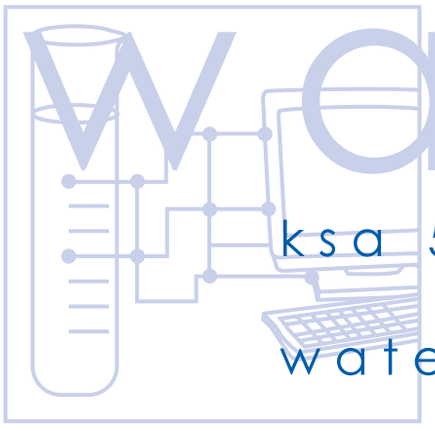


ksa 5

water-centred knowledge

Scope

The WRC is a knowledge organisation and hence its fundamental business 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 users.

For the WRC knowledge management will be considered as the process through which it will generate value from its intellectual and knowledge-based assets. This will generally involve:

- Identifying usable information from research studies
- Capturing the information
- Transferring the knowledge in a form that facilitates use
- Maintaining the information
- Sharing the information among employees, government departments, organisations and individuals in an effort to devise best practices in water management

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, both internally and externally.

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 (internal and external) with reusable codified knowledge
- Develop document management systems, to deal with information IN and information OUT
- 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
- Foster innovations by encouraging the free flow of ideas
- Improve customer service by streamlining response time
- Boost revenues by getting knowledge products and services to external users faster
- Streamline operations and reduce costs by eliminating redundant or unnecessary processes

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 can be grouped as follows:

Internally focused

- 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 develop and maintain consistent data architecture to enable the flow of content through a knowledge management system

Externally focused

- 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 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 achievement of the above objectives will be supported by a structure or a framework of a number of thrusts (which form a number of management areas/functional groups). A creative approach to knowledge management will be achieved within these management areas. The thrust structure (management areas) has been reviewed and activities will now be grouped into the following key areas:

Thrust 1: Knowledge Management (KM)

The focus of this thrust is knowledge-sharing and knowledge dissemination to meet the objectives of the WRC (of being a knowledge hub) in its knowledge creation and learning activities and the core process of knowledge generation. It will develop a culture based on the understanding that "knowledge resides in the user and not in the collection of information "… it is the reaction of the user to a collection of information that matters". Thus there needs to be a clear link between the KSA and the other water KSAs, who will be at the core of the KM activities. Further, this thrust will oversee that the WRC maintains access to the necessary information to make appropriate decisions internally as well as externally. This management area will also act as a resource centre to meet information requirements of the WRC and other external bodies, and will lead and participate in other knowledge-sharing and public understanding of science initiatives while working with a variety of institutions, internally and externally, It will also strengthen the WRC's ability to exchange information and data on developments around water management issues.

Thrust 2: Information and Communication Technology (ICT)

This area aims to meet the information and communication needs of the WRC's stakeholders and also the internal needs of the WRC regarding knowledge management. This is essential as ICT has become the popular service delivery tool to the WRC stakeholders. Further development of enabling systems and tools, E-publishing and E-business, and supporting the community of practice will be part of our forward focusing activities within this thrust. Key focus will be on designing tools for driving water-centred knowledge dissemination; linking external databases and in the long run building nation-wide knowledge engines/networks and increasing public understanding of water-related issues. Another key focus is improving the organisation's information processing abilities, and its competencies concerning information security and risk management. This thrust has already received priority attention in the year 2003/04 and planned activities for next year will be built on the solid foundation that has already been established.

Thrust 3: Publications and Document Management (PDM)

Key focus for the next financial year will be on driving the handling and storage of documents, archiving, and maintaining library and information services. Key focus is on dissemination of knowledge created via the support of the WRC as well as other sources (originating from the national and international arena) through publication of an internationally rated journal and the ongoing publication of research reports and technology transfer (TT) documents. Working with Thrust 1 (see above), there will an effort to support the proper repackaging for better sharing of knowledge.

Thrust 4: Intellectual Property Rights and Commercialisation (IPC)

This thrust will focus on the effective management of all the WRC's patent portfolios, all issues relating to intellectual property rights and their protection. It will also support innovation and commercialisation of research and research products, while also supporting the WRC in the management of its contracts with researchers and suppliers.

Budget for 2003/04

The approved funding of fixed costs, running costs, printing and publishing costs and human resource costs leads to committed funding of R 5.9m in 2003/04.

Core strategy

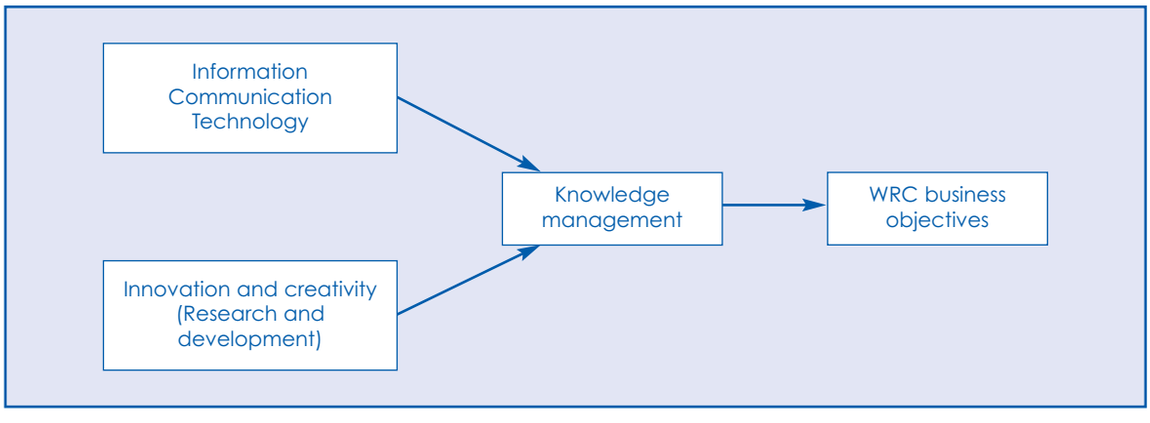
Strategic context

Given the dangerous perception about knowledge management as seamlessly entwined with technology, this KSA clearly has to promote the understanding of the strategic distinction between knowledge and information. Critical to management is a shift from the mindset of information being the scarce resource, to human attention being the scarce resource.

In addition, this KSA will also promote the view that information generated by various sources is not a very rich carrier of human interpretation for potential action. Knowledge resides in the user's subjective context of action based on that information. It is therefore logical to account for human attention, innovation and creativity needed for renewal of archived knowledge, creation of new knowledge and innovative applications of knowledge in new products and services that may be transferred or commercialised.

Proper positioning of ICT within the WRC should be based on the understanding that "…knowledge resides in the user and not in the collection of information … if the user reacts to a collection of information that matters…" – CW Churchman. The shift from information processing to knowledge creation will be defined by reconciling knowledge management and the WRC core strategy (see diagram below).

This KSA should therefore redefine itself as addressing the critical issues of organisational adaptation, relevance, and competence in the face of increasing discontinuous environmental change. Essentially, this KSA will aim to embody organisational processes that seek synergistic combination of data and information processing, capacity of information technologies and the creative and innovative capacity of human beings. Through knowledge management we will be able to access the pool of external knowledge to leverage our own knowledge resources and to add value to it. The diagram below illustrates the KSA's conceptualisation of knowledge management:



The business objectives of the WRC are externally focused and are based on investing in water research and development and developing competence and skills while making optimal use of the latest global information/knowledge and other available technologies. While the four water-centred KSAs are focused on investment in the creation of new knowledge and capacity-building, using the latest technologies and tools, the products thereof are linked and enhanced through other externally available information to prepare it for dissemination transfer or knowledge sharing. Through this, and continually supporting the core processes of the WRC, the WRC business objectives are achieved.

Through this knowledge management approach, the following shifts in mindset within the organisation are considered to be important (Table below). These shifts are necessary to ensure that the WRC achieves its business objectives of being a knowledge hub.

Organisational resources	Classical business approach	Knowledge management focused business
Strategies	Prediction	Anticipation of surprise
Technology	Convergence	Divergence
Management	Compliance	Self-control (self - management)
Knowledge	Utilisation	Creation/renewal/ sharing
Assets	Tangible	Intangible
Organisation	Structure	Edge of chaos

The table illustrates the comparison of the classical business view of typical issues in an organisation and the necessary shifts, e.g. the "compliance" approach to management as opposed to self-management (decentralised decision-making, empowerment).

Knowledge management systems designed to ensure compliance might ensure obedience to given rules; however, they do not facilitate detection and correction of errors. Hence, it has been suggested that the role of senior management needs to change from command-and-control to sense-and-respond. Furthermore, if knowledge, unlike information, is about beliefs and commitment, the new emphasis should be on building commitment to organisational vision rather than compliance to rules and pre-specified best practices.

Having implemented the above, this KSA assists in positioning the WRC as a knowledge hub characterised by efficient systems for knowledge sharing and dissemination and providing strategic advice to the public and private organisations nationally and internationally.

Needs analysis

Proper understanding of users and their needs is the main determinant of how knowledge should be packaged – it is the collection of information that matters. The users are both internal and external customers.

- **Internal customers**

Appropriate information is required by research managers and staff of the WRC for planning activities and decision-making. Staff members need to be able to access the information based on the organisation and be empowered to take decisive action.

The overarching need is to develop one seamless system for employees to navigate, even though the information may ultimately be pulled from several different systems "behind the scenes". From the user's point of view it is a system that is always ready to supply the content that is needed, may it be performance data, budget, policies, professional contacts, experts and specialists, current research data, etc.

- **External customers**

The level of knowledge of water-centred knowledge management in the communities in general is limited. The following issues are therefore considered to be 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

The main external customers are:

- **Government departments, decision-makers and policy-makers:** At every stage of knowledge accumulation, the above-mentioned category of users is almost always the main target group. It is important that the "knowledge workers" in this sector make their decisions by increasing the amount of relevant information they have access to, introducing the elements of expertise and experience through collaboration capabilities and shortening the time it takes to make better decisions.
- **Stakeholders and user communities:** These will include water boards, municipalities, community associations, development groups, consultants, etc. Encouraging free flow of information fosters innovation, and in today's information-driven economy, organisations may uncover the most opportunities, and ultimately derive most value from intellectual assets. Knowledge sharing must serve as the foundation for collaboration.

- **Researchers and service providers:** The ongoing reassessment of key assumptions, renewal of existing knowledge, creation of new knowledge and its application, requires that the knowledge available at a certain point in time and context be accessible.
- **Communities and general public:** 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 in general also faces the challenge of being able to link up and work globally and regionally.

Overview of 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. 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.

Information technology supports the following processes: Knowledge acquisition; information distribution; and information interpretation. At the planning level scenario planning tools can be used for generating possible futures. Similar use of groupware tools, intranets, E-mail and bulletin boards is continually improving the processes of information distribution and information interpretation. Other key technologies are those that enhance organisational memory and enabling continuous updating and refreshment such as database systems

It should be mentioned specifically that the emergence of the Internet and the World Wide Web as sources of unlimited information is continually influencing the way organisations manage information. Management support systems and group support systems should also be noted as their presence begins to streamline more and more organisational processes.

Document management systems linked to workflow are in the KSA's high-priority acquisitions for the near future. Recent developments have rendered these systems highly reliable.

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.

Other key stakeholders include the water sector, service providers, user communities and the general public.

Other players

A number of national and international organisations work in collaboration with the WRC and in some cases formal agreements exist. These include the following as examples:

- American Water Works Association Research Foundation (AWWARF)
- International Water Association (IWA)
- Water Research Foundation (WRF)
- International Water Management Institute (IWMI)
- Water and Sanitation Collaborative Council (WSSCC), etc.

Creative approach to knowledge management

Intellectual property
In order to encourage successful invention and subsequent solid patents, the WRC will attempt to address the creative needs of the researchers and foster an inventive environment within the research area. The WRC will respond to the pressure to obtain more intellectual property and to make sure that the property generates or protects revenue through proper staffing (appropriate skills and increased efficiency). By supporting the creation and protecting technological developments the WRC strives to further improve the utilisation and commercialisation of its research results (in collaboration with its research providers and the water sector at large)

where and when applicable.

Strategic research advice
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 an 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, 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 it in IT aimed at facilitating 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 the agility demanded 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. However, it should be noted that progress in this part will depend on the establishment of proper structures to support this; hence this activity will receive higher priorities in the following years rather than the current year.

Information and communication technology
Specific short-term focus will be around developing the interface between our service providers and the WRC and users of our knowledge products and the WRC, while enhancing the search engines for information hunters. The creation of virtual communities of users and customers is among the key priorities of our vertical portals to be developed. The challenge of walking the tightrope between adopting the latest technologies and remaining up to speed with ongoing business and technology developments is becoming more acute in the E-world.

Knowledge management
There is a need to view any organisation as a human community capable of providing diverse meanings to information output generated by such activities as research and development. The challenge is to make the organisational information base accessible to external organisations and individuals. This is important, given the increasingly fast-paced and dynamic business environment that creates disconnections between the process of decision-making at the top and implementation of such decisions at the grassroots. This is even truer in the water sector.
The preferred approach to information processing should be tested in the near future. Two approaches (water metaphors) should be considered:

- It is important to find useful knowledge, bottle it, and pass it around
- There is a great big river of data out there. Rather than building dams to try and bottle it all up into discrete little entities, we just give people canoes and compasses.

