KNOWLEDGE REVIEW 2004/05

Water Research Commission

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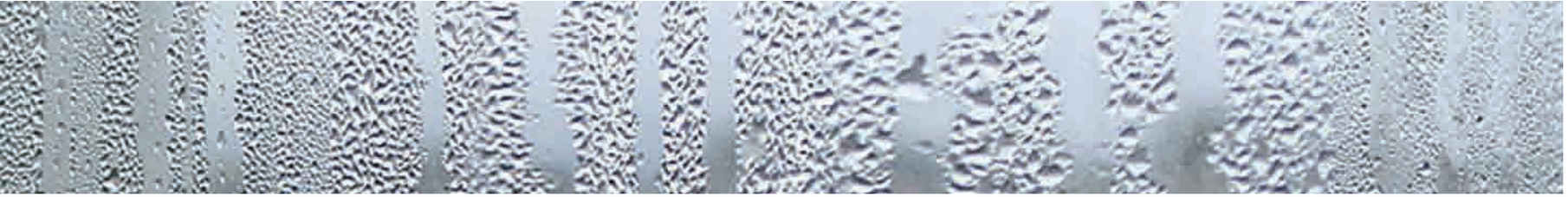
VISION

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.

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.

the visible difference



the visible difference

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INTRODUCTION

The Role of the WRC is Critical to Meet the Water-Related Challenges Facing our Nation

Dr R Kfir
Chief Executive Officer
Water Research Commission

Being a water-stressed country, South Africa needs progressively to find innovative ways of managing water resources to ensure that the basic needs of its citizens are met, that social and economic development are not restricted through lack or poor quality of water, and that sustainability of water resources and of water-dependent ecosystems is secured.

South Africa remains threatened by water shortages. At the same time, water quality issues are becoming more acute and climate change may result in a higher frequency of extreme events. The management of water resources needs to adapt dynamically to such changing circumstances. Challenges posed by the integrated management of both the resource and its uses, issues of water supply and sanitation and the provision of related services and the building and sustaining of a competence-base that will allow the water sector to maintain and further grow its capabilities, skills and ability to address these key issues, are overwhelming. The role of the WRC as a water-centred hub and its dynamic, strategic realignment with the needs of our country and more specifically, the water sector, are therefore critical to the meeting of these challenges. The WRC has already built a substantial knowledge base, rendering the country in a much 'better' position to deal with many of its current and future water-related problems.

During the past three years, the WRC has steadily progressed towards developing the organisation and building it to serve South Africa with a greater level of relevance in an effective and efficient manner. The WRC has undergone a major restructuring, followed by a consolidation period aimed at laying the foundation for ongoing revitalisation and renewal. The organisation has followed a strategy which ensures that, as South Africa's dynamic hub for water-centred knowledge, it provides the nation with knowledge that serves to improve the quality of life of all its citizens. In accordance with this strategy, the WRC has widened its activities from investing in the creation of new water-centred knowledge to the dissemination, sharing, transfer and application of this knowledge.

Functioning as a dynamic 'hub' the WRC continuously and widely engages the water sector and other key stakeholders in order to assist in reviewing and re-directing its research portfolio. During 2004/05 the WRC undertook a survey to determine how stakeholders view and rate the performance of the WRC. Special emphasis was put on the WRC's vision, mission and key strategic objectives. The findings of the survey indicated an average overall rating of above 4 (out of 5) and that the majority of stakeholders agreed that the WRC is relevant and is true to its mission and vision. The WRC attempt to improve its knowledge dissemination and sharing activities was highly appreciated and the feedback given in the above survey indicated that WRC's publications are regarded of high importance and high quality.

Although the WRC has supported the creation of appropriate new knowledge and has been actively seeking innovative knowledge dissemination and sharing mechanisms many key challenges are still facing our nation, the water sector and the WRC. One of such challenges is the possible role the WRC (and the South African water research community) can play in Africa supporting the spirit of NEPAD and other government initiatives. Another immense challenge facing our country is the building of future professional capacity and a future generation of researchers. The WRC has put great emphasis on strengthening the water-centred knowledge base of South Africa. During the 2004/05 financial year the WRC, with the support of the Minister of Water Affairs and

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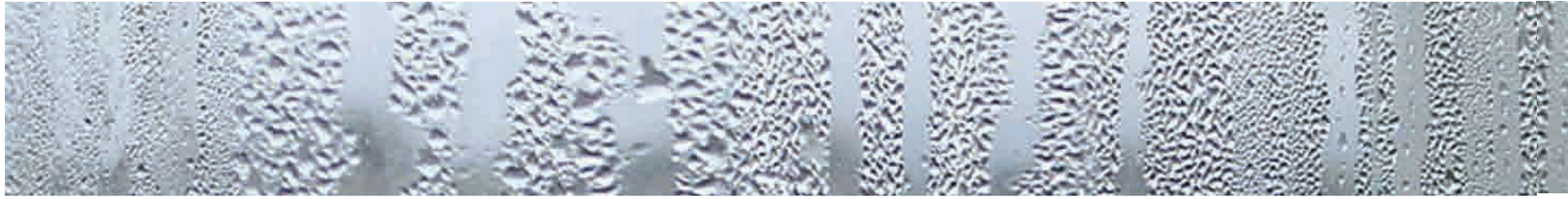
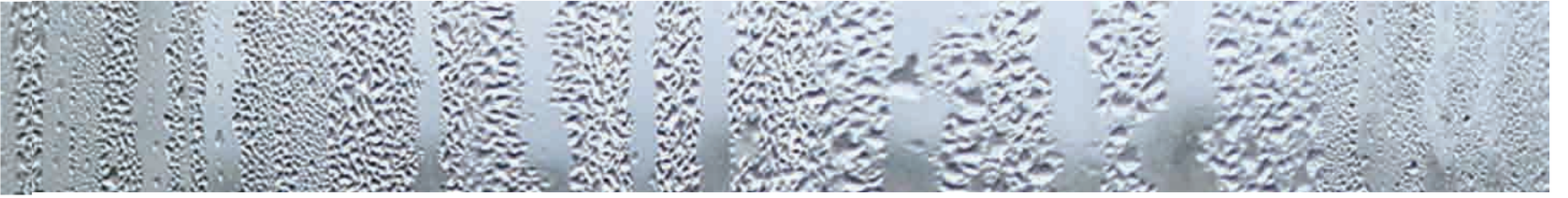
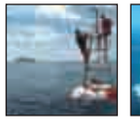


Forestry, launched and widely distributed a booklet *Water @ Work-A Career Guide* addressing potential careers in the water field. In the area of capacity building the WRC has further improved its support to students with special emphasis on historically disadvantaged students. Currently about 465 students are supported by WRC projects of whom about 60% are disadvantaged (see table below).

Organisation	Number of disadvantaged students	Total number of students
BKS	2	2
C Swartz	5	5
Coaltech 2002	1	1
Council for Geoscience	1	1
CSIR	14	31
Digby Wells and Associates	2	4
DSS	1	1
Durban Institute of Technology	6	6
Emanti Management (Pty) Ltd	2	2
Envi-Sabi Scientific	1	1
ERWAT	1	1
Golder Associates Africa (Pty) Ltd	5	9
Hlathi Development Consultants	1	1
Human Sciences Research Council	1	1
Independent Economic Researchers	1	1
Institute of Natural Resources	7	10
Mvula Trust	1	1
Nelson Mandela Metropolitan University	9	17
Ninham Shand (Pty) Ltd	1	1
Cape Peninsula University of Technology	4	4
PD Naidoo & Associates	1	1
Phillip Pybus	1	1
Pulles, Howard & de Lange	11	15
Rand Water	1	1
Rhodes University	12	23
TBR Project	1	1
Tshwane University of Technology / Technikon Pretoria	12	14
Umgeni Water	2	2
University of Cape Town	13	25
University of Free State	17	30
University of Fort Hare	12	12
University of Johannesburg	4	4
University of KwaZulu-Natal	47	88
University of the North	4	6
University of Pretoria	10	24
University of Stellenbosch	10	48
University of the Western Cape	17	28
University of the Witwatersrand	10	18
University of Venda	20	21
University of Zululand	2	2
Zakhe Training College	1	1
	274	465




A special edition of *The Water Wheel* was published in March 2005 to commemorate National Water Week. This edition, which featured articles of interest to learners and included a water quiz, was distributed at the SABC Career Fair, SciTech and delivered to schools in the Gauteng area. The WRC also participated in initiatives for the improvement of public understanding of science such as the Youth Water Prize, Sasolburg Scifest and the WRC-Rhodes University Open Day.

Capacity-building activities have been widened to provide support for African and global initiatives aimed at building capacity in Africa, examples being the WRC's role in the NEPAD initiative aimed at building water-related centres of excellence in Africa and the leadership role the CEO of the WRC plays in *Streams of Knowledge*, a network of capacity-building organisations focused on water and sanitation, with most members being from various parts of Africa, including two institutions from South Africa (Mvula Thrust and NSCWI). In addition, the WRC is represented on the Board of the Water Research Fund of Southern Africa (WARFSA). WARFSA is a water research fund supported mostly through Swedish funding. The purpose of this fund is to build research capacity among individuals and institutions as well as to promote the utilisation of results in the planning and management of water resources in the sub-region. This is in appreciation of the fact that water research activities in the water sector of the Southern African Development Community (SADC) are limited largely due to lack of capacity to develop and carry out sound research projects as well as funding constraints.

The WRC also strongly supports and houses the Water Information Network (WIN). WIN is a network of organisations (both governmental and non-governmental) in the water services sector that works to ensure that this body of knowledge is well-managed, readily accessible and applicable, and leads to improved decision-making and performance in the areas of water and sanitation. The WRC also provides leadership and management to WIN.

In the area of knowledge application/commercialisation, the WRC continues its drive to provide the country with applied knowledge and water-related innovation. One of the recent examples of achievement in this arena is the licensing of the BioSURE™ process (Rhodes University) to ERWAT. Another significant achievement is the transfer of solar still technology to the Municipality of Kerkplaas in the Cape Province. A number of other licensing agreements have been reviewed and some are being re-negotiated. During January 2005 a new licensing agreement addressing the Petro™ process was signed. In addition to the above, the WRC has discussed its new IP policy and benefit-sharing policy with many of its research providers with the aim of clarifying its contractual requirements for future research projects and improving the understanding regarding the protection of IP within the water research community. The WRC has also taken an active part in the activities of the South African Research and Innovation Association (SARIMA).

The WRC has maintained its effectiveness in fund management as reflected in the high ratio (about 75%) between funds invested in knowledge creation/funding and supporting activities and its total income budget. It is planned to maintain and even improve this ratio in the 2005/06 financial year.

THE WRC'S RESEARCH PORTFOLIO AND KEY STRATEGIC AREAS (KSAs)

INVESTING IN THE CREATION AND SHARING OF KNOWLEDGE

During 2004/05 the WRC, based on the assessment of its research portfolio during the previous year when there was wide-ranging consultation with many of its stakeholders concerning the scope of its operations and its strategic direction, continued to invest in the creation of knowledge via four main key strategic areas (KSAs). These areas include **Water Resource Management, Water-Linked Ecosystems, Water Use and Waste Management**, and **Water Utilisation in Agriculture**. In general, the portfolio as planned for the year was well received by the various stakeholders. The KSA-based structure, with its four water-centred KSAs (as mentioned above), supported by the knowledge-centred KSA, continued to form the core operating framework for WRC-funded R&D, was further consolidated during the year and became accepted generally.

Funds invested in the creation of new water-centred knowledge during 2004/05 followed a similar pattern of fund distribution among various types of research providers as in previous years, with higher education institutions being the major recipients.

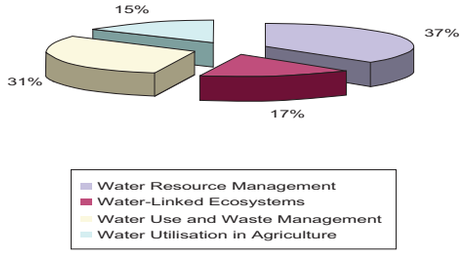
The WRC supported a total of 454 research projects, of which about 78% (356 projects) were active projects (ongoing and new) and about 22% (98 projects) were finalised. The active projects comprised 274 ongoing projects and 82 newly initiated projects that commenced during 2004/05. The various mechanisms of funding include both non-solicited projects, accommodating projects within the broad research strategy of each KSA and solicited projects, where research projects are developed in accordance with clear terms of reference, aimed at solving specific problems. The WRC supported 41 solicited projects, which translates to about 12% of active projects. While 19 solicited projects were ongoing, 22 newly solicited projects commenced during the year.

In comparison with the previous year, 2004/05 shows a 12% decrease in the number of projects, i.e. 454 projects in 2004/05 vs. 517 in the previous year. The number of active projects was reduced by about 10% (from 395 in the previous year to 356 projects during the year under review). The trend of reduction in the total number of projects is a result of a drive to improve management of research projects, with emphasis being placed on prompt finalisation of projects, as is also reflected in the high numbers of projects finalised both during 2003/04 (122 projects) and during 2004/05 (98 projects). While there is a clear trend of a reduction in the total number of projects, there is also a trend towards an increase in the number of new projects, which was up by about 52% (54 new projects commenced during 2003/04 and 82 during 2004/05). The finalisation of 220 projects and initiation of 136 new projects during the past two years illustrates a strong emphasis on renewal of the research portfolio. By using the mechanism of solicited research, the WRC has effectively managed the relevance of the research portfolio and provided leadership with regard to the creation of new water-centred knowledge. During the year the WRC increased the number of solicited projects from the 6% of active projects in 2003/04 to about 12% of active projects in 2004/05. The increase in the number of solicited projects also contributed to the overall reduction in active (ongoing and new) projects during the year under review, as solicited projects are often large multi-year, multi-provider (consortia-based) projects, often with annual budgets in excess of R1m. per annum.

Utilisation of funds by the various KSAs

The percentage utilisation of research project funds (based on amounts actually paid out) by the KSAs during 2004/05 was as follows:

Utilisation of Research Project Funds



About 54.5% was invested in projects that focused on water resources (including water-linked ecosystems) and about 45.5% in projects that focused on water utilisation (including effluent treatment and management, as well as agriculture).

While, based on cash paid out, the overall investment in research projects (knowledge creation) was R53.7m., investment in the total support of knowledge creation, sharing and dissemination amounted to R62.5m. Both the investments in research projects and in research support, expressed as a percentage of total expenditure, were close to the set budgeted ratios. The ratio addressing funding of the creation of new knowledge (research projects only) is very similar to that of the previous year, with a slight (2%) increase. The decrease in the ratio for research support is due to savings in publication costs and the more effective management of the WRC's patent portfolio that resulted in an additional saving of about R0.33m.

KEY STRATEGIC AREAS (KSAs)

During 2004/05 the KSAs funded research and other related knowledge-sharing, dissemination and application activities using their business plans and more specifically, their revised strategic research portfolios, as the basis for their operational frameworks.

Based on the outcome of a recent customer/stakeholder survey, the WRC in its current strategic structural format, provides leadership and direction to South Africa. Consequently, no major changes in the core KSA structure, i.e. the four water-centred KSAs and the knowledge-centred KSA, are envisaged for the next financial year. The knowledge-centred KSA will continue to support the water-centred KSAs in knowledge dissemination and IT services as well as contributing towards water-centred knowledge management in Africa and globally.

Water Resource Management

Scope

The strategic focus for research in this KSA continued 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 NWA 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 places 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. During 2004/05 the research focus shifted 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 places 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 2004/05 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R19.35m. was invested (paid out) in 168 projects. Of these, 28 projects were initiated during the year under review while 113 were ongoing. Of the 141 active projects (new and ongoing) about 9% (12) were solicited. During the year under review 27 projects were finalised and 30 reports published.

Water-Linked Ecosystems

Scope

Research undertaken within this KSA during 2004/05 continued to address the conservation of aquatic ecosystems in order to provide the knowledge for their sustainable functioning in support of the National Water Resource Strategy (NWRS) focus on resource protection, the national commitment to international conventions and the ongoing provision of goods and services that ecosystems deliver. No major changes in strategic direction were implemented during the year under review.

Water-linked ecosystems are defined as in-stream (fully aquatic), riparian (dependent on water stored in the riverbanks and linked to the river) and water table-dependent (dependent on a water table, but not on surface water). This KSA continued to focus 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).

During 2004/05 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R8.77m. was invested (paid out) in 56 projects. Of these, 9 projects were initiated during the year under review while 30 were ongoing. Of the active ongoing and new projects (39 projects) about 15% (6) were solicited projects. During the year 17 projects were finalised and 12 reports published.

Water Use and Waste Management

Scope

This KSA focused mainly on the domestic, industrial and mining water sectors. It aimed 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 supported 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 was included. A further focus was 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 focused 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 effects on human and environmental health.

During 2004/05 the KSA continued its activities in the light of the results of strategic needs analysis and stakeholder engagement. Feedback from these exercises has ratified the KSA direction and contributed many valuable inputs in strengthening the portfolio. A new dedicated and focused thrust addressing issues regarding sanitation and hygiene was introduced and the scope of the thrust Wastewater Treatment and Technology was broadened to include stormwater and sewerage research. These two subjects are strongly related to wastewater management and are best integrated and incorporated into this thrust. These changes contributed to strengthening the portfolio of the KSA and provided the KSA with greater relevancy and focus.

During 2004/05 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R17.37m. was invested (paid out) in 181 projects. Of these, 38 projects were initiated during the year under review while 99 were ongoing. Of the active ongoing and new projects (137) about 7% (10) were solicited projects. During the year under review 44 projects were finalised and 40 reports published.

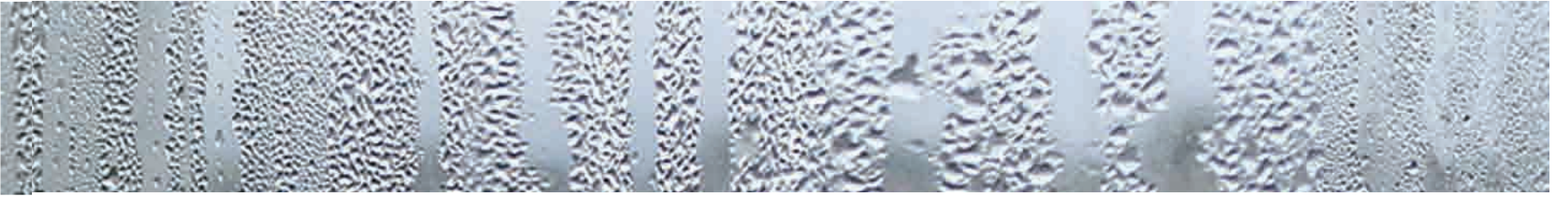
Water Utilisation in Agriculture

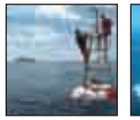
Scope

The strategic focus in this KSA has been on increasing the efficient use of water for the 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 continued to be addressed through the 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 has been 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 2004/05 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R7.9m. was invested (paid out) in 49 projects. Of these, 7 projects were initiated during the year under review while 32 were ongoing. Of the active ongoing and new projects (39) about 33% (13) were solicited projects. During the year under review 10 projects were finalised and 6 reports published.

Water-Centred Knowledge

Scope

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.

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 WRC's mission statement requires the WRC's R&D portfolio to contribute to a better quality of life for all South Africans. This means that investment in the creation of water-centred knowledge must seek outcomes which promote social development and societal well-being, economic growth that benefits all, a better environment and minimisation of health risks. Achieving these goals has called for the establishment of four crosscutting domains: **Water and Society; Water and the Economy; Water and the Environment**; and **Water and Health** to serve as frameworks for integrating research initiatives across the KSAs and for ensuring that the R&D portfolio of the WRC as a whole is sufficiently well focused on these important national issues. Not only are these issues of national importance, but they also enjoy regional and international priority, as clearly indicated by the agendas of major events and movements such as the WSSD, the 3rd World Water Forum and NEPAD.

The domains draw together relevant programmes and projects that are under way within the portfolios of each of the KSAs and focus them on issues falling within the scope of the various thrusts in each of the domains. It is also the role of each of the domains to provide leadership and support for new KSA initiatives needed to further knowledge with regard to various domain-related strategic thrusts. When necessary, the domains may also drive specific programmes and projects that are overarching and relate to all KSAs in a general manner.

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 derives 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 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 currently being investigated with a view to implementation.
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.

Water and the Environment

Scope

The scope of research in this domain will remain the same following changes introduced at the commencement of the 2004/05 financial year as a result of extensive stakeholder consultation.

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 resources 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 resources management that meets the changing needs of society, by combining:

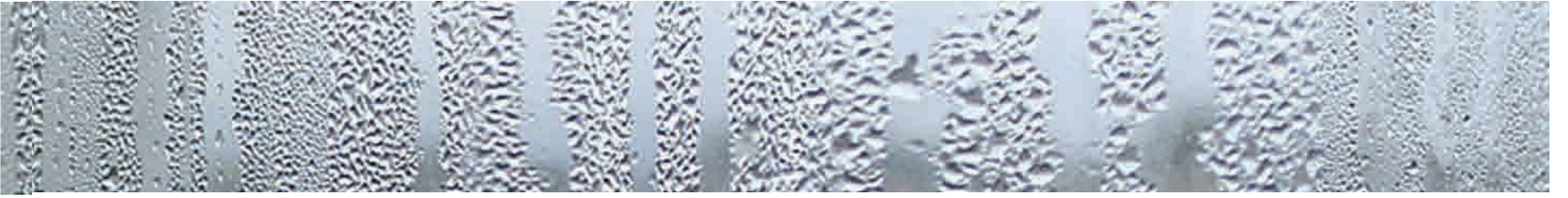
Our understanding of good governance principles; with
Our knowledge of environmental components (atmospheric, marine, terrestrial, aquatic, subterranean) and processes within the hydrological cycle.

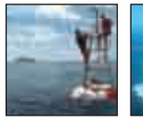
The primary focus of the domain is to integrate existing and new insights generated by research within and between the KSAs and by other institutions working in related fields. In addition, this domain will stimulate the generation of specific new knowledge and understanding that will equip the water 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

Water-related health forms a crucial and integral component of our daily quality of life. Health-related



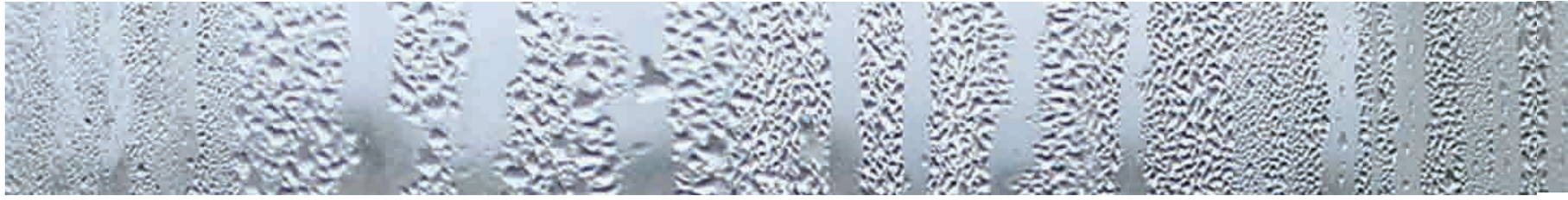




water research is undertaken with the aim of improving water quality and hygiene practices in order to save lives and reduce the cost and effort in treating diseases and their symptoms.

This domain continues to play an essential role 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 in the appropriate KSAs.

The focus is on water-linked health impact 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 human and animal health and the need for, and efficiency of, various water treatment options. 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 |

Knowledge Generated on the Resource Base Underpins the Use

Dr Kevin Pietersen
Director

Scope

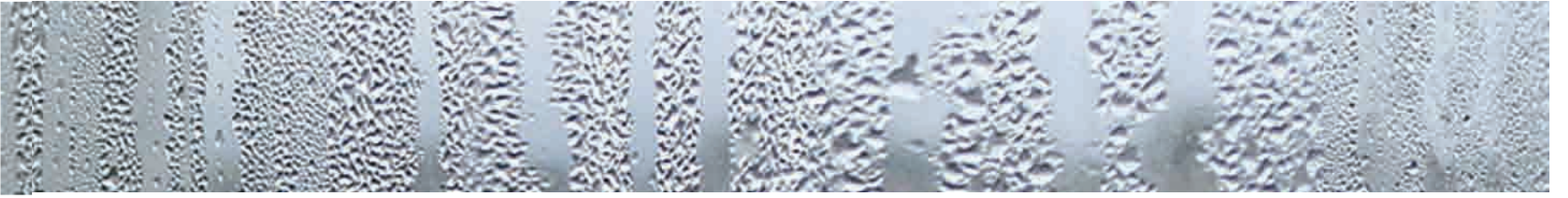
The strategic focus for research in this key strategic area (KSA) is largely guided by the principles and objectives of the National Water Act (NWA) of 1998. The primary principle of the Act is that water resources should be managed to achieve optimum long-term social and economic benefits for all; this 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.

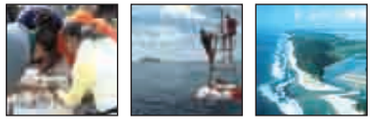
The research focus is shifting from supporting policy making to providing guidance for policy implementation and development of policy instruments. The challenge for research in this KSA is to provide the necessary information systems, guidelines, decision-support systems, prediction tools and technologies/methodologies 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.

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. The research portfolio for 2004/05 addresses this primary objective as reflected by the following aims to:

- Improve policy for promoting equitable, efficient and sustainable conservation and 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 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
- 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
- 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 water resources





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

Thrusts and programmes

THRUST 1: WATER RESOURCE ASSESSMENT

Scope: This thrust focuses on developing a scientific understanding of the hydrological cycle (and inter-linkages) in order to promote a systematic assessment and variability of the quantity and quality of water available for development in South Africa.

- Groundwater occurrence in fractured-rock aquifers
- Catchment hydrology
- Understanding and predicting hydroclimatic 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. Integration of social, economic and environmental considerations is crucial for sustainable water resource development and management. These aspects 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
- Urban water resource management

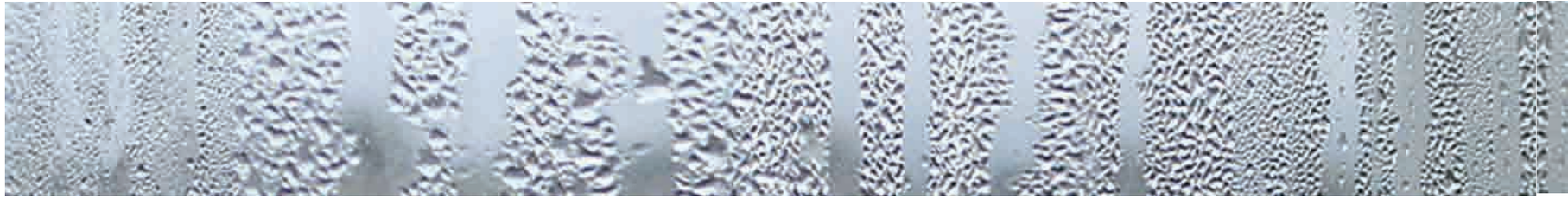
THRUST 3: MANAGEMENT OF NATURAL AND HUMAN-INDUCED IMPACTS ON WATER RESOURCES

Scope: Research in this thrust focuses on developing appropriate quantitative understanding, tools and strategies for managing the impacts of climate variability and change as well as human interventions on the hydrological cycle and related water resources, with the aim of supporting the development of policy responses, at regional, national or catchment scale, to existing and emerging problems. This includes development of systems (e.g. river flow and inundation forecast models, drought impact monitoring systems) for managing floods, droughts and pollution. 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 the generation of information and understanding in order to improve water quality management, with reference to point sources as well as diffuse sources, and addressing chemical, microbial, and biological pollution impacts on surface water and groundwater.

- Predicting the impact of global climate change
- Groundwater protection
- Protection and management of surface water quality
- Human-induced impacts
- Integrated flood and drought management

THRUST 4: POLICY DEVELOPMENT AND INSTITUTIONAL ARRANGEMENTS FOR WATER RESOURCE MANAGEMENT

Scope: This thrust focuses on instruments supporting effective water resource management, ranging from support for the development of appropriate policies and their implementation to research concerning the establishment of governing bodies and institutional arrangements (at catchment, national and transboundary levels). The thrust supports research on tools and methodologies for decision support for IWRM, aims to provide strategic support for new policy development and improve the understanding regarding the effective functioning of institutional structures for implementing IWRM



- Decision support for IWRM at catchment and WMA level
- Water policy development and strategic policy support
- Institutional arrangements and processes for IWRM at catchment, WMA and national level
- Transboundary water resource management
- Governance, law and regulation
- Institutional development and collaboration in the Eastern Cape

Research portfolio for 2004/05

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 emphasis of the KSA during 2003/04 was on consolidating the strategic processes introduced during the previous business planning processes. Further consultation with stakeholders will take place at local and regional level. This will be an important task to identify research needs and priorities. The projects to start in 2004/05 will further enhance the sustainable use and management of water resources in South Africa.

Budget for 2004/05

The approved funding of the research portfolio for 2004/05 leads to a committed funding budget of R22.5m. The focus of this portfolio will continue along the current trends.

Core strategy

Strategic context

The state and management of South Africa's water resources are crucial for social development and supports various critical economic sectors such as agriculture, mining and tourism. The water resource base is also important for ecological functioning.

The mean annual runoff is estimated to be 50 000 x 10^6 m^3/a and represents 9% of rainfall. Groundwater resources are estimated to be 20 000 x 10^6 m^3/a. The natural water availability is also highly variable, due to poor spatial and temporal distribution. As a result, water resource managers are faced with many challenges as they strive to achieve water security for the needs of all different groups of water users including water-related ecosystems. These challenges include the following:

- What is the quantity and quality of water resources of South Africa, i.e. developing knowledge of the different components and inter-linkages of the resource and its condition in relation to reference conditions
- What are the threatening processes to water resources in South Africa, e.g. global climate change, water resource degradation, over-commitment of the resource, impact of land-use and water storage and diversion on the water resource?
- Which policies and institutions are required for

promoting equitable, efficient and sustainable conservation and allocation of water resources among competing needs?
- Which management tools and institutions are required to integrate environmental, economic and social issues within a catchment or a water management area?

In response to these challenges, South Africa has adapted its approaches to water resource management through the National Water Act of 1998 (NWA). The primary principles of the NWA are that:

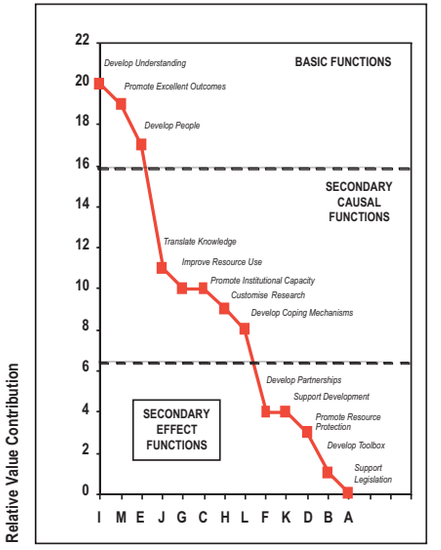
- Water resources should be managed to achieve long-term social and economic benefit for all
- An optimum balance between protection of the environment and efficient utilisation is maintained

In order to implement the NWA continuous cultivation of new knowledge and the progressive refinement and practical extension of existing knowledge are required. 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.

Against this background the strategic focus of this KSA is on:

- Developing a scientific understanding of the water cycle (and the inter-linkages) in order to promote a systematic assessment and variability of the quantity and quality of water available for development
- Supporting implementation of programmes with regard to integrated catchment management of the water resource base
- Developing tools and methodologies for managing the impacts of climate change and human interventions on the hydrological cycle

Fig 1: Functional numerical evaluation graph



Basic Functions are the *Research Target*
- What is to be researched
- Purpose of the research

Secondary Causal Functions are the *Research Framework*
- How it has to be researched
- How we achieve the purpose of the research
- Research evaluation considerations

- Supporting policy development, implementation processes and evaluation of policy impacts

Needs analysis

This KSA aims to be pro-active and responsive to the water resource management research needs in South Africa. A workshop was held to establish a research framework that will support long-term benefit for water resource management in South Africa. The participants were drawn from the WRC Board and management, government departments, research institutions and universities. The aims of the workshop were:

- To identify trends and scenarios that could influence and inform where research is required in 2005-2010
- To develop a stakeholder participation process in order to refine/adapt these trends and scenarios to show continued benefit.

The following functions were developed for this KSA:

- The workshop used an integrative values approach to define the role of research to support IWRM in South Africa. This approach uses functional thinking to derive value functions. A graphical representation of the relative ranking and prioritisation of the value of the functions is prepared from the scores in the functional numerical evaluation matrix (Fig. 1).

- The outcome of the evaluation of the functions shows that the critical basic functions for success for achieving the stated objective were identified as **Develop Understanding, Promote Excellent Outcomes** and **Develop People**. These were established as the research targets for directing and focusing the WRM research portfolio in the future.

- The participants established a research framework as incorporating the secondary causal functions of **Translate Knowledge, Improve Resource Use, Promote Institutional Capacity, Customise Research** and **Develop Coping Mechanisms**. These are the priorities for how the research should be done and require the development of cost-effective and value-adding research proposals that will address these functions while aiming to realize the research target functions.

- Through the proper implementation of the research the secondary effect functions of **Develop Partnerships, Support Development, Promote Resource Protection, Develop Toolbox** and **Support Legislation** will also be achieved.

The participants developed a number of generic models and frameworks that identified various areas for focusing research activities and action for each of the research frameworks. These need to be developed further through the active participation of a wider selection of stakeholders.