Progress against set KPAs for 2003/04

The following examples illustrate the progress made to date:

- An efficient, user-friendly HelpDesk has been created and is proving to be an invaluable support tool for all internal WRC staff.
- Increase in circulation and the number of advertisements in *The Water Wheel,* hence increase in revenue
- E-business - A scanning system has been installed, all publications are now bar-coded. E-publishing has been implemented, but needs to be marketed
- Feedback regarding the *Knowledge Review* indicates this document to be widely requested and of high value to the water sector, both locally and internationally.
- New hardware and software have been installed, resulting in greatly reduced downtime and concomitant

improved internal effectiveness
- High level of Internet security has been achieved(highly effective for both internal and external customers)
- The operating modality regarding the continued financing of *Water SA* is being reviewed
- The WRC has played a major role in knowledge management: The establishment of the Water Information Network (WIN) is one example
- The publication database(currently available only for internal use) has been completed
- A new, upgraded server has been installed that ensures increased storage capacity and a faster working environment
- A continuously updated list of WRC publications is posted on the WRC Website (www.wrc.org.za) for perusal by users and orders for reports may be placed either electronically, telephonically or by fax.
- An IP policy has been developed and implemented

Highlights for the 2003/04 financial year in terms of thrusts

Thrust 2: Information and communication technology (ICT)

WRC Website highlights

The IT section has created an efficient web support desk that has gone a long way in ensuring that information is updated regularly and timeously. We have tried to create a home page that is reader-friendly, appealing and eye-catching. The content of the WRC web page is updated at least every fortnight.

A web-based questionnaire has been implemented to gauge stakeholder perceptions of the WRC website as well as WRC publications.

The usual gremlins associated with on-line submission of project proposals have been eliminated, ensuring that the WRC now has a streamlined system to deal with this function.

The latest reports are available on the site within a week of publication. The WRC also publishes other newsletters from sister organisations, thereby living up to its image of truly being South Africa's water knowledge hub.

The web page also creates access to certain downloads, some important WRC publications, media releases, policy documents as well as interesting information of happenings in the water sector.

IT highlights

- An efficient, user-friendly HelpDesk has been created and is proving to be an invaluable support tool for all internal WRC staff. This e-mail-based system is totally interactive; requests are automatically assigned a tracking number and a track log enables easy follow-up and recall.
- A new, upgraded server has been installed that ensures increased storage capacity and a faster working environment.
- Data security has also been improved with the installation of a new, centrally managed antivirus system.
- The central backup system has been improved with the installation of top-of-the-range tape streamers. Backup tapes are now stored off-site – an additional measure that ensures increased data security.
- A WRC Intranet is being implemented using an Open Source Content Management System. This will greatly improve internal collaboration and interactive information exchange.
- All managers now have mobile access to the Internet; this is a great technological advantage and enables them to have 24-hour access to the WRC network wherever they may be.
- The 2nd phase of the Business Analysis Project has now been completed. The way forward will involve the development of a fully integrated, organisation-wide Fund Management System.

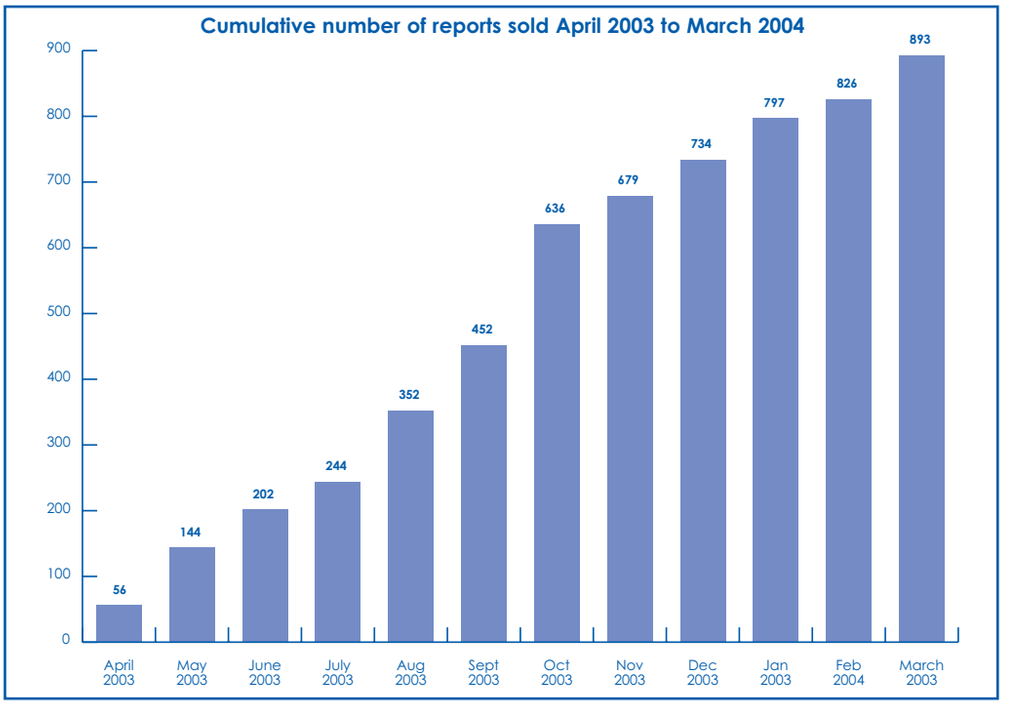
Thrust 3: Publications and document management (PDM)

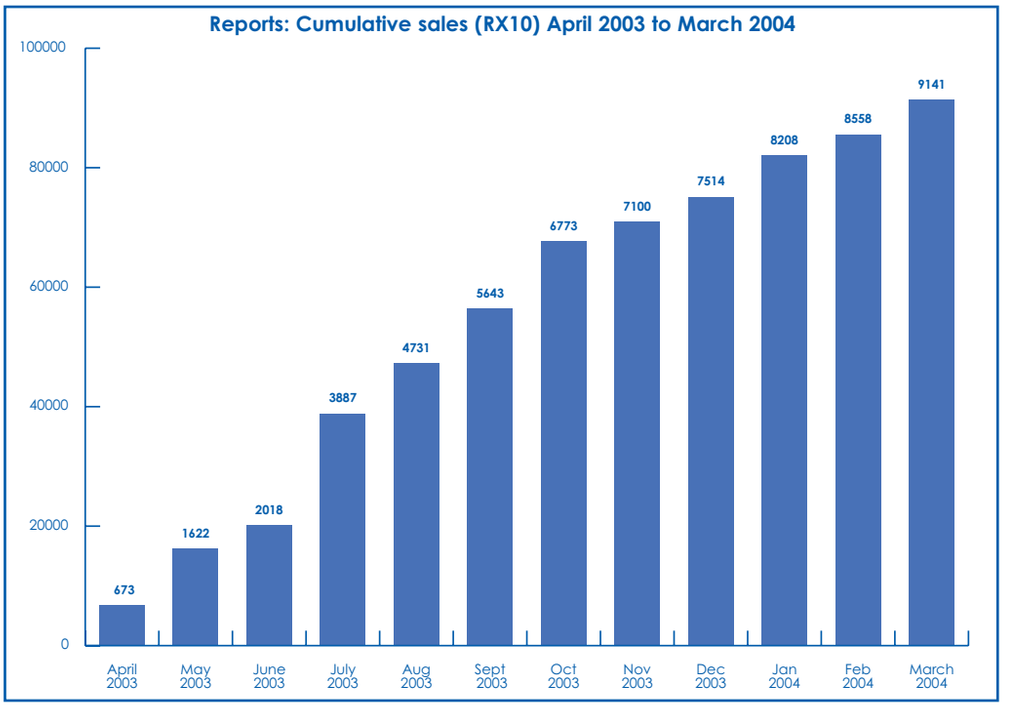
At the conclusion of a project and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof.

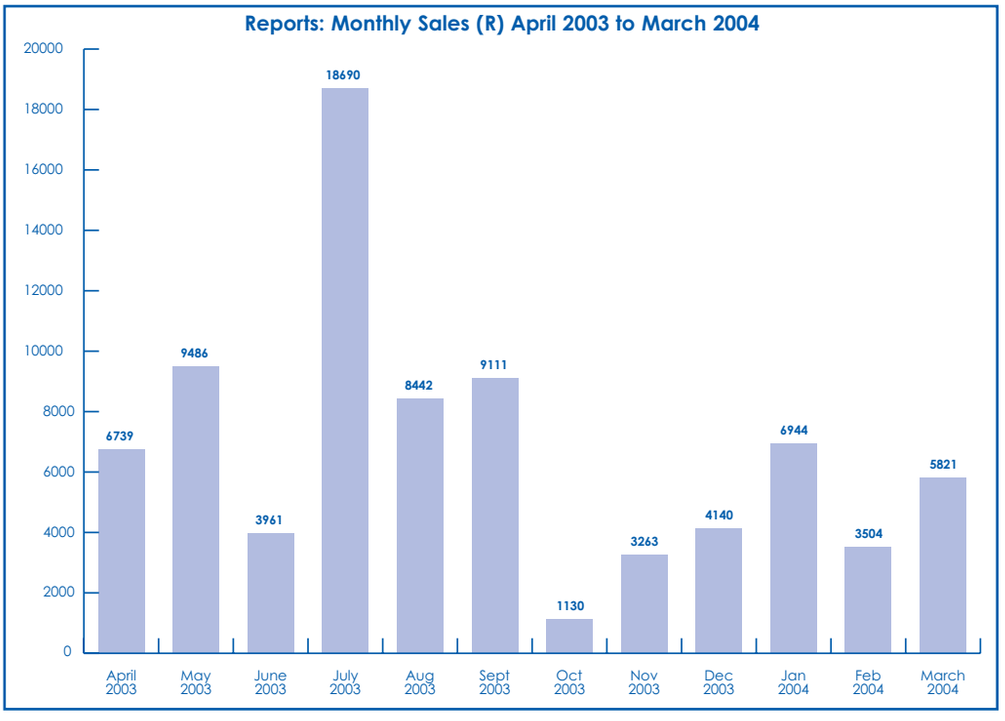
An effective marketing strategy for the knowledge assets was developed. A report catalogue of selected TT reports has been compiled and is being widely distributed. During the year under review 145 new reports were published (38 000 copies printed) and approximately 30 000 copies of reports were dispatched upon request from

stakeholders; some of these were sold and the income generated in this way came to R91 410.
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.

The following graphs illustrate the cumulative figures for the number of reports sold during the year under review (893), the income generated (R 91 410) as well as the monthly sales and income over the period (1 April 2003 to 31 March 2004)







The Water Wheel – highlights

A special supplement, *Interviews with People Successful in the Water Field*, focusing on the careers of a few prominent South African water scientists, was published to promote and stimulate an interest in career paths in the greater water sector in South Africa as well as being part of the WRC's drive towards capacity building and strategic contribution to the country's human resource development, especially in the area of scarce skills.

Following the success of the supplement, a permanent feature *Careers in Water* has been added to the *Wheel*. Interviews with young scientists in the water field such as Tshepo Maeko, Jack Armour and Bongikhosi Mthembu were published.

A selection of the year's most popular articles from the *Wheel* has been compiled in a special edition for the *2004 National Water Week*. Most of the magazines were distributed to secondary schools and municipal libraries to enhance the awareness and public understanding of water and water research.

Agriculture and water play a key role in the development of Africa and therefore a series of articles were featured, ranging from water harvesting, a key to food security for Africa, to agroforestry – the planting of fodder trees. The articles show-cased the WRC's many excellent research initiatives and knowledge products in this field.

A series of articles on water user associations (WUAs) (the former irrigation boards) were included in the magazine to raise awareness about these associations and the role they are playing in the DWAF's implementation of the new Water Act.

The "Viewpoint" articles in *The Water Wheel*, aimed at stimulating debate about complex water-related issues, elicited lively discussions and many letters to the editor. Some of the topics featured included: South Africa and the World Commission on Large Dams, New attitudes needed on water use patterns, and climate change – is there any need for concern?

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 2003/04 *Water SA* published 70 articles written by 198 authors and reviewed by 194 international and Southern African reviewers. *Water SA* has an extensive local as well as overseas readership. Currently there are 2 962 subscribers to *Water SA* of whom 837 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 free of charge on the Internet via the WRC website (*http://www.wrc.org.za*).

Thrust 4: Intellectual property rights and commercialisation (IPC)

Improved commercialisation of intellectual property (IP) has been achieved. During 2003/04 the WRC developed and adopted an IP policy and a benefit-sharing policy aimed at improving the transfer and application of water-centred knowledge and increasing revenue via related commercialisation activities. The WRC has reviewed its patent portfolio and identified a new modality for managing this portfolio. One of the products resulting from WRC funding, Synexa Bio, was sold to Merck (a pharmaceutical company) in the USA by its licence holder. This product, developed jointly by Dr Winston Leukes of Rhodes University and Dr Ed Jacobs of the University of Stellenbosch, comprises high-value enzymes that will be used in research on HIV.

Contracting procedures have been revised.

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Scope

This domain addresses water as a social good and the vital role water plays in social development. It will provide an integrating framework for, and further facilitate expansion of, that research and development within the different KSAs which contribute to a sound balance between the manner in which water resources are used and cared for by society, and the benefits which society as a whole derives from the use of water. Ways must be found to assist society in developing a sound understanding and appreciation of the various issues around water as a scarce resource, as they relate to the need for equitable (including transboundary) sharing of the resource, avoidance of conflict, promotion of co-operative water resource management and productive and sustainable resource use. Finding improved, sustainable and socially acceptable ways of meeting society's needs for water services remains an important focus area because of the continuing service backlog. Interlinkages between poverty issues, gender issues and access to water and water services have to be established, and the knowledge gained applied in promoting poverty alleviation and better quality of life for society as a whole.