Due to the importance of incorporating additional input from other stakeholders, the participants discussed and derived recommendations for stakeholder involvement. This will form the broader consultative process to be conducted in 2004/05. As a result of the workshop the following issues are still relevant to 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 resource-directed measures (RDMs) and source directed controls (SDCs)
- By providing greater understanding of threatening process 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.

Overview of technological trends related to needs

The technological trends identified in the previous year remain the same and are repeated for ease of reference.

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 this 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 readily 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 ground-water. 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. There needs to be greater emphasis in basin characterisation of groundwater systems and further integration of available tools.

Key stakeholders

Major stakeholders fall within three 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, mines, 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 of all the key stakeholders.

Other players

As indicated in the previous year 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 this KSA is conducted by Universities, i.e. about 54%. Science councils and consulting firms are responsible for most of the rest. There is limited participation by DWAF and the Water Boards.

STRATEGIC INTIATIVES UNDERTAKEN DURING 2004/05

National initiatives

The KSA has participated and actively contributed to the following national initiatives:

- Chapter on Research and Development for the *South African Water Sector Report* (all KSA research managers contributed)
- DWAF *Policy Sharing Symposium* Water Management Institutions and Water Resource Governance (Kevin Pietersen)
- Chairperson: Groundwater Organising Committee for *GROUNDWATER 2005 Conference* (Kevin Pietersen)
- Project steering committee member: DWAF Remediation Strategy Task Team (Kevin Pietersen)
- Member of Organising Committee: International Workshop on Water Resource Management (WRM 2004) (Kevin Pietersen)
- Member: Karst Working Group (Kevin Pietersen)
- FETWATER (Groundwater RDM Network) (Kevin Pietersen)
- WRC Research Expo (All RMs)
- Member of *Working for Wate*r Review Panel (Renias Dube)
- National Advisory Committee for Water Resource Modelling (Renias Dube)
- Member of the South African National Committee for the International Association of Hydrological Sciences (SANCIAHS (Renias Dube)
- Member of the Project Steering Committee for the DWAF/DANCED Integrated Water Resource Management (IWRM) Project (Renias Dube)
- Member of the Integrated Water Resource Planning Systems User Forum (Renias Dube)
- Chairman of the *Working for Water* Hydrology Review Panel (Renias Dube)
- Project manager on a national project (DWAF/WRC) to develop an Inventory for Water Resource Studies (Renias Dube)
- Member of Adjudication Panel for *Women in Water Awards 2004* (Heather MacKay)
- Member of organizing committee for national conference of the Southern African Society of Aquatic Scientists, July 2004 (Heather MacKay)
- Member of National Expert Panel on DWAF/DFID Water Allocation Toolkit Programme (Heather MacKay)
- Member of Executive Committee of FETWater (Framework for Education and Training in Water) (Heather MacKay)
- Member of steering group (and rotating chair) of National Initiative on Planning for Representative Freshwater Biodiversity Conservation (Heather MacKay)
- Member of steering committee for DWAF project to design and implement the national water resource classification system (Heather MacKay)
- Requested by SAWS (supported by DWAF) to draft SA nomination documents for *International Weather Modification Prize* (George Green)

African initiatives

- NEPAD Business Working Group (Kevin Pietersen)
- SADC 2nd Regional Water Policy Workshop (Kevin Pietersen)
- SADC-Harmonization of Water Policy Workshop (Kevin Pietersen)
- Vulnerability of water resources to environmental change in Africa using the river basin approach. Nairobi, Kenya (Kevin Pietersen)
- Vice-chair, Executive Committee of the African Water Forum (AWF), and Chair of Environment Theme Group in the AWF (Heather MacKay)
- Member of the World Bank Window on Environmental Flows, providing technical and policy support to Bank clients (primarily African countries) related to environmental flows and water policy (Heather MacKay)

International initiatives

- Alliance for Global Sustainability (AGS) Annual Meeting, Göteborg, Sweden
- UNESCO Mission Sustainable Integrated Management and Development of Arid and Semi-arid Regions of Southern Africa, Gaborone, Botswana
- Partner: CGIAR Challenge Program on Water and Food Project 17: Integrated Water Resource Management for Improved Rural Livelihoods in the Limpopo Basin
- Vice-chair of the Scientific and Technical Review Panel of the Ramsar Convention on Wetlands, 2002-2005.
- RAMSAR STRP focal point for South Africa 2002-2005
- Leader of the RAMSAR STRP Working Group On Water 2002/05, providing water-related guidance for RAMSAR contracting parties

- Lecturing at the *International Course on Groundwater Development in Hard Rock Areas*. Göteborg, Sweden (Kevin Pietersen)
- Elected team leader for Southern Africa: *Study on the Vulnerability of Water Resources to Environmental Change* (Kevin Pietersen)
- Coordinator to prepare the freshwater section on the *African Environment Outlook* (Kevin Pietersen)
- Board member: Water Research Fund of Southern Africa (WARFSA) (Kevin Pietersen)
- Lecturing at the *Refresher International Course on Groundwater Development in Hard Rock Areas*. Pretoria (Kevin Pietersen).
- Trainer at World Bank Training Workshop in Washington DC on environmental flows, for the Bank's task managers (Heather MacKay)
- RAMSAR Scientific and Technical Review Panel, Netherlands, July 2004. Vice-chair of proceedings and leader of the 2-day session on water (Heather MacKay)

Implementation plan

Research portfolio for 2004/05

The primary objective of research in this KSA has been supported by the needs analysis process and 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 2004/05 addresses this primary objective as reflected by the following aims to:

- Improve policy for promoting equitable, efficient and sustainable conservation and 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 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
- 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
- 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 water resources

The plan reflects some changes in the portfolio from the previous business plan based on feedback from needs analysis, consultation with stakeholders and Board input. These changes are:

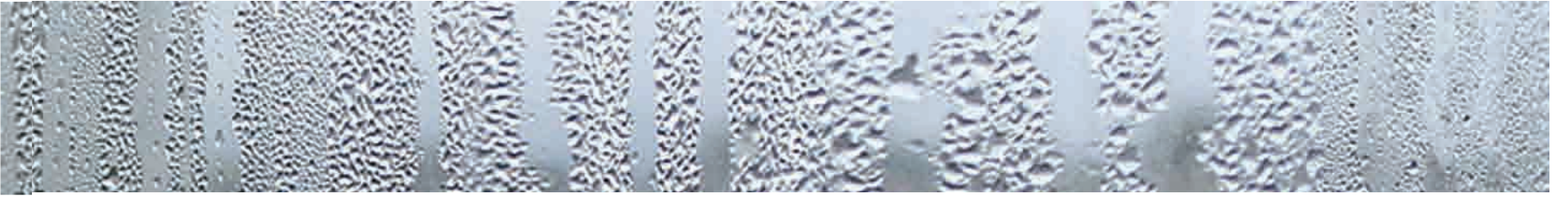
- Redefining the thrust and programme as reflected in their descriptions. This was necessary to remove duplications between thrusts and programmes.
- Widening the focus of the programme ***Understanding and predicting rainfall variability*** to ***Understanding and predicting hydroclimatic variability***.
- The addition of a programme focusing on urban water resource management in Thrust 2. This programme will link the provision of water services to water resource management.
- Changing the programme from ***Integrated Flood Management*** to ***Integrated Flood and Drought Management***.
- A complete revision of Thrust 4 and programmes. This revision was based on the outcomes of the consultative workshops that were held with stakeholders.

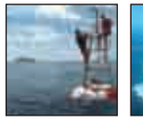
An overview of KSA 1 research thrusts and programmes is presented in **Table 1**.

TABLE 1: Overview and description of thrusts and programmes funded within KSA1

THRUST 1: WATER RESOURCE ASSESSMENT

Scope:	This thrust focuses on developing a scientific understanding of the hydrological cycle (and inter-linkages) in order to promote a systematic assessment and variability of the quantity and quality of water available for development in South Africa.
Programme 1*: *Groundwater occurrence in fractured-rock aquifers	**Scope:** This programme focuses on improved understanding of groundwater resources in fractured rocks. About 90% of aquifers 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 managements
Programme 2*: *Catchment hydrology	**Scope:** This programme seeks to establish and continuously provide current information on how much water is naturally available in South Africa and its distribution in time and space. The programme links the climate, vegetation, soil, and water management variables to water flows in an integrated perspective for the better management of South African Catchments. 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.
Programme 3*: *Understanding and predicting hydroclimatic variability	**Scope:** The ultimate goal of this programme is to better forecast of the variability of rainfall, flow and groundwater recharge. This is of great importance for water resource management. The ability to forecast at very short time scales (48 down to a few hours ahead) 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 all 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:** The quality of water is an important factor in determining the quantity of water that is potentially available for productive use. Determining the amount of water available for different uses is further complicated by the considerable variation that exists in quality requirements between and within different user groups. This programme is aimed at developing and refining fitness-for-use criteria, developing the means to monitor and assess water quality at regional and national level, improve the way in which water quality information is conveyed and the identification of emerging water quality issues.
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.




the visible difference

THRUST 2: INTEGRATED WATER RESOURCE DEVELOPMENT

Scope: Research in this thrust focuses on providing information to support integrated water resource development. Integration of social, economic and environmental considerations is crucial for sustainable water resource development and management. These aspects 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 stream flow reduction activities. Methods developed should clearly stand out as the preferred solutions in South Africa through how they are proposed, developed and implemented.
Programme 3*: *Urban water resource management	**Scope:** An integrated approach to water resource management is essential to sustainability of the urban and peri-urban cities of South Africa. In many cities, water shortages stem from inefficient use and degradation of the available water by pollution. This programme will search for a better integration of land use and water management within the overall environmental management, standardise water quality regulations and increase incentives and sanctions for their enforcement.

THRUST 3: MANAGEMENT OF NATURAL AND HUMAN-INDUCED IMPACTS ON WATER RESOURCES

Scope: Research in this thrust focuses on developing appropriate quantitative understanding, tools and strategies for managing the impacts of climate variability and change as well as human interventions on the hydrological cycle and related water resources, with the aim of supporting the development of policy responses, at regional, national or catchment scale, to existing and emerging problems. This includes development of systems (e.g. river flow and inundation forecast models, drought impact monitoring systems) for managing floods, droughts and pollution. 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 the generation of information and understanding in order to improve water quality management, with reference to point sources as well as diffuse sources, and addressing chemical, microbial, and biological pollution impacts on surface water and groundwater.	
Programme 1*: *Predicting the impact of global climate change	**Scope:** 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 development of coping strategies will require the development of informed, quantitative scenarios of potential impacts at regional and catchment level on rainfall regimes and rainfall variability, hydrological and geohydrological regimes, water availability and reliability, water quality, ecosystem structure and functions and ecological processes.

THRUST 3: MANAGEMENT OF NATURAL AND HUMAN-INDUCED IMPACTS ON WATER RESOURCES (CONTINUED)

Programme 1*: *Predicting the impact of global change climate	**Scope:** 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 African 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 and flow 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? How will existing management strategies and tools need to be adapted? What are the main socio-economic impacts likely to be, given the structure of society in Southern Africa, and what are appropriate technological, social and political coping strategies?
Programme 2*: *Groundwater protection	**Scope:** This programme focuses mainly on identification, quantification, prediction and management of the impacts on groundwater quality of intensive land-uses. 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 programme outputs will establish: (i) 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 flow into the environment and the ultimate fate of these pollutants, and (ii) options for management and mitigation of the impacts on groundwater quality of intensive land uses. The programme also investigates the natural occurrence of hazardous constituents in groundwater, with the aim of developing strategies for minimising potential negative effects on groundwater and surface water users.
Programme 3*: *Protection and management of surface water quality	**Scope:** Increased industrialisation and development lead to the exposure of the water environment to a range of chemical, microbial and biological pollutants as well as micro-pollutants. Furthermore, improved analytical techniques lead to continual reduction in detection limits of pollutants. Research in this programme is aimed at providing strategies for improving the prevention, mitigation and control of pollution of surface waters, based on sound understanding of the scope, significance and impacts of changes in water quality. The programme addresses both point sources and diffuse sources of pollution, which can result from activities within the water environment or on the catchment surface.
Programme 4*: *Human-induced impacts	**Scope:** Various kinds of human activities can influence the quantity, quality, reliability and ecological health of water resources, including activities which take place in other environmental compartments within the hydrological cycle. This programme includes research to improve our ability to assess, evaluate and predict the effects on surface and groundwater resources of human activities and human-induced impacts, with a view to developing strategies for management and mitigation of negative impacts.
Programme 5*: *Integrated flood and drought management	**Scope:** Flooding and drought are major natural hazards to human society and have important influences on social and economic development. This programme focuses on research that will result in the development and implementation 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. Research related to drought management will focus on integrated tools and strategies for early identification and mitigation of the social and economic impacts of drought, with the aim of supporting collaborative, multi-institutional processes and programmes.

THRUST 4: POLICY DEVELOPMENT AND INSTITUTIONAL ARRANGMENTS FOR WATER RESOURCE MANAGEMENT

Scope: This thrust focuses on instruments supporting effective water resource management, ranging from support for the development of appropriate policies and their implementation to research concerning the establishment of governing bodies and institutional arrangements (at catchment, national and transboundary levels). The thrust supports research on tools and methodologies for decision support for IWRM, aims to provide strategic support for new policy development and improve the understanding regarding the effective functioning of institutional structures for implementing IWRM.	
Programme 1: Decision support for IWRM at catchment and WMA level	**Scope:** Information, tools and methodologies for assessing and finding equitable balance between social, ecological and economic aspects of decision-making regarding protection, development, allocation and management of water resources. 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 2: Water policy development and strategic policy support	**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. Capturing and dissemination of "stories"(case-based) and best practices for IWRM at policy, planning and implementation levels.
Programme 3: Institutional arrangements and processes for IWRM at catchment, WMA and national level	**Scope:** Generating knowledge and understanding to support the design and development of appropriate institutional structures, functions and processes for the implementation of participatory IWRM, including both statutory and non-statutory organisations and social groupings. Developing appropriate business models for water management institutions. Improving understanding and tools for building capacity to manage and participate in IWRM.
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, including development of appropriate institutional forms and functions, development and harmonisation of policy and regulation in shared river basins, strategies for knowledge-sharing and joint management of shared river basins.
Programme 5: Governance, law and regulation	**Scope:** Supporting improved understanding, consistent interpretation and further development of water law and regulation, including linkages and harmonisation with other legislation. This programme addresses customary law as well as conventional law.
Programme 6: Institutional development and collaboration in the Eastern Cape	**Scope:**The Eastern Cape has a number of research institutions active in the water resource management field. An opportunity exists to develop a collaborative framework in a province that is in dire need of water services and water resource management knowledge. This will present a pilot study for institutional development and multi-institutional partnerships at national level. This programme will contribute to knowledge, understanding, tools and capacity for management of water resources in the Eastern Cape.

RESEARCH PROJECTS FOR 2004/05

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 of new projects which commenced between 01 April 2004 and 31 March 2005.

COMPLETED

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

This project introduces a new three-dimensional poro-elastic model for the flow of groundwater through the Karoo aquifers. The main purpose with the model was to investigate to what extent deformations are responsible for the observed physical behaviour of Karoo aquifers in South Africa, which cannot be explained with the conventional porous flow model. This applies in particular to the effect that linear and non-linear deformations may have on the behaviour of the aquifer. The following results are relevant for the practical use, management and control of groundwater resources:

- The pumping of a borehole causes deformations in an aquifer
- The magnitude of the deformations depend linearly on the discharge rate and decrease with distance from the pumped borehole
- Groundwater levels observed in the field are implicit functions of the deformations
- The specific storativity of an aquifer is determined by the dilatational strains associated with the deformations and therefore depends on both the discharge rate of the borehole and the distance from the borehole
- The hydraulic conductivity of an aquifer is determined by properties of the rock matrix and the deformations and therefore depends on both the discharge rate of the borehole and the distance from the borehole

Cost: R 598 000
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

This study investigated the recharge processes and rates of the Central Namaqualand area of the Northern Cape. The area is characterized by a semi-arid to arid climate with groundwater occurring in the crystalline basement and alluvial aquifers.

The chloride mass balance, saturated volume fluctuation (SvF) and the cumulative rainfall departures (CRD) methods were used to quantify recharge rates. The stable isotopes, O and H, and the radiogenic isotope C were used to assess groundwater recharge processes and mean residence times of the groundwater respectively. Statistical and GIS approaches were to delineate recharge areas and discharge areas or where recharge is negligible. The findings are:

- Groundwater recharge rates are estimated to be within 0.1 to 10 mm/yr.
- Isotope data indicate water ranging from very young to very old (<50 years > 30 000 years)
- Recharge mainly occurs when rainfall is above normal. Flood events will produce significant recharge, mainly to the alluvial aquifers

Cost: R1 701 000
Term: 1999-2003

Feasibility study on the use of chemical geothermometers for tracing deep groundwater flow
Division of Water, Environment and Forestry Technology, CSIR (Stellenbosch)
No 1331
This report is a feasibility study to investigate chemical geothermometers for estimating groundwater circulation depths. The rationale behind this study rested on two central premises:

- There is a relationship between temperature and depth below the earth's surface
- There is a relationship between the composition of a solution in contact with a mineral assemblage and the temperature of the chemical system

Quantification of these two relationships should allow the estimation of depth to be made from measurements of the groundwater composition in a suitable water-rock system. Decreasing equilibrium rates with decreasing temperature allows the groundwater composition to "remember" the temperature at which it last equilibrated with the minerals in the aquifer, even if the water cools ascending to the surface.

There are two commonly used types of solution geothermometers, namely silica geothermometers and cation geothermometers. Silica geothermometers are based on temperature-dependent variations in the solubility of individual silica minerals such as quartz, chalcedony and amorphous silica. Cation geothermometers make use of temperature-dependent exchange reactions with hydrothermal minerals such as clays and feldspars which fix the ratios of dissolved cations according to the equilibrium temperature. Other geothermometers make use of isotopes, gas concentrations or temperature-dependent variations in mineral saturation indices, but these are not as widely applied.

Chemical analysis data for groundwater samples from the Table Mountain Group aquifer in the Klein Karoo were used to test the applicability of chemical geothermometers in quartzite. As expected, silica geothermometers, particularly the quartz geothermometers give the most plausible geotemperatures for this environment. The silica geothermometers produced higher temperature estimates for the Nardouw subgroup than for the Peninsula Formation. This conforms to observations of groundwater flow in the two formations, but slight differences in mineralogy, rather than deeper flow in the Nardouw may be responsible for the higher temperature estimates.

There is some promise that reasonable depth predictions could be made for aquifers of simple quartz mineralogy if very accurate field and laboratory data were available, the geological and flow environment well understood and a carefully calibrated quartz geothermometer can be used. The quality of the predictions is not sufficient as a basis for important aquifer management decisions, without an independent verification of the outcome.

Cost: R99 600
Term: 2002-2003

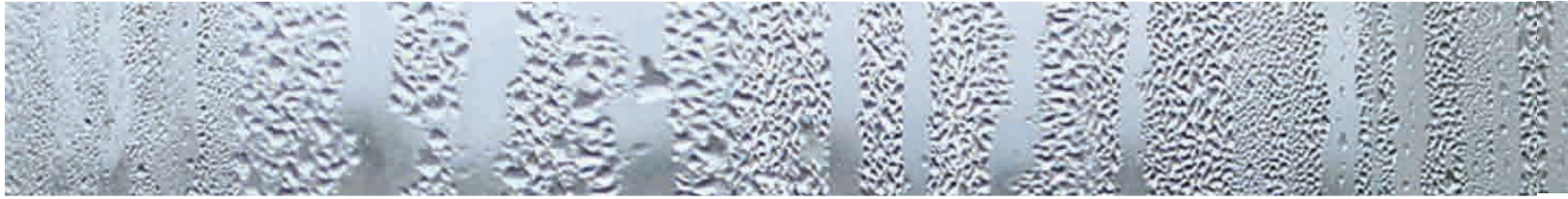
Identification and prioritisation of type areas for detailed research in terms of regional variability of aquifer systems
SRK (CE) Inc
No 1332

The TMG aquifer system is a regional fractured aquifer system with the potential to be a major source for future water supply in the Western and Eastern Cape. This study identified suitable type areas for detailed research into the impacts of large-scale groundwater abstraction from TMG Aquifer Systems on the ecology and the regional hydrogeological characteristics taking into account regional variations within the TMG aquifer system.

This report details the methodology and modelling techniques employed to identify and prioritise the key research type areas as well as describing the important distinguishing characteristics of each type area. The study produced the following:

- Exploitation map
- Exploration map
- Development potential map
- Ecological importance map

Cost: R244 000
Term: 2002-2003



Programme 2*: *Catchment hydrology

Monthly multiple site streamflow model

BKS (Pty) Ltd.

No 909

South Africa's hydrological data resources are very limited in terms of continuity in time and in how the data source points are spatially distributed. In the case of rainfall and runoff a trend exists where some areas especially wet areas have a dense distribution of gauges while drier areas remain un-gauged or have poor and unreliable record capturing systems. The provision of synthetic hydrological data in areas where natural data does not exist or is scarce using stochastic models has been one of the key competences of the South Africa's hydrology community. One of the most important developments in stochastic hydrology was presented in 1985 through the stochastic generator in the Water Resources Yield Model (WRYM). This project looked at further developments to the stochastic streamflow generator in the WRYM. This research also sought to repackage this stochastic generator as a stand alone model that can be used without having to run the cumbersome systems analysis model (WRYM).

The project work involved further research on stochastic modelling, rewriting of the model code, testing and repackaging of the stochastic streamflow generator as a stand-alone tool that could be used for a variety of hydrological uses, especially in dealing with data scarcity in South Africa and other countries with similar data shortcomings.

The original stochastic module (1985) produced stochastic streamflow sequences of the same length as the input historical data. The model developed in this study can generate stochastic sequences longer than the available historical records, to stimulate up to a thousand 100-year stochastic streamflow sequences. The project delivered a stand-alone, stochastic model supported by a graphical user interface and an illustrative user guide. The model presented is easier to load and run and was developed using Delphi which is object-oriented, thus making provisions for further interfacing with other models when the need arises.

The stochastic sequences generator presented in this project will be very useful in a number of new hydrological research initiatives where researchers are looking at developing integrated environmental decision support systems which utilise long sequences of hydrological data.

Cost: R91 000
Term: 1998-1998

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

Department of Civil Engineering, University of Stellenbosch

No 1270

There were two distinct parts to this project, as shown clearly in the aims below:

- The development of sound theory for rating natural controls in a river such as rapids and rock barriers for accurate measurements, particularly of low flows
- The development of fish-ways to be used in combination with various types of gauging structures, without any negative impacts on the accuracy with which flows are to be gauged

Work on the two sub-projects was conducted separately. The reasons for conducting Part 1 in this investigation, the rating of natural controls for flow measurement, is that flow, particularly low flow, in Western Cape rivers, is very difficult to measure due to the high large-scale roughness. Not only are gauging weirs expensive, but they form migration barriers to aquatic biota. The aim was to determine a system through which various types of natural controls could be calibrated, by establishing a relationship between the discharge coefficient and the physical characteristics of each control type. Two types of critical controls were identified and investigated, namely step-pool controls and horizontal constriction controls as well as one type of uniform flow control, namely the plane bed control. Step-pool controls were found to be very robust controls that provided efficient critical controls for a wide range of flows. Horizontal constriction controls proved to be reasonably accurate measurement sites and, because of their physical characteristics, they are able to measure the full range of flows from low to flood flows. Uniform controls are widely used for flow measurements on deep

rivers, but such measurements become highly unreliable when flow depths are small and bed roughness is high as is the case with cobble-bed rivers. Under conditions of high roughness, generally speaking, critical controls can be calibrated more accurately than uniform controls and are therefore to be preferred.

Natural controls will be acceptable for use where the required accuracy (+ 10%) is lower than achieved by well-maintained gauging weirs, in environmentally sensitive areas, or where a fish-way would normally be required, as natural features form better fish-ways than constructed weirs.

The second part of the project was to examine the possibility of developing fish-ways on gauging structures. However, after this project had started and partly in response to strong representation from DWAF, the three have been co-ordinated very closely to achieve products that will fill the national need. The product of this project is considered 'DRAFT' because it will be widely distributed and comment will be requested which will feed into the final product of the third and biggest of the 3 WRC funded fish-way projects. As such, the product gives a number of protocols around the use of fish-ways. It examines the biological requirements for fish-ways, and then gives guidelines for the design and monitoring of the fish-ways.

Cost: R776 050
Term: 2001-2004

Programme 3*: *Understanding and predicting hydroclimatic variability

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

High variability and short instrumental records conspire to limit understanding of longer-term climate patterns and variability (decadal and centennial scales) in South Africa. Proxy data series from continuous cave speleothems presented significant new opportunities for addressing this gap. Accordingly, this project originally aimed to construct a regional, sub-decadal scale record of precipitation, temperature and vegetation response in the north-eastern, summer rainfall region using such data. High resolution dating methods were used to establish sound age models congruent with the high resolution of the proxy data sampling, and to allow comparisons with other high resolution series such as ice cores. The proxy data concern mainly the oxygen and carbon isotope series. The rapid shifts observed in the stalagmite records provide a strong indication of the rapidity of changes in rainfall and vegetation patterns, which are on the order of years to decades. Whereas overall trends and variability at low frequencies (longer time scales) are more stable and to some extent even predictable, variability is noisy at higher frequencies (multi-decadal and, to a lesser extent, centennial scales). This means that, while most objectives of the project were achieved, the goal of achieving greater clarity regarding subdecadal climate variations could not be immediately met.

Cost: R 375 000
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

This project on the dynamic modelling of the climate system built on an earlier project, thereby consolidating recently developed capacity to undertake climate simulations and at the same time addressing key questions about the regional climate system of Southern Africa, of concern to the water and other sectors. The research questions addressed with atmospheric models focused on those aspects of the climate system for which there remains poor understanding. Central among these is the climate sensitivity to feedback mechanisms and the dynamic responses to external forcing-especially land-surface feedbacks to the atmosphere. The modelling studies showed that the land-surface may play a notably more important role than has been previously thought in governing intraseasonal variability, extreme events, and possibly the strength of the regional climate response to global climate change. During the course of these studies,

characteristics of the models were tailored to optimise performance over the Southern Africa domain. As a consequence of this, modelling tools are now well understood in terms of their skill and error. Building on this, the models have been stretched to understand the limits of their performance, and in one application, successfully simulated local-scale weather systems down to 500m resolution, and in doing so provided valuable insight on extreme events in the Western Cape.

Cost: R1 616 000
Term: 2000-2003

Development of an improved gridded database of annual, monthly and daily rainfall
School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal
No 1156

Most water resource planning, management and operations rely on good hydrological data especially rainfall. Rainfall is the main input in hydrological assessments, water resource modelling, and other information generation to guide decision making on issues such as civil constructions, travelling, agriculture and disaster management. Availability of hydrological data in Southern Africa is very limited. Areas stretching over hundreds of square kilometres have no gauging facilities for hydrological parameters. In addition to this limitation in spatial distribution of hydrological data recording facilities, there are numerous organisations and agents, which record data and operate gauging stations. These data sources generate data of differing quality and formats. It is time-consuming and costly for anyone working on a project to put together all the relevant data from the different establishments. This project generated a readily accessible package of time series data on rainfall and temperature, which was collected from several different organisations.

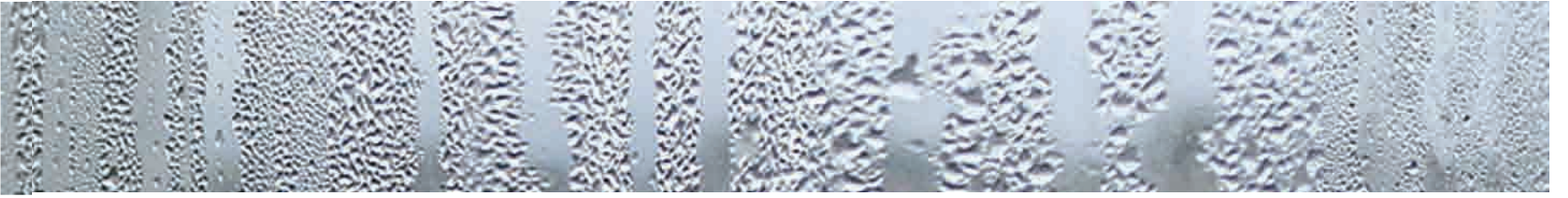
In this study the researchers aimed to provide a comprehensive quality controlled spatial and temporal daily rainfall and temperature database of South Africa and neighbouring countries. In the rainfall database, the neighbouring countries included: Namibia, Botswana, Zimbabwe and Mozambique. The temperature database covered South Africa, including Swaziland and Lesotho.

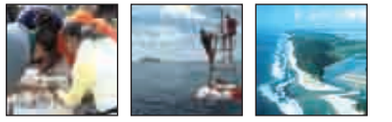
In this project infilling and data extension techniques were developed and applied to improve the time series data. These data were quality checked, and simple processing was done to generate hydrological statistics. The infilling techniques used were documented to assist users of project outputs.

Another important output in this study was a raster database of rainfall and temperature data at a spatial resolution of one arc minute covering South Africa. In the rainfall database, the estimated mean annual precipitation (MAP) was used as the key variable in the generation of raster data. Different techniques for estimating the raster MAP were investigated and documented in the project. Geographically weighted regression (GWR) technique was selected and used for the rainfall raster database. A limited coverage of the one-minute grids data was included on the CD as well as the documentation of techniques for generating the grid data. This method relies on unfilled recorded data, the spatial distribution of the existing gauges and other factors as documented in the project report. Users can use the packaged software to expand the raster database to other minute grids as the need arises. All the recorded data that could be found are included on the CD. These consist of approximately 300m. rainfall values for about 14 000 stations.

A different technique for generating temperature data at any one of the 429 700 one arc minute grid points in South Africa (including Swaziland and Lesotho) was developed. Unlike rainfall data, the spatial distribution of temperature gauging stations was found to be even sparser. In South Africa, Lesotho and Swaziland, only 23 weather stations had temperature data stretching over 50 years. An additional 950 stations were in-filled and extended to 50 years using different techniques that are described in the temperature report. The gridded or raster temperature method relied on extended and in-filled recorded values, lapse rates and methods for adjusting spatio-temporal lapse rate discontinuities.

Unlike many projects that generate data for a limited area,





this project generated daily, monthly and annual rainfall and temperature data for the whole country and provided it on a single CD. In the past many water managers or other users of such data have had to pay and obtain data for a few stations. As a result the use of project outputs from this research started well before the project was completed as users requested and obtained the data CD. This project has made daily data, readily available to water managers at no added cost. Areas that previously had no rainfall or temperature data due to the absence of gauges can now be assessed or simulated using techniques and data from this project. WRC projects such as **K5/1490** and **K5/1491** are set to benefit directly from the methods and data produced in this project.

Cost: R2 277 600
Term: 2000-2002

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

After rainfall, evaporation is the second most important variable in hydrological modelling and other water resource management methods which use water balance techniques. While rainfall has been widely recorded over most of South Africa over the past decades evaporation measurements and measurement points are still very sparsely distributed. The measurement of evaporation is a difficult process which involves the measurement of a number of other parameters and then applying these parameters in equations and theories such as the Penman-Monteith theory to give total evaporation estimates. Water resource management modelling techniques require measured physical variables to calibrate modelling processes and to improve the methods used to estimate the model variables. This study involved the measurements of physical variables in different vegetation covers and then applying the recorded variables to the improvement of evaporation simulations in locally used models. Existing records were compiled and further physical measurements were done in selected sights where measurements had not been done before. These sites consisted of a coastal bushveld, valley thickets and moist upland grasslands.

The Bowen Ratio Energy Balance Technique was used to estimate total evaporation. In this technique, the available energy flux density, the air temperature and water vapour pressure profile differences above a surface were measurement and used to generate total evaporation in millimetres. Measurements were taken in the selected sites over the period 2002 to 2003. The ACRU, SWAT and SWAP models were used to simulate evaporation in the areas where the measurements had been taken. The outputs from the models were compared with the physical measurement results and the model performance evaluated in the light of the measurements and the assessments of prevailing conditions as observed by the researchers.

The study revealed several weaknesses in the inputs and simulation procedures of three models used in this study, that is the SWAP, SWAT and ACRU models. It was concluded that the models investigated in this study were oversimplified such that they could not adequately cope with most real life catchments where vegetation exist in complicated mixes of different vegetation compositions and stages of succession. The models used average vegetation parameters which lacked in representing the normal vegetation variability in the study areas. A shift towards mechanistic modelling approaches rather than conceptual modelling to relate evaporation routines more closely to the actual physical processes was recommended. In this project the researchers identified that better results in evaporation simulations were possible if the models used more representative reference evaporation, crop growth routines that relate more accurately to the physical processes. The research provided a basis for the proposed revision of total evaporation simulations in water resource models, especially the ACRU model.

Cost: R530 600
Term: 2001-2003

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

Department of Soil Sciences, University of KwaZulu-Natal (Pietermaritzburg)

No 1335

There is currently no generally accepted standard or benchmark for measurement or estimation of evaporation from land (which includes transpiration by vegetation) and water surfaces. This makes quantification of the process disconcertingly uncertain. Yet the demands of modern-day water management require that actual evaporation, one of the largest components of the hydrological cycle and the one responsible for the majority of consumptive uses of water, be estimated with increasing precision and degree of reliability. The main objective of this project was to investigate a recently-developed technique, surface layer scintillometry (SLS), for its ability to provide reliable estimates of areally averaged sensible heat flux density over natural, heterogeneous surfaces, as an essential step towards obtaining reliable, areally averaged evaporation estimates via the energy balance equation. With there being no accepted standard or benchmark, reliability assessment had to be accomplished against the background of comprehensive theoretical analyses and extensive in-field comparisons with alternative indirect (usually point) measurements of evaporation, such as with Bowen ratio (BR) and eddy covariance (EC) techniques. The project showed that with correct usage, the SLS method may be applied with confidence to obtain spatially integrated measurements. Whilst meeting its objectives, this project also produced a comprehensive reference manual on the theory and practice of evaporation measurement, a potentially valuable teaching aid.

Cost: R652 600
Term: 2002-2004

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

Impoundments and associated bulk water supply infrastructure are present in most South African river systems. Because of the disparate natural occurrence of rainfall and runoff and its mismatch with water demand concentrations, many of these schemes have to incorporate inter-catchment transfers. Furthermore, water quality deterioration, because of human impacts, threatens to diminish the utilisable part of the runoff in many catchments. These complexities offer challenges to water managers that require innovative management philosophies and management tools. This project aimed to advance integrated catchment management (ICM), through the development of an integrated information system specifically for water quality (WQIS).

To be useful to ICM, this WQIS must provide diagnostic and predictive utilities to serve technical planning and operational decision-making in a river system, but, simultaneously, provide appropriate information to support water managers in the engagement of and communication with stakeholders and communities. To serve as prototype for development of the WQIS approaches and to provide a relevant database, the Riviersonderend-Berg River System (RSE-BR) was selected, as it contains all the challenges and complexities referred to above.

Simultaneous with the formulation of the WQIS described above, the Department of Soil and Water Science (DSWS) at the University of Stellenbosch formulated a research proposal to investigate the causes of and quantification of apparently increasing salinisation of the Berg River, one of the prime water sources to meet growing demands in the Greater Cape Town and West Coast Region. The WRC proposed that the two research proposals be merged into a single project with two related research themes, viz.:

- Development and/or application of decision support software for general water quality management in a river system with diverse components and human impacts.
- Water quality-related research in the form of field-scale

process studies and large-scale soils data interpretation, with a strong focus on salinisation processes

The main product developed under the first theme is a WQIS for the Berg River that is both integrated and interactive. It has been developed in close cooperation with its intended technical users to provide water resource operational and planning decision support. The WQIS has a user-friendly GIS-based Graphical User Interface and incorporates interfaces with DUFLOW and CE-QUAL-W2. DUFLOW is a one-dimensional hydrodynamic river flow and water quality model. It was applied to the Berg River to demonstrate its usefulness to support decision-making for various water quality management scenarios. CE-QUAL-W2 is a two-dimensional hydrodynamic reservoir water quality model. It was applied to the proposed Skuifraam Dam in the Upper-Berg to illustrate its utilisation to support decision-making for various in-dam water quality management scenarios and to provide realistic upstream boundary conditions for DUFLOW scenario runs.

The main products developed under the second theme are a soils map and a salinity hazard map that were compiled for the Berg River catchment. These maps and images from the Berg River catchment are available in PDF-format on an accompanying CD-Rom. From field work valuable insights were also gained about field-scale salt mobilisation and irrigation return-flow processes. It was recognised that our understanding of the return-flow processes operating below the root zone is still inadequate and that there is still a lack of understanding of the contribution of dry-land activities to salinisation.

Cost: R1 317 194
Term: 1998-2002

Pilot study to demonstrate implementation of the National Microbial Monitoring Programme (NMMP)
Division of Water, Environment and Forestry Technology, CSIR
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: 2000-2001

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 KwaZulu-Natal
No 1217

This project aimed, firstly, to pull together, for flood forecasting in a real world application, the outcomes of previous research funded by the WRC in the areas of radar estimation of rainfall, space-time modelling and forecasting of rainfall, linear catchment modelling and river-flow modelling, and, secondly, to provide decision makers in Umgeni Water and Durban Metro (and eventually the Umgeni Catchment Management Authority) with tools enabling proactive rather reactive response in the context of flood warning. Some of the innovations

relating to the Flood Forecasting System and its components included the following: development of algorithms for merging raingauge and weather radar estimates of rainfall over large areas; employment of GIS to capture real-time rainfall over sub-catchments as input to the rainfall/runoff model; derivation of a short-term rain-field nowcasting method for anticipating rain-fields in the immediate future; exploitation of the speed and efficiency of a linear transfer function rainfall/runoff model developed under a previous WRC project; and, the establishment of a GIS-based information base in the eThekwini Metro Disaster Management Centre, giving instantaneous visual display of real-time information on whereabouts of storms (and their nowcasts) relative to suburbs, townships, rivers, roads etc. With the new flood forecasting capability, 6 to 12 hour warning of an impending flood will enable appropriate action to be taken to limit damage to life and property.

Cost: R350 000
Term: 2001-2002

THRUST 2: INTEGRATED WATER RESOURCE DEVELOPMENT

Programme 1: Integrated catchment management

The model for water demand management planning and monitoring

BKS (Pty) Ltd.

No 905

With a population of 46 million, most of whom do not have access to adequate water services and a climate prone to droughts and floods, South Africa faces an enormous challenge in how to allocate, use and protect its limited water resources. Like many other countries, little effort has been given in the past to utilizing water in an efficient manner. The focus has rather been on increasing supplies. The Vaal Augmentation Planning Study and continuous studies undertaken by DWAF revealed that the implementation dates of water supply upgrading options in the Vaal River system can be postponed by at least eight years with the implementation of demand management initiatives. The associated potential savings were shown to be in the order of R4bn. The results of these and other projects prompted a major initiative by DWAF and others to further the implementation of water demand management as a matter of priority. A number of such initiatives were initiated in the municipalities. This study was one of the first such studies to look at national water demand management for the purposes of water use records monitoring and use projections, with the overall aim of supporting decision making on the implementation of new water provision facilities.

In this project a graphical model was developed where the user can define the water supply institution and the supply system under its control. Detailed information that is relevant to use patterns of the various water user sectors is provided through an interactive model input system. The model simulates projected water use in the system based on a selected base year and compares this with the observed use patterns. Each simulation relates to a particular demand management plan. By comparing the actual and observed water use trends, an evaluation can be made of the validity of a particular demand management scenario.

The WDM model was developed in Delphi code and has an interactive graphical interface which makes it user-friendly and easy to interface with other modelling tools developed using the object-oriented programming languages. The model outputs presented using this WDM model allows for user improvements in time as the user obtains new observed records. This tool will be useful in evaluating the water demand management initiatives in various municipalities.

Cost: R456 000
Term: 1998-1999

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 report describes guidelines on setting resource quality objectives (RQOs) for groundwater as part of the implementation of the Resource Directed Measures under the National Water Act. Step-by-step guidelines on an

approach to setting RQOs which is aligned to the overall approach defined for all water resources and the classification of groundwater. The steps to set a suite of RQOs to protect a significant groundwater resource are recommended as follows:

- Broadly characterise the groundwater resource
- Define the aquifer attributes which support or limit the recognised uses
- Define the risk to uses with respect to hazards present in the catchment and aquifer vulnerability
- Select key measurable indicators which relate to the resource itself or land-use impacts
- Quantify the reference conditions, present status, sustainability threshold and variability of these resource indicators
- Outline the management actions that may be necessary to ensure that different levels of modification / protection are maintained
- The Minister, in consultation with the CMA, sets a value for the resource indicator, the RQO

Cost: R200 000
Term: 2001-2003

THRUST 3: MANAGEMENT OF NATURAL AND HUMAN-INDUCED IMPACTS ON WATER RESOURCES

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

The overall aim of this project was to contribute to a groundwater protection strategy, which will take both pollution and the phenomenon of natural accumulation of nitrate in groundwater into account.

Nitrate in groundwater can be derived from various sources. These can be grouped into two main categories:

- Anthropogenic nitrogenous pollution
- Natural nitrate accumulation, primarily in arid and semi-arid regions.

In South Africa the available data show that this widespread diffuse source from agriculture generally only provides a background concentration of nitrate in the water, largely derived from the soil nitrogen pool due to the tilling of the soil. This is particularly the case in areas with highly productive soils such as the black cotton soils overlying the basalts. Point sources are generally associated with pollution activities, e.g. sewage sludge drying beds, land application of sludge, and irrigation of (partly) treated wastewater. Near the large cities, high levels of sewage sludge application to land have caused serious groundwater pollution.

The research results from South Africa, other Southern African countries, and most developing nations show that on-site sanitation is the major source of groundwater nitrate in groundwater, apart from the naturally occurring groundwater nitrate in developing countries. The abandonment of well-fields, mainly because of nitrate pollution, is continuing and it is also occurring in South Africa. For large parts of Southern Africa on-site sanitation remains the only viable option. Not all such practices lead to groundwater pollution, but in the wrong hydrogeological and environmental conditions, the effects on groundwater can be disastrous. On-site sanitation is generally a cost-effective approach and any nitrogen management strategy has to contend with realistic on-site sanitation options. However, it also means that on-site sanitation needs to be planned with the particular hydrogeological scenario in mind. There is no general rule that can be applied everywhere. It is necessary to have a pragmatic approach in this regard, but where sensitive and sole source aquifer systems are at risk, alternative sanitation options have to be found. The occurrence of methaemoglobinaemia (also in developed countries such as the USA) was mostly associated with private drinking water wells which were polluted by on-site sanitation, e.g. French drains associated with septic tanks. Nitrate pollution of groundwater from sanitation systems has tended to be overlooked or downplayed in many of the policies and strategies relating both to water supply and sanitation and to water quality management in South Africa. The reasons for this are varied, ranging from a

historical focus on surface water in South Africa (where nitrate is less of a problem than for groundwater) to the drive to supply sanitation services as fast as possible to fulfil the obligations in terms of the sanitation policy and to reach all members of the previously disadvantaged sectors of the population. Doubts have been expressed about the true severity of the nitrate impacts from this source, but little data have been collected to disprove the extent of the impacts. In the short term, health impacts from pathogens are a far more pressing issue and most recommended mitigation measures revolve around providing sufficient separation between sanitation systems and water supply points to ensure that bacterial contamination cannot migrate to the point of groundwater abstraction. Little consideration appears to have been given to the long-term sustainability of this approach, which may delay the impacts, but ultimately will not prevent nitrate contamination of the water supply. Mitigation of impacts by appropriate measures, e.g. *in situ* denitrification provides alternatives where on-site sanitation was not the ideal but the only practical solution. For any rural water supply project using groundwater in an area where on-site sanitation is practised groundwater quality monitoring at strategically selected points is essential.

A management strategy has been developed consisting of a situation assessment, immediate actions, medium and longer-term actions. The management and reduction of groundwater nitrate levels depend on an understanding of the nitrogen sources and the pollution and nitrification mechanisms. A successful groundwater protection strategy has to consist of a dual approach, i.e. legislation for pollution control and for reducing nitrogenous inputs to the environment, which is supported by an education and public awareness programme.

With regard to natural nitrate accumulation, management options are limited and consist essentially of developing alternate low nitrate sources or denitrification.

Nitrate in groundwater involves various risks for human consumption. Mortalities as a result of methaemoglobinaemia are a reality. New information became available on earlier cases of methaemoglobinaemia, while spontaneous abortion may constitute a further risk related to nitrate in water. Microbiological and other risks related to polluted water may aggravate the situation.

The risks associated with nitrate ingestion have to be evaluated in terms of the total dietary intake of nitrate and nitrite.

Livestock are also at risk and nitrate poisoning of livestock has been recorded in Southern Africa and elsewhere.

Cost: R450 00
Term: 1999-2001

Quantification of the impact of irrigation on the groundwater resource underlying the Vaalharts irrigation area

Institute for Groundwater Studies, University of the Free State

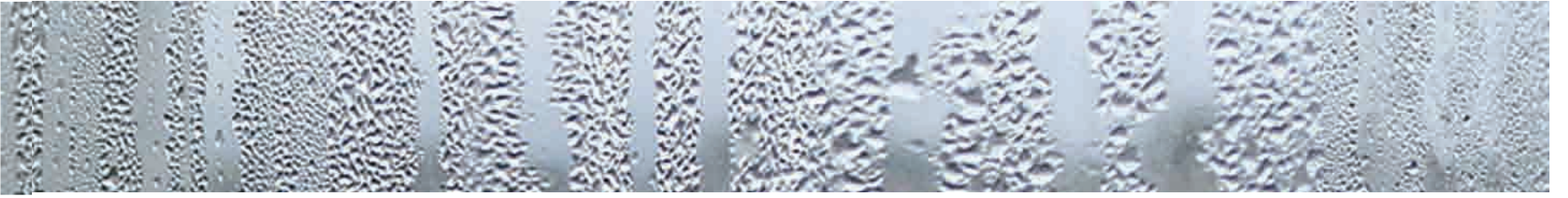
No 1322

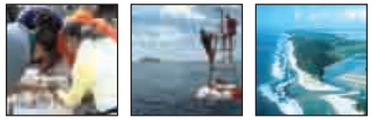
The Vaalharts Irrigation Scheme is the largest irrigation scheme in South Africa at approximately 32 000ha. A report discussing the long-term salt balance for the scheme stated that there was 100 Kt annual loss of salts to groundwater, and predicted that as these salts were not being measured in the Harts River, that they would be seen in the form of a sudden flow reversal to the Harts River, thereby adding strain to an already stressed system. This study investigated the aquifer system and salt migration to test the above hypothesis.

The study indicated that the greatest contribution to the incoming salt load is irrigation water sourced from the Vaal River. The salts added in this way are more than double those from fertilizer addition and management of this incoming water is, therefore, the way to the salt accumulation in the irrigation scheme. Two management options were presented:

- Evaporation basins
- Water use efficiencies

Cost: R510 000
Term: 2002-2003





Application of *in situ* groundwater treatment as robust low-cost water supply option
Environmentek, CSIR
No 1325

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 which remove contaminants while the groundwater resides 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 the South African application include:

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

Cost: R201 355
Term: 2002-2003

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

Contamination of South Africa's urban aquifers presents a threat to the sustainability of this water resource. Man's activities, use of chemicals and generation of wastes tend to concentrate potential sources of contamination in the urban areas. The threat caused by undesirable substances is recognized in this country, but the understanding of the extent of the problem in South Africa's urban catchments is poor. This project was therefore geared towards filling the gap in the understanding of groundwater contamination in South Africa's urban environments. By doing so, the principal pollutants could be identified and, based on their risk, prioritized. This would facilitate better management of groundwater quality in South Africa by assisting future land-use planning and vulnerability studies.

The initial stages of the project involved the collection of information that would give a general overview of the status of urban groundwater pollution, mainly from textbooks and published international literature. Information on general sources of groundwater contamination and types of groundwater contaminants in the urban environment were summarized. Various approaches that have been used to classify groundwater contaminants and their sources were discussed.

General information on urban groundwater contamination was related to the South African context using information on local urban areas and summary statistics from Statistics South Africa (South African census data); Chamber of Mines (South African mining statistics); State of the Environment Reports (South African Metro Areas); municipal websites (South African Metro Areas) and WRC Reports. These were used to identify potential sources of groundwater contamination in South African urban areas.

Case studies of reported contaminated sites were identified from archives of newspaper articles; conference and workshop proceedings (International Association of Hydrogeologists, Water Institute of Southern Africa, Institute of Waste Management) and project reports and monitoring databases, where available. Case studies from literature were intended to provide a baseline of the current level of groundwater contamination in South Africa's urban areas. The availability of published data and information, however, proved to be a major limitation in quantifying groundwater contamination in South Africa's urban areas.

The products resulting from this research were:

- A tiered risk-based prioritization software tool with which both sources and contaminants can be rated.
- An Excel-based data information system in which contaminants, associated sources and contaminant properties are stored

Using the above-mentioned projects, contaminants found in the urban environment can be prioritized on a national, regional and local scale. Therefore a source and contaminant prioritization list was established for:

- South Africa
- Gauteng
- Durban
- Cape Town
- Port Elizabeth

The documentation and the associated software should serve as a good guide to expected contaminants associated with different activities. Methodologies have been created whereby a water manager in any urban area can identify and prioritise the potential groundwater contaminants in the area. The software packages should be very useful tools for persons ranging from municipal water managers to researchers and hydrogeologists with detailed knowledge of a site.

Cost: R1 000 000
Term: 2002-2004

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 influence cloud formation over Southern Africa and to quantify the relative contributions of natural and anthropogenic aerosols to effective (rain-producing) CCN. For the first time it was possible to characterise the nature and availability of CCN in relation to the production and transport of anthropogenic aerosols over South 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. The industrialised Highveld is a major continuous source of industrial aerosols which may act as fine-sized cloud condensation nuclei (CCN). Depending on concentration, size distribution and chemical composition (especially hygroscopicity) relative to natural CCN, these anthropogenic CCN could impact either negatively or positively on raindrop formation. Large numbers of fine-sized CCN with a narrow particle spectrum, common in industrial emissions, were found compete for available cloud water and inhibit raindrop growth. By contrast, relatively fewer but on average larger particles, such as naturally found in cleaner air or air typical of coastal areas, resulted in reduced cloud droplet concentrations with a broader size spectra, faster drop growth rates and thus higher possibilities of rainfall. The processes are, however, extremely complex and dynamic and only with further study will it would become possible to predict and properly manage specific impacts of air pollution on the hydrological cycle.

Cost: R1 390 000
Term: 1998 -2002

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

The original aim of the project was to develop a rapid, low-cost human cell toxicity test that could be used for the universal monitoring of complex effluents. This would be based upon earlier work listed in the References, and the aims listed below were formulated as necessary stages in reaching this final objective:

- Determining the range and sensitivity of the assay
- Simplifying the assay
- Controlling 'drift' in cellular responses to toxic agents

There were some basic problems identified in the earlier development of this test which needed to be overcome to achieve the necessary accuracy. The greater accuracy was required because cells exhibited a hormetic response to some stressors, particularly heavy metals. The first of these is known as `drift', and is manifest by the response of a cell culture to a stressor changing over time. The second is the relatively wide range of variability typically shown by biological systems when exposed to stressors. Theoretically,

it was realised that when grown in a complete medium cells could be in a range of metabolic states depending on the functioning of the Krebs cycle within individual cells. It was shown that both the above problems could be controlled by stabilising the glutamate metabolism within the cells through changing the culture medium in the run-up to the tests through glutamine free and then serum free, and the tests were run in a medium that was both glutamine and serum free. This ensured that the cell response did not drift, and that all the cells were in the same metabolic state, thus reducing the variability of the response of the culture. Costs were decreased by doing away with the need to maintain sterile working conditions during the test procedure by working in clean, non-sterile conditions and then sterilising the prepared plate using UV light, by sterilising disposable equipment in alcohol and by developing software for the interpretation of results, thus reducing the necessary skill level of the operator.

The result of this is that there is a competitive and affordable test that gives results repeatable with close tolerances. Being based on a human cell culture, the results are closely applicable to human tolerances. One criticism raised by a steering committee member is that the healthy human body presents a number of checks and balances which offer a degree of protection against environmental influences, and these are not replicated in the test. Thus, the test may be too sensitive.

Cost: R252 000
Term: 2000 -2001

Design and development of an implementation plan for a national eutrophication monitoring programme (NEMP) for South Africa s water resources
Environmentek, CSIR
No 1147

Much eutrophication-related monitoring has been done in South Africa over the past three decades. Before the promulgation of the National Water Act there was no legal requirement to assess the degree of eutrophication at a national level. However, this act now requires monitoring, recording, assessment and dissemination of information on national water resources. This project aimed to specifically address this requirement in respect of eutrophication, by providing DWAF with a conceptual design and implementation plan for a National Eutrophication Monitoring Programme (NEMP) which has been tested and can be implemented in water management areas in South Africa.

The initial conceptual design emanated from a series of mini-workshops with a wide variety of people throughout South Africa, which resulted in an *Interim Discussion Document*. Follow-up discussions led to the first draft of the implementation manual which formed the basis of the pilot studies to test the practicalities of the design. Further refinements, ongoing discussions and a total of four versions of the manual submitted for comment, culminated in the implementation manual recommended to DWAF. The products of this project comprise this manual entitled *National Eutrophication Monitoring Programme Implementation Manual* as the main deliverable and a research report that describes the methodology that was followed to develop the manual.

The manual is comprehensive and primarily aimed at DWAF officials. It defines the minimum design requirements (in respect of sampling variables, sampling frequency, choice of sampling sites, etc.) that DWAF must satisfy to meet the national objectives of the NEMP. In addition, this Manual provides for regional and local implementation to cater for local objectives that go beyond the minimum requirements for the NEMP. This approach is intended to simplify the process of designing local monitoring programmes and create better buy-in of local and regional participants to the NEMP because local objectives are also shown to be important. An initial version of the Manual was tested by the Universities of Fort Hare and the North West who monitored impoundments in there respective areas based on the manual. Follow-up visits to the universities provided the project team with useful feedback that resulted in refinements to the implementation Manual.

As part of the project the project team furthermore developed an impoundment prioritisation process to facilitate the initial choice of impoundments during the proposed phased implementation of the NEMP so that the cost-effectiveness of the monitoring resources is maximised. An examination of the 15 principles identified

by DWAF to meet its goal to manage water resources equitably, efficiently and sustainably, indicated that the manual addressed each principle in an appropriate way.

The project achieved the aim of developing a plan for DWAF to implement national eutrophication monitoring. The fact that a wide range of parties contributed to the final plan makes it likely to be a sound and practical approach to achieving the ultimate goal of being able to make national statements regarding the status and trends in eutrophication.

Cost: R724 000
Term: 2001-2002

THRUST 4: POLICY DEVELOPMENT AND INSTITUTIONAL ARRANGEMENTS FOR WATER RESOURCE MANAGEMENT

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

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

A previous study in the Crocodile River catchment analysed water use efficiency based on direct economic benefits generated in specific primary production activities (forestry, irrigated sugarcane and five irrigated sub-tropical fruits), i.e. at the farm level. Accordingly, indirect economic benefits realized upstream or downstream from the primary sector in question were not accounted for. The social costs and benefits of the major environmental impacts of the studied activities were also not investigated. The aims of the present study were therefore to account for total economic benefits (direct and indirect) of water use in the catchment, and to investigate the environmental (natural) and social costs and benefits of the above production activities.

The point of departure of the study was the mapping and quantification of the value chains of each of the three land-use types analysed: forestry, irrigated sugar-cane and five irrigated sub-tropical fruit types. This was done in a two-stage process where, firstly, the product flows of the relevant land uses were mapped through the identification of forward and backward linkages. Secondly, each value added, through extensive survey and primary data collection in each of the three value chains in Mpumalanga.

Economic, social and environmental impact analyses were then completed for each value chain. Direct impacts were defined as the economic, social and environmental impacts occurring within each of the land uses (i.e. at farm level) as the result of water-based production activities. Indirect impacts were defined as the resultant impacts occurring in the forward and backward linkages of the respective value chains. The economic impact analysis set out to measure and compare total economic benefits (direct and indirect) from water use by plantation forestry, irrigated sugarcane and five types of irrigated subtropical fruit (oranges, grapefruit, bananas, avocadoes, mangoes) in the Crocodile River catchment. The environmental impact analysis identified the value chain of direct and indirect product flows within each sector. This was used as a basis from which to build a hybrid life-cycle assessment of the respective sectors and focused on the environmental aspects of the life-cycle analysis. The social impact analysis set out to measure the impact of the respective value chains on households and individuals. This part of the study examined direct and indirect employment and enterprise linkages, and assessed the external social benefit and costs on households that result from these three land uses.

Water apportionment decisions remain, for the largest part, dependent on accurate water use information. This study has shown for instance how estimates of forestry water use figures changed with the adoption of new forest hydrology modelling data. The measurement of irrigation water use remains an important issue in the determination of actual on farm water use, and prediction models for this are currently not adequate. Comparative analysis of forestry and irrigation water use must be done carefully, as the terminology and definitions used in forest hydrology and irrigation planning are different. Water use per ton of

product in the respective value chains, defined as indirect water use for the purposes of this study, are very small in comparison to the direct crop water use.

The study revealed the importance of considering indirect economic benefits in comparing the social worthiness of alternative productive uses of water and other economic resources. This was especially evident from the value added (VAD) and employment multiplier effects, which were between 2- and 20-fold larger than the direct benefits. The multiplier effects were more pronounced for the longer value chains, i.e. those that comprised of more intermediate value adding activities between the farm and the final consumer.

Cost: R558 000
Term: 1999-2001

Principles and processes for supporting stakeholder participation in integrated river management
Division of Water, Environment and Forestry Technology, CSIR
No 1062

The study was based in the Sabie-Sand catchment, which was chosen as a study site for this project for a number of reasons. These include the fact that much research had been done there, providing a solid bases for understanding of the ecosystem, and that there was an existing and active catchment working group (the Sabie River Working Group) representing all major players that could act as a 'surrogate client' for this work.

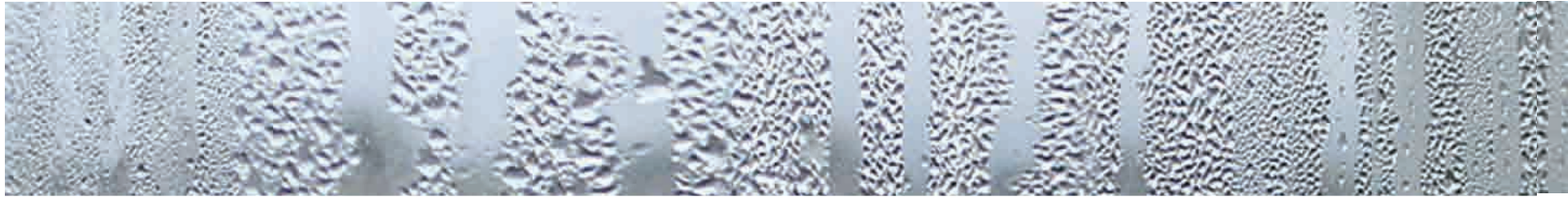
The report is structured into three parts. Part 1 addresses the question of how best to support stakeholder participation in integrated river management and it provides details on the constitutional and legal context underpinning stakeholder participation. It discusses the principles that arise from this context, as well as the processes that would be needed to achieve sustainable and equitable outcomes through integrated management. The lessons learnt from this project are also outlined. Part 2 provides an overview of the detailed findings of the project. These findings are based on a range of papers and reports that were produced as the project progressed. Part 3 focuses on the issue of capacity building. Capacity building is a vitally important aspect of research investment. As the project sought ways of empowering people to participate in the management of water resources, particular attention was paid to this issue. The theoretical understanding of capacity building is documented and a list of people in whom capacity has been built as well as a list of products (outputs from capacity building) that have been produced by the project is provided.

Scientists, especially those engaged in natural resource management in support of sustainable development, should strive to adapt (where appropriate) their approaches to implementation projects. It seems that by encouraging a structured 'bottom-up' approach, the benefits of stakeholder wisdom and empowerment will be brought to the fore. This will require a mind-shift, from one of 'telling' or 'teaching' to one of sharing knowledge, influencing wise decision-making, and facilitating the identification of problems as well as solutions. This seems to be the most important lesson arising from this study and it should go some way towards directing the way forward.

This project has also shown that it is indeed possible for people to modify their own perceptions and behaviour willingly in support of a co-operative process that is likely to deliver equity, sustainability and efficiency in the water resource management process. The willingness of participants in this process to learn (and change) together, combined with the fact that water issues are likely to organise people around the debate for years to come, suggest that these interactions can form a platform to promote the principles, values and ethics that underpin democratic behaviour.

Cost: R1 500 000
Term: 1999-2002

the visible difference



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 demand for water in South Africa is steadily increasing while the opportunity for developing new sources of water supply becomes scarcer and the remaining potential sources are becoming increasingly more expensive to develop. In the face of this potential imbalance between supply and demand it is logical to emphasize ways in which the existing supply can be used more efficiently. It requires a shift from the previous philosophy that water is a free good that can be used without regard to its scarcity value to one where water is considered to be an economic good.

The point of departure for this study is, therefore, to determine to what extent the NWA reflects this philosophy as far it relates to the use of the market mechanism for allocating water use. The principles that inform South Africa's new approach to water management and specifically the provisions contained in the NWA that facilitates a water market must be assessed. A detailed evaluation of the legal issues contained in the NWA as it relates to a water market is made. It is concluded that although reference is never made in the NWA to a water market, it contains no provision that prevents its functioning.

The ways in which trade is taking place at present and in which it is supposed to unfold in the future are subsequently investigated. The approach to water management as outlined in the NWA cannot be implemented immediately. The reality is that the transformation from the old to the new approach involves a large number of time-consuming steps.

In addition, the NWA provides for a number of new administrative structures such as catchment management agencies (CMAs) at the regional level, water user associations (WUAs) at the local level and various advisory bodies to be created as needed.

The draft National Water Resource Strategy (NWRS) 2002 contains a plan as to how and when these required procedures and structures will be instituted. It will take considerable time before all the structures are in place and fully operational. For instance, according to the NWRS it will take up to 20 years for the licensing procedure to be completed.

Although all the structures are not in place, trade is at present taking place reasonably satisfactorily judged on the basis of the time it takes to approve an application. Implementation problems, many of which are caused by the newness of the system and others caused by processes that must at present be followed to provide for the licensing of water use, will decline as the new approach becomes more familiar. Once water use entitlements are licensed the time needed to consider routine applications to trade should not be a factor that inhibits trade.

The recommendations relate to considerations about the unease about some of the consequences of trade. It is argued that reliance must be placed on evaluation procedures to take both private and social costs and benefits into account. Administrative aspects are influenced by the fact that all the structures provided for in the NWA are not yet in place and it is, therefore, recommended that it be evaluated periodically as the process unfolds. For water markets to function properly all the relevant information is needed, and more could be done to provide such information.

Lastly, the new decentralized process of dealing with water management, which includes trade, is dependent on the availability of skilled personnel. It is proposed that a human resource development strategy be implemented to deal with this potential bottleneck.

Cost: R622 100
Term: 2002-2004

Multicriteria decision support for Reserve determination and other catchment management
Department of Statistical Sciences, University of Cape Town
No 1298

and

Decision support of stakeholder involvement in Reserve determination and other catchment management agency responsibilities
Department of Statistical Services, University of Cape Town
No 1186

This project considers the role of multiple criteria decision analysis (MCDA) in water resource planning, particularly in the light of the requirements of the National Water Act, Act No. 36 of 1998. The report is subdivided into two main parts. Part 1 provides guidelines for the use of MCDA methods, and is organised to reflect the key stages of the water management cycle. The intention is to provide potential users of the approach with understanding of the underlying assumptions and methodologies and the potential they offer for facilitating different stages of the management cycle. The activities in the water management cycle are resource-directed measures, water resource planning and management strategies and water use authorisations. Part 2 describes a number of case studies in which these approaches were used. The case studies are:

- Thukela project
- City of Cape Town
- DRIFT and DRIFTSOLVER
- Usutu-Mhlatuze GIS-based DSS

Cost: R262 000
Term: 2002-2003

Decision support for water policy making
University of Stellenbosch
No 1509

This project was terminated during 2004/05 at the request of the project leader. No deliverables were completed, and no report is available.

Cost: R122 000
Term: 2004-2006

Programme 2: Water policy development and strategic policy support
Development of a framework for the introduction of waste discharge charge systems in South African catchments
Stewart Scott Water Quality cc and Development Planning and Research
No 949

This project followed on **Project No 793** that developed the philosophy and a methodology for the implementation of the polluter-pays principle and had as objective to build on previous research by including a wider range of pollutants and focussing on implementation issues. The DWAF decision to implement a WDCS, largely superseded the aims of this project. The WRC consequently decided to join forces with DWAF and allow this project to be incorporated into their larger initiative to develop a strategy for the implementation of the WDCS. The phase of the process towards the implementation of the WDCS to which the joint project would apply, would only develop the framework for the actual implementation of the WDCS.

The WDCS forms part of DWAF's Pricing Strategy for Water Use Charges in terms of Section 56 of the National Water Act (NWA). An important difference between the draft strategy as developed during this phase and the final strategy is that the draft strategy is a generalised national strategy that does not take account of specific regional variations, which the final strategy will do. The draft strategy is based on research and analysis to determine the viability of the proposed WDCS in terms of its economic and financial impact. It comprises of the policy framework for the WDCS, the charge structures that can be adapted for specific pollutants in specific situations, the institutional systems required for implementing the WDCS and an implementation strategy.

The development of the draft strategy consisted of the following steps or tasks which were to some degree iterative but were largely carried out sequentially (for each of the steps a task report was produced):

- Problem conceptualisation
- An inception report
- An investigation of international best practice
- Assessment of pollution regimes
- Consideration of various charge scenarios
- An economic impact assessment
- An investigation of institutional systems
- The formulation of interim charge system options
- Financial impact modelling
- Evaluation of options
- Regional consultation
- Strategy formulation

It was recognised that while the rationale behind the introduction of a WDCS is to address the problem of excessive water pollution, it would have the following supporting objectives:

- To encourage efficient resource utilisation (incentive objective)
- To recover costs of activities aimed at pollution abatement and damage caused by pollution (financial objective)
- To discourage excessive pollution (deterrent objective)
- To promote sustainable water use (social objective)

The framework document proposes that the WDCS would consist of four different tiers, namely:

- **Basic/administrative charge (Tier 1):** The basic charge is intended to cover the administrative costs of the system, which include water quality monitoring, the management of financial systems and customer relations.
- **Load-based charge (Tier 2):** The load-based charge is introduced when the discharger exceeds the target concentration for the water resource. The target concentration refers to the required effluent concentration, or recommended resource-directed value.
- **Deterrent charges (Tiers 3 and 4):** A deterrent charge is introduced when the discharger exceeds the maximum allowable resource-directed value (MARDV). The MARDV is set so as to achieve the upper limit of the in-stream quality applicable to the class according to which the water resource is classified. A Tier 4 charge can be introduced in cases where toxic or inhibitory levels are reached.