Objectives

The domain aims to facilitate and integrate WRC research and development initiatives which promote:

- Healthy perceptions and balanced awareness of key issues relating to water as a scarce and shared resource
- Water services which are socially acceptable, affordable and available to all
- Communities which are empowered to participate effectively in water institutions
- Ready access to water for the poor, women, the youth and the disabled.

Thrusts

Thrust 1: Water as a Shared Resource

This thrust focuses on investigating hydro-political issues within South Africa and the SADC region. Issues include the intersectoral and transboundary sharing of water, water scarcity in relation to demand, water quality, and the roles of water in various economic and societal sectors. Appropriate research initiatives will aim at alleviating impacts of scarcity and degraded water quality on society and the water environment, thereby reducing potential for conflict, and promoting healthy co-operation with regard to integrated, sustainable management. Research in this thrust will support policy and decision-making regarding the allocation of water (over and above the Reserve) to various development sectors, namely domestic, industrial and agricultural.

Thrust 2: Social Needs for Water Services

The focus of this thrust will be to analyse and understand society's needs for water services, which will lead to guidelines aimed at enhancing utilisation of limited water resources and finance in sustainable service provision. Such understanding will ensure that the real needs of society are known and addressed in a flexible and socially acceptable manner. Issues around payment for water, ownership of potable water schemes, hygiene and sanitation will be investigated.

Thrust 3: Gender and other Limitations Regarding Access to Water

Research within this thrust will focus on investigating the extent to which gender, age and physical disability influence access to water resources. Knowledge will assist in the development of policy guidelines for improving equity in water access among users.

Thrust 4: Poverty Alleviation

Research within this thrust will focus on the linkages between water and poverty. This will lead to effective strategies for using water resources to break the poverty cycle and promote food security

Research portfolio

The funding for research projects supported by the various KSAs and focusing on this domain is estimated at about R 23 million for 2003/04. The projects presented are linked to various KSAs and are implemented and managed within various KSAs.

COMPLETED

Thrust 1: Water as a Shared Resource

Security, ecology, community: Contesting the "water wars" hypothesis in Southern Africa
Centre for Southern African Studies, University of the Western Cape
No 1106

The focus of this project was on issues of river basin security: examining and confirming the premise that water resources in a river basin can and should rather be a catalyst for cooperation and enhanced security than a source of conflict, irrespective of the particular water-resource management context under consideration. River-basin security is a condition closely allied to the achievement of the goals of integrated river basin management (IRBM) and integrated water resource management (IWRM). Field investigations and case studies were done in two Southern African river basins. Institutional reform, urban water supply and urban food security were the security-related foci for the case studies. On the whole, the project revealed a climate of co-operation which does not, however, negate the fact that smaller conflicts exist, many of them resulting, paradoxically, from moves to increase water security. There are many potential lessons to be learned from the project findings.

Cost: R400 000
Term: 2000 - 2002

Thrust 2: Social Needs for 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
No 1139

Local governments in South Africa face the critical challenge of delivering services to the poor while facing severe financial and capacity constraints. There is a changing politico-institutional framework in which there are high expectations of delivery from the poor. The KwaZulu-Natal BPD was launched as a trisectoral model involving local government, civil society and business. The KZN-BPD formed a component of an international exercise to test new and innovative approaches for partnership. Eight international projects formed the cluster under the auspices of the World Bank. The problem of social delivery is a global question. And the vision was to bring together the strengths and abilities of local government, business and civil society in providing services to the poor. At one level it was the engagement of fairly equal partners in the mutual exploration of what is possible. It was flexible and innovative. It did not take the form of a legal instrument between local government and business, but worked through mutual understanding to develop a new outlook on working with poor communities.

Although firmly rooted in actual on-the-ground projects, the partnership was fundamentally a learning (or research) experience (though never an academic exercise). A better understanding of how to achieve service delivery through democratic participation was being generated by each of the partners. There are no formulae, only learning from successes and failures. To give a few examples of the wide learning involved:

- Local government management benefited particularly by learning the need for close communication with poor communities through experience with the NGO. It also accessed the knowledge of a multinational firm (working in many socio-economic environments in many countries), and developed a better understanding of private sector operations (with particular lessons in resource management and planning and the use of GIS)
- The private sector learnt about working as a team with the NGO particularly in education and awareness
- The NGO, which has extensive knowledge of rural conditions, gained an understanding of the issues in operating water services in poor urban communities.

Altogether the partnership completed 16 projects in Pietermaritzburg and 14 in Durban on a fairly modest budget; a key element was the research component which captured the lessons and experience of this initiative.

Cost: R880 000
Term: 2000 - 2001

The preparation of a guideline for water services providers dealing with customer services issues
Umgeni Water
No 1207

The concept of "customer service" has received little attention in South Africa, perhaps related to the historic situation where the water supply and sanitation services were provided on a monopolistic "take it or leave it" basis, provision is strongly associated with the application of good business principles. This implies a services orientation, with a primary focus on the customer. It also implies a mutually beneficial relationship between customer and service provider where the customer must fulfil their responsibility to pay for the service.

While there is increasing recognition of the conceptual importance of customer service, there are only a few services providers, which are putting this into practice. One reason for this is that there is insufficient understanding of what customer service involves. This is partly related to the lack of capacity to run services properly in the transitional period when coverage has to be increased rapidly in a situation of resource scarcity and partly it relates to lack of information on the topic.

The results of this study, presented in a discussion report, are aimed at improving the understanding of what customer service involves through providing information both in written form and through interaction with management of water services providers at workshops. Emphasis is placed on good business practice, drawing as much as possible from private sector marketing techniques which are grounded upon principles of good communication. However, it is recognised that there is much more to customer service than just marketing; the product also has to be good. But, while the issues associated with providing a good product, in a technical sense, will be briefly addressed, the emphasis has been on the softer elements of customer service.

Cost: R370 000
Term: 2001 – 2002

Sanitation demand and delivery in informal settlements
Peninsula Technikon
No 1280

This research is the culmination of the first phase of developing a framework for sanitation delivery to informal areas . The Framework is intended for application in planning and to improve the efficiency and effectiveness of delivery by facilitating the development of implementation guidelines. It uses current approaches of sanitation delivery, while drawing from local case studies to inform the City of Cape Town, This would be of relevance to the rest of the country. The framework does not propose a "quick fix" for the suggested change of paradigm that is needed for approaching delivery strategically. Accepting that there are financial and legal constraints to be addressed, the focus of the Framework is to facilitate the building of capacity and changing of roles, including the recognition that communities are key activists in sanitation improvements and sustainability. The challenge for strategic approaches to sanitation provision is to move forward in ways that are appropriate to the task in hand, and that respect the way in which knowledge and skills are distributed amongst the stakeholders. Strategic sanitation planning is based on three strategic elements, suggesting that the development of three strategic programmes require planning within, and across, the relevant local authority departments. The associated key programme elements are those that have emerged from the research of current approaches in the City of Cape Town.

Cost: R250 000
Term: 2001 - 2002

Thrust 3: Gender and Other Limitations Regarding Access to Water

Gender dimension of the water policy and its impact on water and sanitation provision and management
Department of Development Studies, University of Fort Hare
No 1021

The main objective of this study was to analyse the gender dimensions of the National Water Policy with special emphasis on the implementation aspect of the policy, and the impact it has on water and sanitation provision and management in the lives of men and women in the Peddie district. The study analysed five pieces of legislation that pertain to gender equity as well as the relevant sections of the Constitution. It also reviewed international literature on gender and development. This was followed with semi-structured interviews with men and women from the Peddie district to evaluate their perceptions on the implementation of the gender equity component of the policy within water supply and sanitation projects. The study identified several impediments to the implementation of equity within the water supply and sanitation sector. These included a lack of monitoring

and evaluation systems for ensuring that the National Gender Equity Policy is adhered to by the project implementing agents. The study also showed that most water committees had achieved the 30% quota required in terms of the White Paper on Water Supply and Sanitation (1994). However, women's contribution to decision-making was minimal because of cultural constraints that prohibit women from addressing public gatherings of men and women. The lack of skills and high levels of illiteracy among women were identified as barriers to the achievement of gender equity at project level. The study highlights the importance of ensuring that gender policy requirements take cognizance of cultural norms that restrict women's freedom of expression and association. There is a need to create an enabling environment that can harness the meaningful participation of rural women in decision-making on water services delivery within the local context. The critical analysis of the implementation of gender equity policies at the local level provided by this study will guide the policy makers and project implementation agencies in ensuring that they become more mindful of the local context when implementing the national policy of gender equity within the water supply and sanitation sector. The study will also contribute to the review of the National Gender Equity Policy.

Cost: R303 000
Term: 1999 - 2002

Thrust 4: Poverty Alleviation

An investigation into the potential of sustainable irrigation in Black developing communities of two subcatchments of the Pongola and Thukela Rivers
Sineke Development
No 1138

Emerging irrigation farmers need farming systems which should be developed on the basis of understanding of local social and economic circumstances of developing communities where the irrigation scheme is to be established. The history of irrigation development in black communities shows that the socio-economic realities to sustain irrigation is inadequately incorporated in the irrigation development process. During establishment of irrigation schemes, clear actions to address the circumstances of such communities are seldom taken.

The aim of this project was to determine community circumstances that, if overlooked, will impact negatively on established irrigation schemes, leading to failures of development initiatives. Two small-scale irrigation schemes, Keat's Drift and Esiphongweni, both located in KZN, were analysed for the purposes of this study.

Gender biases experienced in most development initiatives have ignored women in most irrigation scheme development stages. Full participation of women, in particular the predesign stages, is critical but difficult to achieve. In cases where there has been a balance in crafting local irrigation institution, that are sensitive to women needs, performance has increased. The study further indicates that women are involved in the most laborious work within irrigation schemes, while men are only involved in opening and closing pump and controlling pests using pesticides. There is a need to find an appropriate balance between the productive roles of the members of the scheme.

Given the socio-economic circumstances of black communities in SA, irrigation development will continue to be supported by funding agencies. It is these agencies that must be sensitive to issues/factors that may or may not be quantifiable – which ultimately lead to success or failure of the irrigation scheme

Cost: R995 000
Term: 2000 - 2001

CURRENT

Thrust 1: Water as a Shared Resource

Short-term weather forecasting techniques dedicated to flood management systems
Chair of Meteorology, University of Pretoria
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 area 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
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 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 - 2002*

An evaluation of the role of water user associations in water management in South Africa
Pula Strategic Resource Management
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
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 - 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
No 1197

Rural communities with low per capita income, such as those on the Luvhuvhu 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
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: *R350 000*
Expected term: *2001 - 2003*

Hydropolitical history of South Africa's major international river basins
Centre for International Political Studies, University of Pretoria
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 trialling guidelines for participatory water resource management at catchment and water management area scales
Geography Department, Rhodes University
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*
Expected term: *2001 - 2002*

Promoting democracy through the IWRM process: Developing a model for sustainable relationships for the management of a scarce natural resource
CSIR/Environmentek
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 multidisciplinary, 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*
Expected term: *2002 – 2003*

Multicriteria decision support for reserve determination and other catchment management activities
Dept of Statistical Sciences, University of Cape Town
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 multicriteria decision analysis over several years with WRC support. This proposed 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*
Expected term: *2002 - 2003*

Integrating flood-plain agriculture into a diverse rural economy by enhancing co-operative management: A case study of the Pongolo
INR
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*
Expected term: *2002 - 2005*

Community-based research on the influence of rehabilitation techniques on the hydrology of degraded catchments
CSIR/ Environmentek
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*
Expected term: *2002 - 2006*

Institutional arrangements for groundwater management in dolomite terrains
IUCN
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*
Expected term: *2002 - 2004*

Thrust 2: Social Needs for Water Services

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
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*

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
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
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*

Researching payment strategies and price elasticity of demand for water for the lower income group at four selected urban communities
MSSA Water Research
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 to short-term and long-term water management policy, may be undertaken.

Estimated cost: *R 700 000*
Expected term: *2002 – 2004*

Developing indicators and measuring the impact of water provision on the livelihoods of rural households in SA
Mvula Trust
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*
Expected 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
No 1376

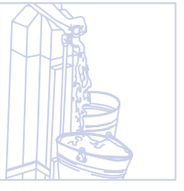
This study will provide guidelines which will assist municipalities in planning and implementing water supply projects in an integrated participatory manner. It seeks to promote "ownership" of the development process by rural communities. The main objectives of this study are to pilot a people-centred 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-centred development planning approach

Estimated cost: *R430 900*
Expected term: *2001 - 2004*

Review, consolidation and evaluation of key performance indicators for successful sanitation, health and hygiene promotion programmes
Rural Support Services
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*
Expected 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
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*
Expected term: *2002 - 2005*

The development of a strategy for effective public participation in rural water supply projects
Nemai Consulting
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*
Expected term: *2002 - 2004*

The development of a marketing plan for sanitation promotion - A participatory approval
Limakhozu Development
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*
Expected term: *2002 - 2003*

Raising community awareness for the provision of potable water and empowerment communities to conduct water quality surveillance activities
Dept of Biochemistry and Microbiology, University of Fort Hare
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 based 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 in 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*
Expected term: *2002 - 2004*

Thrust 3: Gender and Other Limitations Regarding Access to Water

Assessing the impact of gender in water and sanitation provision and maintenance
Networks for Development
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*

Thrust 4: Poverty Alleviation

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
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 multi-cropping 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.

Estimated cost: *R1 001 000*
Expected term: *1999 - 2005*

Sustainable local management of smallholder irrigation
Faculty of Agriculture, University of the North
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.

Estimated cost: *R863 500*
Expected term: *1999 - 2004*

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
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.