Cost: R334 532
Term: 1998-2002

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

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

In the Orange River basin, one of the most important irrigation areas in South Africa, knowledge is lacking regarding the value of water to irrigation farming and water use sectors.

An institution that has considerable potential to improve efficiency and that is acknowledged in the White Paper on a National Water Policy for South Africa, is the water market. For water markets to work effectively, appropriate institutional arrangements must be in place. These markets started to emerge in the Lower Orange River, as well as in other rivers like the Great Fish and Sunday Rivers. Capacity sharing as developed in Australia and based on clearly defined property rights, is an institutional arrangement that is especially geared to provide information and support for water markets to function optimally. The main aim of this research is to evaluate capacity sharing (CS) as an alternative institutional arrangement and determine its applicability to South Africa. A comprehensive literature review of water institutions was done. In particular the theoretical determinants of CS were compared with the requirements incorporated in the National Water Act of 1998.

A linear programme (LP) matrix for representative farmer groups was developed and seasonal gross margins calculated at various water application levels, from which short term marginal value products (MVPs) were

determined. Seasonal hydrological inflows into Vanderkloof Dam were compiled and used with the gross margins derived from the LP output to run a pre-dynamic programming simulation. A dynamic programme and finally a post-dynamic programming simulation were conducted.

It was found that the provisions in the NWA for the establishment of CMAs and WUAs and the progress made thus far in this regard opens the door for a more decentralised water management environment where CS is most likely to be considered. CMAs (or through delegation WUAs) for instance will progressively monitor and measure streamflows, storage levels of the reservoir and record all losses due to evaporation, seepage and reservoir spills. These records, together with ordered releases by each of the bulk users, will assist CMAs to update capacity shareholdings of users.

Two crop mix cases were investigated with linear programming models, namely, lucerne, maize/wheat (LMW) and potato, maize/wheat (PMW). For the crop mixes investigated, the MVPs differ significantly for the two seasons. For LMW MVPs range between R0.09 and R0.39/m3 and for PMW between R0.09 and R3.64/m3.

In the comparison of using of water under stochastic dynamic programming (SDP) derived rules (i.e. based on optimal policies generated from SDP) as against no rules (i.e. using water as it becomes available in the capacity share), contents of reservoir capacity shares and CS inflows were calculated at the beginning of each season. It was noted that both reservoir capacity and inflow shares were better managed using SDP derived rules than using no rules.

Capacity sharing has considerable potential as one of the appropriate alternative institutional arrangements in South Africa and can be used fully or partly to augment the current arrangements. The concept of CS should not be viewed as a too complex and unworkable water institutional arrangement. Adequate provisions should therefore be made for its implementation a least at the bulk share level, sectorally and at retail level for the agricultural sector in a selected catchment, to test its feasibility.

Cost: R949 000
Term: 2000-2002

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

The hydropolitical histories of South Africa's four international river basins-the Orange, Limpopo, Incomati, and Maputo-are complex and fascinating. They show similarities as well as disparities in their development trajectories. Where the hydropolitical histories are similar, is where the rivers' development follows the general socio-economic and political progression of South African society. This project has provided, in a single source for ease of reference, a detailed history of all known water development and allocation initiatives in the four above-mentioned basins since pre-colonial times. This can be used as the basis for understanding current patterns of water use and social development linked to water, as well as for indicating potential areas of tension around water in the future, notably as part of the forthcoming water allocation reform process.

Cost: R398 100
Term: 2001-2003

CURRENT

THRUST 1: WATER RESOURCE ASSESSMENT

Programme 1: Groundwater occurrence in fractured-rock aquifers

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 km3). Aquifer permeability is due to a pervasive set of fractures, including bedding-parallel and bedding-normal fractures, as well as jointing and faulting at various scales.

Traditionally boreholes have been drilled to maximum depths in the range of 90 to 150m. Over the past few years, limited deep drilling below 150m has resulted in boreholes yielding >32 _/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

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

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

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

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

Estimated cost: R200 000
Expected term: 2002-2003

Recharge mechanisms in TMG aquifer systems
Groundwater Group, Department of Earth Science, University of the Western Cape
No 1329

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

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

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

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

The aims of the project are:

- Quantification of realistic recharge rates and the processes of recharge in the TMG aquifer systems
- Evaluation of the sensitivity to rainfall patterns (spatial and temporal patterns) with a view to understanding the impacts of climate change on water resources
- The use and development of innovative techniques to assist in recharge estimation in TMG aquifer systems.

Estimated cost: R800 000
Expected term: 2002-2005

Geothermal studies of TMG aquifer systems
Umvoto Africa cc
No 1403

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

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

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

The research aims to:

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

Estimated cost: R150 000
Expected term: 2002-2003

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 3: Understanding and predicting rainfall variability
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

Formalisation of terms of reference for the update of the *Surface Water Resources of South Africa*
SRK Consulting (SA) (Pty) Ltd
No 1315

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

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

The aims of the project are:

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

Estimated cost: R351 000
Expected term: 2002-2003

Development of a continuous simulation modelling system for design flood estimation in SA
School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg
No 1318

The wide-scale destruction of hydraulic structures and loss of life caused by the February 2000 floods in the north-eastern part of South Africa and other recent floods has raised the issue of the adequacy of procedures for design flood estimation in South Africa.

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

Easy-to-use methods which produce consistent results by different users are necessary for design flood estimation in South Africa. Event-based deterministic procedures such as the synthetic unit hydrograph and lag-route methods for design flood estimation were developed for South Africa in the late 1970s. With longer records from rain and flow-gauging stations now available for analysis, the development of climatic, elevation, land-use and soils databases available at a national scale, the increased computing power, the development of space-time

stochastic rainfall models for South Africa, the availability of GIS and the development of new internationally accepted approaches to design flood estimation, it is imperative that a comprehensive updating of techniques for design flood estimation in South Africa is initiated as has been completed, for example, for Australia and the UK. A phased approach for South Africa is envisaged and this project, following on the pilot studies performed in the project **Rainfall statistics for design flood estimation (WRC K5/1060)**, is viewed as the next logical step in this process.

The research aims to:

- Develop a methodology for the estimation of the frequency of floods in South Africa using a continuous simulation modelling approach. The computed exceedance probabilities of floods would not be inferred from rainfall, but would reflect the joint probabilities and complex interrelationships between rainfall, antecedent soil moisture conditions and runoff. The envisaged system would also have the ability to account for current or future land covers and management practices and the generation of long time series of runoff, using either historical or stochastic rainfall series, will decrease the uncertainties in the estimated design floods. The proposed system is consistent with current international trends and could form the basis to update the deterministic event-based design flood estimation procedures developed for South Africa during the late 1970s.

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

Definition and up-scaling of key hydrological processes affecting critical perturbations to water resources for application in models
School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, Pietermaritzburg
No 1320

There has been much research of hydrological processes at hill-slope and small catchment scales and an abundance of observations have been made in large-scale catchments. However, observations that could link appropriate process descriptions and parameter sets from the small to the larger scales are rare. In addition, the transfer of process descriptions derived from hill-slope and small catchment-scale observations to process descriptions at larger-scale catchments cannot be achieved easily, even when using distributed,physically-based models. Nevertheless, in order for the perturbations in streamflow caused by SFRAs to be identified, it is crucial that techniques be made available to model at the large-catchment scale, while retaining the ability to identify effects of small-scale processes.
There is a clear need for the simultaneous observation of processes over a range of scales. This is hypothesised as the only way to improve the process descriptions and parameter sets of distributed hydrological models employed at the medium-and large- catchment scale. These models will then also be better equipped to estimate the impact of the spatial distribution of land uses and SFRAs on discharge and low flows at points of interest.

This research effort addresses directly one of the key issues itemised in the WRC listing for SFRA's research needs and aims to define key hydrological processes at a range of scales by observation and experimentation at these scales.

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

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

Heavy rainfall causing severe floods occurs frequently over Southern Africa. These floods are often extensive and lead to large financial losses, severe damage to infrastructure and tragically to the loss of life. The loss of life as a result of the September 1987 floods (>300), damage to the infrastructure (> billion Rand) as well as the recent flood

disaster, which occurred in the Northern Province and Mozambique, are examples. Water resource management becomes extremely difficult, if not impossible, without prior warning of widespread heavy rains. Better information on the spatial rainfall distribution and the identification of areas of heavy rainfall can be of vital importance to the survival of many communities who are living in informal settlements along the many flood plains of Southern Africa. Yet weather forecasters, at present, have insufficient tools to compile reliable prediction of the spatial and temporal distribution of heavy rainfall.

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

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

- Development of methods to isolate heavy rainfall developing in weather systems classified as: Tropical, anti-cyclonic disruption (cut-off low), tropical temperate trough and ridging anti-cyclones
- Develop means to model the enhancement of rainfall by steep topography
- Develop ensemble rainfall forecasts using model output from several models or model runs
- Development of an interactive rainfall prognosis by incorporating observed rainfall rates
- Run a training workshop for participants from Southern African countries in order to disseminate the knowledge gained and to empower delegates to run the system.

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

Estimated cost: R578 000
Expected term: 2002-2005

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

Programme 5: Water quality assessment studies and information systems

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

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

Department of Civil Engineering, University of Stellenbosch

No 1301

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

- National Water Resource Strategy (NWRS), which provides a large-scale planning framework, procedures and guidelines to ensure that water deficits or poor water quality do not arise on a regional basis at the scale of declared water management areas (WMAs) and that international water-sharing obligations are met
- Catchment Management Strategies (CMSs) inside

WMAs, which ensure sustainable, equitable and optimal water resource utilisation at catchment scale with due ecological protection of the resource and with full participation by stakeholders and affected communities.

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

Because the NWA implementation is still in its initial stages, no compulsory re-allocations have hitherto been undertaken, even though the initial screening of catchments in preparation for the first edition of the NWRS has indicated a number of catchments which fall in that category. Consequently, no deep understanding currently exists of what would constitute best practice procedures in the water allocation process. From the DWAF Strategic Plan for the period 2001-2005 it is evident that the earliest compulsory licensing that is foreseen would be during 2004. There is, therefore, time in hand to engage in a learning process so as to develop adequate understanding of what the compulsory re-allocation and licensing procedures need to entail both in a technical WRM context and in a participatory WRM context.

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

The research aims to:

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

Estimated cost: R683 000
Expected term: 2002-2004

Origin and fate and clinical relevance of water-borne pathogens in South Africa
Collaborators: 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 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 resource 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
Daily rainfall mapping over South Africa through radar, satellite and gauge measurements: (2) Modelling
Department of Civil Engineering, University of KwaZulu-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 1: Integrated catchment management
The development of a computerised system for auditing real-time or historical water use from large reservoirs in order to promote the efficiency of water use from the reservoirs
CPH Water
No 1300

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

10% saving in water use by irrigation has the potential to liberate more water than the water used by the entire afforested area in South Africa.

The research aims are to:

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

Estimated cost: R902 000
Expected term: 2002-2005

Development of guidelines for the design and operation of river diversion structures to deal with the problem of sedimentation
Ninham Shand (Pty) Ltd
No 1302

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

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

The research aims to develop hydraulic guidelines for the layout, design and maintenance of river diversion structures in South Africa to limit the influence of sedimentation. These structures include small pump stations to large hydraulic structures for major water transfer schemes. Specific techniques to be investigated to ensure sustainable operation include hydraulic flushing within the diversion structure (pump station).

Estimated cost: R598 000
Expected term: 2002-2004

Influence of spills and releases on the river geomorphology downstream of a selection of existing dam spillways
PD Naidoo Associates
No 1314

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

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

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

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

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

Estimated cost: R500 000
Expected term: 2002-2004

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

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

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

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

Estimated cost: R203 000
Expected term: 2002-2004

Programme 2: Low flows and streamflow reduction activities

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

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 paleo-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.

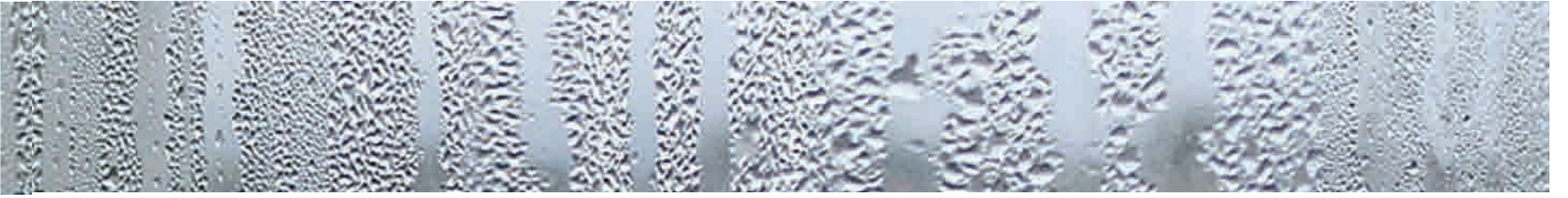
Estimated cost: R233 000
Expected term: 2002-2003

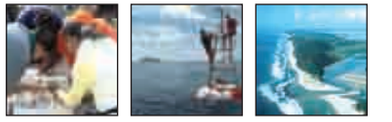
Global climate change and water resources in Southern Africa: Potential impacts of climate change and mitigation strategies

School of Bioresources Engineering and Environmental Hydrology, University of 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 2 240 000
Expected term: 2003-2005

Programme 2: Groundwater protection

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

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

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

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

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

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

The aims are to:

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

Estimated cost: R300 000
Expected term: 2002-2003

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: Protection and management of surface water quality
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 (CE) 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 **(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

Cyanobacteria 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

Community-based research on the influence of rehabilitation techniques on the hydrology of degraded catchments
School of Applied Environmental Sciences, University of KwaZulu-Natal (Pietermaritzburg)
No 1316

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

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

The research aims to:

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

Estimated cost: R984 000
Expected term: 2002-2006

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

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

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

The aims of the project are to:

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

Estimated cost: R924 000
Expected term: 2002-2005

Development of a system of simplified methods of vegetation water use based on the principle of limits to evapotranspiration
Division of Water, Environment and Forestry Technology, CSIR, Stellenbosch
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, 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

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

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

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

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

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

The research aims to:

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

water quality assessment and management.

Estimated cost: R669 700
Expected term: 2002-2004

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 KwaZulu-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

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

The political changes which have taken place in South Africa during the last decade have had profound impacts on the development of new water policy, and have opened the way for significant shifts in policy and legislation generally, in relation to sustainable management of natural resources.

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

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

The project aims to:

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

Estimated cost: R720 800
Expected term: 2002-2004

Programme 2: Development and implementation of water policy instruments

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

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

Farmer Support Group, University of KwaZulu-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

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

Institute for Natural Resources, University of KwaZulu-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

Promoting democracy through the IWRM process: Developing a model for sustainable relationships for the management of a scarce natural resource
Division of Water, Environment and Forestry Technology, CSIR, Pretoria
No 1294

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

The overall objectives of this project are to:

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

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

Institutional arrangements for groundwater management in dolomite terrains
SA Country Office, IUCN
No 1324

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

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

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

This project therefore seeks to develop institutional

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

The aims of the project are to:

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

Estimated cost: R600 000
Expected term: 2002-2004

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

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 resource 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 costs: 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 costs: 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 South Africa, 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 costs: 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 nation-wide water resource assessment in 1990, WR90, became essential tools for water resource 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 costs: R6 700 000
Expected term: 2004-2007

Programme 3: Understanding and predicting hydroclimatic 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 costs: R436 000
Expected term: 2004-2007

Hydroclimatic 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 costs: 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 costs: R500 000
Expected term: 2004-2006

WQ2000: Enhancement, training and user support

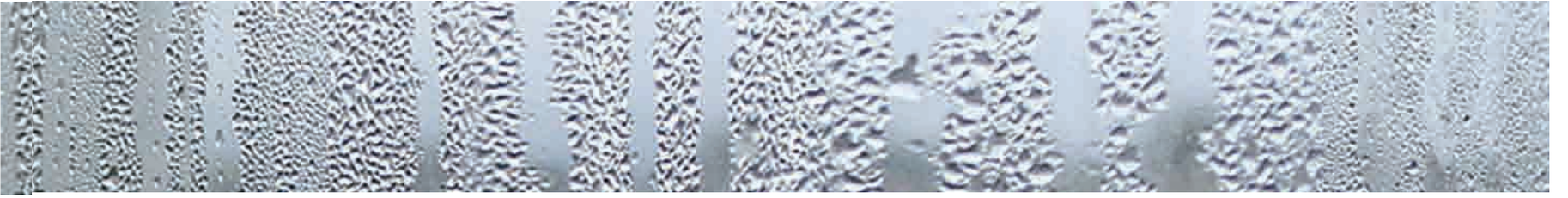
Umfula Wempilo Consulting cc
No 1495

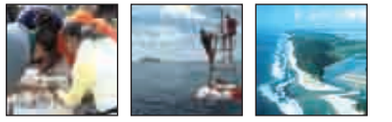
The WQ2000 interactive system has been successfully developed for the Vaal River catchment (WRC **Project No 950**). This system provides a means of rapidly assessing salinity at a quaternary catchment level. WQ2000 runs the sophisticated WQT monthly time step hydro-salinity model in the background, 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 costs: R328 000
Expected term: 2004-2006





THRUST 2: INTEGRATED WATER RESOURCE DEVELOPMENT

Programme 1: Integrated catchment management

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 resource management and the skills of water resource managers involved in water-use licensing, particularly SFRAs.

Estimated costs: R3 800 000
Expected term: 2004-2007

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

For the past 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 costs: 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 costs: 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 costs: R198 000
Expected term: 2004-2005

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 costs: 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 costs: R3 058 000
Expected term: 2004-2007

Programme 3: Protection and management of surface water quality

PCR-based markers for identification of toxic cyanobacteria

Department of Genetics and the Forestry and Agriculture Biotechnology Institute (FABI), University of Pretoria

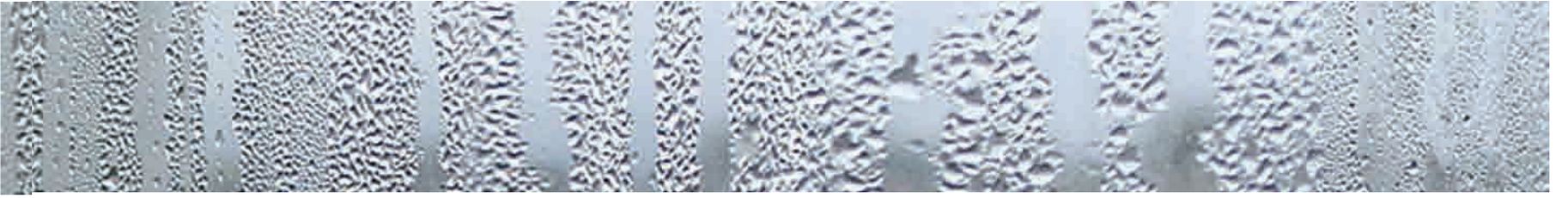
No 1502

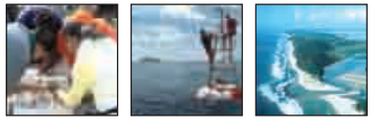
The quality of many water sources in South Africa is declining. The decline is primarily as a result of eutrophication and pollution by trace metals. During April 2003 a blue-green algae bloom of 30 cm thick and a diameter of 4 ha was detected in the Hartbeespoort Dam. This cyanobacterial bloom did not 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 costs: 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:

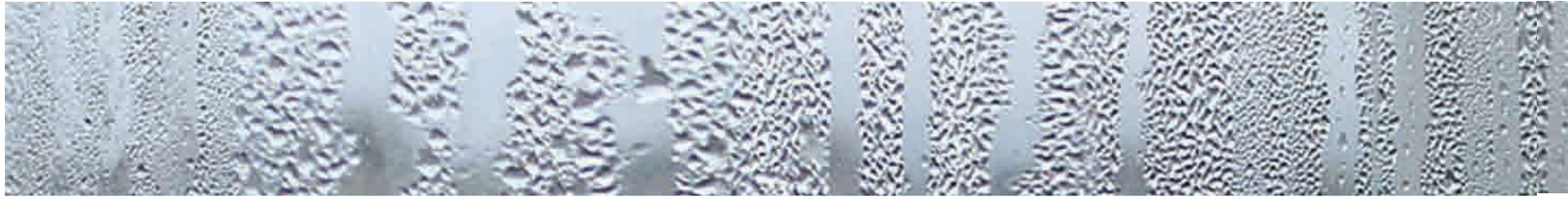
The central objective of this project is to develop a thorough understanding of water and salinity dynamics in the regolith (soil plus vadose zone) of a small dry-land catchment representative of semi-arid conditions in the Berg River basin. The perspective will include both salt sources and storage 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 costs: 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 costs: 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 costs: 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 costs: 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 resource developments and natural events.

Estimated costs: 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

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 costs: 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 25ℓ /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 costs: 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.

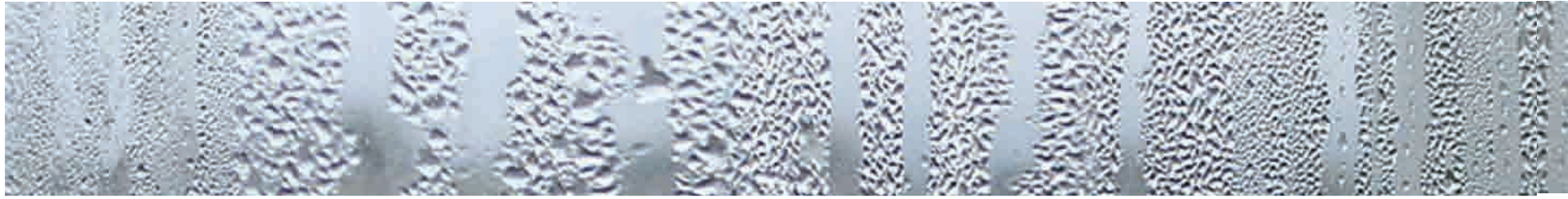
Estimated costs: R200 000
Expected term: 2004-2005

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 costs: 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 costs: R270 000
Expected term: 2004-2005

CONTACT PERSONS

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KSA 2

| WATER-LINKED ECOSYSTEMS |

Sustaining Ecosystem Services for People through Research

Dr Steve Mitchell
Director

Scope

Research undertaken within this KSA addresses 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.

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 necessarily 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 contaminants (EDCs)

THRUST 3: ECOSYSTEM REHABILITATION

Scope: This thrust addresses the rehabilitation of the aquatic environment (including both the abiotic and the biotic components) which has 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 2004/05

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 2004/05

The approved funding of the research portfolio for 2004/05 leads to a funding budget of R10 200 000 in 2004/05. The focus of this portfolio will continue along the current trends.

CORE STRATEGY

The core strategy is fundamentally unchanged from 2003/04. Research funded from within this KSA will continue to address, within the mission and vision of the WRC, issues of sustainable use and the needs of the legislation and international conventions of South Africa.

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 funded through this KSA provides knowledge for protection of the resource and biodiversity of aquatic ecosystems. 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, polishing of effluents, 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

As identified in the previous year there is still 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. It is becoming increasingly apparent that with the switch to largely addressing the needs of management over the last decade and a half, we are reaching the limits of current knowledge. More research needs to be initiated in selected areas of this to ensure that our knowledge remains ahead of the need to apply it.

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.

Trends in ecological research

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 interaction with the management agencies as well as the social and economic aspects of the environment if the work was going to make a difference to environmental management in the long term.

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

As indicated in the previous year's business plan national research drivers in ecosystem research are aligned with international trends, although the emphasis is on the local situation. Research drivers continue to 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 and covers wetlands, rivers and estuaries.
- 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, Eastern Cape Province).

Key stakeholders

The key stakeholders remain largely unchanged. They are the national government departments which have water under their jurisdiction (DWAF and DEAT), specifically at this time when they are implementing new legislation. Provincial and local government are also key stakeholders, and the anticipated needs of catchment management agencies (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. The IUCN is an international NGO that funds specific projects within its mandate in this field. Funding may also be available from industry for specific projects.

Other players

As stated previously, there are 2 main groups in this category nationally, funders and end-users of research not mentioned above. As mentioned above, the NRF has a thrust which overlaps to some extent with the field covered by this KSA. 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 the 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

There is basically no change in the providers of new knowledge in the field covered by this KSA. Researchers are located at the Universities (Venda, The North, Witwatersrand, Johannesburg, Potchefstroom, Free State, Zululand, KwaZulu-Natal (both Pietermaritzburg and Durban), Transkei, Rhodes, Nelson Mandela Metropolitan, 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 consultant firms which do work in the field of ecological research and management normally focus on the more applied aspects for rapid implementation. This is a good way of rapidly implementing research results and getting feedback into the research process at the same time.

STRATEGIC INITIATIVES UNDERTAKEN DURING 2004/05

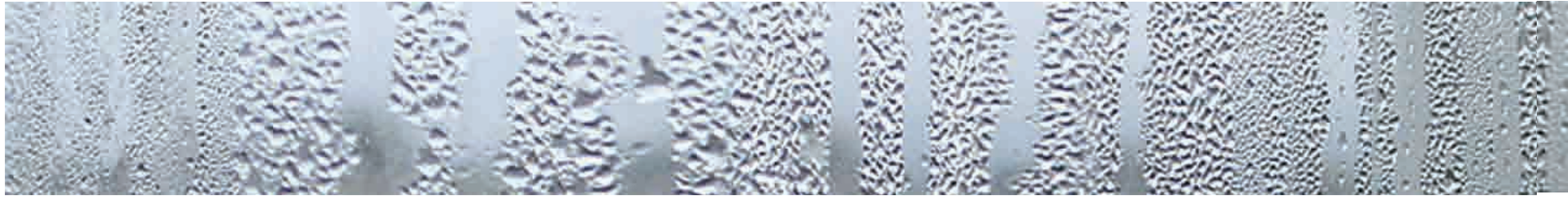
International collaboration

- The WRC is involved in the various projects and initiatives of the GWRC (e.g. EDCs in the environment, algal toxins) and other international research institutions on health-related aspects
- WARFSA-The WRC continues to support WARFSA activities and Dr Mitchell hosted the WARFSA Board meeting in April 2003 in Pretoria and participated in a board meeting and a conference in October 2003 in Gaborone
- Dr Mitchell attended a UNESCO-IHE workshop addressing capacity building in the water sector; 14-18 July 2003
- The KSA is strongly involved in the activities of Framework for Education and Training (FET) in Water, a joint UNESCO, Belgian and South African programme aimed at building more capacity in integrated water resource management

National collaboration

KSA staff are involved in the following national committees:

- Steering Committee (National)
  - The South African Steering Committee on the World Commission on Dams
  - The ***River Health Programme***. The WRC is one of three national custodians of this programme
  - Operational policy for treatment and disposal of land-derived water and water containing waste in coastal areas of South Africa (DWAF)
  - Resource Directed Water Quality Management Policies (DWAF)
  - Development of a planning tool for the systematic conservation of river biodiversity in South Africa-project steering group
  - South African Environmental Observation Network (SAEON)-Technical Committee
  - Committee Member of the technical division of the health related aspects of WISA and member of organising committee of the IWA conference hosted and organised by WISA



- DWAF programme for the development of the NTMP
- The National Toxin Monitoring Programme of DWAF has to be implemented in 2008. The WRC will participate in the development of this programme and will fund 2 of the 10 projects in Phase 2 of the development programme. The one will be on the development of a capacity-building plan and laboratory needs for the implementation of the programme. The other will provide the frequency of sampling and model for predicting the fate of the toxins in the environment

- Board Members (National)
  Staff members of this KSA serve on a number of Boards including:
  - Institute for Environmental and Coastal Management, UPE
  - Institute of Water Research, Rhodes University
  - National Community Water and Sanitation Institute, University of the North (Chairman)
- Board Member (SADC)
  - WARFSA (linked to WaterNet)

International partnerships

- The first report of the GWRC on the status quo of EDC research which includes a priority list of targeted EDC chemicals to be tested for, and the ToRs of proposed research projects have been circulated to the members. One of the WRC's researchers has attended a workshop in Germany to develop and discuss the analysis methods needed to do these projects
- A telephonic workshop has been held by the GWRC and from SA 4 participants have given their comments on the proposed project on a battery of biological assays to be developed for testing EDC activity in water systems

General

The *Domestic Water Quality Series* **(5 volumes)** are still very much in demand and used widely as text books and by laymen. They are also being used as training material by DWAF and others. It has been reprinted for the 4th time. The usefulness of the new series on the management of microbial diseases has already been recognised before its publication.

The abstraction (translation) of the knowledge contained in WRC technical reports into more accessible documents for non-specialist consumption will have been completed for 2 reports and initiated for a third.

IMPLEMENTATION PLAN

Research portfolio for 2004/05

In essence, the implementation plan follows that of last year in that 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.

The current portfolio of programmes and projects will continue to run. The ***Kruger National Parks Rivers Research Programme*** was phased out at the end of 2003/04. Thrust 2 remains the most heavily supported (the name of Thrust 2: Programme 4, has been changed, and the ***Endocrine disrupting compounds*** **(EDC)** research has been separated into Programme 5), but emphasis will shift to Thrust 1 **(Ecosystem Processes)** and Thrust 3 **(Ecosystem Rehabilitation)** to accommodate emerging research issues.

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

TABLE 1: Overview and description of thrusts and programmes 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.
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 crosscutting domain **Water and Health** and includes the research being done on endocrine disrupting contaminants.

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION CONTINUED

Programme 4: Environmental water quality	**Scope:** 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)	**Scope:** 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 a-biotic and the biotic components) which has 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.

RESEARCH PROJECTS FOR 2004/05

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 1 April 2004 and 31 March 2005.

COMPLETED

THRUST 1: ECOSYSTEM PROCESSES

Programme 2: Riverine processes

Hydraulic analyses for the determination of the Ecological Reserve for rivers

Department of Civil Engineering, University of Witwatersrand

No 1174

The holistic methods developed to determine the reserve depend on the integration of abiotic and biotic factors. The discipline which links hydrology to the biotic components of an ecosystem is hydraulics, as this translates flow into habitat. Hydraulics provides a critical link between the way hydrologists, engineers and managers, on the one hand, express flow and the way in which river ecologists, on the other hand, express environmental water requirements. It is a quantitative science and as such may be modelled.

However, traditionally ecological flow determinations have relied on information derived from 2-dimensional cross-sections or single-stage discharge relationships. This project seeks to develop methods to assess spatial changes in hydraulic characteristics across entire geomorphological units in order to provide better input into the process of determining environmental water requirements. Although there are now 4 levels at which the reserve may be determined (desktop, Rapid, Intermediate and Comprehensive), the input required from hydraulics is the same; it is the confidence of the results which differs.

In order to address the conflict between water use and sustainability, this project has worked on hydraulics providing the capability to make the best decisions. The critical decision making need is around low flows, and existing formulae do not accurately predict low flows, particularly in the presence of large-scale roughness. New formulae have been developed in laboratory (flume) experiments, and these have been tested under natural river conditions such as in stream vegetation. The hydraulic reserve model has been designed as a module for SPATSIM (WRC **Project No K5/1160**) and is increasingly being used by DWAF for decision making on resource management).

Hydraulic indices have been developed to describe in quantitative terms the integrated hydraulic characteristics of a river reach, site or channel in a way meaningful to ecologists to assess the biotic response to flow changes.

Cost: R1 050 000
Term: 2000-2003

Research into tracking the movement of large fish species through a river system: Method development and links with flow and reproduction

Department of Zoology, University of Cape Town

No K8/536

Planned water resource development on the Doring River, one of South Africa's few remaining un-impounded rivers, would prevent access to the whole river by the fish population. This project aimed to continue developing the knowledge on the use of river systems by large fish to enable the correct input on the management of large fish to be made in management decisions concerning the impoundment of rivers and the need for fishways. This information is particularly relevant in the Doring River, as all three of the large fish species are endemic and either threatened or endangered. The study showed that there are very few adult fish in the main stem of the river, and that juveniles are totally absent. This scarcity is largely the result of alien fish species, of which the most destructive are small-mouthed bass.

The primary aim of this study was to lay the groundwork for telemetry studies to be conducted on the threatened endemic fish species of the Olifants and Doring Rivers. To achieve this aim, the following objectives needed to be met:

- Establish the effects of capture, tagging and transmitter implantation, on the study species: the Clanwilliam yellowfish *Labeobarbus capensis*, sawfin *Barbus serra*

and Clanwilliam sandfish *Labeo seeberi*
- Develop methods for acquiring biological information (particularly their gender on the basis of external morphology) on tagged fish using non-lethal methods
- Describe the physical conditions of the study area
- Access funds for radio telemetry studies

Objective 1 was addressed by several parallel actions. Fyke nets were evaluated as an alternative to gill nets as a suitable capture method. These successfully limited injury to the fish compared with gill nets but catch rates were much lower. Catch rates of non-native species (bluegill sunfish and smallmouth bass), however, tended to be higher, suggesting that fyke nets are selective for these species. Alpha tags were evaluated as an alternative to the T-bar anchor tags used in earlier surveys for marking captured fish. These are small and less intrusive, but the difficulty of inserting the tag may limit their usefulness for widespread application by non-technical personnel such as recreational anglers which would be important for any long-term tagging programme to succeed. Trial runs on captive fish using dummy radio-telemetry transmitters were undertaken at the University of Cape Town and the Two Oceans Aquarium in collaboration with the Norwegian Environmental Institute NINA. The trials indicated that the target species (Clanwilliam yellowfish, sawfin and sandfish) would recover from surgery and insertion of transmitters should telemetry studies take place.

There was insufficient time to map the lower Doring River (Objective 2) during the course of tagging studies, and insufficient numbers of fish were caught to determine whether they could be sexed on the basis of external morphology (Objective 3). The search for funds for the radio telemetry study is ongoing (Objective 4).

Cost: R200 000
Term: 2003-2004

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION

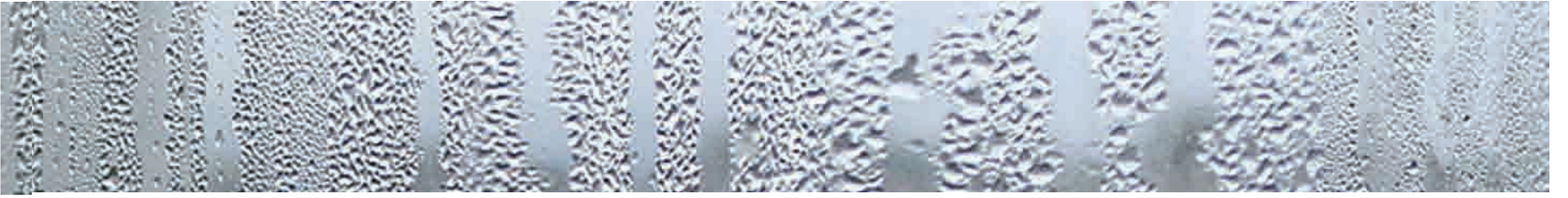
Programme 1: Ecological Reserve
Development of DRIFT, a second generation methodology for instream flow assessment
Southern Water Research and Ecological Consulting cc
No 1159

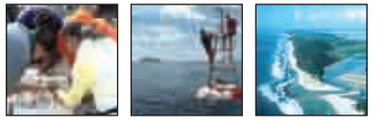
DRIFT (Downstream Response to Imposed Flow Transformations) is a second generation methodology for the determination of environmental water requirements (EWR). Preliminary development showed it to have 6 important attributes as follows:

- It provides a holistic approach to EWR assessment in that it addresses all parts of the intra- and inter-annual flow regime and the abiotic parts of the river system from source to sea
- It is scenario-based, combining data, multidisciplinary scientific experience and local knowledge to provide predictions on the effect of flow changes
- It provides the capacity to predict the effect of these changes on common-property subsistence users of the resource
- The outputs comply with the requirements of DWAF
- All the accumulated data / knowledge is stored in a database that may be used in the future to make predictions for other scenarios as required
- It is embedded in a growing range of customised software that allows much of the application to be automated.

The aims of the project were as follows:
- Development of a second generation methodology for instream flow assessments, in liaison with water managers, to ensure their needs are met
- Compilation of guidelines for applying the methodology; liaison with biophysical specialists to ensure the correct date are collected
- Database development, creation of an expert system shell for use in instream flow assessments where the methodology is used; transfer of the technology into the management milieu

These aims were modified to include the development of `generic lists' of variables to standardise the input from the experts, and to take advantage of a Reserve study on the Breede River to compare the three methodologies available (DRIFT, the Building Block Methodology and the





Flow-Stressor Response Methodology). The three methods gave results that were within 5% of each other and the costs of the processes were similar, although DRIFT scored highest in the assessment of overall ability to holistically assess the complex inputs.

Cost: R 848 000
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
includes:
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

This report is the agglomeration of 3 separate contracts. This was not specifically planned this way, but as the work progressed in became apparent that presentation of the outputs in this way would give the best integration of the work.
SPATSIM (spatial and time series information modelling) has been developed at the Institute for Water Research, Rhodes University, with partial funding from the WRC. This product replaces the DOS-based HYMAS system developed by the IWR in 1993/4 and has incorporated some new aspects. A primary motivation was to integrate many of the Ecological Reserve determination methods into a single integrated software package, thereby ensuring that all aspects required by the process are given consistent consideration. This report and software has taken a concrete step away from the present dependence on experts.

The aims of the three projects are as follows:
1160
- Develop a consistent protocol for the quantification and assessment of the Ecological Reserve within a risk-based framework
- Design and program (using Delphi) an automated Decision Support System (DSS) which will accommodate all the steps and procedures required for quantifying the Ecological Reserve
- Develop a risk-based process for the assessment of the water quantity aspects of the Ecological Reserve by combining biotic stress/response relationships with flow time series
- Further understand the ecological conditions which require different flow regimes for their functioning

1312
- To write Delphi code that will allow the technical integration of existing water quality data, tools, techniques and methodologies with the Ecological Reserve DSS being developed in **Project No K5/1160**
- To evaluate the use of salinity as a foundation step in the water quality Ecological Reserve
- Co-ordinate this with water quality work being done at UCT

K8/510 (the emphasis of this work was on water quantity)
- Identify requirements and limitations of DWAF in implementing the Ecological Reserve
- Develop procedures and tools required by DWAF for implementing Reserve requirements
- Train relevant DWAF staff in the use of the procedures and tools for implementing the Ecological Reserve.

This report draws together research results from a number of sources, and the use of the software assumes competence (operator trained) in Reserve determination.

Flow-stressor response method:
This was developed further within this project, and has been used in several Reserve determinations. This method calculates the response (stress) of organisms exposed to decreasing water quantity on a time series basis which is comparable to flow duration series. No way of making this compatible with high flows has yet been developed.

The water quality module includes variables in the categories inorganic salts, nutrients, physical variables and response variables.

It was found that implementation lags, in some instances, behind the development of Reserve methods, so this section of the work is not straightforward. The management of the high flows also increases the complexity. The results are displayed as flow duration curves and are directly comparable with the assurance rule curves that are the standard output from the Reserve determination process.

The terms of reference of each of the three projects have been met and the software has reached a level of development such that adding new facilities is relatively quick and straightforward. However, there are still outstanding issues. Development and implementation of the Reserve is a dynamic process that is not complete. New issues are being raised, and new people and organisations are becoming involved, so there is some way to go before concepts are fully developed and understood by all. There remain some unresolved technical details around the water quality tools. Training of DWAF staff continues, but it became apparent during the one year consultancy that some staff are not yet ready for training.

1160
Cost: R1 089 000 (actual cost R1 085 696)
Term: 2000-2002

1312
Cost: R720 000 (actual cost R696 723)
Term: 2002-2004

K8/510
Cost: R140 000
Term: 2003-2004

Information requirements for the implementation of resource-directed measures for estuaries
Dept Zoology and Botany, Nelson Mandela Metropolitan University
No 1247

The initial proposal for this programme consisted of four projects, each covering specific estuarine processes for which knowledge is needed for the proper implementation of the estuarine Reserve. Funding was cut and three topics were addressed through sub-contracts with selected experts. These three topics were:

- Improving the biodiversity rating of SA estuaries
- Quantifying water quality criteria that affect different taxa
- Responses of the biological communities to flow variation and mouth state in two KwaZulu-Natal temporarily open-closed estuaries

Each of these has been reported on as a separate project.

Improving the biodiversity rating of SA estuaries
Recent existing data on water birds and invertebrates on estuaries were collated. Recent existing data on fish were listed but not collated due to shortage of funding. The bird data were brought up to date for the Wild Coast estuaries through counts done on 67 estuaries. Predictors were developed for estuarine biodiversity. As each estuary is unique, it proved unfruitful to use individual species as predictors, but it was found that species richness was the most predictable attribute, and this was strongly correlated to the slope of the river and the mouth condition. This information was used to update the overall estuary importance rating, and in spite considerable differences in the scores for invertebrate biodiversity.

Quantifying water quality criteria that affect different taxa
Quantitative information on the response of estuarine taxa to changes in water quality has been collated. This is presented as tolerance bands, exposure times and information tables. This information will be used in Reserve studies during the development process and will be used in all Reserve studies from now on.

Responses of the biological communities to flow variation and mouth state in two KwaZulu-Natal temporarily open-closed estuaries
This CERM-wide study was based on case studies on the Mdloti and Mhlanga Estuaries as these were scheduled for rapid Reserve determinations during the study period, and investigated the hypothesis that the river-estuary interface (REI) zone, which is characterised by higher biodiversity, does not occur in estuaries when the mouth is closed. This hypothesis was revised as the estuaries used for the case study, in common with other estuaries in the region, are

perched. Those of the Eastern and Southern Cape, on which the initial studies were done, are not perched. Both these estuaries receive high volumes of treated sewage effluent, so are nutrient-rich. This also had the effect of increasing the frequency of mouth-breaching events so the interval between breaching was not long enough to allow the build-up of taxa between events. The perched character meant that much of the exposed mudflats of the open estuary were supra-tidal, so did not support the interstitial fauna normally found in inter-tidal mudflats, so did not contribute to the biodiversity as would have been the case in non-perched estuaries.

It was shown that overtopping of the berm by waves performed two important ecological functions. On the KZN north coast where there is a high freshwater input, this maintained a low salinity in the estuary which is important for the survival of certain taxa, and that fish fry were able to `ride the waves' to get from the sea to the estuary.

Cost: R1 125 000
Term: 2001-2003

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 KwaZulu-Natal

No 1246

The spatial dimensions of estuaries and their location on the coast are such that most individual estuaries are contained within the boundaries of a single coastal municipality. Few straddle two municipalities and even fewer are contained within formally protected areas. Local government therefore, has the most direct relationship with estuaries, and local people benefit most from the goods and services that derive from these complex natural assets. From a legal and development perspective, this relationship is established by the Municipal Systems Act of 2000 that requires all municipalities to implement integrated development planning in ways that promote participation of civil society and connect vertically and laterally within and between other tiers of government. Integration has particular significance for estuaries because their structure and functioning are strongly determined by what happens in distant parts of the catchment and in the sea.

Since democracy was established in South Africa, there has been a strong emphasis on promoting the participation of civil society in governance and in managing the use of natural resources. The legal foundation for this is reflected in the South African Constitution and Acts that have followed. This has brought new challenges for government, civil society and for researchers whose contribution is increasingly measured as growth in understanding leading to social benefits that can be sustained in the longer term.

Acknowledging this context, the challenges posed to researchers in this programme were to better understand the needs of society, to develop the scientific basis for management and to promote informed co-operative governance and management of the use of estuary resources.

The project aims were as follows:

Overall aims:

- Participatory management for the sustainable use of Eastern Cape estuaries is facilitated and enhanced through directed research which is informed through practical engagement of management of estuaries
- Participatory management for the sustainable use of South African estuaries is facilitated and enhanced through Eastern Cape Estuary Management Research Programme
- Collaboration and generative learning amongst estuary researchers and managers achieved
- Culture of integrated estuary management and research established

Specific aims:

- Co-operative governance systems are appropriate, easily understood and implementable
- Co-operative management systems (including integrated planning) are appropriate, easily understood and implementable
- Guidelines for a strategy for the protection of the national heritage of estuary biodiversity are adopted by appropriate authorities
- Protocols for defining levels of sustainable use are adopted by appropriate authorities
- Protocols for monitoring estuaries to promote compliance with policies and legislation at whatever level is appropriate are adopted by appropriate authorities
- Protocols for the rehabilitation of estuaries are adopted by appropriate authorities
- A sustainable knowledge management system is constructed, implemented and used
- A self-sustaining capacity building programme is constructed and implemented

Each of the specific aims is addressed in separate full reports published in **Volume 2**, with some of the contributions being in **Volume 3** as well. A number of recommendations emanate from the overall aims that relate to estuary governance and the way in which local government needs to be mandated to perform the day to day management of estuaries. A highlight of this programme is that the protocol for estuary management established in the co-operative governance project has been adopted by DEAT (MCM) as their model and is in the process of being incorporated into national policy.

Cost: R1 920 000
Term: 2001-2003

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

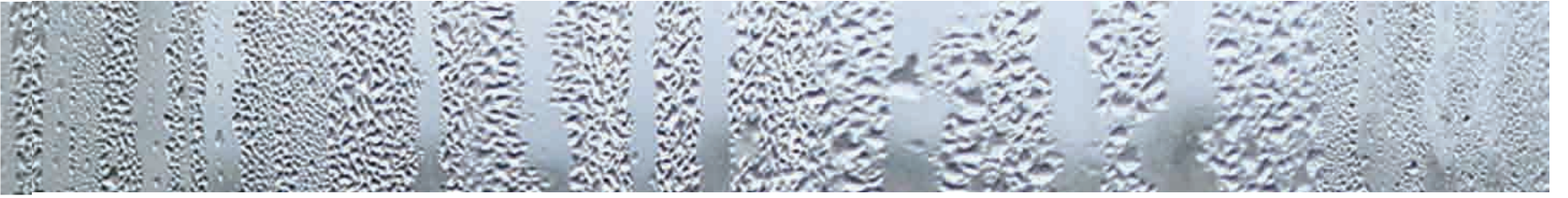
Sediment flux in estuaries is in a dynamic balance between that brought in from the land and that from the sea. While the ingress of non-cohesive marine sediment is dependent on long shore transport and tides, cohesive land derived sediment is dependant on river flow. Floods are important in the removal of both cohesive and non-cohesive sediment, and the natural flood cycle is influenced by upstream impoundment and abstraction of the water. The philosophy behind Ecological Reserve is that sufficient water should remain in the system to enable the natural processes to continue.

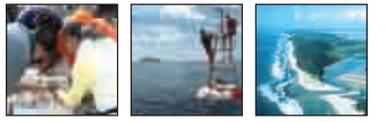
The aims of this project were to:

- Formulate a hydraulic description of sediment transport processes through the estuary during tidal cycles as well as during floods
- Formulate a hydraulic description of flushing efficiency of estuaries with or without mechanical breaching of the mouth
- Develop guidelines to determine and manage the estuarine water Reserve to ensure a long-term equilibrium estuarine morphology

The process of marine sediment ingress is both complex and slow, and the accurate physical measurement of the process has proved impossible with instruments currently available. Indirect methods such as bathymetric surveys and water level measurements are recommended for the determination of sediment ingress. Sediment flushing occurs during floods, and the opportunity to take measurements during a flood did not occur during the course of the project. However, it was shown that mathematical modelling does predict sediment movement, and the modelling of marine sediment ingress was verified by field measurements. Predictions on flood-induced sediment movement could not be verified due to the absence of floods during the study period.

Scouring of an estuary mouth during breaching was both measured in the field and modelled. It was shown that the effectiveness of the process increases considerably with the amount of water in the estuary at the time of breaching, with the higher water levels before breaching creating a wider, deeper mouth and the mouth to remain open for longer.





The following recommendations come out of this project:

- The role and modelling of cohesive sediment dynamics, including during floods and in tidal currents, needs to be better understood
- The effects of man-made obstructions such as causeways, bridges, marinas, weirs, to the flow in an estuary needs to be better understood and this understanding incorporated into management at the national, provincial and local level
- The interrelationship between vegetation, hydrodynamics and sediment transport needs to better understood before it can be fully incorporated into management decisions
- The interrelationship between abiotic and biotic components in an estuary need to be better understood
- Our knowledge of the relationship between off–shore freshwater and sediment requirements for prawn banks and the near-shore fishing industry, particularly related to floods, needs to be understood before it can be meaningfully managed
- We need guidelines for the management of dredging in estuaries

Cost: R950 500
Term: 2001-2003

Valuation of changes to estuary services in South Africa as a result of reductions in freshwater inflows
Department of Economics, Nelson Mandela Metropolitan University
No 1304

There are just over 250 functioning estuaries in South Africa and of these an increasing number are subject to river inflow deprivation. River water is abstracted upstream of the estuaries for urban and agricultural use, and runoff into rivers is affected by forestry and the spread of high water consuming alien vegetation. As a result of the reductions in river water inflow, the services rendered by these estuaries are eroded.

The main purpose of this study was to develop a method of valuing changes in freshwater inflow that would better inform estuary managers on economic issues relating to the problem of freshwater deprivation.

The Contingent Valuation Method (CVM) was selected for the purpose of estimating the marginal social values because it is highly suited to quantifying the benefits to the public of environmental goods and attributes. It serves as an alternative to indirect techniques (the travel cost and hedonic pricing methods) for quantifying these benefits. These values may be used in decision-making with respect to the management of the environment and, if desired, incorporated into cost benefit analyses. For most of the estuaries both high and low forecasts are generated of the impacts of changes in freshwater inflow into estuaries. For proposed increases in freshwater inflow the former relate to optimistic scenarios and the latter to pessimistic scenarios, but for proposed decreases in freshwater inflow, the former relates to pessimistic scenarios and the latter to optimistic scenarios. The forecasts of impacts on estuary services of changes in freshwater inflows were generated on the basis of expert opinion.

The main findings of this report with respect to values, are measured in the form of the total willingness to pay (TWTP) in Rand for freshwater inflow into the estuary-the product of the median willingness to pay (WTP) bid per annum per household and the total number of user households per estuary.

The CVs reflect a wide range of values-from 1.1 c/m^3 in the case of the Klein Brak low estimate scenario, to 10.5 c/m^3 in the case of the Groot Brak high estimate scenario. The median estimate of the 11 valuations reported 4.9 c/m^3 of water and the mean estimate is 4.78 c/m^3 of water.

It was expected that the estuaries most prone to high change in services from changes in freshwater inflow would yield the highest values per cubic metre, for example, temporary open/closed estuaries. The results corresponded with this expectation. The Groot Brak Estuary heads the value list and it is particularly affected by freshwater inflow reductions. The Knysna Estuarine Bay, on the other hand, is only marginally affected by freshwater

inflow reductions from the Knysna River and is near the foot of the value list.

Relating to river flow management the main argument of this study is that efficient management of freshwater allocations to South African estuaries can only be accomplished if it is informed by current estimates of marginal social costs and marginal social values of this inflow. Based on findings with respect to the estimated bid functions and observations made in this study, it is also recommended that resources continue to be committed to educating the public affected by estuary services on the link between these services and the quantity of freshwater flowing into the estuaries.

Cost: R336 000
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

The problem of sedimentation in estuaries is increasing for several reasons, amongst which the increase in the sediment load of rivers resulting from poor land husbandry combined with decreased flows entering estuaries resulting from water abstraction are important. A secondary effect of the latter reason is the increased ingress of marine sediments into estuary mouths. The overall result is that there is a declining trend in the capability of estuaries to deliver the goods and services required of them. The economic impact may be substantial, as in the case of the Kowie Estuary at Port Alfred where the estuary has become less navigable resulting in both dissatisfied civilians as well as the commercial fishermen being unable to operate effectively.

The Guide produced supplements some of the more technical WRC publications such as *Towards the Management of Marine Sedimentation in South Africa* (WRC **Report No. 1109/1/03**) and *Towards the Conservation and Sustainable Use of Eastern Cape Estuaries* (WRC **TT Report No. 237/04**) and complements the handbook on *Managing Estuaries in South Africa: A Step by Step Guide* (WRC **TT Report No. 243/04**).

The handbook is written in layman's language and covers the importance of estuaries, adaptive management and why it is important, the causes and symptoms of problems in estuaries and the relation of these to human activities both in the estuary as well as in the catchment. There is a chapter on the prevention of problems which includes a summary of the legislation dealing with estuaries and a chapter on solving problems. The final chapter guides the breaching of closed estuaries, a controversial topic which, if managed badly, will lead to increasing future problems.

Cost: R160 000
Term: 2002-2004

Programme 3: Ecosystem health
Development of a classification system of the Kruger National Park and a model for analysing trends in the condition of these rivers
Rhodes University
No 881

The background to this work is that most of the research during Phases 1 and 2 of the Kruger National Park Rivers Research Programme was undertaken on the Sabie River which is the smallest of the 5 major rivers flowing through the Kruger National Park. The question was, how applicable is this research to the other 4 rivers? And, can it be extrapolated to the other rivers in the Park?

Four types of data were used in the classification of the rivers in question. These were catchment information, river flow data, water quality data and biological data. Although many data exist for the Sabie River, most of these were not used in this project because the data filter used was that there should be information at the equivalent level of detail for each of the 5 rivers to enable valid comparisons.

Each data set was subjected to principal component analysis. River flow was not found to be useful in the analysis of similarities and differences even although two of the rivers, the Letaba and the Luvuvhu, have changed

from perennial to seasonal flow in the last few decades. This was not taken further. The most important factors in water quality were salinity (cations accounted for 51% of the variability and anions 15%) and nutrients (10% of the variability). Analysis of the macroinvertebrates and fish showed that natural biodiversity accounted for the main differences between the rivers in terms of these biota. However, while the fish data were collected at the species level, the invertebrate data were collected at the family level (using SASS5 methods) and so the definition provided by the latter was insufficient to show any differences that may have existed.

In conclusion, this approach should not be taken further. It would be better to use the freshwater biodiversity conservation planning tool that is currently being developed in the jointly funded (CSIR, DWAF & WRC) project being led by the CSIR.

Cost: R113 600
Term: 1997-2001

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

The aims of this project were:
1. Apply the concepts of desired future state (DFS) (Rogers and Bestbier, 1997) to ensure that the models developed are in line with management needs. In particular:

(a) Develop a conceptual framework of problems pertaining to fish biodiversity (Sensu Noss, 1990) for the Sabie River in the context of established "agents of change"
(b) Evaluate and refine the thresholds of probable concern (TPC) prescribed for both fish and geomorphology as defined in the DFS report of Rogers and Bestbier (1997)
(c) Reassess the existing BLINKS models and develop further conceptual models to address the "problem world"
(d) Conversion of existing biotic-abiotic links models (BLINKS)
(e) Construction of other QRBM modules if necessary to address the conceptual "problem world"

2. Transfer and implementation of prototype QRBMs to KNP management
3. Design and implementation of monitoring programmes for the auditing of each fish QRBM
4. Design and implementation of monitoring programmes for the auditing of each fish QRBM as well as the calibration requirement needs for the abiotic models
5. Refinement/calibration of final QRBMs

Aims 1 and 2 were addressed by the development of a qualitative rule-based model (RBM) based on a selected indicator to monitor conditions in the Sabie River. Successful indicators of ecosystem health provide the required information in a robust way at minimal investment of resources. The process of strategic adaptive management relies on indicators to identify when changes beyond the envelope of variability occur to alert management to the fact that action needs to be considered. This envelope of variability is defined by a threshold of probable concern (TPC) which is set at a level of change that is considered unacceptable for the indicator being monitored. During the Kruger National Park Rivers Research Programme river water temperature was identified as an indicator of change in flow, as the river water warms up more quickly at low flow. This would indicate reduced flow, in the short term caused by changes in the pattern of water abstraction from the river upstream of the Kruger National Park. The first part of the Sabie River's course has a steep gradient as it descends the escarpment, and at Hazyview the gradient decreases as the river flows into the Lowveld, at which point the water temperature increases.

Amongst the rich diversity of fish species in the river are two species of sucker-mouth catfish (*Chiloglanis* spp.), one cold-water tolerant and the other warm-water tolerant. The cold tolerant species is the only species occurring to just downstream of Hazyview where the upstream limit of the warm-water tolerant species occurs. The cold-water tolerant species disappears from the river quite quickly below this point, although there are pockets of this species

in well-shaded and cooler areas downstream.

Water temperature was regarded as being the agent of change, and so the TPC selected to monitor conditions in the river was the point where the dominance of the two species of catfish changes. This addressed Aims 1 and 2, although Aim 1a was not addressed as it needed a fishery biologist to do this properly.

A water temperature-monitoring network was established in the Sabie River that monitored temperature at hourly intervals for over a year (the extent of the field sampling programme) at a number of stations outside and inside the Park. This addresses Aim 4. The model was transferred to the KNP management, but it is not being used at the moment. Thus Aim 3 was addressed in principle, but the technology transfer is not complete. The other RBMs represent, at this stage, hypotheses only. Refinement and calibration will only be achieved through ongoing monitoring and data collection.

In the longer term, this may also be used to monitor temperature-related climate change in the Lowveld.

Cost: R552 000
Term: 1999-2003

To ascertain the value of the South African diatom collection, and to report on the opportunities it affords as well as the needs for its proper curation
Southern Waters Ecological Research and Consulting cc.
No K8/508

The South African Diatom Collection (which extends beyond South Africa's borders) was established over the period 1950 to 1995 by a number of collectors and is amongst the larger collections worldwide. The changes in science funding over the past 2 decades has meant that funds for the curation of this national asset have not been available and, of course, the collection was assembled in the pre-electronic era, so it is not easily accessible.
Internationally, the use of diatoms for the assessment of water quality is becoming increasingly widely used, and some good software has been developed to support the indices which have been developed.

A number of case studies were carried out which showed the relevance of the OMNIDIA software package (use of diatom-based water quality indices) for South African conditions. In one case study, the indices were compared to SASS5. Another of the case studies indicated the changes that have occurred in the Jukskei River, Gauteng, over the past decades.

The general conclusion is that the data and information contained in this collection will add value to, and have a place in, the current suite of assessment tools currently being used for the management of the surface water resource in South and Southern Africa.

Cost: R200 000
Term: 2003-2004

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

This project is one of a series which addresses the lack of knowledge regarding data on water quality. This is particularly the case for guidelines on sub-lethal concentrations and the tolerance of indigenous organisms for sub-lethal concentrations of salts. This work is done in the context of the NWA and the NWRS, and is placed in the context of environmental water quality (EWQ). EWQ enables the setting of effective resource quality objectives as well as the cost effective licensing and control of complex industrial effluents.

EWQ has three main approaches, water physico-chemistry, biomonitoring and ecotoxicology. The latter is the newest of the three, and internationally it has been shown to be a core technology for water quality management. DWAF have, at present, a policy document, a technical manual and a methods manual on the use of

ecotoxicology for licensing complex effluents, but the methods are based on mortality. This project aimed to develop methods to enable the use of sub-lethal ecotoxicology data in the development of protective water quality guidelines, to develop methods for the use of ecotoxicology to research the use of sub-lethal responses to complex industrial wastes and to communicate the concept of EWQ widely and effectively in the South African water sector.

The indigenous freshwater limpet, *Burnupia stenochorias*, has so far been the most successful experimental organism, as it can be bred and reared in the laboratory, and it can be handled easily. *B. sentochorias* was compared to *Daphnia pulex*, a standard laboratory organism, and found to be more sensitive. This makes it potentially more useful as a test organism for setting guidelines to protect indigenous biota. The number of indigenous species with tolerance to the salts of sodium chloride and sodium sulphate was widened, and chronic mortality data for these organisms were obtained.

One of the products of this project is a book providing simple accessible information on environmental water quality for use by resource mangers. The text of this book was refined through a number of open workshops held country-wide while addressing the third aim of the project. This iterative testing and revision has resulted in a book which successfully addresses the aim of the project.

Cost: R1 397 000
Term: 2001-2004

THRUST 3: ECOSYSTEM REHABILITATION

Programme 2: River rehabilitation

Consultative project to situate, contextualise and plan for a river rehabilitation programme 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 cc

No 1309

The aims of this project were as follows:

1. Situation/anchoring of river rehabilitation in a South African context and establishment of links with relevant current water initiatives
2. Consultatively developed plan for a long-term program for the development and implementation of river rehabilitation in SA
3. Trialling of Australian river rehabilitation procedures on a small degraded urban river in South Africa

Aims 1 and 2 are addressed in **Volume 1**, and Aim 3 is addressed in **Volume 2**.

Volume 1 begins by defining the meaning of river rehabilitation and other related terms to foster the correct general understanding amongst people in the field. This part of the project began with 6 regional workshops which were attended by a total of 150 people. At each of these workshops a number of presentations were made followed by a facilitated discussion. As each of the workshops had a different mix of practitioners, managers, decision makers, consultants and researchers, each of these discussions developed differently. These discussions highlighted a number of areas requiring research, development or application, and these are detailed in the report. In addition, the identified needs were distilled into the terms of reference for a solicited project on the topic.

Volume 2 covers a case study of the rehabilitation of the Ihlanza River, East London. The Ihlanza River runs through the suburbs of East London and discharges into the sea on the city's top surfing beach. It was highly degraded and polluted.

Through an extensive process of public participation, funds were mobilized (largely through Buffalo City Metro) to rehabilitate the river. The 12 steps of the process followed are detailed in the report in such a way that they can be followed by others wanting to achieve the same outcome, and include everything from planning and public participation to supervision, monitoring and maintenance on the ground.

Cost: R372 650
Term: 2002-2004

The costs and benefits of urban river and wetland rehabilitation projects with specific reference to their implications for municipal finance: Case Studies in Cape Town
Independent Economic Researchers
No K8/564

Rehabilitation is often undertaken by metropolitan areas in order to control flooding. In the past, hard engineering structures have been used with little consideration of the natural systems. The cost-effectiveness of this compared to methods majoring on natural systems (bio-engineering) was investigated in 3 case studies in the Cape Town metropolitan area.

The 3 case studies selected were:
- The Lower Silvermine River
- The Kuils River
- The Westlake River in Kirstenhof.

The benefit / cost ratio was calculated from the cost of the project on the one hand and the change in property values (hedonic pricing) on the other hand.

The Lower Silvermine River was rehabilitated primarily for flood control, and a range of both hard engineering and bio-engineering solutions was used. A benefit cost ratio of 4.58:1 (over a 30-year period using a discount rate of 8%) was calculated for this project. The total cost was dominated by flood control hard engineering, although the benefits were dominated by the improvement (from the lifestyle perspective) by aesthetic and recreational benefits from landscaping and other bio-engineering interventions. This has now become a growth point in the Fishoek and Clovelly area.

The Kuils River project was dominated by canalisation with landscaping being limited to planting grass on some of the river banks. The benefit cost ratio of 0.4:1 (over a 30-year period using a discount rate of 8%) reflects the high cost of hard engineering which does little to improve the aesthetic and recreational benefits of the project.

The Westlake River project was done to improve the aesthetics and recreational value of the area to complement flood control. Ongoing maintenance definitely enhances the ability of the area to control floods, but this was not quantified. The benefit cost ratio of 2.4:1 (over a 30 year period using a discount rate of 8%) reflects the appreciation and success of bio- (soft) engineering as opposed to hard engineering.

The report concludes by saying that municipal funding for rehabilitation is not likely to increase in the foreseeable future, so projects should be designed with the possibility of raising the rateable property base by increasing property values in the areas surrounding the rehabilitation project.

Cost: R200 000
Term: 2003-2004

Programme 3: Influence of instream-constructed barriers
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 WAS TERMINATED

Cost: R300 000
Term: 2003-2004

CURRENT

THRUST 1: ECOSYSTEM PROCESSES

Programme 1: Estuarine processes
Phytoplankton primary production and community structure in two temporarily closed estuaries
Department of Zoology and Botany, Nelson Mandela Metropolitan University
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

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

Estimated cost: R200 000
Expected term: 2003

Programme 2: Riverine processes
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

Programme 3: Wetland processes
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 University of Johannesburg
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

Programme 4: Groundwater-dependent ecosystems
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

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION

Programme 1: Ecological Reserve

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, Volumes 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

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 3: Ecosystem health
Evaluation of the fish assemblage integrity index to assess river health, and its refinement to ensure high levels of accuracy
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: R593 000
Expected term: 2001-2003

Programme 4: Environmental water quality
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

This toxicology 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

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

Programme 5: Endocrine disrupting compounds (EDC)
WRC Programme for endocrine disrupting contaminants (EDC)
Consortium Members: US; UFH; MEDUNSA; Techknikon Free State; Tshwane University of Technology; SABS; CSIR Environmentek; ARC-PPRi; Consultant manager
No 1402 (includes Projects 1469, 1470, 1471, 1472 and 1473)

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

THRUST 3: ECOSYSTEM REHABILITATION

Programme 1: Wetland rehabilitation
Wetland rehabilitation
Consortium: School of Life and Environmental Sciences, University of KwaZulu-Natal (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
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

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

NEW

THRUST 1: ECOSYSTEM PROCESSES

Programme 2: Riverine processes
Habitat, use and movement of freshwater fish species
Freshwater Research Unit, UCT
No 1483

This project presents a unique opportunity to investigate the movements of large fish in an un-impounded river, the Doring River in the Western Cape. This is knowledge which cannot be obtained from elsewhere in the country

as there are so few un-impounded rivers remaining. The two things making this opportunity unique are that the Doring River, which is one of the last un-impounded rivers in the country, will be impounded within the next decade or so, and that we have a researcher capable of the task. DWAF have asked for information on the movements of fish in a river system for use in their planning of fish-ways, and this research will complement the existing projects researching fish-ways by providing additional information that these projects will not be able to provide. This work has previously been funded as a consultancy, and progress has been made in both initial aims of the project, as well as in the sourcing of funds for the radio telemetry tracking of the fish.

Estimated cost: R688 000
Expected term: 2004-2007

Conservation planning for river biodiversity
Environmentek, CSIR
No 1486

Conservation planning was developed for use on terrestrial systems. Using it on river biodiversity is a new application which started during the planning of the Greater Addo National Park. It worked well, but areas needing refinement were identified. Currently both DWAF and the CSIR are funding some of this refinement, and this proposal will further develop what promises to be a useful method for river prioritization.

Estimated cost: R 352 300
Expected term: 2004-2005

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION

Programme 1: Ecological Reserve
Environmental water requirements in non-perennial systems
University of the Free State
No 1414

Methods for the determination of environmental flows for the Reserve have been developed and used for rivers with permanent flow. However, many rivers in the semi-arid west of the country are ephemeral. The NWA requires that the Reserve be determined before licences may be issued, and currently used methods have not been verified for ephemeral rivers. Verification needs to be done and, where necessary, new methods developed.

Estimated cost: R600 000
Expected term: 2004-2007

Programme 2: Estuary management
Valuation of estuary services in South Africa
Dept of Economics, Nelson Mandela Metropolitan University
No 1413

Estuaries are delicate systems that are not only in high demand for development, but also deliver important goods and services with a value out of proportion to the geographical area occupied. The continued delivery of these goods and services is dependent on adequate freshwater inflow, and with the high rates of abstraction this is decreasing. The Reserve determination process takes into account ecological processes and functions, but does not adequately account for the values placed on estuaries by people.

This follow-up project will build a database of the value of freshwater inflow into estuaries using the contingent valuation method to value the goods and services provided by the freshwater inflow and based on the value attributed to the freshwater inflow by estuary users.