Estimated cost: *R1 500 000*
Expected term: *2002 - 2006*

Investigation of different farm tenure systems and support structures for establishing small-scale irrigation farmers in long-term viable conditions
Tlou Water Management
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*
Expected 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
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*
Expected term: *2002 - 2005*

On-farm application of in-field water harvesting conservation techniques on small plots in the central region of SA
ARC/ISCW
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*
Expected term: *2002 - 2004*

NEW

Thrust 1: Water as a Shared Resource

Integration of indigenous knowledge systems in the conservation and protection of wetlands in communal areas of South Africa
Magwa Consultants
No 1417

This project aims to identify and describe the indigenous knowledge systems contributing to the conservation of wetlands in communal areas, and to provide guidelines on how this knowledge can be integrated into current systems to enhance sustainable management.

Estimated cost: *R300 000*
Expected term: *2003 - 2004*

Evaluation of the requirements and mechanisms for co-operative governance between catchment management agencies and local government
Pegasus Strategic Management (Pty) Ltd
No 1433

The recent demarcation process and the on-going specification of the powers and functions between the district, local and metro councils have further clarified the roles and functions of local government. Local government is constitutionally responsible for the implementation and control of a range of activities that affect water resources. This research will amongst others provide recommendations on the requirements for co-operative governance and the most appropriate approaches and mechanisms to foster co-operative governance between CMAs and local government, to achieve a range of objectives under differing circumstances.

Estimated cost: *R290 000*
Expected term: *2003 - 2004*

Thrust 2: Social Needs for Water Services

An identification and review of the factors in rural water services that facilitate and impact on local economic development in the Eastern Cape
Rural Support Services
No 1437

Water supply and sanitation are considered to be a very good catalyst which can stimulate local economic development in poor areas. Yet many initiatives both locally and internationally tend to obviate this opportunity. This study aims to investigate the factors which would influence LED and the outputs will be guidelines that would influence LED during implementation of WSS projects.

Estimated cost: *R300 000*
Expected term: *2003 - 2005*

Guidelines for basic sanitation services to informal settlements – Promotion, institutional arrangements and capacity building
Peninsula Technikon
No 1438

There is a lack of guidelines that take cognizance of local conditions and challenges in the provision of sanitation to informal areas. This study aims through an action-orientated process of evaluation, monitoring and pilot studies to develop guidelines relevant for the sector. It aims to cover the key areas of institutional models for service delivery, marketing and communication sanitation and capacity requirements.

Estimated cost: *R550 000*
Expected term: *2003 - 2005*

Thrust 3: Gender and Other Limitations Regarding Access to Water

Gender mainstreaming in water resource management: Situation analysis
Mbumba Development Services
No K8/496

Women play an important role in the provision, management and safeguarding of water and other natural resources. The role of women is recognised by the Rio principles. However, since the adoption of these principles in 1992, progress towards gender mainstreaming has been very slow. This consultancy will provide a situation analysis report on the level of women participating in decision making within water management and water services institutions.

Estimated cost: *R298 800*
Expected term: *2003 - 2004*

Thrust 4: Poverty Alleviation

Principles, approaches and guidelines for participatory revitalization of smallholder irrigation schemes
ARCUSS Gibb Consortium
No 1463

No generally applicable guidelines are presently available for revitalisation of irrigation schemes in SA. The need, therefore, exists to develop an adaptable, generic approach to participatory revitalization of irrigation schemes. Contrary to rehabilitation, the study will look at revitalisation, which is a broader concept referring to institutional and social development, involvement of management in the process and empowerment of all participants on the scheme.

Estimated cost: *R750 000*
Expected term: *2003 - 2006*

Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research
Pretoria Technikon
No 1464

This research aims to empower rural people, both within and around irrigation schemes, through engagement in practical methodological development. The study will develop, test, monitor and evaluate technologies aimed specifically at addressing constraints in smallholder agriculture

Estimated cost: *R700 000*
Expected term: *2003 - 2007*

Sustainable techniques and practices for water harvesting and conservation and their effective application in resource-poor agricultural production
Zakhe Agricultural College Consortium
No 1465

The study aims to identify and implement water harvesting and conservation techniques while benefiting rural farming communities. The study takes into account social, economic and environmental factors. Perceptions and possible adjustments to water harvesting and conservation practices in order to improve food security and rural livelihoods will be analysed. Guidelines will be developed for effective facilitation and technology adoption.

Estimated cost: *R1 500 000*
Expected term: *2003 – 2008*

Contribution of aquaculture to rural livelihoods
Rhodes University
No 1466

At present there is a lack of information on the importance of fish production systems in agricultural activities, the contribution it makes to household food security and constraints or opportunities which exist for expansion. This study should highlight specific topics for research projects that need attention. Particular emphasis will be placed on research of water-related issues that will lead to an improvement of rural livelihoods.

Estimated cost: *R350 000*
Expected term: *2003 - 2004*

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water and the economy

Scope

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 is 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. Almost without exception, there is an increasing interest in assessing the economic value of water, using water as a catalyst for the generation of wealth and prosperity, and using economic instruments to increase efficiency and effect desired behavioural change among water users. The use of water tariffs to effect changes in water consumption and the use of waste discharge charges to internalise pollution costs and, in so doing, effect pollution reduction and desirable improvements in water quality, are management options worthy of investigation and are, in fact, provided for in the National Water Act along with the selling of water use licences under specific circumstances.

This domain will integrate the economic aspects of water-related investigations funded by the 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 and the use of economic instruments in changing the behaviour of society at the appropriate micro-, regional and national levels.

Objectives

This domain aims to be instrumental in integrating the economic aspects of water-related investigations that are under way within the WRC's KSAs, and in identifying and initiating further important investigations which may be needed in this domain, water and the economy.

The primary aim of the research portfolio facilitated through this domain is to demonstrate the applicability of economic principles in the water field and to provide convincing evidence as well as sound knowledge and support to water management institutions and implementing authorities. The legal framework is already reasonably accommodating and stakeholders are therefore expected to be receptive to the knowledge generated.

Secondary objectives are to:

- Assess the value of water for different sectors of the economy
- Investigate the economic advantages and disadvantages of water resource development
- Assess the use of economic instruments to effect behavioural change regarding water utilisation
- Evaluate the use of economic instruments to promote equitable and efficient water allocation and distribution.

Thrusts

Thrust 1: The Value of Water to Different Sectors of the Economy

The value of water is different for the various sectors of the economy (e.g. to agriculture, cities, ecology, forestry and industry, health services) 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.

Thrust 2: The Economic Advantages and Disadvantages of Water Resource Development

This thrust focuses on quantifying the economic benefits which might arise as a result of the chain effect that water resource development has on wealth creation, or the costs which might be incurred as a result of pollution of the water environment.

Because of the economic benefits and associated multiplier effects, water resource development is often a powerful stimulus to wealth creation and secondary development. Conversely, water development can also have negative effects such as environmental pollution or a reduction in the availability of water for the environment. Most projects to date have dealt with the economic effects associated with irrigation development. A completed study has addressed the negative economic effects associated with salinity. Further 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.

Thrust 3: The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation

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 are presently being conducted.

Thrust 4: The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution

Economic instruments can be powerful instruments to achieve equitable and efficient water utilisation. Examples of issues included in this thrust are the use of cross-subsidisation to promote equitable distribution of water, privatisation of water services to promote efficient service delivery, and trading of water use licences to achieve optimal redistribution of water in the interest of greater economic efficiency and most efficient use of resources.

Research portfolio 2003/04

The research portfolio for 2003/04 is funded via the various KSAs (ongoing and new projects commencing during 2003/04) to the total amount of about R3m.

COMPLETED

Thrust 1: The Value of Water to Different Sectors of the Economy

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
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.

Cost: R750 000
Term: 1998 - 2002

The value of water as an economic resource in the Vaal River system
Greengrowth Strategies
No 990

Water supply has traditionally been augmented in line with growing demand. However, in view of the increasing shortage of new supply options, water demand management and specifically the optimisation of water distribution is of increasing importance. Thus there is a growing need to understand the economic features of water demand in South Africa.

In order to address the objectives of the project, it was necessary that proper natural resource accounts be drawn up for the Vaal River system, for the period 1980-1998. Natural resource accounts, which supplement a country's traditional national economic accounting system, are designed to assist in the analysis and design of sustainable development strategies through the optimisation of natural resource utilisation over the long-term. For modelling purposes, a system dynamics model of the Vaal River system was developed. STELLA, a software package for

developing system dynamics computer models, was used to model a variety of complex systems by attempting to understand the underlying relationships between the different parts of the system. For the purpose of this study, the total system has been consolidated into two "dummy dams" represented in the Upper and Middle Vaal systems by the Vaal and Bloemhof Dams, respectively. The economic value of water for the various users was calculated by estimating their demand schedules. The following procedures were used to derive demand schedules for the various use categories. By applying the demand schedules above, the economic value of water for the total Vaal River system was calculated to be R13.3 billion for 1998. Of this total the contribution of the Upper Vaal is R11.6 billion (87%) and that of the Middle Vaal R1.7 billion (13%). It is important to note that this is a flow variable, i.e. it is a recurrent value.

Cost: R807 180
Term: 1998-2002

Thrust 3: The Use of Economic Instruments to Effect Behavioural Change Regarding Water Utilisation

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
No 1043

Due to the unique characteristics of agricultural non-point source (NPS) pollution, it is not straightforward to quantify exactly who has caused the pollution and how much of it. In part this is due to the complex relationship between agricultural production and damages from water pollution involving physical, biological and economic links. How well NPS pollution control policy performed often depends on how well these links are understood.

The main objective of this research was to develop a spatial decision-support system capable of quantifying economic environmental tradeoffs of alternative NPS pollution abatement instruments.

Specific objectives included:
- Development of procedures to integrate a catchment level NPS pollution simulation model with an economic optimisation model.
- Development of a spatial economic optimisation model capable of linking the spatial use of alternative management practices to a total catchment outlet water quality standard.
- Evaluation of the cost-effectiveness of alternative NPS pollution abatement instruments through the quantification of economic environmental trade-off curves.

The research was conducted in the Gamtoos River catchment. The drainage area of the 70km long Gamtoos River, which is surrounded by the Baviaanskloof Mountains, constitutes an area of 1 357 km^2. About 7 400 ha were utilised to produce citrus, potatoes and other vegetable crops by 242 irrigators using micro-, drip- and centre-pivot irrigation. The Soil and Water Assessment Tool (SWAT) was selected to simulate inputs for the spatial optimisation models that were used to quantify the economic and environmental tradeoffs. Spatial variability in the Gamtoos catchment was taken into account by delineating 22 subcatchments and 129 hydrological response units of which 53 were used for irrigation purposes. The effects of 229 alternative crop, water and fertiliser input combinations on nitrate pollution parameters were thereafter simulated with SWAT.

Results from the baseline analysis indicated that significant variability exists between different subcatchments with respect to gross margins per unit emitted nitrate. However, it could not be concluded that subcatchments with relatively high values would have higher pollution abatement costs when the aim was to abate pollution at the catchment outlet, because each of the subcatchments was contributing differently to the pollution problem at the catchment outlet.

The ability of the non-linear spatial programming model to determine cost-effective economic environmental tradeoffs was clearly demonstrated. Significant tradeoffs were modelled at the subcatchment level due to the existence of both positive and negative tradeoffs, while little trade-off was modelled at the catchment level up to a 20% pollution abatement level. Thus, choice of pollution abatement levels based on catchment level tradeoffs may not be socially acceptable since it may make profitable farming for some farmers impossible.

Controlling the spatial use of alternative management options (crop, planting date, soil and input use) and a pollution tax were proposed as methods to achieve cost-effective pollution abatement. However, these options were very difficult to implement due to the large number of entities that needed to be controlled and the additional cost of obtaining the necessary water quality data at the sub-catchment level.

Another important result was that increasing water cost would not necessarily improve water quality, especially if

farmers were using water more efficiently without decreasing the areas irrigated. Increasing water use efficiency would reduce streamflow via reduced return flows. Reducing the amount of water available to dilute the pollution emissions would increase the concentration of the pollutants, thereby decreasing the quality of the water.

Results from the research not only showed that the developed procedures were suitable to quantify economic environmental tradeoffs necessary for NPS pollution abatement policy, but also suggest important policy implications:

- To improve the cost-effectiveness of pollution taxes, taxes should be based on the pollution contribution of each source to the pollution problem at a specific location and not on reduced emissions loads or pollution concentrations at the source
- The cost-effectiveness of taxes on input use was very low
- Water conservation policies with the aim of increasing water application efficiencies would increase water quality problems if farmers were allowed to increase areas irrigated using conserved water

Only through the application of the decision-support system developed in this research would policy makers be convinced about the relative effectiveness of alternative policy instruments to control NPS pollution. Application of these models would further enhance the understanding of the interaction between water legislation, water policy administration, technology, hydrology, NPS pollution and human value systems necessary to advance water policy.

Cost: R683 000
Term: 1999 - 2002

Identifying examples of successful cost-recovery approaches in low income, urban and peri-urban areas
Sigodi Marah Martin Development Consultants
No 1131

The purpose of the study was to identify the main determinants of successful cost-recovery for water services in South Africa and to use this information in the development of practical strategies to overcome obstacles to cost-recovery

The national survey of cost-recovery yields the most up-to-date available information about water services infrastructure, billing and payment, and cost-recovery outcomes in South Africa. The results highlight severe constraints on cost-recovery – especially for the provision of basic water services to the poor. Combining consumer poverty, low "RDP" service levels (e.g. public standpipes), and the associated inability to punish non-payment by selectively restricting services, is the surest recipe for failed cost-recovery. Although case studies have identified a few potentially instructive exceptions to this rule, the national survey data suggest that expectation of recovering the operation and maintenance costs of "RDP" water services through user fees is an unrealistic premise for national policy in the foreseeable future. There is a close fit between the empirical observations from the case study and the result of the simulations from the National Survey. Predictors of success are individual water meters (in whatever form), prompt and firm response to non-payment, progressive tariffs, good community relations and convenient payment facilities.