Estimated cost: R2 170 000
Expected term: 2004-2007

Integrated development planning for estuaries
Institute of Natural Resources, Rhodes University
No 1485

The Eastern Cape Estuaries research and management programme which was initiated in the late 1990s to empower the communities living beside these estuaries to manage the resource sustainably, has had a big impact in the area, and has resolved some long-standing problems both between national government policy and communities as well as between communities themselves. It has also

piloted some estuary-based ecotourism commercial enterprise. This work has also leveraged substantial additional funding from government and private enterprise.

The integration of knowledge generated so far into the Integrated Development Planning (IDP) process is a necessary step towards sustainable management of additional estuaries. The IDP is required of local government, but the capacity to include environmental matters in the IDP is not available in the smaller local authorities. This same capacity will also be required by national government in the soon to be set up CMAs, and by new provincial environmental affairs structures, and so building the capacity here will entrench it for the future.

The project on estuarine resource economics **(No. 1413)** will form the link between this work and resource economics for the IDP process.

Estimated cost: R1 220 000
Expected term: 2004-2007

Programme 3: Ecosystem health
Integrated management of water hyacinth in South Africa
School of Animal Plant & Environment Sciences,
University of the Witwatersrand
No 1487

Water hyacinth is difficult to control and is a problem worldwide. Chemical control is expensive and ineffective in the long term. Biological control has provided a sustainable and cost-effective control in certain conditions, but the harsh South African winters are more detrimental to the control agents than the weed, allowing the weed to regenerate in the spring of each year. This project will refine earlier work **(WRC Project No. K5/915)** to control this problem weed by low-dose levels of certain herbicides without unduly damaging the populations of the control agents.

Estimated cost: R1 655 600
Expected term: 2004-2009

Programme 4: Environmental water quality
Application of chronic (sub-lethal) toxicity endpoints to the development of resource quality objectives
Centre for Aquatic Toxicology, Rhodes University
No 1484

It is necessary to know the chronic levels of a toxicant for the process to determine water quality in the Reserve, so that safe levels may be prescribed. This project will refine work on acute toxicity of various stressors in order to verify extrapolations of chronic toxicity levels to acute levels.

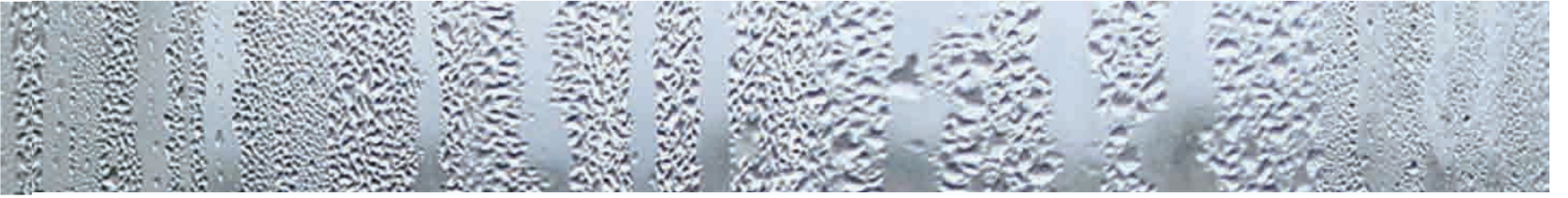
Estimated cost: R1 340 000
Expected term: 2004-2007

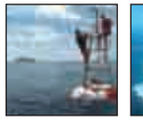
THRUST 3: ECOSYSTEM REHABILITATION

Programme 1: River rehabilitation
River rehabilitation guidelines
Laughing Waters
No 1412

Biophysical river rehabilitation is a relatively new science in South Africa. Much money is being spent on it by local authorities (known as river improvement which entails enhancing flood water removal through canalisation), but this destroys the capacity of the river ecosystem to deliver goods and services. The Australian experience is comparable to the South African situation. This project aims to modify the Australian approach to river rehabilitation where necessary and to test this on selected South African rivers

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




the visible difference

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KSA 3

WATER USE AND WASTE MANAGEMENT

Managing Water, Sanitation and Waste for People, Prosperity and Planet

Mr Jay Bhagwan
Director

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 provision and supply of water of adequate quality and quantity for economic and public health purposes remain continuous challenges. Water is a finite resource and specifically in the context of South Africa, becoming incrementally scarce. Managing water use and the waste released to the water environment is thus of paramount importance to ensure the sustainability of the resource and the activities relying on it.

Water use and waste management in South Africa is consequently a key factor for social and economic growth, as well as our environment. The entire way we think about and use water is thus an important factor in determining our future. A changing institutional environment and the need for strong institutional capacity add to this challenge.

Objectives

The primary objective of this KSA is to provide knowledge that ensures reliable, affordable and efficient water use and waste management 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

This KSA focuses on a revised portfolio of five thrust areas, these being:

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.

Current programmes are:

- Cost-recovery in water services
- Institutional and management issues-Water services
- Innovative management arrangements-Rural water supply

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.

Current programmes are:

- 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.

Current programmes are:

- Biological sewage treatment processes
- Sludge characterisation, treatment, utilisation and disposal
- Treatment and recovery of organics from agro-industrial processing
- Treatment and recovery of inorganics (including sulphate and metals) in industrial and mining effluents
- Training in wastewater treatment plant operation
- Biotechnological co-treatment of industrial / mining effluents with sewage wastewaters
- Sewerage reticulation
- Stormwater management

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.

Current programmes are:

- Quantification of water use and waste production
- Regulatory mechanisms to improve industrial and

mine-water management
- Minimising the impact of waste on the water environment
- Minimising waste production
- Improved ability to predict and quantify effects.

THRUST 5: SANITATION AND HYGIENE EDUCATION

Scope: This is a new thrust which includes some programmes which previously fell under other thrusts. This thrust addresses the research required to assist the national government to achieve its goal of clearing the sanitation service backlog by 2010. It also identifies research that is essential to support planning for basic sanitation service delivery beyond 2010. The focus is on low cost and affordable sanitation technologies.

Current programmes are:
- Health and hygiene education
- Peri-urban sanitation research
- Knowledge/information management and advocacy
- Institutional and management aspects of sanitation service delivery
- Technical sustainability of sanitation services
- Financial sustainability
- Social development aspects

Research portfolio for 2004/05

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 placed 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 which 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 greywater and stormwater)
- 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.

Based on the strategic processes and initiatives introduced in the previous years, the key focus for the year 2004/05 will be on consolidating and strengthening the activities of the KSA related to strategic direction, technology transfer, project management and business processes, towards meeting the broader KSA and organisational goals.

Workshops and consultations with the sector role players will be a key engagement towards further identifying research needs and developing a strategic research portfolio for the KSA and its thrusts.

A number of workshops are planned to effect this, and also to test the outputs and provide finalisation for the strategic direction, programmes 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 years 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 2004/05

The approved funding of the research portfolio for 2004/05 leads to a committed funding budget of R27.5m. The focus of this portfolio will continue along the current trend.

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 last 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) or 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 last 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. An example is treatment processes that can target development of new media and increasing treatment flow through. 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.

Against this background the challenges posed are medium to long term and require greater interdisciplinary solutions. In line with the strategic context presented in previous years which has regularly undergone both internal and external reviews, there are no major changes, as shown above, but there is greater emphasis towards solving the water supply and sanitation problems. It is worth noting that the importance of research and development has also been strongly emphasized. Any major emerging changes are incorporated and absorbed into the current context.

Needs analysis

During 2003/04, the KSA embarked on a needs analysis exercise to identify any gaps in its newly proposed and developed strategic framework and to identify priority research topics and areas requiring attention. The process consisted of a questionnaire survey to some 350 randomly identified WISA 2002 attendees from a variety of disciplines. The questionnaire consisted of two parts, one which questioned the appropriateness and relevance of the KSA and its thrusts, and the second part which requested identifying priority research topics and themes. From a 35% response rate, it was clear that there was support for the KSA and its structure. The few concerns highlighted were research focus on issues related to stormwater, sewerage and the need for greater emphasis on sanitation.

In synthesizing this wealth of information generated it was clear that the key challenges facing the water sector in South Africa were as predicted in our strategy with very little deviations. The challenges ratified are as follows:

- 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 and related legislation. The aspects of community participation and local economic development are central to these objectives.
- The water services environment has undergone dynamic change over the past few years. The newly published Strategic Framework for Water Services (DWAF, 2003), has set a new set of challenges and goals for the sector. It will be imperative that the success of this framework will help realize the ultimate goal of national water policy and local government legislation.
- The World Summit and World Water Forum 3 impetus on setting water and sanitation targets, has generated a new urgency and priority to this area of activity. South Africa's ambitious declaration of obtaining full coverage by 2010 has prompted greater importance to the provision of water and sanitation.
- Since 1994, greater emphasis has been placed 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.
- Over the past few years great strides have been undertaken in covering water and sanitation backlogs resulting in significant achievements. This has also resulted in the expansion and growth in infrastructure in urban and rural areas. More small schemes have come into existence and from international and local experience, they pose greater challenges in their sustainable management. Further the infrastructure and associated resources are the assets of our country and contribute to improving the quality of life and these need to be managed effectively.

Technological trends

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 and the World Summit and World Water Forum 3 impetus on setting water and sanitation targets, has generated a new urgency and priority to this area of activity. South Africa's ambitious declaration of obtaining full coverage by 2010 has prompted greater importance to the provision of water and sanitation. 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 the emphasis is on efficient use of water and managing demand, as well as looking at the contributory elements such as energy, pipe components and materials, water supply components and behavioural aspects. In terms of treatment technology the current international trends are toward the increased removal of more and more specific contaminants in the water. In addition, it is aimed at adding fewer and fewer chemicals to the treated water product. The removal of pesticides, heavy metals, endocrine disruptors, disinfection by-products and other harmful organics is receiving attention. The 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 developing countries the emphasis continues on breaking the transmission of water and faeco-oral related diseases, through understanding practices and behaviours which contribute to the spread of diseases. Improved education and knowledge are central strategies to tackle these problems.

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 this KSA in particular. They are divided into internal and external stakeholders. Over the years our international partners and business partners have also proven valuable to us.

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)
- SALGA, 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
- The public
- International coalitions such as GWRC, WSSCC, WUP, ET, UNEP, IRC, WARFSA
- Business

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.

STRATEGIC INITIATIVES UNDERTAKEN DURING 2004/05

National initiatives

- The PESTLE analysis process was undertaken. The emphasis of this exercise was to test the research thrusts of the KSA and identify new and emerging areas across the broad water use and waste management area (industrial, mining and domestic). This step was essential in verifying the current KSA thrusts and determining typical trends and priorities, as well providing a framework for the kind of issues to be addressed. The exercise supported the current framework of operation of the KSA and highlighted greater emphasis on local government water services delivery issues. Supporting this, a number of initiatives were undertaken within the thrust areas to identify research needs and develop a portfolio of strategic research needs to be addressed over the short- to medium-term (2 to 5 years). Three research strategies have been developed as follows:
  - Towards a research strategy and agenda to support water services in South Africa
  - Research strategy to support water treatment and distribution
  - Research strategy to support mine-water management.
- A study was initiated to determine the status of stormwater drainage and sewerage, and identify research needs. This area has been identified in many strategic exercises as requiring greater attention and priority.
- A workshop was held with general water stakeholder input on the current state and future direction of membrane technology and application
- The KSA arranged an open day for the transfer of a WRC solar distillation water treatment plant, developed from WRC funded research, to the Kannaland District Municipality in the Karoo for water supply to a local church community
- KSA members continue to occupy key positions on a variety of strategic bodies and forums. Examples of these are the DEAT-Cleaner Technologies Steering Committee (waste minimisation); Mine-Water Group; Water Sector Leadership Group; Water Information Network (WIN); JASWIC; WISA; Minister's Advisory Council.
- KSA member appointments include the Presidency of WISA, Strategic Management Committee of Waste Minimisation initiative of DEAT
- A special edition of KZN SANTAG newsletter was published to highlight the WASH activities in the country.
- On average the KSA hosts a minimum of 10 workshops and technology transfer actions which are not undertaken by the sector

International initiatives

- Ten innovative drinking water developments from South Africa were presented at the biennial *Emerging*

Technologies Forum held in Italy in April. South Africa was one of the leading countries regarding new technologies. All 10 innovations were wholly or partly funded KSA 3 projects.

- The KSA was involved in a survey of reverse osmosis and nanofiltration activities in South Africa as part of a Global Water Research Coalition initiative
- The KSA is contributing toward the *State of Science Report on Water Reuse* under another participative project with the Global Water Research Coalition and provided information on water reuse in Southern Africa. Benefits of these activities will accrue to the WRC when a workshop is held in April 2005 to generate an international cooperative research programme on water reuse.
- The KSA is contributing toward GWRC joint activities in endocrine disruptor and algal toxin research, coordinated by Ms Annatjie Moolman
- Further GWRC initiatives include cooperation in a membrane bioreactor research strategy plan and in a water reuse project. The KSA presented a report on the status of water reuse in the region to the GWRC
- The KSA participated at the Global WASH Forum in Dakar and undertook the rapporteuring of the stream on Local Government
- Jay Bhagwan was elected to the Steering Committee of the WSSCC, demonstrating his and the WRC's (South Africa) participation at an international level
- The KSA provided facilitation and support to DWAF and WSSCC. In partnership with DWAF, the South African sector achievement towards meeting the MDGs and WASH goals were presented and highlighted at the Global WASH Forum, Dakar
- KSA co-ordinated an exhibition titled the *SA WASH Café*, where the achievements of DWAF, WRC, SALGA, DPLG, Mvula Trust, Umgeni Water and Rand Water were exhibited

African leadership

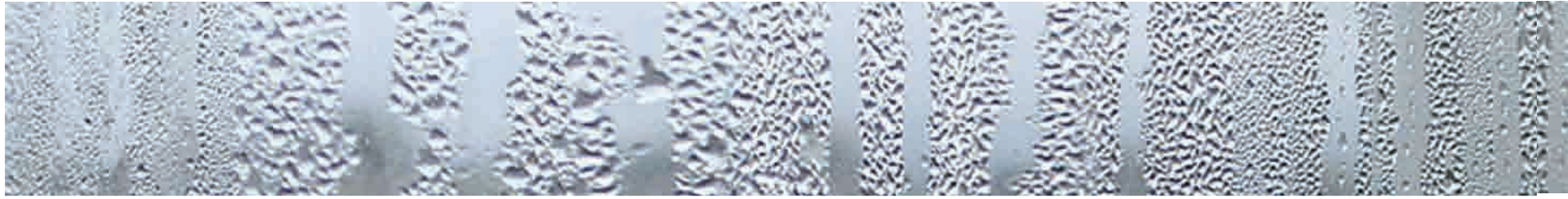
- The KSA co-ordinated the South African input into the regional WASH meeting in Zimbabwe
- The KSA also exhibited at the event
- The KSA participated at the IWA Marrakech Conference
- The KSA participated in the AfDB Water Week Tunis and in the setting up of the African Water Facility
- The KSA in partnership with WUP hosted a regional training seminar for water utilities
- The KSA arranged the WUP training course Johannesburg May 2004
- Participated in the World Economic Forum workshop on public/private partnerships 18 and 19 October, Durban
- Meeting and presentations to NEPAD Secretariat, 20 July 2004

IMPLEMENTATION PLAN

Research portfolio for 2004/05

The KSA's continuous activities in light of the results of the strategic needs analysis and stakeholder engagement, with regard to its objectives and thrusts have been well supported. Feedback from these exercises has ratified the KSA direction and many valuable inputs assisted in strengthening the portfolio. Thus the primary and secondary objective of the KSA remain the same; however the KSA portfolio undergoes some change to incorporate new emphasis as highlighted by the stakeholders. A new dedicated and focused thrust addressing issues regarding sanitation and hygiene is being introduced and the scope of **Wastewater Treatment and Technology** is being broadened to include stormwater and sewerage research. These two subjects are strongly related to wastewater management and best integrated. It was recommended to be best incorporated into this thrust. These changes contribute to strengthening the portfolio of the KSA and direct the KSA towards greater relevancy and emphasis. This process is continuous and will further build and strengthen the research portfolio of the KSA.

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

The new portfolio of projects aims at providing solutions which 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 re-use 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

The scope and expected outcomes of the thrusts and programmes are provided in **Table 1**. The KSA would like to once again highlight the **new dedicated** Thrust 5 on **Health and Hygiene Education** and the introduction of two new programmes in **Thrust 3** which incorporate aspects related to stormwater and sewerage.

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

TABLE1: 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,, 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.

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. 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 community involvement, cost-recovery, effective O&M, 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.

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY (CONTINUED)

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: The ongoing provision of sanitation services and expansion of industrial development, both of which are national developmental priorities, continually increase the need to better manage and treat the resultant wastewater and effluent flows, mitigated as far as possible by reduction-at-source measures, so that the effluent produced not only meets discharge requirements but can also be considered as a resource. Research in this thrust aims at developing technologies and systems that optimize the wastewater and waste management chain in the municipal (domestic), mining and industrial sectors, including also the institutional and infrastructural arrangements operative in these sectors. From the needs analysis carried out in 2003 and preliminary strategic research planning, the scope, definition and priorities of some of the programmes within Thrust 3 will alter from 2005/6, involving both the establishment of new programmes and the consolidation of some of the existing programmes.	
Programme 1: Biological sewage treatment processes	**Scope:** This programme addresses the ongoing development of new or modified processes and optimisation of established aerobic and anaerobic processes for biological sewage treatment systems. Expected outcomes are greater cost-effectiveness, technical and operational control, process efficiency, performance processes security, sewage affordability and application.
Programme 2: Sludge characterisation, treatment, utilisation and disposal	**Scope:** This programme deals with the systematic characterisation, quantification and categorisation of sludges from domestic and industrial sources in the RSA. The overall expected outcome is a greater capability for the development of technically-secure, cost-effective, environmentally acceptable and sustainable treatment process technologies, utilisation strategies and disposal practices.
Programme 3: Treatment and recovery of organics from agro-industrial processing	**Scope:** Addresses the development and piloting through to full-scale implementation of treatment and/or conversion technologies for problematic organic effluents from agro-industry processing including forestry (pulp and paper) and livestock products, particularly in respect of organic components which are too concentrated, refractory, inhibitory or even toxic for the biological treatment processes normally available at municipal sewage works.
Programme 4: Treatment and recovery of inorganics (including sulphate, metals) in industrial and mining effluents	**Scope:** This programme aims to develop a range of processes for effective treatment and disposal of industrial and mining effluents containing components such as heavy metals and inorganic salts, which 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. Expected outcomes include the potential recovery of materials and water for beneficial reuse and fundamental scientific/engineering support for process development.
Programme 5: Training in wastewater treatment plant operation	**Scope:** Aims at the research, development and delivery of appropriate tools, course material, management systems and training for wastewater treatment operators. The purpose is to strengthen and enhance the skills base (competency and expertise) necessary for effective control and management of the diverse needs of the water industry in the RSA.

THRUST 3: WASTEWATER AND EFFLUENT TREATMENT AND REUSE TECHNOLOGY (CONTINUED)

Programme 6: Biotechnological co-treatment of industrial and mining effluents with sewage wastewater	**Scope:** The programme 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.
Programme 7 (new): Sewerage reticulation	**Scope:** This programme aims at addressing technical design, operational, maintenance, refurbishment and management aspects of sewerage reticulation systems, which have been identified as a concern in the sustainable provision and protection of asset infrastructure in the extended delivery of sanitation services as a national priority.
Programme 8 (new): Stormwater management	**Scope:** This programme addresses strategic and technical aspects of managing stormwater flows and impacts in urban, peri-urban and rural contexts, with their different implications for water resources, community health, environmental impacts, etc.

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.

THRUST 5: SANITATION, HEALTH AND HYGIENE EDUCATION

Scope: This thrust addresses the research required to assist the national government to achieve its goal of clearing the sanitation service backlog by 2010. It also identifies research that is essential to support planning for basic sanitation service delivery (O&M, sustainability etc.) beyond 2010. The focus is on low cost and affordable sanitation technologies.	
Programme 1: Health and hygiene education	**Scope:** The main objective of this programme is to support integration of health and hygiene into the delivery of water and sanitation in order to ensure that these services lead to maximum health benefits for the beneficiary communities.
Programme 2: 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.
Programme 3: Knowledge/information management and advocacy	**Scope:** The overall aim of research under this programme is to improve access to sanitation research information and to develop effective mechanisms for promoting implementation of best practice by the sector role-players. The focus would be on ensuring that an enabling environment supports the process of sanitation knowledge and its uptake, which in turn empowers decision makers in providing sustainable sanitation.
***Programme 4: Institutional and* management aspects of sanitation service delivery**	**Scope:** The main objective of this research programme is to develop institutional models, tools and guidelines that will support the improvement of delivery (O&M, sustainability etc.) of sanitation services.

THRUST 5: SANITATION, HEALTH AND HYGIENE EDUCATION CONTINUED

Programme 5: Technical sustainability of sanitation services	**Scope:** To develop tools, procedures and guidelines that will guide those responsible for implementing projects in their selection of appropriate sanitation technologies that are social, environmental and financial sustainable.
Programme 6: Financial sustainability	**Scope:** The main objective of research under this programme is to develop models, tools and guidelines that will enable managers to provide financially viable sanitation technology solutions for communities and to make provision for both capital investments and O&M costs for the different sanitation technology choices.
Programme 7: Social development aspects	**Scope:** To support people-centred development approach, that is people's needs must be at the centre of sanitation and hygiene promotion programmes. Sanitation infrastructure must be accepted and owned by households and local people must acknowledge the need for hygienic practice and positive impacts to their health and quality of life. The focus of this programme is to develop knowledge that will empower local people in the uptake of sanitation and hygiene.

RESEARCH PROJECTS FOR 2004/05

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 of new projects which commenced between 01 April 2004 and 31 March 2005.

COMPLETED

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

In many municipalities prepayment water meter technology has become a prominent instrument of water management contributing, with other measures, to the sustainability of water provision. This study aimed at providing an understanding of the social and institutional context in which the technology fails or succeeds. This understanding is derived from an examination of the available literature, the analysis of surveys and by examining case studies. Specifically, the objective was to understand how the technology could best be used to ensure sustainable water provision by local authorities. Key objectives were to determine how the changing institutional environment impacted on the uptake of the technology and, similarly, how socio-economic contexts affected its adoption.

The project methodology included:

- Desktop research for a literature study.
- Discussions with relevant stakeholders like DWAF, SALGA, DPLG to gain an understanding of the environment in which water service providers operated.
- Conducting a national survey of water service providers (the NPS).
- Analysing returns from the National Postal Survey (NPS) in combination with data from the Labour Force Survey (LFS) and the DWAF WSSP database
- Analysing eight case studies.

The National Postal Survey revealed a number of key insights including:

- More than half of all South African households fall under a "billed" system. This means that many poor households have to cover the high transaction costs associated with that system.
- When compared to consumers who pay for past

consumption those using prepayment meters are charged significantly less for each litre they consume
- Service providers believed that the vast majority of consumers were positive or indifferent to prepayment water technology
- Household consumption is price sensitive and consumption varies loosely with the price charged
- The implementation of prepayment meters does not per se reduce water consumption of households
- Although there has been a tendency to install prepayment meters in the dwellings of the poor one third of users had a household income of more than R1 200 per month

The information from the NPS and LFS was combined with data on water charges to unpick the attitudes and perceptions of current users. Aspects considered include perceptions of satisfaction with the technology in general and with cost effectiveness and technical reliability in particular. Prepayment meters in private houses, instead of communal taps, were viewed more critically by their users.

Among service providers there was a strong correlation between technical reliability and general satisfaction with the technology. The role of on-going support for the technology was highlighted by the correlation between support levels and high satisfaction levels regarding the meters in general and their technical reliability in particular. Contrary to popular perception vandalism was not cited by service providers as a particularly serious problem. Somewhat surprisingly service providers indicated that the FBW policy would have a minor impact on anticipated uptake of the technology.

Case studies on eight municipalities were conducted to ensure a cross-section of experiences with the technology. This exercise revealed that the
- The drive to introduce prepayment water technology was motivated by a need to combat institutionalisation of non-payment
- Planning, installation and operation were characterised by many technical problems. However, instrument suppliers were initially willing to provide strong technical support.
- In many cases there was an initial lack of public participation. This situation has since improved.
- The Free Basic Water Policy has had an important influence on municipalities installing the technology. The FBW, *inter alia*, altered their perceptions as to where the technology was most appropriately placed.
- Expected future trends were highly varied. Some municipalities planned to expand coverage, while others planned to replace their prepayment meters with conventional ones. The last were generally motivated by high maintenance costs or the unreliability of the instruments.

In general the study concludes that prepayment water meter technology has a valuable role to play in sustainable water service delivery. The major recommendations arising from the study were:

- Water policy (including free basic water provision and the use of equitable share grant) should be packaged in a manner that enables municipalities to better interpret and apply it.
- Municipal structures and their agents need assistance to understand and address social conflicts relating to service payment. The impact of indigent policy and the insights gained from case studies need to be more widely shared.
- A working partnership between stakeholders such as DWAF, SALGA, DPLG as well as WRC, must be generated. This partnership should be used to ensure that policy measures and interventions blend. The resulting shared understanding and application of policy should be communicated to municipalities in an accessible and easily understood manner.
- Municipal water service providers should be equipped to see the differences between community resistance to payment and the means by which payment is effected. Similarly consumers have to be informed that free-riding is no longer an option-irrespective of the means by which consumers are called to account.
- Municipal structures must actively educate constituencies as to the implications of “free-riding”. This education should highlight the cost of “free-riding” in terms of reduced service delivery in other service sectors. Political representatives should play a

more prominent role in articulating the grievances of their constituencies while promoting the decisions of the elected local government

Cost: R375 500
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

Research reports have been completed on payment strategies for low-income water consumers in the then Pretoria, Durban, Johannesburg and Cape Town Metropolitan areas and on determination of the price elasticity of demand for water amongst low-, medium- and high-income groups in Alberton and Thokoza. As a consequence of the interest engendered by these studies from local government departments and private companies such as consulting engineers, the WRC commissioned a more in-depth study with the following objectives:

- To compare different water payment strategies and investigate the attitudes and behaviour of low, mid and high-income level residential water users as a consequence of these payment strategies

- To determine the price elasticity of demand for water of low, mid and high-income groups, to enable effective water demand management to be put in place in the selected areas

Both the participative payment strategy testing (PPST) and contingent valuation (CV) methodologies required a systematic process of interaction between researchers and water consumers, which culminates in data being gathered by means of two surveys (called Survey No 1 and Survey No 2) for each methodology. For the CV experiment, these surveys recorded the different ways consumers use water, i.e., for indoor/outdoor usage, cooking, washing, etc. and changes to the amount of water used for these different purposes as the price charged for water changes. For the PPST experiment, these surveys recorded data about household water consumption, their water bills, their perceptions about the quantity of the water used and other related perceptions regarding their payment behaviour.

Surveys were conducted by face-to-face interviews among samples of low-, medium- and high-income population groups of residential water users in three newly created metropoles, Tshwane, Ethekwini and the city of Cape Town.

From the PPST experiment three issues emerged as being important with respect to water payment strategy policy formulation. These issues are the water account, payment options, consumer's water usage and their estimation of that water usage. Because of the lack of understanding with water accounts in the three metropoles, particularly amongst the low-income group, it is recommended that water accounts be made simpler and more user friendly than the present ones. It is also recommended that more suitable payment points be provided particularly for the low income group. With regard to understanding water usage and the economic value of water which would aid in the implementation of payment strategies, it is recommended that an educational programme be implemented, and in addition each household should be encouraged to record its water usage so that a greater understanding of the value of water in South Africa (where water is a scarce resource) may be engendered. In formulating payment strategies it is also recommended that any help that can be given to low-income consumers with respect to the cost of water should receive careful attention, for example, discounts for early payment.

From the results of the CV experiment certain tariff policies were suggested and also some advice was offered on water system design and the tariff of water. With respect to tariff design, it was suggested that tariffs should cover all costs, they should be made as simple as possible, that they should be collected regularly, emphasising that a sound tariff policy should promote the efficient use of the resource and provide an adequate service to all its consumers. The question of cross-subsidisation and tariff design was considered and it was pointed out that cross- subsidies can create serious distortions that affect the efficient use of water and they require a considerable administration structure for them to be effectively managed.

With respect to the design of water resource developments, the price elasticities of demand found from the CV experiment could be used by designers to use investment funds efficiently by means of staged system design, thus using the funds available in the most efficient manner.

Cost: R700 000
Term: 2002- 2004

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

The Free Basic Water Policy was officially implemented in July 2001. The policy was rolled out in most urban areas on or near this date. However, in rural areas it was much more difficult, and there are many areas that have not yet seen the implementation of free basic water (FBW). This is due to varying financial, technical, political and logistical problems at the local and district municipality level.

This research investigated the current situation in rural municipalities, looking specifically at FBW policy, institutional arrangements, O&M costs, cost *per capita* and affordability in relation to the Equitable Share allocations. Five case study areas were chosen: the uThukela Water Partnership (KwaZulu-Natal); the Alfred Nzo District Municipality (Eastern Cape); the Ngqushwa Local Municipality (Eastern Cape); the Vulindlela Water Scheme (KwaZulu-Natal) and the Nlhungwane Community Scheme (KwaZulu-Natal).

From this research it is clear that water service authorities (WSAs) are at varying levels of implementation, with few having a fully operational policy that is reaching the rural areas. Some communities have not been informed about FBW and are still paying for all their water.

The institutional arrangements for FBW implementation are unique to each WSA, but a common factor in efficient, cost-effective provision was noted to be the contracting of an organisation with the expertise and capacity to successfully manage water provision within a budget.

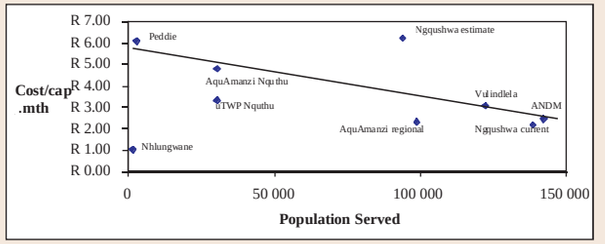
For each case-study area the O&M costs were determined (as far as possible), and from this, the cost *per capita* per month for water provision. One recurring cause for concern was the lack of asset replacement costs in WSA budgeting. This will cause a major problem in the future when infrastructure needs to be replaced. It was noted that where a WSA had not developed an FBW policy an *ad hoc*, unreliable operations and maintenance system tended to be in place, with higher costs than encountered where a reliable, comprehensive service was provided. This highlights the need for WSAs to prioritise FBW, regardless of their budget restraints, as FBW-by-default could result in greater expenditure than if the time, resources and budget are allocated for the development of a sound FBW policy and implementation strategy.

There was a large range in costs *per capita*, with a trend that showed the influence of economies of scale. This is illustrated in the graph below that shows the benefits of a water service provider covering a large population.

The median of these *per capita* costs was used as a recommended cost *per capita* to which WSAs could align their budgets. This cost has proven to be attainable by service providers in different environmental, financial, social and political environments encountered in this research. The recommended cost *per capita* per month is R5.84 (in 2004/05 value).

For poor rural areas the affordability of FBW is primarily determined by the equitable share (ES) allocations. The study investigated these allocations, when compared with the median cost calculated above, and found that the ES allocations are insufficient to cover the O&M costs in all but one of these rural areas. Using the portion of the ES that is allocated by National Treasury for the supply of water and dividing this grant money (at R5.84/cap.month) by the population served by the water service provider for the case study areas, within the percentage cover that is currently required at reported indigence levels and service levels, it was found that even if it is taken into account that, for example, only 80% of the population should qualify for

FBW, and that only 55% of the population currently have access to potable water, the ES is insufficient to supply for this portion of the population.



Correlation between cost *per capita* and population served

These problems with affordability highlight the need for WSAs to have effective and efficient cost-recovery systems that ensure payment for water by those that are not poor, and by all users who consume more than the free basic allowance. Cost-recovery was a noted problem in each of the case study areas and needs practical and politically acceptable solutions if FBW is to be sustainable.

FBW in the rural areas of South Africa is difficult, but possible. With good management FBW could be sustainable in the long term as long as national government provides sufficient levels of ES revenue to municipalities. From the lessons learned in this research, the key factors in successful implementation are: good planning; the honest assessment of the WSA capacity and the consequential contracting of experts to fulfil the roles and responsibilities they cannot; political support for FBW policy; and accountability.

Cost: R500 000
Term: 2002-2003

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 used in a wide range of applications, *viz.* disinfection of bacteria and viral inactivation, removal of iron and manganese, oxidation of organic pollutants, destruction of odours and tastes, improvement of colour and many more. Ozone is often the only feasible method for many of these water treatment problems. Secondary uses, e.g. treatment of industrial effluents and sewage, find equally wide application.

Historically, ozonation in South Africa was considered to be too expensive to find widespread use. Large-capacity ozone generators have to be imported, with the associated problems of maintenance and spare parts. Deteriorating water quality in South Africa will no doubt benefit greatly from the properties of ozone if the equipment is available locally at competitive prices.

The main aim of this project was the development of South African ozonation technology, to make ozonation available locally and test it on typical, eutrophic, water. The technology is novel (patented) and based on high-frequency surface corona discharge using proprietary materials. A range of ozone generator sizes of increasing production capacity was developed and are being commercialized. These range from an output of 2 g/h of ozone, to 1 kg/h units in the prototype stage. Inherent modularity allows easy expansion to larger throughputs. These units are now available for introduction into the marketplace. As these units are being sold at markedly reduced costs than comparable international units, a significant impact is expected in terms of increased use of ozone in applications where it had always been regarded as being too expensive.