There can be no shortcut to successful cost-recovery. It must be a broad-brushed approach involving technical, financial and community aspects. It must be implemented with a unity of purpose between the political and administrative arms of the municipality. Finally it must be seen as a sustainable means by which the standard of service delivery to the public can be enhanced.

Cost: R438 000
Term: 2000 - 2001

Thrust 4: The Use of Economic Instruments to Promote Equitable and Efficient Water Allocation and Distribution

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
No 1384

The overall objective of the study has been to make an assessment of the level of cost-recovery as far as local government is concerned, and identify which measures are the most effective in increasing the rate of collection. This study highlights the substantive implications of the findings for municipal officials and national policy makers

seeking to overcome obstacles to successful cost-recovery. An assessment is also made of the impact of the free basic water policy, and the issue of unaccounted-for water.

In analysing the data and the concepts of debt ratios and repayment rates as indicators of cost-recovery performance (debt ratio is the ratio of current debt to total debt. If payments are made on time, then the ratio will be one), it was found that, even though the free basic water policy removes a substantial proportion of households from the debtors list, the average ratio from the municipalities studied was about 0.5. One municipality received only 3% of the amount they billed in a quarter. The use of the repayment rate (proportion of households who pay on time) gave very similar results.

The study indicates that the reconfiguration of the municipalities, coupled with the implementation of the free basic water policy has had a marked influence on how recovery of costs can be enhanced. On the one hand initiatives geared towards the lower end of the market are increasingly overshadowed by the impact of the free basic water policy. On the other hand, the implementation of punitive sanctions against non-indigent consumers who fail to pay a progressive, volume-related tariff, takes on increasing importance. However, it must be noted that just as punitive sanctions become increasingly necessary, they also become more expensive to implement. Water services providers are no longer able to cut the flow of water to defaulters – the policy would suggest that they have to ensure that the free basic allowance remains available to all.

Cost: *R400 000*
Term: *2002 - 2004*

CURRENT

Thrust 1: The Value of Water to Different Sectors of the Economy

The value of water as an economic resource in the Great Letaba River catchment
Economic Project Evaluation
No 989

Apart from separate sectoral analyses in defined sub-regions, 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*

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
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**

Valuation of changes to estuary services in South Africa as a result of reductions in freshwater inflows
Department of Economics, UPE
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
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

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
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
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
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*

Integrating flood-plain agriculture into a diverse rural economy by enhancing co-operative management: A case study of the Pongola
Institute for Natural Resources
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

Development of a framework for the introduction of waste discharge charge systems in South African catchments
Stewart Scott
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 1 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*

Establishment of a methodology for initiating and managing waste minimisation clubs
School of Chemical Engineering, Pollution Research Group, University of Natal
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*

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
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*

Payment strategies and price elasticity of demand for water in different income groups at three selected areas
Marketing Surveys and Statistical Analysis
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 6k_) 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

Generalised whole-farm stochastic dynamic programming model to optimise agricultural water use
Department of Agricultural Economics, University of the Free State
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 - 2005*

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
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*

Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers
Tlou Water Management
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
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
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 - 2005*

Development of models to facilitate the provision of free basic water in rural areas
Mvula Trust
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
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*

NEW

Thrust 2: The Economic Advantages and Disadvantages of Water Resource Development

An identification and review of the factors in rural water services that facilitate and impact on local economic development in the Eastern Cape
Rural Support Services
No 1437

There has been ongoing debate in the water and sanitation sector regarding the importance of viewing water services projects as part of an integrated development programme rather than as one-off projects that are seen as an end in themselves. One of the main issues related to this is the importance of, and ongoing need for, local economic development in rural areas. This is an issue that should be addressed in both the planning and implementation stages of any project with the full participation of community members. However, the current framework for delivery does not allow for the facilitation and promotion of economic development. This is particularly problematic given the current context of unemployment and poverty in rural areas. Water supply and sanitation are considered to be very good catalysts which can stimulate local economic development in poor areas. Yet many initiatives both locally and internationally tend to obviate this opportunity. This study aims to investigate the factors which would influence LED and the outputs will be guidelines that would influence LED during implementation of WSS projects.

Estimated cost: *R 300 000*
Expected term: *2003 - 2005*

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water and the environment

Scope

The scope of research in this domain has been re-assessed and re-defined following extensive stakeholder consultation and a needs analysis during 2002 and the early part of 2003. A detailed description of the new scope of research and the investment strategy for this domain is provided in WRC *Report No. KV 148/04*, available on request from the WRC. From 1 April 2004, reporting by this domain will be according to the new scope, thrusts and strategy.

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 what 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 the 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.

The scope of this crosscutting domain will differ from that of the KSA for Water-Linked Ecosystems 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, and in order to facilitate sustainable development practices and environmental sustainability, the main aims of this crosscutting domain are, therefore, to:

- Better understand the impact of various land uses on the different components of the hydrological cycle and subsequent risk to environmental functioning (e.g. biodiversity loss).
- 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 and poverty).
- Understand impacts of policy on the water environment, by investigating and recommending integrative and co-operative mechanisms to bridge the various legislative frameworks and policy directives.

Thrusts

Thrust 1: Environmental Governance Systems for Water in the Environment

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 are fragmented. The focus of this thrust is on investigations which:

- Facilitate the creation of institutions that enable the participation of civil society in democratic and accountable environmental decision-making, and
- Develop integrative mechanisms to "simplify" environmental governance.

Thrust 2: Biodiversity Protection

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 such as over-exploitation, invasive species, pollution, global warming, and habitat loss. This thrust area focuses 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
- Promotion of indigenous knowledge systems and local protection of the water environment.

Thrust 3: Environmental Functioning and Governance Systems

Managing ecosystems holistically and sustainably requires a detailed understanding of their function and condition. The KSA for Water-Linked Ecosystems was established to deal with ecosystem management and utilisation and ecosystem protection. This crosscutting domain will extend this focus to the terrestrial and atmospheric component of the environment. Better scientific understanding of the carrying capacity of ecosystems and thresholds for reversible and irreversible change would greatly benefit management efforts. This thrust focuses on:

- Impacts of different scenarios of ecosystem loss (or change) through land use
- Understanding the environmental components (air, land and water), and their inter-linkages 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 and water resources.

Thrust 4: Resource Management and Use

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)
- Determine the irreversible impacts such as erosion and aquifer degradation on the water environment.

Thrust 5: Ecosystem Functionning

Managing ecosystems holistically and sustainably requires a detailed understanding of their function and condition. 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 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)
- Developing strategies and means to reduce net impacts of environmental change on ecosystems and water resources.

Research portfolio for 2003/04

The research portfolio for 2003/04 is funded via the different KSAs (on-going and new projects commencing during 2003/04) to the total amount of R 4.7m.

COMPLETED

Thrust 2: Biodiversity Protection and Environmental Functioning

The use of isotope (13C) techniques to define the riparian zone in commercially afforestated catchments
Environmentek, CSIR
No 1218

The riparian habitat is a physical structure and associated vegetation of the areas associated with a watercourse, characterised by alluvial soils, and inundated to an extent, with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.

The relative abundance of water in the habitat makes it an attractive prospect for commercial exploitation by the forestry and agricultural industry. However, increased riparian tree biomass leads to decreased riparian functioning – which led to the forestry industry deciding to protect the riparian zone.

Forestry is often classified as SFRA (streamflow reduction activity) based on the ability of trees to intercept rainwater and to transpire water that has already entered the soil. Whether the water tapped by the trees is pyretic (retained in the soil above the saturated zone) or vadose (from, at or below the saturation zone), it remains relevant in the policy framework as the Act considers a holistic concept of the "water reserve".

The policy requires commercial forest owners to pay for the water that their trees use, and to protect the riparian habitat. In both instances the precise delimitation of the riparian area is required. The study used trees as integrators of the edaphic conditions in the vicinity of their roots. Using this approach, the objective was to explore the physical and chemical characteristics of wood that relate to water uptake of the trees and to use these to demonstrate reduced water stress associated with riparian water access. The spatial differentiation of characteristics that proxy water use was combined with the established criteria for defining the riparian habitat to give a more precise measure of the water-use or savings associated with the protection of the riparian habitat. This study is a pilot work focusing on the use of isotope and related techniques to determine water-use strategies of trees.

Cost: R200 000
Term: 2001-2003

Thrust 3: Water Pollution and Ecosystems

Reduction of urban litter in drainage systems through integrated catchment management
Department of Civil Engineering, University of Cape Town
No 1051

Few data are available on the nature and quantity of the litter that finds its way into stormwater systems. Previous South African studies have concentrated on removing litter from drainage systems once it is already there rather than reducing the amount of litter entering them in the first place. Litter management in South Africa has been hindered by the shortage of scientifically verified data indicating the likely effectiveness of any of these options. To address this lack of data, a two-year monitoring programme was conducted in nine pilot catchments (covering a range of different land uses, socio-economic levels and densities) in the Cape Metropolitan Area. The monitoring programme had two objectives:

- To improve the knowledge of the source, type and amount of litter reaching the drainage systems from different types of urban catchments
- To measure the effectiveness of different catchment based litter management options.

The principal findings were the following:

- There appears to be an inverse relationship between income and litter loadings in residential areas when garden refuse is excluded. This is largely due to the more effective and reliable household refuse removal service enjoyed by affluent areas.
- The installation of grids over catch-pit openings resulted in a significant decrease in the amount of litter trapped in catch-pits in Summer Greens and Montague Gardens.
- There was a significant reduction in litter loads in Ocean View during the monitoring period. The sensitizing of the community to littering issues from the end of 2000 and a more frequent and comprehensive litter removal service by the local authority are plausible reasons for this improvement.
- Sand entering the catch-pits is a major problem in many catchments as it tends to become entrained in other litter such as plastic bags resulting in blockages and flooding of the stormwater system.
- Street sweeping is an extremely effective method of reducing the quantity of litter reaching the stormwater

system as was demonstrated in the Cape Town Central Business District.
- Construction rubble is a significant contributor to the waste stream. Catch-pit grids are an effective way of reducing the amount of rubble entering the stormwater drainage system.
- Plastic items contributed between 19% and 50% of the litter stream by mass when sand, stones, vegetation and rubble were excluded. Plastic was the largest major litter category in all the catchments except for the formal residential areas of Summer Greens and Welgemoed.

Cost: R690 000
Term: 1999 - 2002

Water-related impacts of small-scale mining – Nature of the impact and development of management options
Pulles, Howard & de Lange Inc.
No 1150

This study was undertaken to identify and characterise the critical aspects relating to water-related impacts of small-scale mining and to develop and recommend appropriate tools to assist in environmental management for small-scale miners.

The project team identified the small-scale mining types that have the greatest impact on the water environment through consultation with national representatives of DME and DWAF. A limited number of sites for in depth regional site surveys were selected based on information gathered during initial screening site visits. The most important environmental impacts caused by small-scale miners appear to be related to accelerated erosion of areas adjacent to workings that have been de-vegetated for construction materials or fuel-wood. This leads to increased suspended sediment loads in nearby streams and rivers. Furthermore, alteration of river channels and excavation of flood terraces and riverbanks increases their instability and enhances the likelihood of increased flood scouring. While the communities living in close proximity to small-scale mining operations were aware of issues such as rehabilitation and the environmental impacts associated with mining activities, the miners largely ignored environmental issues and impacts. They viewed the required mining documentation, such as EMPRs, as a licence to mine only and not as providing further guidance on rehabilitation and closure. Regulators had difficulty in visiting, least of all regulating, the vast number of small-scale mining operations and concentrated on the more formal larger-scale mining operations.

Interested and affected parties assisted the project team with the design, planning and implementation of a handbook to assist small-scale miners in responsible mining. The contents of the handbook take into account the needs, interests, and values of the community, mining sector, regulators, etc. A stakeholder workshop with wide representation was convened to discuss possible education and implementation strategies and to engage in an understanding of the water-related issues of small-scale mining. This handbook is expected to play a significant role in assisting the regulating authorities to sensitise small-scale miners about their environmental impact and to assist them with devising environmentally responsible mining options

Cost: R738 000
Term: 2000 -2003

Thrust 4: Resource Management and Use

Sediment-induced density current formation in reservoirs
Department of Civil Engineering, University of Pretoria
No 911

Reservoir sedimentation causes an average annual loss in storage capacity of 130 million m^3 in South Africa. Density current venting is a management technique whereby high river sediment loads can be transported through a reservoir and released to the downstream river through bottom outlets, without water level draw-down. This study investigated the use of a theory based on minimum stream power at the plunge point, to predict the formation of a density current. Laboratory tests were carried out with sediment transport to verify the theory.

The guidelines provided in this study to determine density current formation were expected to become useful in the planning, feasibility and detailed design studies by DWAF in sediment management projects.

Cost: R91 000
Term: 1998-2003

The ocean's role in South Africa's rainfall
Department of Oceanography, University of Cape Town
No 953

The aim of this project was to investigate aspects of the role played by the Indian, the Atlantic and the Pacific Oceans as well as the Agulhas Current on rainfall over Southern Africa. It has contributed to unravelling some of the physical mechanisms linking the ocean and climate variability in South Africa. It has further elucidated the considerable effect of the Indian and Pacific Oceans on the yearly variation of rainfall over South Africa. The Agulhas Current has also been shown to play an important role, especially through enhancing local weather systems and storms.