Cost: R 398 000
Term: 2000-2001

Development of guidelines for the disposal of water treatment sludges to land

School of Applied Environmental Sciences,
University of KwaZulu-Natal

No 1148

In order to produce potable water from turbid primary sources it is necessary to remove suspended and dissolved solids, organic matter and other contaminants. Although slight variability exists between the actual methods used in the water treatment process, the underlying principles remain the same. The ever-increasing demand for clean water has led to an increase in the number and size of water treatment facilities around the world. A consequence of this is an increase in the production of water treatment residue (WTR), which requires suitable disposal methods. In many parts of the world, including South Africa, WTR has conventionally been disposed of in landfill but due to increased costs land application is becoming the preferred disposal method.

Land disposal is based upon a 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. The aim with this project was thus to produce research data which will assist in the development of environmentally acceptable guidelines for South African conditions for the disposal of water treatment residues to land, and to study the effect of land disposal of water treatment residue on the physical, chemical and fertility properties of soils and on the chemistry of the local groundwater and nearby surface waters. For this purpose a number of WTRs were subjected to laboratory analysis and their interaction with soils evaluated in pot and field trials.

This investigation has produced a considerable amount of data on the Midmar WTR and by extension on all similarly produced polymer WTRs. However, knowledge of the other WTRs investigated is restricted to the reported laboratory and glasshouse studies. The dangers of extrapolation from these to the field situation are indicated by the differences in phosphate and nitrate behaviour of the Midmar WTR in laboratory and field studies, problems experienced with Faure WTR in glasshouse studies due to high Mn levels and the high EC measured in the pot experiment using the Rand Water WTR. The problems with extrapolation to field situations are compounded for WTRs because they vary both spatially and temporally from the same treatment works. However, it is clear that the laboratory and glasshouse experiments exaggerate the problems and reflect worst-case conditions.

Despite this, it is also clear that all aspects of the work reported reveal a highly consistent result, i.e. that land application of WTR is safe and is likely to have no negative impacts on soils, vegetation or groundwater even at very high disposal rates that are unlikely to occur in the field. Indeed, it appears that the land application of WTR can have positive effects such as improving water retention in especially coarse-textured soils and increasing hydraulic conductivity in fine-textured soils, reducing P sorption in high P sorbing soils and increasing P sorption in sandy soils, increasing the sorption of heavy metals (thereby reducing their pollution threat) and increasing properties such as cation exchange capacity and plant-available Ca and Mg.

Notwithstanding the above, there are some aspects that require further investigation before formalised guidelines for the land disposal of WTR can be fully produced. However, the positive effects of land disposal of WTR clearly outweigh the assumed negative impacts that were the impetus behind this investigation. Thus, even without formalised guidelines, the results given in this report offer compelling evidence for DWAF to consider declassifying WTR in order that land disposal, with minimal regulatory control of the site, may be an approved option for water treatment authorities.

Cost: R663 000
Term: 2000-2002

Ultraviolet light in combination with cavitational flow

Rand Water

No 1224

Infections by protozoa, specifically *Giardia* and *Cryptosporidium parvum* are now accepted as a common world-wide cause of acute, self-limiting diarrhoeal disease

in the human host. The faecal-oral route, transmission of protozoa amongst humans and animals and the consumption of contaminated water are the principal modes of transmission.

UV treatment presents an ideal method of instantaneous disinfection, although it does not produce a residual concentration to maintain the microbiological water quality after disinfection.

Mice were used for the inactivation of bacteria and bacteriophages. The mouse infectivity results were as follows: Histopathological examination of the ileum of each mouse of each replicate was performed to determine *Cryptosporidium* infestation. Only two of the three positive control replicates were positive. This could be due to oocyst dosage being too low.

None of the three replicates, which received water treated with ultrasound plus UV light, had any positive mice. In the group that received the water that had been treated with ultrasound, one out of three replicates with three out of six mice was slightly positive. In the group where the water had been treated with UV light, one replicate out of three was positive. In the positive replicate five out of seven mice showed a moderate infestation. Two out of the six mice in the negative control group showed slight infestation with oocysts. The sections of ileum removed from the mice were stained with Giemsa stain to confirm that these organisms were *Cryptosporidium* and not coccoid bacteria.

UV and ultrasound treatment resulted in the highest percentage inactivation of micro-organisms and the lowest infestation of mice in both the experimental procedures. It can be concluded that the combined UV and ultrasound treatment was the best to inactivate *Cryptosporidium*.

Cost: R300 000
Term: 2001

Programme 2: Water treatment for rural communities
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 in Southern Africa has been demonstrated in **(WRC Project No. 1032)**. It has been shown that this technology offers an economic alternative to freshwater piping or transport. However, further investigations required were identified (also forming the aims of the project). These were:

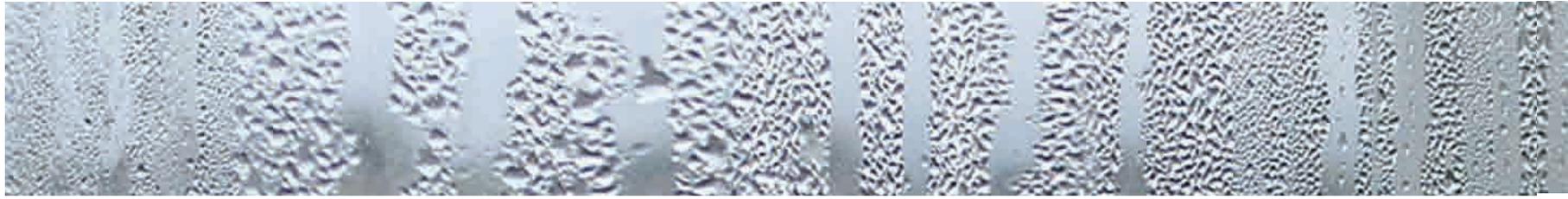
- The expected life cycle (durability) of equipment
- The bacteriological quality of the product water
- Performance improvement to increase winter-time water supply without increasing water production costs

Solar still units from an experimental solar still plant at Kerkplaas in the Klein Karoo were used for the durability study, whereas the other studies were performed at the University of Stellenbosch.

The durability of the stills was improved considerably by improving on the materials used and assembly method of the materials. A novel method of scale control was demonstrated. It was found that, although inactivation of bacteria in the basin is via thermal inactivation or solar irradiation, the principal mechanism for ensuring both biologically and chemically purified water is the process of distillation of the water, thereby separating the purified water from the basin water. The winter productivity increase measured in the laboratory, using various reflector configurations, did not translate into significant productivity gain in the field and these modifications would not be cost-effective. The project succeeded very well in making solar still units affordable to single households and these stills are seen to play an important role in the supply of potable water to small communities in the arid areas of the country.

Cost: R252 000
Term: 2002-2004

the visible difference



Programme 3: Drinking water quality

Systems for the abstraction of surface water through river sand-beds

Chunnett, Fourie and Partners (CE)

No 829

The term sand abstraction system could be applied to a wide variety of applications and different types of abstraction systems. This research has focused on the investigation into those systems used for abstracting water from river sand-beds, be it perennial rivers or ephemeral sand rivers. Although sand abstraction systems offer many advantages, the behaviour of these systems was found to be somewhat unpredictable and problems with reduced yield were experienced at some of the relatively large sand abstraction systems in Southern Africa. The erratic performance of these sand abstraction systems, together with the findings of the initial investigations into the cause of the problems have led to the initiation of this research.

Part of the research was to investigate typical problems that occur at sand abstraction systems and to determine whether there are any significant correlations between system performance and any other external parameters that might have an impact on system performance. This information were to be presented in such a manner that it could be used for the identification of potential problems that would cause reduced system performance and the risk of occurrence of such problems under prevailing conditions. After establishing the research objectives some hypotheses regarding the failure of sand abstraction systems were formulated. These hypotheses were based on published reports and articles on the performance of sand abstraction systems and practical experience. Further, a literature review was carried out on the application of sand abstraction systems, which included the relevant aspects of system performance and guidelines on the design, construction and O&M of sand abstraction systems as addressed in the objectives of the research. A comprehensive survey was also carried out to identify and log the characteristics of existing sand abstraction systems in Southern Africa.

In addition to the literature and field surveys some scale-model testing was conducted in a laboratory to evaluate the impacts of different parameters, such as screen types, sand density, abstraction rates and development, on the performance of a sand abstraction system. The data and test results obtained from this testing were analysed and are summarised in the relevant appendices to this report.

Although not all sand abstraction systems could be identified during the research project, a total number of 67 sand abstraction systems were identified, of which 39 were visited in the field. About 40% of the systems visited had vertical well points installed, whereas about 43% made use of horizontal well screens connected to a caisson or collector sump. The remainder of systems visited were mainly caissons installed in the riverbed or the riverbank.

The sand abstraction systems were mainly used for domestic water supply and in a few instances for irrigation purposes. The design yield varied from 2ℓ/s for a gabion type collector sump with horizontal well screens to 1 020 ℓ/s for a bank of vertical well points. About half of the systems experienced problems of low yield, while one third of them suffered from iron and manganese related problems. Only half of the systems with low yield problems also had iron and manganese related problems. About 20% of the systems experienced some known flood damage during construction or operation of the system. Only one of these systems, the biggest well-point system, with a design yield of 1 020ℓ/s, did not suffer from a reduction in yield after the flood event. Generally it was found that most of the sand abstraction systems were suitably designed from a structural and hydraulic point of view. However, the geohydrological aspects and the hydraulic flow through the sand formation were mostly neglected in the design of sand abstraction systems. Similarly not much attention was given to aspects such as O&M during the design phase

Cost: R544 346
Term: 1997-1999

Programme 4: Water distribution and distribution systems

Investigation of the performance of domestic copper pipe in coastal areas

Pipeline Performance Technologies

No 1208

There have been a number of so-called pinhole leaks of domestic copper piping in the past few years. Whilst their distribution has been random in general, there did appear to be an increase in the number of leaks occurring in the Blaauwberg Municipal area, and particularly in the Bloubergstrand and Melkbostrand suburbs, in the Cape Town Metropolitan Area. Leaks have occurred in piping that has been in service for many years, and in piping that has been in service for less than one year. It would also appear that the majority of the leaks have occurred predominantly in piping conveying cold water.

Thus, the aim of this study was to investigate a number of key factors which could be responsible for the problem. The investigation carried out shows that the observed corrosion failure of copper piping, resulting in pinhole leaks in the Western Cape cannot be attributed to any deficiencies or shortcomings in the actual piping materials nor in the composition of the water. In addition, the observed corrosion cannot be attributed to stray currents since they would only affect the external surface of the tubes and not affect the internal surface. None of the failed samples investigated showed flux as a contributing factor in the failure. All the observed pinhole failures of copper tubes in the Cape Town Metropolitan area were due to internal corrosion that ultimately led to perforation of the tubes. It is likely that the problem is being caused, or assisted, by the action of certain types of bacteria present in the water system. This can also explain why the pinhole leaks are being experienced in copper tubes of various ages. It is important to consider the concentration of residual chlorine in the water since if there is sufficient residual chlorine in the system, aerobic bacteria can be controlled. The results of this study are the same as those obtained in a similar study conducted in the USA during the same time period. In the USA study, further detailed work, and a pilot programme are being conducted in order to fully understand the pinhole corrosion problem.

Cost: R192 000
Term: 2001-2004

Integration of software packages for the probabilistic analysis of complex water supply systems

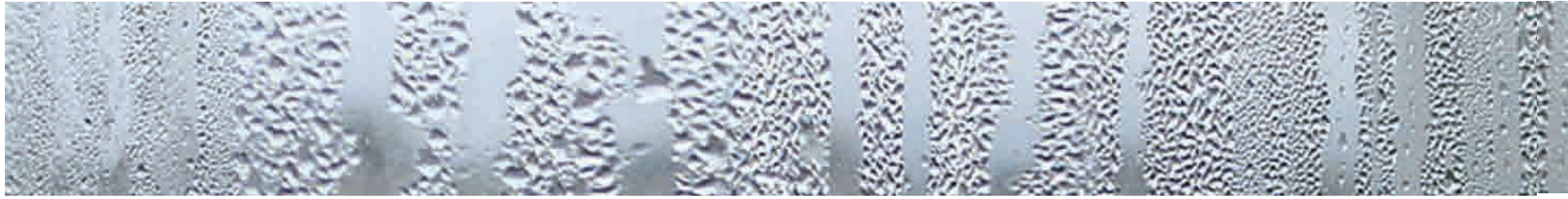
Department of Urban and Civil Engineering, Rand Afrikaans University

No 1389

The demography and water resources of South Africa are such that the vast majority of its inhabitants live a substantial distance away from the closest water source. This necessitates a vast, expensive and often complex network of bulk water supply systems (consisting mainly of pipes and storage tanks) to transport water from its source to the immediate neighbourhood of the consumers. With the current national emphasis on bringing water to the previous unserved communities (often those which are furthest away from existing sources), huge capital investments are being made towards new additions to the bulk supply systems. Ensuring that the systems are optimally designed to provide acceptable service at an affordable cost, is of obvious importance.

Current design standards for bulk water supply systems do not allow much design flexibility. Firstly, they generally do not allow the designer to differentiate meaningfully between urban and rural systems, and secondly they do not allow the designer the freedom to assume different levels of reliability. A small rural community, which had been limping along for many years with their own rudimentary water supply system, may opt for a cheaper system, even at lower reliability, since they have an alternative during the short periods of non-supply. Likewise, a large industry which can ill afford to shut down due to a water shortage, may opt for higher reliability, even if at higher cost.

For these reasons, a methodology was deemed necessary to allow the designer to couple reliability with system storage capacity. Whereas similar methods are commonplace in many other fields of civil engineering, e.g. hydrology, no such tools are generally available to designers of bulk water supply systems. This report aims to establish a solid theoretical framework for such a



probabilistic method, and to stimulate the use and further refinement of this approach in engineering practice.

The RAU (now University of Johannesburg) Water Research Group has developed methods for the probabilistic analysis of water networks for determining their reliability. Recently, the progress made over almost 10 years of research was integrated in a WRC report (**No. 985/1/02**) entitled: *Development of a Stochastic Technique for the Optimisation of Pipe and Reservoir Systems*. This project demonstrated the added power and insight brought to water systems analysis by the probabilistic analysis approach. The project also created a software package called Mocasim Version 1, with which simple, linear supply systems can be analysed. In summary, this project clearly established probabilistic analysis as a viable, necessary approach for the design of better, more efficient systems.
The biggest drawback of the first version of the Mocasim software is that it uses a simple mass balance model for calculating the flows in distribution systems, and does not incorporate the full hydraulic behaviour of these systems. While this approach works well for simple, linear supply systems, it is not adequate for the complicated hydraulic behaviour associated with most water distribution systems.

A need was therefore identified to include system hydraulics in the stochastic analysis methodology. This would allow complex bulk-water distribution and reticulation systems to be analysed and thus extend the reach of the stochastic analysis methodology substantially. This project was a response to this need.

In implementing the project, a number of technical obstacles had to be overcome to achieve the aim of hydraulically linked stochastic analysis of water distribution systems. Stochastic analyses require very long simulation runs, the ability to implement stochastic demands, fires and pipe failure events, and the ability to handle pressure-dependent demands and isolated network sections. This has resulted in two models:

Epanet

Hydraulic calculations were done using the hydraulic modelling package Epanet. Epanet was developed by the United States Environmental Protection Agency to help water utilities to better understand the movement and transformations undergone by water in water distribution systems.

Epanet can perform both snapshot (steady-state) and extended-period hydraulic analyses of incompressible flow in pipe networks. It can handle various hydraulic components including reservoirs, tanks, pipes, pumps and control valves. Epanet can also model water quality by simulating the behaviour of chemical constituents in the water distribution system with time. The Epanet hydraulic and water quality engine has become the standard for the modelling of water distribution systems and is used by several commercial software packages. Epanet also has its own user interface and is available as a stand-alone software package.

Epanet is public domain software and can be downloaded from
http://www.epa.gov/ORD/NRMRL/wswrd/epanet.html

Ooten

To provide an efficient interface between Mocasim II and the Epanet hydraulic engine, a programmers' toolkit called Ooten was developed. Ooten (Object Oriented Toolkit for Epanet) is an object-oriented shell for the Epanet source code. It gives programmers easy access to the Epanet source code functions through a number of objects and methods.

OOTEN was developed in standard ANSI C++ code and can be incorporated in any compatible programming code. It was developed for this project, but is generic in nature and can be used for any software project in which hydraulic calculations needs to be performed. For this reason Ooten was developed as a stand-alone code library with a comprehensive help function.

The Mocasim II software uses Ooten to handle hydraulic simulations of water distribution systems. Long simulation runs are implemented by repeatedly running a daily simulation in Epanet. Continuity is ensured by updating

the starting tank levels to reflect the ending levels of the previous day.

Stochastic demands and fires are calculated in advance for a day and implemented in using standard Epanet demand patterns. Pipe failure events are implemented by closing pipes using controls.

Cost: R120 000
Term: 2002-2003

Benchmarking leakage
WRP Consulting Engineers
No 1447

In an attempt to get a better handle on the level of leakage at a municipal and national level, this study was undertaken in order to assess the levels of leakage in various water utilities throughout South Africa. The standard water auditing model BENCHLEAK, previously developed through a WRC study, was used for the analyses since it is relatively simple to use and follows the standard IWA and BABE leakage benchmarking methodology. BENCHLEAK introduces the concept of Infrastructure Leakage Index (ILI) as a standard method for the purpose of leakage evaluation, as it has been found to be the most reliable and meaningful indicator. The effect and impact of ILI is presented in the figure below for 27 of the water utilities considered in this study.

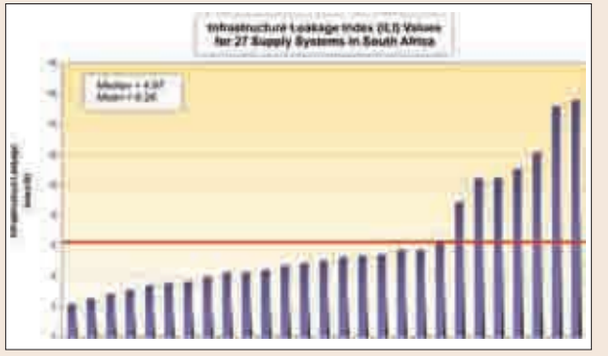


Figure 1: ILI results for 27 systems in South Africa

From the figure it can be seen that the ILI values for the South African data range from 2.0 to approximately 15.5 with an average value in the order of 6.0. This data-set can now be compared to several other international data-sets compiled by various WDM specialists from around the world and the corresponding results for the UK, North America and Australia are provided in the main report.

In this study, data from approximately 60 water suppliers were obtained and after careful screening the sample data-set was reduced to 30 suppliers. For each supplier, various performance indicators were evaluated. From this data it was concluded that:

- The South African water supply industry is generally lagging best international practices with respect to leakage management in potable water distribution systems.
- The information required to calculate the various performance indicators used in this case study is often not available from the water suppliers, despite the fact that the information is very basic
- While the benchmarking procedure was initially developed for complete water distribution systems, the same approach can easily be used for individual management zones within a single supply system if there are more than 2 000 connections and the zone is relatively homogeneous. In this manner this approach can be used to identify problem management zones within a system as well as to compare one system with another.
- Water supply systems in South Africa are poorly metered with regard to both bulk and consumer metering
- For South African conditions it would be unusual to achieve an ILI value of below 2.0 and values in the order of 5.0 are common and represent systems in a reasonable condition

Cost: R 250 000
Term: 2003-2004

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

Algal integrated ponding system (AIPS) technology was introduced to the RSA from the USA by the WRC as a promising low-cost alternative wastewater treatment technology eminently suitable for South African conditions. To demonstrate the feasibility of the process, the WRC sponsored **Project No. 651** entitled **Appropriate low-cost sewage treatment using the advanced algal high rate oxidation pond (AHROP)**, in which the main aim was to construct a demonstration plant to prove the underlying principles of the AIPS process and to effect technology transfer. The plant was officially opened at Grahamstown by the Minister of DWAF, directing the attention of decision makers to the potential application of AIPS in the government's RDP programme. The plant was designed for a population equivalent of 500 people and consists of a primary facultative pond incorporating a submerged fermentation pit followed by two high-rate algal ponds (for research purposes), an algal settling pond and an algal drying bed.

This **Project No. 799** constituted the second phase of AIPS technology development, involving a monitoring programme to collect operational data and a first-order assessment of both potential problems and opportunities for process improvement under South African operating conditions. The specific aims were to undertake a comprehensive monitoring programme on the integrated AHROP plants constructed for treatment of tannery, sewage and abattoir effluents to establish confidence limits for these novel systems; to evaluate and recommend parameters for optimisation of the process; to report on the value-added potential of algal biomass produced in AHROP systems; and to report on constraints and future research needs relating to the wide-scale application of AHROP technology.

The findings of the project led *inter alia* to the development of the independent high rate algal pond (I-HRAP) as a free-standing wastewater treatment unit operation. The I-HRAP may be used in a number of applications, including both renovation of raw wastewaters and tertiary treatment operations for nutrient removal. Algal biomass recovered from I-HRAP systems was demonstrated to be a viable feed source for aquaculture operations, opening up the potential for community benefit enterprises integrated with wastewater management. A number of shortcomings in the (then) current design of AHROP/I-HRAP systems were identified, for example low and unreliable anaerobic digestion under shock loading conditions, due to poor sludge retention characteristics. Significant opportunities for extending the applications of algal ponding technology were also identified, including the potential for nutrient (nitrogen and phosphate) removal from domestic and industrial wastewater, for rapid alkalisation of acidic industrial effluent; and for odour control on anaerobic waste stabilisation pond installations.

The final report on this project (**No. 799**) along with the final reports on **Projects 1073** and **1362** (due 01/04/05), is to be published as **Report 7** in the series *Salinity, Sanitation and Sustainability-A Study in Environmental Biotechnology and Integrated Wastewater Beneficiation in South Africa* (ISBN Series 1-86845-853-9, **Volume 3**, Part 4: *Integrated Algal Ponding Systems and the Treatment of Domestic and Industrial Wastewaters-System Performance and Tertiary Treatment Operations*.

Cost: R510 000
Term: 1997-2001

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

Algal integrated ponding system (AIPS) technology was brought to the RSA from the USA by WRC as a promising

low-cost alternative wastewater treatment technology eminently suitable for South African conditions. To demonstrate the feasibility of the process, the WRC sponsored **Project No. 651** entitled **Appropriate low-cost sewage treatment using the advanced algal high rate oxidation pond**, in which the main aim was to construct a demonstration plant to prove the underlying principles of the AIPS process and to effect technology transfer. The plant was officially opened at Grahamstown by the Minister of DWAF, directing the attention of decision makers to the potential application of AIPS in the government's RDP programme. The plant was designed for a population equivalent of 500 people and consists of a primary facultative pond incorporating a submerged fermentation pit followed by two high rate algal ponds (for research purposes), an algal settling pond and an algal drying bed.

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

This project (**No. 1073**) aimed at a scale-up evaluation of laboratory findings indicating potentially improved performance of the AIPS anaerobic pit digester utilising UASB-type configurations, and at developing the application of the AIPS high rate algal pond as a free-standing tertiary treatment unit operation for nutrient removal from sewage effluents. These aims were accomplished and reported on to the Project Steering Committee. The final report on this project (**No. 1073**), along with the final report on **Projects 799** (out) and **1336** (due 01/04/05), is to be published as Report 7 in the series *Salinity, Sanitation and Sustainability-A Study in Environmental Biotechnology and Integrated Wastewater Beneficiation in South Africa (ISBN Series 1-86845-853-9,* ***Volume 3****, Part 4: Integrated Algal Ponding Systems and the Treatment of Domestic and Industrial Wastewaters-System Performance and Tertiary Treatment Operations*.

Cost: R942 000
Term: 1999-2002

Computational fluid dynamic support to water research projects
Pollution Research Group, University of KwaZulu-Natal
No. 1075

Almost all water treatment equipment relies on the flow of water through equipment and tanks. This equipment and tanks are, however, not always optimally designed because of the inherent intricacy of the process, the flows and the fluids flowing through these units. Computational fluid dynamics (CFD) is a technique whereby the liquid volume in a process unit is divided into thousands of little cubes. The hydraulic conditions are subsequently determined or estimated at each of these little cubes and mathematically plotted to provide an integrated picture of, for example pressure or flow direction, at each location in the liquid volume. This project was initiated as a "service" to other research projects endeavouring to improve water treatment equipment through CFD modelling exercises. The aims were to improve modelling of water treatment plant and equipment by the use of this powerful technique, and to promote the use of CFD by water suppliers, consultants, water researchers and students. In this project, CFD was employed to improve operation and/or design of an ozonation contact tank, a sand filter backwash system, a potable water treatment settling tank and a secondary sewage treatment settling tank.

These studies showed that CFD can be used successfully in characterising a variety of water and effluent treatment

process containers. Because of the fundamental nature of CFD, detailed flow patterns can be obtained, which often explains aspects not possible with other methods, such as residence time distribution methods. However, it is advisable that CFD is always done in conjunction with residence time distribution analysis in order to achieve additional benefit. The disadvantages of CFD are that the compilation of the model can be time consuming and thus expensive, and that, by nature of the complexity of the equations generated, highly skilled people are required to perform these studies successfully. In spite of these disadvantages, this project has demonstrated that CFD can be used successfully in practice and that the technique will impact positively in future to improve both the design and operation of intricate liquid processing equipment and plant.

Cost: R795 000
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

Process engineers and wastewater treatment plant operators have traditionally used mixed liquor suspended solids (MLSS) and in particular, mixed liquor volatile suspended solids (MLVSS) to indicate the concentration of biological mass (biomass) in the activated sludge system. However, these measurements do not take cognizance of the fact that a certain fraction of the reading consists of unbiodegradable particulate and inert organic matter and either dead or metabolically inactive organisms. Only the *active* heterotrophic biomass component mediates the biodegradation processes of COD removal and denitrification, and the rates of these processes are therefore directly related to the *active* heterotrophic biomass fraction present in the mixed liquor.

To account for this activity factor, activated sludge design and kinetic simulation models use "heterotrophic active biomass" as a model-fitting parameter but, although theoretical estimations derived from the simulation models and oxygen utilization measurements derived from batch test procedures support one another, the parameter has little structured or physical meaning at present, primarily due to the lack of suitable direct experimental or measurement techniques. Conventional cultivation techniques are not sufficient for total community recovery (only 5 to 15% of total bacteria can usually be recovered even when using optimized media).

The overall objective of this project was to utilise new molecular biology techniques to directly measure the active heterotrophic fraction in activated sludge and to correlate these measurements with steady-state model and respirometric batch-test values. Specifically, as indications of heterotrophic activity in activated sludge, the relationships between the RNA/TNA (ribonucleic acid / total nucleic acid) index and FISH (fluorescent *in situ* hybridization) measurements with rRNA-targeted nucleic acid probes were explored experimentally, and a coefficient for converting cell numbers to VSS units was determined. This project was coordinated with two other concurrent WRC projects, viz. **Activity of heterotrophic and autotrophic biomass in BNR activated sludge, (Report No. 1179/1/2002) and Microbial characterization of activated sludge mixed liquor suspended solids (Report No. 1191/1/03)**.

The relationship between ribosomal RNA/cell and metabolic activity reflected by the oxygen utilization rate (OUR) was investigated in pure culture studies and in several natural mixed populations in a variety of environments. Respirograms of OUR and RNA/cell vs. time showed an appreciable drop in RNA/cell after the cessation of metabolic activity, confirming the validity of the rRNA molecule as a target for detecting active biomass. Community analysis of the activated sludge using FISH displayed a more realistic (higher) degree of diversity in the microbial community compared to cultivation-dependent enumerative methods. To compare the FISH results with engineering model outputs, conversion factors between cell numbers and VSS mass units were determined for 12 monocultures. The mean VSS/cell value found was 8.49 x 10^{-11} mg/cell, with a range from 4.4-16.2 x 10^{-11} mg (reflecting the variation in bacterial cell size (mass) with species and growth rate). Using this mean conversion

factor, active heterotrophic biomass estimations from OUR batch tests were compared with molecular probing results. The researchers concluded that there was a close correlation between the values from the two methods, with differences being ascribed to sensitivity in the regression analysis of logarithmic OUR data.

The results obtained demonstrate that molecular biology can be a powerful tool for the direct determination and separation of activated sludge mixed liquor components. A cross-link between the engineering and microbiological paradigms has been developed with the *in situ* measurement of heterotrophic biomass, although further work will be required in order to tighten up on confidence limits in the relationships explored between molecular biology parameters and engineering models.

Cost: R875 000
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

To comply with more stringent effluent legislation, engineering (design) and technology (implementation and operation) of activated sludge systems have been advanced over the past two decades to progressively include the biological removal of carbon (C), nitrogen (N) and phosphorus (P). In the mathematical models developed, the mixed liquor organic (volatile) suspended solids (MLOSS) in the bioreactor is made up of the active biomasses of the ordinary heterotrophic organisms (OHO), autotrophic organisms (AO), phosphate-accumulating organisms (PAO-in biological excess phosphorus removal (BEPR) systems), their endogenous residues, and inert material. The active biomass components of the MLOSS mediate the biological processes: OHOs for chemical oxygen demand (COD) removal and denitrification, AOs for nitrification and PAOs for BEPR and COD removal. Specific rates for the biological processes should thus be expressed in terms of the appropriate active biomass concentrations. Historically, however, MLOSS has been measured as a lumped parameter, via standard volatile suspended solids (VSS) or COD tests, and specific biological rates have been expressed in terms of this lumped parameter. In kinetic simulation models, active biomass concentrations are included as hypothetical parameters on a mass balance basis, but, crucially, although there is consistency between observations and predictions over a wide range of conditions, biomass activity parameters have not been directly determined experimentally due to the lack of suitable experimental techniques.

Specific aims of this project were to measure the OHO active biomass concentration in biological nutrient removal activated sludge (BNRAS) systems using engineering techniques (UCT, this project 1179), and to link these measurements with new microbiological and biochemical analytical techniques for studying micro-organisms *in situ* in activated sludge (UP, **Project No. 1191**, by measuring the biochemical compound ATP, and DIT, **Project No. 1178**, using a combination of staining (DAPI) and fluorescent *in situ* hybridisation (FISH) to determine both OHO and AO active biomass concentrations. The UCT group operated parent BNRAS systems under closely controlled and defined conditions (enabling the theoretical OHO active biomass concentration to be calculated) and carried out aerobic batch tests (to quantify OHO active biomass concentration through monitoring oxygen utilization rates on mixed liquor samples drawn from the parent BNRAS systems).

From a comparison of the results for OHO active biomass concentrations from the various research groups, it was found that:

- The engineering methods of UCT gave mixed results, with a close correspondence between measured and theoretical values in the parent BNRAS systems but only around 25% of the theoretical values in the aerobic batch tests (with no obvious explanation)
- The ATP method applied by UP gave OHO active biomass concentrations 3 to 6 orders of magnitude smaller than both the theoretical and measured values (suggested to be due to suspended solids interfering in some manner with the ATP measurement method)

- The DAPI/FISH method applied by DIT gave OHO active biomass concentrations only 3 to10% of theoretical and measured values (suggested to be due to storage of samples in dry ice causing bursting of a significant number of cells and thus reducing the DAPI/FISH cell counts being investigated further in WRC contracts **No. K5/1178** with DIT and **No. K8/453** with UCT)

The research in this contract has for the first time placed the magnitudes of the newly developed microbiological/biochemical analytical techniques for determining OHO active biomass concentrations within the context of the engineering/technology platform for activated sludge systems. Despite the lack of convergence at this stage between the two methodologies, the cross-linkages initiated hold the promise of making quantitative information available from the new microbiological/biochemical analytical techniques to potentially improve the engineering / technology design and simulation models developed for activated sludge systems. This will provide greater surety in the mathematical models for design and operation of these systems, and the research should be continued under future WRC-guided projects.

Cost: R322 600
Term: 2000-2001

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 objectives of this study were to attempt to establish the minimum flush volumes required to achieve both liquid and solids separation in digesters as well as the anaerobic digestion/fermentation of the separated solids. The literature predicts that on-site digesters behave in a manner that produces a low-solids effluent, and this has resulted in the use of these systems in conjunction with subsoil drains, and solids-free sewers, both of which clog if solids are introduced. The primary mechanisms in removing the solids are settlement and anaerobic digestion.

The project consisted of three separate experimental approaches comprising:

- Batch reactor experiments that were designed to investigate the effects of increasing ammonia concentrations, achieved by both increasing the volume of urine added as well as decreasing the volumes of dilution, representing different flush volumes on the degradation of faeces. The difference in the reaction rates was to be measured using acidified water displaced from inverted measuring cylinders.
- The use of respirometery, and specifically the Micro Oxymax™ Respirometer to record the differences in the respiration rate of different combinations of urine, faeces and water with similar objectives as the batch reactors
- A set of digesters with different shapes and volumes receiving different flush volumes to establish whether shape and residence time influenced the performance of the digesters, using effluent quality parameters, COD, TSS, ammonia and TKN concentrations (measured in the free water in the tank) as an indicators of performance

The results of the batch reactor trials were inconclusive due to experimental set-up problems encountered that could not be resolved within the time and budget constraints of this project. However, indications from the batch reactor trials are that effective solids settling can significantly reduce both the COD and nitrogen content in the final effluent.

Findings from the batch reactors conclude that settlement of solids is more important than biological digestion in reducing the COD and nitrogen content of the effluent.

Due to the sensitivity of the methane and carbon dioxide sensors, it was not possible to obtain meaningful results under anaerobic conditions using the respirometer. As these conditions prevail in digesters, the results obtained under aerobic conditions cannot be used to derive any information that can be applied to the objectives of the research project.

The study concludes that the respirometry technology is not suited to use with samples with such low rates of activity.