This project has highlighted significant changes in the teleconnections linking Southern African rainfall variability to oceanic and atmospheric conditions. In particular, the most severe droughts affecting the region between 1950 and the 1970s were associated with regional oceanic-atmospheric anomalies, involving mainly the South-West Indian Ocean, whereas since the 1970s they are mostly related to El Niño – Southern Oscillation (ENSO) events. A stronger relation to ENSO is also diagnosed through an overall correlation between rainfall variability over Southern Africa and ENSO indices. Numerical experiments suggest that this enhanced relation to ENSO is linked to the long-term evolution of the SST background, which is a part of the observed global warming trend.

This project has contributed to a better understanding of some of the physical mechanisms responsible for drought in Southern Africa, the first step towards producing accurate forecasts for the rainy season with sufficient lead time.

Cost: R1 395 000
Term: 1998-2003

Climatology of water vapour sources, sinks and transport in Southern Africa
Department of Environmental and Geographical Sciences, University of Cape Town
No 1012

This project on moisture transport, sources and sinks, sought to investigate the underlying dimension of atmospheric moisture on which the South African rainfall is inherently dependent. The research followed two complementary pathways. Firstly, a trajectory model was developed and then applied to investigate the time-evolving transport paths of the atmospheric moisture, and the related sources of moisture. The trajectory model took advantage of low-cost computing infrastructure, and was developed to specifically address large-volume trajectory calculations. From this was developed a 20-year climatology of moisture transport for Southern Africa that was then examined in terms of seasonal and sub-seasonal attributes. Secondly, the large-scale seasonal mean moisture dynamics were examined to identify key source regions of moisture contribution to the atmosphere. Both approaches developed different insights into the climate system, which complemented and supported one another.

Cost: R562 000
Term: 1999 -2004

Predicting the impact of farming systems on sediment yields in the context of integrated catchment management
ISCW, ARC
No 1059

Sedimentation is a major threat to water quality, its storage and how it is distributed. The use of computer simulations to predict impacts of farming practices and management on sediment yield in small catchments has had limited application in South Africa. In this project modelling tools, WEPP and ACRU were used in predicting the impacts of farming practices and management on sediment yield.

The study sought to improve methodologies used to predict the impact of selected land uses on sediment yield in South Africa. The improvements in methodologies also involved an assessment of the quality, availability and the spatial distribution of input data for the two models used in the study.

The study considered that integrated catchment management involved three phases which are identification of system characteristics, prediction of the behaviour of the system and management of the system. The study focussed on the behaviour and ways of managing agricultural lands through the use of modelling tools. Three study areas were selected: Weatherly, Zululand and Kokstad. These areas were selected on the basis of a number of factors which included land uses, soil types and patterns, topography, rainfall and availability of data.

Simulations were done in the study catchments for varying land use practices. Both models were applied in each catchment. The results from the models were analysed and compared on the basis of model outputs which included the following:

- Evapotranspiration
- Soil water content
- Runoff
- Sediment yield.

The findings showed that the WEPP Model generated better results on the impact of agricultural practice. The data collection for the WEPP model was, however, noted to be very challenging, as it required very detailed inputs that were not readily available. The ACRU model had the advantage of having readily available datasets for the selected catchments. This study also identified the need to develop approaches that integrate the biophysical environment and the socio-economic environment.

Cost: R843 000
Term: 1999 - 2004

Hydraulics of the impacts of dam development on river morphology
Department of Civil Engineering, University of Stellenbosch
No 1102

The construction of a dam can drastically alter the flow regime and sediment load of the river downstream by altering flood peaks and durations, as well as trapping large amounts of sediment. The imposed changes in the flow can lead to riverbed degradation directly downstream, as a result of very low sediment loads, as well as narrowing of river channels due to decreased transporting capacities further downstream. The broad aim in this project was to obtain a better understanding of the river sediment transport processes due to the impacts of dam development. This entailed the development of a procedure to determine flushing flow magnitudes, duration and frequency downstream of a dam as well as predicting downstream river channel geometry with the objective of maintaining the river morphology as close as possible to the natural (or desired) conditions, based on fundamental hydraulic principles of sediment transport.

Cost: R660 000
Term: 1999-2002

CURRENT

Thrust 2: Biodiversity Protection and Environmental Functioning

Use of grass species for rehabilitation after wattle control
Agricultural Research Council (ARC)
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
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*

Improving the basis for predicting evapotranspiration from dry-land crops and veld types in South African hydrological models
Environmentek, CSIR
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*

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
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
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
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
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^2. 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
No 1350

A joint WRC-Coaltech 2020 project utilising an experimental setup 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 3: Water Pollution and Ecosystems

The impact of urbanisation and industrialisation on the environment
Department of Chemistry (Mamelodi Campus), Vista University
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

The assessment of short-, medium- and long-term impacts on groundwater quality associated with the filling of dolomite cavities
Metago Environmental Engineering
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
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
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
Coaltech 2020
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 that 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*

An evaluation of dedicated land-disposal practices for sewage sludge
Institute for Soil, Climate and Water, ARC
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
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 Inc.
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
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

Aerosols, recirculation and rainfall experiment
Climatology Research Group, University of the Witwatersrand
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*

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
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: *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
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*

The dynamical 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
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
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 ingress of marine sediments that 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 management he 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
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*

Development of guidelines for the design and operation of river diversion structures to deal with the problem of sedimentation
Ninham Shand (Pty) Ltd
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 and transfer schemes such as on the Olifants River, currently under construction, or the Thukela water diversion schemes that 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, University of Natal
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
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
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 palaeo-geohydrological studies. Numerous studies have been documented over the last decade on palaeo-climatic conditions (covering the last say 3 000 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
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)
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
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*

NEW

Thrust 1: Governance Systems for Water in the Environment

Industry-government partnerships for the development, setting and implementation of standards for the water environment
PBAI Associates
No 1416

The aim of this project would be to develop a partnership approach between industry and government for setting of agreed environmental standards, based on the Dutch "covenant" model and utilising the provisions of the National Water Act for setting minimum standards for water uses which impact on the water environment, and implementing these through the use of provisions for Environmental Co-operation agreements which are contained in the National Environmental Management Act. The approach would be to work at pilot scale for one industrial sector and one aspect of the water environment, in order to develop a generically applicable model.

Estimated cost: *R200 000*
Expected term: *2004 - 200*

Review and evaluation of all relevant governance elements which directly relate to or potentially impact upon water in all phases of the hydrological cycle
Pegasus Strategic Management
No 1514

Review and evaluation of all relevant governance elements (principles, policy, legislation, regulation and practice) at international, national and provincial level that are presently in place and which directly relate to or potentially impact upon water in all phases of the hydrological cycle.

Estimated cost: *R500 000*
Expected term: *2003 - 2004*

Thrust 2: Biodiversity Protection and Environmental Functioning

Integration of indigenous knowledge systems in the conservation and protection of wetlands in communal areas of South Africa
CN Maqwa Consultants
No 1417

This project aims to identify and describe the indigenous knowledge systems contributing to the conservation of wetlands in communal areas, and to provide guidelines on ow this knowledge can be integrated into current systems to enhance sustainable management.

Estimated cost: *R 300 000*
Expected term: *2003 - 2004*

The nature and rehabilitation of alien-invaded riparian zones
Dept of Zoology, Freshwater Research Unit, University of Cape Town
No 1407

Riparian zones are important components of river systems, but are particularly prone to invasions by aliens. The *Working for Water Programme* is putting a lot of effort into clearing the invasive aliens from riparian zones, and this project, which will be run in conjunction with *Working for Water*, will characterise the vegetation of undisturbed and invaded riparian zones as well as the parts of the riparian zone invaded by specific invaders. The impact of commonly used learning methods will be investigated through monitoring early recovery and germination experiments on the existing seed banks.

Estimated cost: *R 999 900*
Expected term: *2003 - 2006*

Facilitating the free passage of migratory aquatic biota in South African rivers
Consortium; University of Stellenbosch (lead agent)
No 1409

The need to manage water has led to the construction of barriers in rivers, effectively fragmenting the habitat and curtailing the passage of migratory biota. This project will develop protocols for assessing the extent of blockage to free passage, and so prioritising river systems for remedial measures, for the assessment of sites for use in the EIA and the RDM process. Understanding of the biological/hydraulic requirements of relevant biota will be developed and this, together with data from existing fish-ways, will be used to develop cost-effective designs for local biota.

Estimated cost: *R 2 000 100*
Expected term: *2003 - 2007*

Thrust 3: Water Pollution and Ecosystems

Global climate change and water resources in South Africa: Potential impacts of climate change and mitigation strategies
School of BEEH, University of KwaZulu-Natal
No 1430

The need to prepare South Africa to cope with global climate change is of paramount and strategic importance. This project will develop plausible climate change scenarios for Southern Africa; investigate the potential impacts of climate change on hydrological responses and associated water resources; investigate possible water-related socio-economic impacts in a designated water management area; recommend appropriate strategies to adapt to, and cope with, water-related impacts of potential climate change; determine whether effects of climate change can already be detected; and recommend appropriate monitoring systems for its detection.

Estimated cost: *R 1 112 000*
Expected term: *2003 - 2005*

Freshwater requirements of the marine environment:
A proposed predictive approach to assessment of potential impacts
Environmentek, CSIR
No K8/509

The reduction in freshwater flows in river/estuarine systems is likely to have a significant effect on the offshore marine ecosystems, particularly along the East coast of Southern Africa. It is necessary to define and assess potential impacts on estuarine and offshore marine ecosystems

It is believed that nutrient-rich freshwater and sediment inputs into the coastal marine environment create habitats that sustain highly productive offshore ecosystems (e.g. Tugel prawn industry)

A methodology exists to assess the reduction of freshwater in rivers, groundwater and estuarine environments, but not for offshore marine environments. It is the purpose of this project to provide a framework in support of rapid

and intermediate Reserve Determination Assessment, particularly for offshore marine ecosystems.

It is necessary to:
- Determine where freshwater reduction would have significant offshore impact
- Determine the nature of the physico-chemical and ecological links between estuarine and the offshore marine environment
- Predict and quantify the extent of potential impacts of reduced freshwater with regard to ecosystem integrity and also with regard to regional economy
- Provide rapid and intermediate assessments that are accurate and cost-effective.

The aims are to:
- Provide a preliminary but robust framework for investigating the impact of freshwater reduction on the marine environment.
- Test the efficacy of a proposed low-cost assessment for application in Reserve Determination
- Recommend future research in this field
- Transfer knowledge
- Develop links with the "Catchment to Coast" research initiative between South Africa and Mozambique and EU partners

Estimated cost: *R 200 000*
Expected term: *2003 - 2004*

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water and health

Scope

This domain has an essential role to play in providing an integrating framework for all the WRC's health-related research and development initiatives, identifying gaps and negotiating the initiation of gap-filling research in crucial areas. In fulfilling this role, the domain assumes the responsibility for the structuring of a co-ordinated, needs-driven, dynamic health-related water research portfolio on behalf of the WRC, with contributing projects being funded and managed mainly at KSA level.

Health-related water research is undertaken with the aim of improving water quality and hygiene practices in order to save lives and reduce the cost and effort in treating symptoms of disease. The focus is on water-linked diseases associated with microbial or chemical contamination or transferred via water-associated vectors. The domain aims to improve knowledge regarding the origin, survival and persistence of microbial, biological and chemical agents that may pollute water and may affect human health. The domain supports the development and utilisation of methodologies to identify and quantify the occurrence of pathogens and contaminants in water, as well as risk assessment and epidemiological studies.

A holistic, multidisciplinary approach is followed in order to develop a comprehensive understanding of the origin/sources and spatial extent of pollution; water usage patterns; the effects of degraded water quality on animal and human health and the need for water treatment. The development of guidelines, protocols, manuals and pamphlets could be the tools to disseminate the research findings. 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.

Objectives

The primary objective of this domain is to contribute to protection of human and animal health and that of the aquatic environment by investigating the sources, persistence, and control of water-related diseases.

Secondary objectives are to:

- Develop appropriate techniques, technologies and systems for monitoring of potentially harmful pollutants in water
- Obtain adequate understanding of the origin, survival and persistence of, and inter-relationships between, microbial, chemical and other biological and toxic pollutants in water
- Assess the impacts (actual and potential) of pollutants on human, animal and aquatic health by performing epidemiological investigations and developing health-risk assessment tools
- Investigate the effects of the environmental change on health (e.g. the impact of global warming on the spread of malaria; the link between climate variability and epidemics caused by water-borne diseases)
- Develop scientifically sound educational material on health, hygiene and the effects of /and prevention of pollution and the relationship between these
- Provide guidance for appropriate communication, awareness-building and management strategies

Thrusts

Thrust 1: Microbial Water Quality and Associated Diseases

This thrust focuses on improving knowledge, both of the micro-organisms responsible for water-borne diseases and of the epidemiology of such diseases; assessing associated health risks; and developing cost-effective management strategies for preventing water contamination and diseases. It includes studies on protozoan parasites, viruses and other potentially pathogenic micro-organisms, with emphasis on simple, rapid and cost-effective detection techniques.

Thrust 2: Chemical Quality of Water and Associated Diseases

The overall objective of this thrust is to focus on characterising chemicals in water, both those occurring naturally and those resulting from pollution, which have the potential to cause detrimental health effects in humans , animals and the aquatic environment. An additional focus is to acquire information for assessing the effects of heavy metals and various other chemicals and compounds, singly or in combination, on health, as a guide to development and implementation of cost-effective treatment and control strategies. Special emphasis is given to studies on endocrine disrupting contaminants (EDCs), toxins (both those occurring naturally and those associated with industrial, pharmaceutical and agricultural chemicals and sewage effluents), algal toxins associated with eutrophication of water resources, and fluoridation. Further emphasis is on the development of simple, rapid and cost-effective detection techniques.

Thrust 3: Safeguarding Public Health

This thrust sets out to develop and focus on ways of anticipating conditions conducive to the outbreaks of water-linked diseases and appropriate precautionary and preventive measures which can be taken in this regard. The development and use of pollution monitoring systems, early warning systems (possibly environment/climate-based) and hygiene-practice guides are appropriate in this regard. Examples are the development of protocols, guidelines and manuals for microbial, toxin and EDC monitoring programmes, and the development of public awareness and educational materials such as the guideline series (5 volumes) on *Management of Water-Related Microbial Diseases*.

Research portfolio

The funding for research projects supported by the various KSAs and focusing on this domain is estimated at about R14.5 million for 2003/04. The projects presented are linked to various KSAs and are implemented and managed within these KSAs.

COMPLETED

Thrust 1: Microbial Water Quality and Associated Diseases

Programme 1: 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
No 1164

Viral infections feature prominently among water-borne diseases which have a major public health impact world-wide. Information on viruses in drinking water is restricted because the detection of viruses in water is expensive and requires special skills. In this project the latest technology and expertise has been applied to obtain the most comprehensive data on viruses in a representative selection of South African drinking water supplies on record. The aims were 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.

A statistical model designed by the World Health Organization (WHO) was used to assess the risk of infection constituted by the viruses detected. Mainly due to sensitive techniques not previously applied, viruses were detected in drinking water supplies which were prepared according to international specifications for treatment and disinfection, and which conform to specifications for indicators of water quality such as faecal and heterotrophic bacteria. In addition, the results revealed that the risk of infection constituted by the viruses exceeded an acceptable risk of one infection per 10 000 consumers per year recommended for drinking water in the USA. The detection of viruses in drinking water supplies and risk of infection which exceeds recommended levels have been reported previously in South Africa, as well as other parts of the world where studies of this kind have been carried out, notably the USA. The results of this project do not necessarily imply unacceptable drinking water quality. However, they disclose controversies regarding guidelines for drinking water quality which confuse the water industry and public health authorities. Solutions would require a revision of strategies to ensure drinking water of acceptable quality in South Africa.

Cost: R1 000 000
Term: 2000 - 2002

Health risk assessment in connection with the use of microbiologically contaminated source water for irrigation
Dept of Community Health, University of Stellenbosch and Dept of Medical Virology, University of Pretoria
No 1226

The presence of dense settlements on the river banks in the Western Cape gives rise to water pollution of nearby rivers and severely affects the water quality downstream. Most of the water pollution can be attributed to

inadequate sanitation in these settlements, severe over-crowding, as well as failing sewerage systems.

The study was done in two phases. In Phase A of the project a general overview of sanitation problems associated with dense settlements and background to the study site selection and environment gave an indication of the problems that could cause pollution of the nearby watercourse. *Esherichia coli* were used to quantify the faecal pollution in the river.

The results of the study revealed the high incidence of diarrhoea in the area and faecal pollution in the river over four years. Pathogens carrying considerable health risks were identified in the water. A number of the organisms in the water and in the biofilms on the stones in the water exhibited signs of antibiotic resistance and also resistance to chlorination. A further complication was that some of the organisms surviving the chlorination experiments showed enhanced antibiotic resistance. Several viruses were also detected in the water and the biofilms.

Recommendations were made to the prevention of the pollution, such as ongoing education campaigns that proved to be successful, and remedial actions such as interventions in sanitation and services rendered were proposed.

The risks to health, environmental damage and the problems foreseen with economic activities downstream of a river polluted with faecal matter set the scope for **Part B** of the project which investigated the microbiological quality of irrigation waters and contamination of foods crops.

Food-borne illnesses remain a widespread and growing public health problem in the developed and developing world and the burden of infection is grossly underestimated. Minimally processed foods such as salads, vegetables, fruits and other fresh produce that required minimal processing before consumption are usually contaminated through human contact during harvesting or processing, but contamination via wastewater and sludge, used for crop irrigation and fertilisation, has also been documented. Increased faecal pollution due to the lack of sanitation or wastewater plants not complying with standards may elevate risks of food- and waterborne disease in SA.

The isolation and detection of enteroviruses, human adenoviruses, HRVs and HAstVs from a river used for domestic purposes and as irrigation water suggests that the water could pose a potential health risk, but more data are required to quantify the risk. Pathogenic bacteria such as *Salmonella, Shigella* and *E. coli* were detected in a number of irrigation water samples and minimally processed food samples.

Cost: R100 000
Term: 2001-2003

Programme 2: Method development for known and emerging micro-organisms causing water-borne diseases

Preparation and testing of kits for the detection and quantification by developing countries for *Cryptosporidium oocysts* and *Giardia* cysts in water supplies

Umgeni Water; Dept of Microbiology and Public Health and Dept of Microbiology and Plant Pathology, University of Natal

No 825

Cryptosporidium parvum and *Giardia lamblia* were recognised as important water-borne pathogenic protozoa, with the potential to cause diarrhoeal disease for which there is no treatment and therefore life-threatening to the immuno-compromised. Faecal contamination of waterways could lead to outbreaks of the disease and massive outbreaks have been reported worldwide.

The development of an effective but simple detection method for South Africa for the parasitic protozoa was identified.

An economic system for detecting *Cryptosporidium* oocysts and *Giardia* cysts in water concentrates using the SIA (slide immunoenzymatic assay) based on the enzyme-linked immunoenzymatic assay (ELISA) was developed. A multiple solid-phase SIA test that combined liquid and solid phases for laboratory and field use was optimised for use with water samples of varying turbidity. Three commonly used concentration methods used for concentration of the oocysts and cysts from water combined with an immuno-fluorescence assay for detection were evaluated and compared with the IMS and SIA detection techniques. A neodymium magnet was developed for 'continuous' immunomagnetic capture of (oo)cysts from flowing water and was evaluated using commercially available Dynabeads.

Multiphase SIA was found to be cost-effective and simple and produced optimal colour reactions. Dilutions and

the minimum number of oocysts and cysts present in the samples to give a visible detectable yellow reaction were determined.

A simple low-cost spectrophotometer was constructed, but initial evaluation of the system showed that the instrument was not sufficiently sensitive.

The un-optimised SIA technique could be used to detect and monitor oocysts and cysts at contamination sources where the protozoa are in high quantities such as at runoff points from livestock farms, informal settlement areas or sewage effluents. The operating principles were demonstrated to perform well but the processes generally need to be optimised and refined for greater sensitivity.

There is great potential for this application and the outcome of the project could be used as a base for further development and optimization of the simple low-cost spectrophotometer for reading of SIA slides and an SIA colour chart correlating colour intensity with (oo)cyst concentration as a guide to the direct visual qualification of (oo)cysts in samples.

Cost: R308 000
Term: 1997-2000

Occurrence and source of *Cryptosporidium* and *Giardia* in catchment areas and wastewater works
Microbiology & Public Health/Scientific Services, Umgeni Water; Departments of the University of Pretoria; Environmentek, CSIR; University of Natal; Allerton Regional Veterinary Laboratories; Medical Research Council, Durban (UND Medical School); Institute for Water Quality Studies (IWQS), Rand Water
No 927

The enteric protozoa *Cryptosporidium parvum* and *Giardia lamblia* have been recognised as important causes of both outbreak-related and sporadic diarrhoea in humans. Contamination of a water source arises as a result of runoff, accidental spillage of farm slurry from agricultural land or from sewage effluent particularly from abattoirs or when infection exists in the community. Using untreated surface water as a source of drinking water exposes a great number of the South African population to higher numbers of these pathogens and increases the risk of infection. These pathogens have a high infectivity and are resistant to disinfection; therefore there can never be absolute certainty that viable oocysts will not penetrate water treatment and so pass into supply. This necessitates the examination of large volumes of water when monitoring the quality of drinking and environmental water samples.

The study consisted of two parts, firstly, the use of PCR-based methods for the confirmation of results and evaluation of its compatibility with the commonly used concentration, purification and detection methods were investigated. The second part investigated the incidence of these protozoa in the rivers in the Pietermaritzburg catchment area and the impact of the rural, peri-urban and urban settlements and whether the diarrhoea, suffered by patients in the area, was indeed caused by *Cryptosporidium* and *Giardia*.

It was found that the PCR-based methods have the potential to be used to confirm the presence of protozoan cysts and oocysts in water samples but owing to sensitivity problems it would be difficult to implement this technology on a routine basis at this stage.

The protozoa were detected sporadically and widely in the river and water samples and the conclusion is that they are probably ubiquitous in the study area. A risk assessment was done to provide a quantitative estimate of the probability of illness associated with environmental exposures and focused on human health risk assessment. The sources of contamination were identified and some preliminary guidelines drawn up for the community, veterinarians and for safe-guarding potable water supplies, but the implementation of this is the responsibility of the relevant authorities

Cost: R300 000
Term: 1998-2000

Thrust 2: Chemical Water Quality and Associated Diseases

Programme 4: Eutrophication and associated toxic algal blooms: Detection and management of algal toxins in water resources

Determination of the known extent of cyanobacterial problems in SA water resources and identification of South African cyanobacterial knowledge, information and research needs
(New shortened title: **Cyanobacterial monitoring 1990-2000: Evaluation of SA data**)
Dept of Biochemistry and Microbiology, University of Port Elizabeth; RQS; DWAF
No 1288

Toxic blooms associated with eutrophication during summer months in South Africa have been frequently reported. In several cases death of livestock and fish kills have been reported, although toxicological data on fish does not preclude the possibility that these were not toxin induced. Much of the literature on the subject cites only events where severe blooms, or livestock or fish kills occurred. Despite the recognition that toxic blooms may be an increasing problem in SA, no effort has been made to identify trends in incidence or extent of events in recent years.

The aims of the project were to identify and rectify the gaps in the current knowledge in these areas and to determine the need for guidelines for monitoring and managing water resources, and to identify the research gaps in this field. In order to accomplish these aims, all available data pertaining to phytoplankton levels and selected associated parameters, were obtained from the DWAF database. Several water management bodies (municipal, and other treatment works, and water boards) in various parts of the country were visited and data from these visits were also included in the report.

Results from this study show that cyanobacterial problem events are widespread, frequent, prevalent and typically seasonal in water resources subject to eutrophication. Available data, however, were found to be unsuitable for detailed statistical analysis. The major problems in this regard were variation in sampling method and sampling frequency both spatially and temporally. The results therefore reflect trends only in as much as the data allowed for this.

Geographical variation in the frequency, duration and severity of the problems primarily due to the condition of the catchment, but also the nature of the water source, abstraction points, and regional climatic conditions exits. Insufficient data is available to establish the nature of this variation. No national trend in frequency of cyanobacterial blooms events, toxin, or taste and odour, could be established with the available data. Toxin and geosmin/MIB data are extremely limited due to the limited resources and cost of the analysis.

Recommendations to address the needs identified by the water fraternity were such as the development of a national monitoring, assessment and managing model with the associated administrative structures.

Cost: R70 000
Term: 2001

Thrust 3: Safeguarding Public Health

Programme 1: Monitoring systems

Health-related water quality and surveillance model for the Peddie district in the Eastern Cape
University of Fort Hare/Department of Development Studies
Collaborating Institutions/Departments:
No 727

South Africa with its limited water resources is experiencing rapid urbanization and population growth all over the country, also in the impoverished socio-economic environments, with limited water resources and poor sanitation such as in the Peddie district in the Eastern Cape. The limited water sources are unprotected and are also used by domestic animals, conditions that are associated with an increase in water-related and water-borne diseases.

The aims of the project were to examine the effects of water supply, handling and usage of drinking, farming and other household activities on water quality in the rural and peri-urban areas of Peddie. Both the microbial and physio-chemical quality of water provided to the communities was examined and related to health indices of the study population.

The quality of the water was determined at the point of provision, collection, and use and after transport and storage. The patterns of water usage, including water used for farming, drinking, washing and other hygiene

purposes were investigated but the quantity of water used was not included. The treatment of water by the end-user prior to use was recorded. The water quality at the source and point of use was correlated with the health indices of the population.

A surveillance infrastructure at community and sub-regional levels was established and proposed to ensure that water supplies are kept under continuous public health assessment. Remedial action strategies which will protect the user from the risk of water-borne diseases were developed to provide a scientific basis for prioritising needs identified.

The pilot study revealed that the incidence of faecal coliform pollution varied in the district but was found in the majority of the tested water sources. The majority of the communities are solely dependent on these sources as there are no other water supplies.

The findings of the team were communicated to the communities and authorities. Capacity was built and awareness raised for the communities to lobby the government in providing the infrastructure and recommendations were also submitted to the communities and authorities in the Eastern Cape to ensure safe drinking water for the inhabitants of the area and to prevent pollution of their water sources.

Cost: R393 000 (Additional funds: R 17 400)
Term: 1996 - 1998

Extension of the South African National Microbial Water Quality Monitoring Programme to include groundwater
Environmentek, CSIR
No 1277

A National Microbial Monitoring Programme for surface water is currently being implemented by DWAF. The programme is one of a number of national status and trends monitoring programmes that address the requirements of the National Water Act (No 36 of 1998) to establish national information systems on South African water resources.

Microbial groundwater quality in South Africa, relating to faecal pollution, is not well characterised at present. However, many potential faecal pollution sources exist, such as dense informal settlements with inadequate sanitation and large sewage treatment works. Groundwater is now seen as being of primary importance in supplying safe drinking water, especially to inhabitants of rural areas.

The specific aim was to develop a prototype manual that formally describes a detailed groundwater monitoring system design and all aspects of subsequent implementation of the programme.

The project delivered two reports. The first report describes the development of this programme from the equivalent surface water programme and other national monitoring programmes within the Department. A literature review on pathogens in groundwater is included in the report and describes how contamination occurs; movement and survival of micro-organisms and various indicators of faecal pollution are also discussed. A relative analysis is performed, the results of which provide one tool for deciding on the most appropriate monitoring variables. Factors relating to analytical methods (like the costs, available capacity, etc.), the presence and survival of micro-organisms in groundwater and their likelihood of reaching the saturated zone, are considered. Viruses are not included in the programme at this time due to various constraints.

An overall monitoring philosophy is developed that aims at maximising the ability to make general statements about the microbial quality of aquifers as a whole while minimising the number of monitoring boreholes.

The monitoring focuses on the ability to confirm that faecal pollution from a significant faecal pollution source is contained in the immediate down-gradient flow path from the source. A process for prioritising areas for inclusion in the monitoring programme in the initialisation phase of the programme and a framework for a pilot-study exercise that addresses two focus issues, namely the testing of the core design and practicality of the monitoring philosophy and the inclusion or exclusion of detection of viruses, are recommended.

The second report is the *Prototype Implementation Manual* developed that will be tested in the pilot study (implementation phase) after which corrections will be made to the document if necessary. The Manual will be used by DWAF as a working Manual for the monitoring and full-scale implementation of the National Microbial Monitoring Programme for Groundwater.

Cost: R600 000
Term: 2001 - 2003

A pilot study to demonstrate implementation of the National Microbial Monitoring Programme
CSIR/Environmentek; Institute for Water Quality Studies, DWAF
No 1118

To assess the status and trends of faecal pollution of South Africa's surface water, a National Microbial Monitoring Programme was proposed as early as 1994. In 1996 a conceptual design for microbial quality monitoring of surface water, on a national basis, was compiled by the Institute for Water Quality Studies (IWQS) of DWAF, and Environmentek (CSIR). During the following 2 years the proposed monitoring design was evaluated during pilot-scale studies. The refined monitoring design was used as a basis for a *National Microbial Monitoring Implementation Manual* produced by the WRC in 1999.

This project, the actual implementation of the developed National Microbial Monitoring Programme (NMMP), was initiated in several regions in South Africa including registration of local monitoring programmes, commencement of sampling and water sample analysis, data handling, data dissemination, data quality assessment and ongoing marketing. The lessons learned and the experiences gained during the pilot-scale implementation of the monitoring programme have been incorporated in the revised *NMMP Implementation Manual*, the main deliverable for this project that was published and is being used by DWAF.

Cost: R303 000
Term: 2000 - 2002

Programme 2: Public awareness and education material

An Elementary Handbook of Water Disinfection- An Introduction to the Principles of Water Disinfection Processes
Environmentek, CSIR
No 770

The aim of the Handbook is to provide readers with an introduction to the processes of water disinfection. The emphasis was placed on chlorination and chloramination, the two processes most commonly used in South Africa. Alternative processes such as chlorine dioxide, ozonation, mixed oxidants (the peroxone process), and ultraviolet irradiation are also discussed.

The Handbook is written for non-specialists in chemistry and microbiology. The reader is taken through an introduction of what disinfection is all about. Principles are established to afford a basic understanding for operating a water treatment plant. Those readers who would like to get more specific information to improve their depth of understanding would benefit by the suggested sources for further reading which are also included.
This handbook is an abridged and simplified version of a more extensive work entitled: *Guide to the Chemistry, Biochemistry and Microbiology of Chemical Water Disinfection Processes*, by FHH Carlsson and PW Wade (revised and expanded edition), 1997 (available at the CSIR).

This Handbook will be useful in the education and training of personnel of a water treatment plant. It could be used as an aid to inform people responsible for water disinfection in developing communities of the importance and health implications of water disinfection. It could also be used as a convenient source of information for everyday use on small water treatment plants in particular.

Cost: R70 000
Term: 1996 -1997

Protocol Manual for the Transfer of Methodology Required to Link Ecosystem and Human Health
Pulles, Howard and de Lange
No 1400B

In South Africa the pollution of freshwater aquatic systems can be linked to point-source discharges (wastewater treatment works and industrial effluents) and diffuse surface runoff (agricultural, mining and urban). As a result of these anthropogenic activities, innocent people as well as other life forms may be exposed to harmful contaminants, which may be released without adequate consideration of human health and the environmental effects. Studies have shown that when people are exposed to surface water contaminants through contact recreation, drinking water and the consumption of contaminated food their health may be affected.

A review of the published literature revealed that several surveys were undertaken in South Africa to investigate chemical contaminants in freshwater fish, most of these studies were aimed at contributing to the assessment of the health of the aquatic ecosystem but the health risks to humans when consuming contaminated fish are seldom addressed.

To address this limitation a generic protocol has been developed that would give guidance in the undertaking of fish contaminant surveys to provide information regarding the possible health risk if the fish are consumed by recreational and subsistence fishermen. As well as to give guidance to surveys investigating the chemical contamination of fish for ecosystem health assessment programmes.

The fundamentals of the protocol are based on catchment information (possible anthropogenic activities that can result in chemical pollution), socio-demographic information of consumers of freshwater fish in the catchment, bioaccumulation potential and health risks of analytes, sound sampling design, risk assessment procedures and performing monitoring at different scales and depth. The methodology identifies 10 major steps, namely:

- Selection of scale and depth of survey
- Assessment of the water-body catchment
- Monitoring system design
- Field collection
- Laboratory sample processing and analysis
- Analysis of and reporting of results
- Risk assessment
- Risk management
- Risk communication
- Evaluation and review of the programme to provide guidance to government authorities at national or provincial level and project managers.

The basic requirements of each step are highlighted as limited resources (financial, infrastructure and skilled personnel) in South Africa would limit the possibility of undertaking detailed assessments as undertaken by the US EPA. Nevertheless, by applying the proposed protocol, sound comparable assessments, based on risk assessment methodology, can be made regarding the human health risk associated with the consumption of freshwater fish in South Africa.

Two documents were produced during this project namely an *Overview Guide* and a *Reference Guide*. The *Overview Guide* is written for a wide variety of potential users such as regulators (government, conservation organisations and health authorities), practitioners (consultants and researchers), water resource managers, polluters (agriculture, mines and industry) and educational facilities. This Guide has been developed to give an overview of a South African developed process to determine whether fish are safe to eat. This *Overview Guide* will enable potential practitioners to have a standardised scientifically repeatable process that can be used to determine the health risks associated with consuming fish, what levels of contaminants occur in the fish and can the fish be eaten with minimal risks to humans.

The *Reference Guide* is written for practitioners and spells out the precise methods to be applied as well as supplying a set of standardised data sheets for field and laboratory assessments.

Cost: R196 450
Term: 2002-2003

CURRENT

Thrust 1: Microbial Water Quality and Risk Assessment

Programme 2: Known and emerging water-born, water vector and water-related pathogens causing 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
Dept of Biochemistry and Microbiology, University of Venda
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
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
Dept of Biochemistry and Microbiology, University of Zululand
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*

The origin, fate and clinical relevance of water-borne pathogens in South Africa
University of Pretoria; University of Venda; Rand Water
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: Chemical Water Quality and Associated Diseases

Programme 1: Detection, prevention and management of EDCs in water sources

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
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*

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
No 1399

An initial study of the water quality of the Umtata River (WRC **Project 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; Environmentek, CSIR; ARC-PPRI; Consultant manager
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 pollution 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 2: Detection, prevention and management of toxin pollution in water sources

Monitoring environmental water on the East Rand for the presence of toxic agents: A pilot study
Highveld Biological Association
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 4: Eutrophication and associated toxic algal blooms: Detection and management of algal toxins in water sources

Scope and dynamics of toxins produced by cyanophytes in the freshwaters of South Africa and the implications for human and other users
Dept of Botany and Genetics, University of the Free State
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, and will:

- 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*

Effect of microcystins on the immune system using the pro-inflammatory hormone Interleukin 6 as biomarker
Dept of Zoology, Stellenbosch University
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*

Cyanobacteria programme: Toxin blooms and toxin promotion
Consortium members: PU for CHE; University of Port Elizabeth; Technikon Pretoria
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*

Thrust 3: Safeguarding Public Health

Programme 2: Public awareness and education material

Sub-project: The development of a child-centred course for teachers to promote basic health and hygiene awareness in rural communities
Lenehan Engineering and Environmental Consulting; Pulles, Howard & de Lange Inc.
Consultancy members: Umgeni Water; CSIR; BKS; ARC; DWAF
No 1400 A and C

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 (**Sub-Project No 1400A**)
- Child-centred course for teachers to promote basic health in rural communities (**Sub-Project No 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
Environmentek, CSIR
1400 A

Sub-project: The development of a child-centred course for teachers to promote basic health and hygiene awareness in rural communities
Lenehan Engineering and Environmental Consulting
1400C

NEW

Thrust 1: Microbial Water Quality and Associated Diseases

Programme 2: Method development for known and emerging micro-organisms causing water-borne diseases

Develop and apply an innovative assay system to provide direct and reliable assessments of the role of domestic water supply in causing diarrhoea in rural households
Technikon Witwatersrand
No 1444

Diarrhoeal disease accounts for a high proportion of the preventable deaths and illness in South Africa, especially in deep rural areas. The study aims to apply an innovative water quality screening approach to find a link between water quality and diarrhoea since current assays fail to indicate the presence or effects of metabolites of micro-organisms on human health. Current bio-assay methods for testing these inflammatory effects of pathogen metabolites will be adapted for water quality assessment and application to these communities at risk.

Estimated cost: *R424 400*
Expected term: *2003 - 2004*

Thrust 2: Chemical Water Quality and Associated Diseases

Programme 2: Detection, prevention and management of toxin pollution in water sources

Modelling non-point source pollution in agriculture from field to catchment scale – A scoping study
Sigma Beta Consulting
No 1414

Non-point source (NPS) or diffuse pollution plays a major role in the degradation of water quality, specifically with respect to salinity, eutrophication (nutrient enrichment), sediments, pathogens, pesticides and some heavy metals. It is increasingly accepted that it is infeasible to properly manage water quality without addressing the contribution of non-point sources.

Estimated cost: *R 600 000*
Expected term: *2003*

The development of a prototype implementation plan for a National Toxicants Monitoring Programme (on behalf of DWAF)
CSIR
No 1423

The National Water Act mandates the Minister to establish national monitoring systems to monitor, record, and disseminate information on water resources. This project develops a modular implementation plan for sustained execution of a National Toxicants (poisonous or toxic substances) Monitoring Programme. This will support national strategic decisions in respect of their management.

Estimated cost: *R 1 000 000*
Expected term: *2003- 2007*

To calibrate and verify a predictive model for the occurrence of naturally occurring hazardous trace constituents in groundwater
Council for Geoscience
No 1431

The South African groundwater database does not support identification of areas with high concentrations of trace metals that may form a potential hazard due to incomplete data and difficulties in detecting these trace metals. In this project geochemical modelling will be adopted to determine the presence of trace metals in groundwater. The objectives of the project are: Verification of prediction of naturally occurring trace constituents in groundwater by field sampling at appropriate sites; setting up of leaching tests; verification of geochemical and geological models; and development of a GIS map that identifies areas of special concern.

Estimated cost: *R 3 500 000*
Expected term: *2003 – 2005*

Programme 4: Eutrophication and associated toxic algal blooms: Detection and management of algal toxins in water sources

Generic incident management framework for toxic blue-green algal blooms, for application by potable water suppliers
Rand Water
No 1445

An increase in the eutrophication of surface water resources is leading to an increased incidence of toxic blue-green algae growth – thereby increasing health risks for drinking water from a treatment plant which does not use activated carbon adsorption in its process train. No structured framework exists yet in South Africa to manage the supply of safe drinking water during a persistent blue-green algae bloom in source water. This project aims to establish a pro-active approach by means of a generic algal bloom incident management framework to effectively manage potable water supplies when toxic algal blooms are present. Such a system will be widely applicable to water service providers and will reduce the risk of human health-related incidents related to blue-green toxins by providing this framework for informed and appropriate pro-active management measures.

Estimated cost: *R 236 000*
Expected term: *2003 – 2004*

Thrust 3: Safeguarding Public Health

Programme 1: Monitoring systems

Assessment of the interaction between aquaculture and water quality on farm irrigation dams
Environmentek, CSIR
No 1413

Most irrigation areas make use of on-farm storage to store water until it is required for the irrigation of crops. The existence of these dams presents an opportunity to utilise them also for fish production. There are concerns about the fitness of irrigation water for fish production and the fitness of aquaculture water for crop production. There are potential benefits associated with integrating aquaculture production and irrigation practice Two case studies will investigate benefits and disadvantages with specific attention to water quality effects and precautionary measures to maintain fitness for use.

Estimated cost: *R 1 250 000*
Expected term: *2003 – 2008*

On-line real-time enzyme diagnostic system for the detection and monitoring of sewage levels in drinking water
Dept of Biochemistry and Microbiology, Rhodes University
No 1446

Surface water sources are increasingly becoming contaminated with sewage effluent with a concomitant increase in human and animal health risks. This project intends developing a novel enzymatic diagnostic assay for the detection of the presence of sewage waste in water. It is intended to identify potential enzymatic markers for the identification of sewage waste material and to implement these markers for the rapid detection of sewage in water. It is suggested to produce the markers as a rapid detection test strip containing the enzyme which unskilled operators will be able to use. This will provide a simple, rapid way of determining the presence of any faecal pollution and enable timely warning of any impending health risk.

Estimated cost: *R500 000*
Expected term: *2003 – 2006*

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