With respect to on-site digesters the project was not able to determine how on-site digesters would behave with flush volumes of less than 9ℓ because it was not possible, within the project budget to reduce flush volumes in the toilets and the experimental on-site digesters did not behave as anticipated with the 9ℓ flushes, so that a reduction in flushes would not have produced useful comparative data. Indications that the addition of sullage positively impacted the behaviour of the digester could not be fully explored as the project period was not long enough to allow the digesters to stabilize under the altered loading conditions.

Despite the shortcomings, the project revealed, specifically the full-scale digesters, that digesters may not always behave in the way classically described, namely separation into three distinct zones, a scum layer, a relatively solid-free layer followed by a sludge layer on the bottom. Under the operating conditions, all the solids became trapped in a floating scum layer.

There are three conclusions of value which can be drawn from this aspect of the project, namely:

- The high proportion of paper found in the effluent from institutional uses, such as office blocks, hospitals, schools will result in the digester behaving as a store of faecal matter rather than an anaerobic digester
- An increase in the amount of water into the digester delays the on-set of the formation of a faecal plug, indicating that an increase, rather than a reduction, in the flush volume is required, and lastly
- The proportion of indigestible matter, such as paper, and water is a more important criterion than water only.

The question arising from this study is as to whether it would be worthwhile to attempt further work on the impact of flush volumes in on-site digesters with a larger budget and more sophisticated experimental techniques. The following recommendations are made:

- The use of respirometry would have no value due to equipment unsuitability at this state
- The use of laboratory scale batch reactors may have some value if the reactors can be run for much loner periods and the problems of reflux can be resolved. There may be some value in increasing the size of the reactors considerably to improve the measurability
- There is value to be gained in running further experiments with on-site digesters. Initially such experiments should be focussed on establishing the paper:/water ratio at which settlement occurs, after which biological activity aspects could be studied. However, considerable changes to the experimental methodology would be required to allow for exact measurement of inflows and inflow and outflow characteristics (controlled measurement of paper use, faecal load, water use) characteristics, increased monitoring of the timing of key events in the digesters, etc. The period for which digesters need to be run under specific conditions should also be increased considerably.

If the observations of the behaviour of solids in the current study were to be confirmed it could have implications for the design of digesters where solids separation via flotation and filtration is encouraged as opposed to settlement and digestion.

Cost: R266 000
Term: 2001-2002

Programme 2: Sludge characterisation, treatment, utilisation and disposal

An evaluation of dedicated land disposal practices for sewage sludge

Institute for Soil, Climate and Water, ARC

No 1209

Most of the wastewater treatment facilities in South Africa dispose of their sewage sludge on dedicated land disposal (DLD) sites (sacrificial lands), since this is the quickest and cheapest way to get rid of the waste. The sludge is regularly applied at high rates to the surface soils. No crops are grown and the land is only used for the disposal of sewage sludge. The practice is not viewed as sustainable and its

impact on the environment is believed to be negative. This project was undertaken to evaluate the extent of the current practice and its potential present and future pollution risk it poses to the water environment.

A survey was undertaken in conjunction with **Project No. 1283** to determine the current extent of sacrificial land disposal. Stockpiling is used by most of the sewage treatment facilities (40%), either as the only disposal method or a means to store the dried sludge until it is utilized by farmers and municipalities, disposed of in landfills or composted. Another 40% apply liquid sludge to soils through practices such as irrigation, flooding, sludge ponds, instant lawn irrigation and paddies; 30% of the DLD sites were on sandy soils with a high leaching potential and only 11% on soils with sufficient adsorption capacity to impede groundwater pollution. The majority of topsoil samples had above average macronutrient and organic carbon contents, and 65% of samples had pH-water values <6.5; 88% of the topsoil samples had at least one element that exceeded the Dept of Health's maximum permissible level (MPL) for beneficial use of soils (It should be kept in mind that no MPCs exist in SA for dedicated land disposal practices). Nickel was too high in most of the samples, followed by Zn and Pb. Other elements present in high concentrations were Cd, Cr and Cu.

Of 40 representative sites selected for further detailed studies, 23 had a P-content that was above average for normal soils, none had above average N-content (but of the 9 sites monitoring groundwater, 7 had nitrate levels exceeding DWAF water quality guidelines), while 60% had an organic C-content exceeding 1.2%. Of the 40 sites, 30 had at least one heavy metal that exceeded the MPL for beneficial use of soils. The topsoil Cr-level exceeded the concentration in 50% of sites, Ni in 45%, Zn in 40%, Pb in 35%, Cu in 30%, and Co and Cd in 25% of sites. The NH_4EDTA extractable metal fraction, which provides a measure of potentially bio-availability, indicated a small medium term risk of metals entering the environment. On the other hand, the exchangeable (NH_4NO_3 extractable) Ni, Zn and Cd concentrations are reason for concern because 23-45% of the sites had concentrations above the NH_4NO_3 guidelines Germany set for groundwater protection, indicating a short term risk for groundwater pollution.

A geochemical contaminant fate-and-transport model that was used to simulate the risk of dedicated land disposal on the water environment indicated that sludge-derived humic and fulvic acids can mobilise metals down the soil column and into the groundwater and that hydrous ferric oxides, on their own, will not suffice to immobilise metals. A further finding with potentially far reaching implications is that only when the soil has an appreciable amount of particulate organic matter in it, does the metal ions remain attenuated in the upper soil layers.

Cost: R595 000
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

Sewage sludges typically comprise ≤1% of the total volumetric flow in sewage treatment plants, while their treatment may represent 30 40% of the total costs of the sewage treatment. Primary sewage sludge (PSS) comprises the largest fraction (approximately two-thirds) of the solids. These sludges required to be treated before disposal, and anaerobic digestion is most commonly employed to achieve a stabilized sludge with low residual volume. Anaerobic digestion systems can be operated methanogenically (producing methane and carbon dioxide as the final products); sulphidogenically (reducing sulphate to sulphide) or acidogenically (where neither methanogenesis nor sulphidogenesis occur significantly and the end products are volatile fatty acids (VFAs) i.e. soluble COD). Methanogenic systems are most widely used for sludge treatment (PSS and other). Conventionally, in such methanogenic systems, acidogenesis and sulphidogenesis are considered undesirable-respectively resulting in loss of methane production and generation of odour. More recently, however, in both situations PSS has been considered as a potential beneficial source of substrates (VFAs) for downstream biological nutrient removal (BNR) activated sludge systems, or in the biological reduction of sulphate in the treatment of sulphate-rich acid mine drainage (AMD) such as in the

Rhodes BioSURE™ process where the PSS acts as the electron donor and organic carbon source, with the concomitant production of sulphide and carbonate alkalinity.

The principal aims of this study were to determine and compare the rate of hydrolysis of PSS under methanogenic, acidogenic and sulphidogenic (sulphate-reducing) conditions, to determine the influence of system operating conditions (feed COD concentration, hydraulic retention time and pH) on hydrolysis rates, and to develop a mathematical model for the biological processes mediating PSS hydrolysis in these systems, so that the rate of hydrolysis can be predicted for various operating conditions. The research approach adopted was to operate six parallel laboratory-scale completely-mixed anaerobic digesters with PSS as influent, and to monitor the behaviour of these systems under a range of feed COD concentrations, retention times, pH and feed sulphate concentrations under stable methanogenic, acidogenic and sulphate-reducing conditions.

In the investigation, an extensive data set was collected on anaerobic digestion of PSS under methanogenic, acidogenic and sulphate-reducing conditions, at varying retention times, feed concentrations and pH values. To quantify the volumetric rate of PSS hydrolysis in these systems and to provide a common and systematic basis for comparisons of the hydrolysis rates, a logical mathematical framework was developed in terms of mass balance principles and characterisation of the PSS feed. A simple unified first-order kinetic model was developed to describe PSS hydrolysis under methanogenic, acidogenic and sulphidogenic conditions. The model takes into account the effects of retention time, feed COD concentration and pH, validated both on data collected in this study and on data from independent studies.

In addition to the valuable kinetic and stoichiometric data obtained, which underpin other WRC research programmes in this area, the study also yielded a conclusion of great practical significance, viz. that the rates of PSS hydrolysis under methanogenic and sulphate-reducing conditions are closely similar (but significantly reduced under acidogenic conditions). This result confirms that the Rhodes BioSURE™ process, in which the core rate-limiting reaction is hydrolysis of PSS to soluble organics such as VFAs for subsequent use by sulphate-reducing bacteria, can be competitively deployed for PSS digestion.

Cost: R250 000
Term: 2001-2004

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

Heavy metals are the single most significant factor limiting the agricultural utilization of sewage sludge. Even sludges from predominantly domestic wastewater still have difficulty in meeting the quality criteria proposed in the 1997 sludge disposal guidelines. This project aimed to evaluate different analytical methods with which to characterize the metal content of sludges, to conduct a survey on the metal and plant nutrient content of South African sewage sludges, to classify sludges according to the present guidelines and to determine the impact of the existing guidelines on disposal options.

Seventy-two wastewater treatment plants were selected to represent different sludge types and sludge handling technologies. Samples from these plants were analysed for microbiological, nutrient and potentially toxic metals and elements (PTME) content using four extraction methods.

The response to questionnaires revealed a lack of information and knowledge at plant level regarding responsible sludge management practices and sludge characterisation requirements. This was particularly evident in rural areas. Anaerobic digestion of primary and humus sludge is still employed to stabilise the majority (57% mass basis) of the sludge included in the survey. The majority (74% mass basis) of the surveyed sludge is not treated further than the traditional anaerobic digestion and activated sludge treatment. The classification of the sludge revealed that 51% of the sludge surveyed was a Type B sludge, 24% was a Type A sludge, 14% complied to a Type

C sludge and the remaining 11% complied to a Type D sludge.

In comparing the efficiency of extraction methods (aqua regia (total), EPA 3050 (total), TCLP (leachable) and Parr Bomb (total)) the aqua regia method was found to extract higher levels than the EPA 3050 method.

None of the plants surveyed exceeded the TCLP (leachable) concentration limits as specified in the **Addendum** of the 1997 *Sludge Guidelines*. However, the results from the total PTME extractions showed a different picture. The major PTMEs of concern are Ni and Zn. Respectively 61% and 44 % of the total mass of sludge exceeded the Ni and Zn limits. 40% of the sludge did not exceed any of the total PTME limits, 35% exceeded on one or two PTMEs and only 4% exceeded the limits for more than 7 of the 12 PTMEs analysed for.

Thirty-three plants were sampled both in this study and in a survey done in 1989. The largest changes in compliance of the sludges included in the two studies, were evident for Ni and Pb. Compliance to the Ni limit increased, while compliance to the Pb limit decreased substantially. However, these findings could not be verified when all the data from both studies was analysed and compared.

The major impacts emanating from this project are that analytical procedures for extracting PTMEs can now be standardised by regulating authorities, that the TCLP limits that had been introduced in the 1997 guidelines have little value, that not much progress has been made during the past 15 years in reducing the PTME content of sewage sludges and that their presence will thus remain a significant factor limiting the agricultural utilization of sewage sludge.

Cost: R524 000
Term: 2001-2002

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

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

DB Thermal (Pty) Ltd.

No 1081

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-mono culture in an open reactor, without any sterilisation, while simultaneously purifying the water. The WRC has already funded 3 projects where filamentous organisms were used for the purification of industrial effluents. The last such project (**Project No. 535**) showed that the process is viable for the treatment of a specific effluent containing acetic acid, of which there are many typical examples in the world. Subsequently, attempts have been made to commercialise the process, with a lot of interest from industry. However, when making comparisons with other technologies and when full-scale estimates were done, one aspect became clear: Unless a value can be fixed to the biomass, i.e. whether it can be used as animal feed and at what cost, the risk is too high for industry to invest money in further optimisation and full-scale implementation of the process.

In order to finalise the work that was sponsored so far by the WRC, animal feeding trials have to be done on the biomass to assess its commercial value. With a value fixed to the biomass, the process can be properly marketed and the technology transferred. If the process can be applied successfully in only a few industries in South Africa, approximately 30% of the imported protein (in the form of fish meal or oil cake) can be replaced by a product that is produced as byproduct from a water purification process.

The aims of the project include the following:

- Determine the value of the biomass as protein source in the diets of pigs
- Determine the value of biomass as protein source in the diets of broilers
- Detect any toxic effects caused by the *Aspergillus* biomass
- Detect any growth deficiencies caused by the *Aspergillus* biomass
- Determine a market value for the biomass produced, to enable the final introduction of the process into the industry

- Continue with proper monitoring of the pilot plant in order to accumulate enough data for design of a full-scale plant

Pilot-plant operation was continued at the Illovo, Sezela plant in KwaZulu-Natal and the single-cell protein produced was evaluated as an animal feed by the ARC. Feeding trials were performed on broiler chickens and weaner pigs-which were regarded as a potential market for the protein.

It was found that *Aspergillus fumigatus*, in the form presented to the ARC for evaluation as an animal feed, was not toxic and did not pose a health risk to animals that were fed on a diet that contained *A. fumigatus*. Further, it was reported that *A. fumigatus* could safely and successfully be included into the diets of weaner piglets and broiler chickens on which testing had been carried out. However, the pilot plant operation was not optimized yet and would require further investigation. Overall, (in spite of the administration problems experienced) the project could be described as a success, paving the way for the use of fungal-based single-cell protein production for animal feed as a by-product from industrial effluent purification.

Cost: R196 000
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

The South African vegetable oil industry reportedly uses around $2x10^6$ m^3 of water per year with about 40% of the water taken in being discharged as industrial effluent. The quantity and physico-chemical characteristics of the effluent produced vary for different refineries, but in general there is a high pollutant profile due to pH and high concentrations of COD, greases and (in some cases) phosphates. Three distinct types of effluents are generated: from crude oil production, from oil refining and from packaging (washing and spillages from bottling). South African oil industries generally apply physico-chemical methods for treatment of the effluent: chemical dosing for pH control and physical separation of oil and greases, for example by dissolved air flotation (DAF). Even after such treatment the remaining emulsified greases tend to clog sewer pipes and pumps and the high COD and phosphates create shock loading problems for receiving wastewater treatment plants.

Some vegetable oil industries are considering biological methods in addition to the existing physico-chemical treatment practices. A multistage anaerobic / aerobic process is envisaged in which COD in the effluent is first reduced anaerobically with minimum production of biomass (waste) and phosphates are then removed aerobically, thus producing a good quality effluent. Information on biological treatment of vegetable oil effluent is however scant, and this project aimed at developing a treatment protocol for a combined aerobic-anaerobic process.

Studies conducted using an aerobic-anaerobic sequencing batch reactor with a total hydraulic retention time of 24h gave an average of 75% reduction of COD and more than 90% removal of fats, oils and greases (FOG). Based on these results, a laboratory-scale activated sludge effluent treatment process was designed and operated with two bioreactors (aerobic and anaerobic) in series. Over the study period, the optimum performance achieved was 75% removal of COD, 107 mg/_ reduction in phosphate and more than 95% reduction in FOG. Chemical pre-flocculation would still, however, be required in practice, and a costing analysis indicated that just the chemicals for operating such a biological treatment process (i.e. excluding other items such as capital equipment, power, labour, etc.) would cost around R160/ k_ of effluent, compared to an estimated tariff cost of R24/ k_ for discharging untreated effluent to sewer. There is thus no prospect of implementing the proposed end-of-pipe treatment 'solution' at present as the costs involved are in fact a disincentive.

The project also illustrates graphically, by default, one of the strengths of the alternative 'cleaner production'

approach of waste reduction at source. A major part of the original research programme planned by the researchers was for biological phosphate removal from the effluent, which would have entailed expensive end-of-pipe treatment technology. This need was eliminated completely when the factory concerned, for processing reasons, changed from using phosphoric acid to an alternative oil refining method using caustic soda. This is a good example of a process modification or chemical substitution reaping environmental benefits in respect of the effluent generated a generic option routinely considered in cleaner production protocols.

Cost: R350 000
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

Contamination of soils, groundwater and surface water with toxic and hazardous chemicals, such as phenols, is one of the major problems facing the industrialised world today. The destruction of phenols by white rot fungi, and the enzymes produced by these fungi, has been the topic of much research. The objective of this study was to focus on the integration of an optimised process of enzyme production and phenol degradation by the fungi Trametes versicolor and *Trametes pubescens* with an airlift loop reactor for the large-scale production of these organisms. The physiology of these organisms had to be studied first before any bioreactor work could commence. Bioreactor research consisted of immobilising the fungi onto membranes as well as airlift loop reactor studies. The breakdown of chlorinated aromatics and phenolics produced by the pulp-and-paper and petroleum industries were studied in bench-scale reactors. The integrated fungal reactor systems succeeded in removing phenols from these effluents over an extended period of time. The combination of the airlift loop reactor and the efficiency of the *Trametes pubescens* fungi were especially efficient and form the basis of an effective bioremediation process, which will impact positively on the capability of industry to address pollution by phenolic compounds. Considerable international interest has been shown in this project.

Cost: R533 000
Term: 2000-2002

Membrane reactor for the electrocatalytic minimisation of organic matter in water and effluents
Department of Chemistry, University of the Western Cape
No 1231

The nature of pollution and potential threat to human and aquatic life caused by organic pollutants, especially aromatic compounds, has led to research being conducted on developing new methods for the treatment and management of organic pollutants in water. The research discussed in this report is based on the development of a novel method for the degradation of organic compounds in water. The process is based on a flow-through system, which uses the combination of electrochemistry and membrane technology.

Ceramic-based membranes were modified to exhibit properties for conducting electricity by deposition of various kinds of electro-conductive layers on the membranes' surfaces. Electro-membrane reactors based on tubular ceramic membranes and flat sheet type ceramic membranes were designed and constructed. These purification units were used to study the electrochemical oxidation of aqueous phenol under different pH conditions, applied potential, flow rate and different types of materials that were coated on the membranes. Suitable electro-conductive materials were selected from an array of materials, with respect to their electrical stability, ease of preparation and deposition onto the ceramic substrate. A thin layer of the desired electro-conductive material was deposited, either on the ceramic membranes' surface or throughout the ceramic membranes' matrix.

Initially, the concept was proven on a laboratory-scale flat-sheet electro-membrane and phenols were successfully removed from a synthetic effluent. However, a saline water is preferred because of efficiency and power consumption

purposes. Thereafter a scaled-up version of the flat-sheet type reactor was designed and constructed. The bench-scale purification unit was used successfully for the electrochemical oxidation of phenol under different pH conditions and various types of electrolyte solutions. Complete degradation of a 100 mg/ℓ phenol concentration in phenolic effluent from a Durban oil refinery was achieved over the entire pH range. COD could be reduced to less than 50 mg/ℓ (down from 250 mg/ℓ) when treating this effluent.

The technology shows good potential for industrial application as a low-energy intensive process where some saline effluent or electrolyte (such as acid mine drainage) is available. It can be operated under different conditions, depending on the feed water and the application. Apart from being used as a purification unit, it can also be used for selective electro-synthesis of other organic compounds by simply controlling the operating conditions. Although it still has some way to go, the successful development of this process could have a significant impact on water treatment for oil refineries; plastics manufacturers; municipalities; and South Africa as a whole, in the treatment of organic pollutants.

Estimated cost: R422 000
Expected term: 2001-2003

Development of a reverse-flow microfilter
Department of Chemical Engineering, ML Sultan Technikon
No 1232

Internationally, there has been a progressive swing towards immersed membrane microfiltration (IMM), particularly in membrane bioreactors and in some potable water production applications. In IMM, the membranes are submerged in the feed suspension, and permeate is sucked through the membrane walls leaving the contaminants in the feed suspension. In general, the power requirements for IMM systems may be significantly less that that required for traditional cross-flow systems. This project concerns the initial evaluation of a new, locally developed, IMM technology that utilizes flexible woven fibre tubes the woven fibre reverse-flow microfilter. Here, a tubular porous support is inserted into each woven fibre tube. The tubes are manifolded at both the top and the bottom, and one of the manifolds is connected to a suction pump. Now, permeate may be sucked through the membrane walls from the outside to the inside. Thus the inexpensive woven fibre microfiltration tube assembly (or "curtain") may be used as an IMM. This was a preliminary project to assess the technical viability and potential of the system, and hence whether the new technology should be developed further. Three criteria were chosen to indicate the technical viability: separation efficiency, productivity, and ease of cleaning. Investigations were performed on a laboratory scale immersed membrane rig on four suspensions, viz. limestone, raw river water, a bentonite/kaolin mixture and a biological sludge from an aerobic reactor.

It was found that the reverse flow microfilter system gave permeate turbidities that could be regarded as very good to excellent. The permeate turbidities on limestone ranged from 0.2 NTU to 1 NTU, for a feed turbidity exceeding 999 NTU. On raw river water, a product turbidity of approximately 1 NTU was obtained for a feed of approximately 30 NTU. The product from the bentonite/kaolin trials ranged from 0.2 NTU to 1 NTU, for a feed turbidity of around 750 NTU. For the biological sludge at high fluxes, the permeate turbidity ranged from 0.6 NTU to 1 NTU, while the product from the lower flux runs ranged from 0.8 NTU to 2 NTU. In general, the product turbidities over the range of suspensions tested were < 1 NTU, with the exceptions noted on the low flux biological sludge. Mechanical cleaning was extremely effective in removing the fouling layer on the tubes and wholly restoring the permeability of the membranes. All of the above point to the conclusion that this technology could be an excellent immersed membrane treatment system for niche applications in developing economies, as an alternative to the current IMM technologies being marketed internationally, and that further development should continue.

Cost: R194 000
Term: 2001-2003

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 earns 4.5% of the country's foreign exchange and employs about 28 000 people. The ferrochrome metal is produced from chromite ore, carbonaceous reducing agents (char, coke and coal) and fluxes (quartz, dolomite and limestone) and is used mainly in the manufacture of stainless steel. The production of ferrochrome, however, also generates solid wastes such as ferrochrome slag and bag filter dust (BFD) containing toxic (carcinogenic) and mobile Cr(VI) which poses a risk to health and the environment. The 10 local ferrochrome producers are estimated to generate about 100 000 t of BFD/a.

The overall aim of the project was to optimize the solid stabilization of soluble wastes generated in the production of ferrochromium and stainless steel, by immobilization in cement bricks / 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 was evaluated by internationally accepted test procedures, to assess their potential as building construction materials, the economic potential for the manufacture of these products and their utilization in the national Reconstruction and Development Programme (RDP).

Leaching and mineralogical studies on the chemical and phase composition of ferrochrome BFD showed that Cr(VI) continues to leach from BFD when in contact with water. Treating an aqueous BFD slurry with ferrous sulphate or chloride was effective in removing Cr(VI) in the short term by the precipitation of relatively insoluble, stable $(Cr,Fe)(OH)_3$. Such once-off treatment, however, increases the salt content of the slurry, which introduces an additional contamination threat, and was concluded to be insufficient for stabilization of slimes dams.

As an alternative, incorporation of up to 15 % BFD into cement blocks made with ferrochrome slag proved effective in immobilizing soluble chromate as judged by various leaching tests (immersion in water; TCLP toxicity characteristics leaching procedure; and acid rain). The addition of $FeCl_2$ during the manufacture of the cement blocks was effective in immobilizing up to 99.7 % of the chromate and about half the salts contained in the BFD, as judged by water leaching tests on crushed cement blocks. In terms of DWAF Guidelines, the leachates from whole blocks were within prescribed limits but those of crushed blocks exceeded these values. Disposal of whole cement blocks containing BFD "could" therefore be acceptable. The cost of producing cement blocks in this manner was estimated at R235/t of BFD.

More effective Cr(VI) and salt immobilization was observed in fired clay bricks containing 50% BFD at a minimum firing temperature of 1 200˚C. Leaching tests on the crushed, fired clay bricks indicate that the chromate and salt are effectively immobilized in a glassy phase. The cost of production of the fired clay bricks was estimated to be R190/t of BFD.

As opposed to the above options for disposing of BFD by incorporation into building or other materials of construction, the current tendency in the local ferrochrome industry is to recycle the BFD to closed electric-arc furnaces (where available) by mixing it with fine chromite ore and utilizing excess energy available in the form of CO gas. These recycle options, available only when closed electric-arc furnaces are employed, have only been recently installed in the industry and the long-term build-up of salt and metal ions in the furnace and potential corrosion and production problems posed by this option have as yet not been fully evaluated.

In summary, the project has demonstrated a potentially viable reuse / disposal option for chrome-containing BFD from the ferrochrome industry by incorporation into building materials. Implementation would however depend on acceptance of this route by the regulatory authorities (DWAF and others) and a caveat would be that the toxic (albeit immobilized) substances would thereafter

be dispersed into the natural and human environments rather than being minimized at source, concentrated at their point of origin and recycled into the production process as per the last option indicated above (the most convincing cleaner production route).

Cost: R205 000
Term: 1998-2000

Neutralisation of acid mine-water and sludge disposal
Environmentek, CSIR
No 1057

In spite of efforts to reduce or minimise the formation of acid mine drainage (AMD), it has to be accepted that AMD will, for the foreseeable future, be an inevitable by-product of present and past mining activities. Since their low pH and 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 for the lime required as neutralising agent amounts to about R57m./a. It is thus clear that the use of cheaper neutralising agents or improved efficiency in the neutralisation process will result in significant savings to the country.

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. The project team has conducted pioneering research in this regard with funds provided by the WRC, CSIR and the mining industry. One of their previous innovations was to reduce the chemical neutralisation costs by a factor of three through substituting lime with limestone. This project addressed several of the urgent needs associated with active neutralisation of acid mine-water.

The research was primarily conducted through laboratory-scale beaker and pilot studies, but full-scale application of the findings is discussed as part of the report.

The presence of iron in the reduced state is problematic during neutralisation of AMD since iron precipitates can armour limestone particles and render them useless for neutralisation when iron is oxidised during the neutralisation process. Secondary acidity is furthermore produced upon oxidation of Fe(II). This may happen after release of neutralised AMD into the environment. The project investigated the biological oxidation of iron in a plate reactor and a continuously operated submerged packed-column reactor. It was found feasible to convert Fe(II) at concentrations in the g/ℓ range to the mg/ℓ range.

An integrated neutralisation process comprising a fluidised bed reactor for reacting limestone with AMD was used in various process configurations to determine reaction rates. The study showed that acid content could be reduced from 12 000 to 300 mg/ℓ $CaCO_3$, sulphate concentrations from 15 000 to 2 600 mg/ℓ (mainly as a result of gypsum precipitation), iron from 5 000 to 10mg/ℓ, aluminium from 100 to 5 mg/ℓ, while pH increased from 2.2 to7.

The conventional and high density sludge (HDS) processes are the most commonly used methods to treat AMD. Major shortcomings of these processes are the difficulty with which they are controlled and the relatively low sludge density that is produced. An evaluation of the modified HDS process indicated that it provided for better pH control, improved lime utilisation, higher sludge concentrations and faster settling rates.

The sludge generated by the HDS process contains high metal concentrations and are consequently classified as hazardous waste that need to be disposed of under special conditions. In short term experiments the co-disposal of HDS-sludge and coal discard was found to be beneficial, as the HDS-sludge contained appreciable neutralising capacity which could be used to neutralise coal discard and reduce pyrite oxidation rate and metal leaching.

This project contributed significantly to advance the introduction of limestone as a considerably cheaper replacement of lime for the neutralisation of AMD. It addressed the more pertinent issues in this regard and contributed to the fact that the limestone process is increasingly used in full-scale treatment facilities such as

DWAF's Brugspruit plant.

Cost: R700 000
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

Water works' sludge dewatering is an expensive process and normally carried out using centrifuges. Fundamental research carried out by Research Group of the School of Chemical Engineering, University of KwaZulu-Natal and Umgeni Water showed that tubular woven-fibre filtration technology has potential in both water filtration and sludge dewatering. This report covers research on sludge dewatering (using the woven-fibre tubular filter press, TFP) and water filtration (using woven-fibre crossflow microfiltration, CFM). The project aimed to evaluate these woven-fibre technologies (mostly for sludge dewatering) and to improve their designs in order to improve their cost-efficiencies for general use.

Experiments were run at two of Umgeni Water's Waterworks, during which the performance of these pilot plants was closely monitored and both process and mechanical aspects were modified to improve their operation. The performance of the TFP was found to be satisfactory with cake concentrations between 20 and 32 % solids (m/m), and solids recoveries up to 75%. Filter performance was found to be dependent on sludge characteristics, which in turn were largely influenced by raw water turbidities and treatment chemicals. A design procedure for the TFP has been compiled. Following comparison with a centrifuge, it was recommended that TFP be used in small, batch-scale operations, where other mechanical dewatering systems would be uneconomical. For water filtration, crossflow microfiltration has been shown to produce high quality potable water in water treatment applications and good separation and concentration of valuable material in certain niche industrial applications. Here also, a design procedure for CFM has been suggested. This research represents a significant step forward in the design and application of woven-fibre filtration technology.

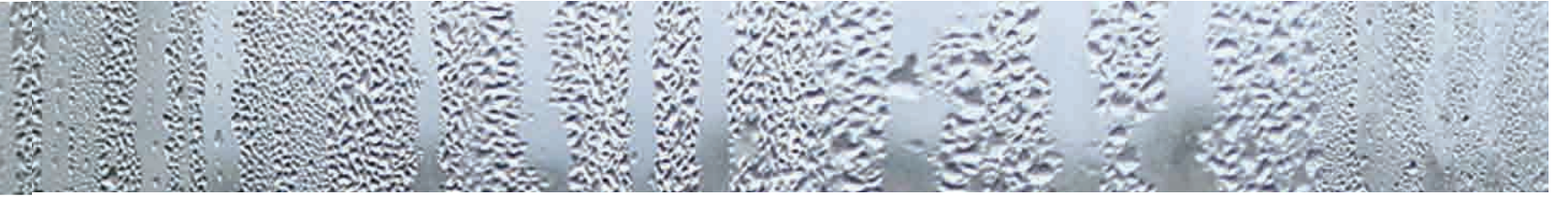
Cost: R587 000
Term: 2000-2002

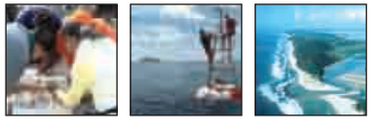
Removal of heavy metals from water by use of biomaterials
Department of Chemical Engineering, Cape Technikon
No 1259

The removal and recovery of heavy metals from effluent streams are important for the protection of the environment. Conventional technologies are generally not able to efficiently remove and recover heavy metals to a satisfactory level, or are costly to implement. The ability of biomaterials to bind and concentrate heavy metals from dilute aqueous solutions has been well-documented, and offers a potentially cost-effective approach to the removal of heavy metal pollutants from industrial wastewaters. This project investigated the feasibility of using biomaterials for the removal of heavy metals from aqueous effluents. The study was carried out in stages, firstly screening trials to identify suitable biosorbents, secondly characterization of the biosorbents and biosorption mechanisms, and finally experimental evaluation of packed columns for using selected biosorbents on an industrial scale. The metal contaminants considered in the investigation were mainly Zn, Ni, Pb, and Cu, with limited experiments on other metals, viz. Cd and Cr. The biomaterials tested were tobacco dust, saw-dust, peat moss and seaweed, all of which are relatively cheap, readily available and easy to prepare.

Biomaterial screening experiments (including the determination of kinetics and adsorption capacity, as well as the regeneration of the sorbents) were conducted in batch adsorption tests with single-species solutions. Limited work with multiple-species solutions indicated that interaction between metal species can play a role in the performance of the biosorbents and that this would have to be taken into account in detailed industrial-scale equipment design.

On the whole, seaweed (marine alga) appeared to be the





most effective adsorbent tested. The adsorption equilibria of Cu, Pb and Cd could be represented by Langmuir isotherms and the capacity of fresh alga for Cu, Pb and Cd ranged respectively around 90 mg/g, 230 mg/g and 80 mg/g. In comparison with conventional ion exchange technologies, the Cu removal performance of the seaweed was slightly better than that of a chelating C467 resin (approximately 80 mg Cu/g) and worse than that of a strong acid IR120 resin (about 101 mg Cu/g). The rate of adsorption onto the marine alga was high and appeared to be controlled by both reaction and film diffusion, owing to the non-homogeneity of the algal surface, which contained a variety of functional groups. Algal particle size played an important role in the adsorption behaviour. Coarse algal particles (0.8 to 1.2 mm) had a higher adsorption capacity and slower adsorption kinetics, and could be regenerated without significant loss of capacity. Finer algal particles (0.075 mm) had a lower adsorption capacity and faster adsorption kinetics, and could not be regenerated with-out significant loss of capacity.

Granulated seaweed was used in a packed column in order to evaluate equipment design criteria. A synthetic heavy metal solution comprising Pb, Ni, Cr, Cu and Zn with a total concentration of 100 mg/ℓ was passed through the column at a flow rate of approximately 15 BV (bed volume). For all practical purposes, 100% of the Pb and Cr was removed, approximately 95% of the Cu, and 75% of Zn and Ni. Sorption equilibrium was reached within 10 minutes for all heavy metals. Pb and Cr removal remained constant at close to 100%, whereas removal of the other heavy metals peaked around 90% and then decreased steadily afterwards. The decrease in Ni and Zn removal could be attributed to the displacement of these heavy metals with Pb and Cr, showing the selectivity of seaweed for Pb and Cr. Using a 2M HCl solution, 95% of the Cr and Pb could be de-sorbed within 120 minutes. Initial heavy metal removal was fast, with more than 70% being removed within the first 20 minutes of operation. An attempt was made to describe the biosorption capacity of the materials in terms of lignin and organic content, but this was not particularly successful.

In summary, although further work still needs to be done to assess the reuse of seaweed after repeated biosorption and regeneration cycles, the technology appears sufficiently promising to continue with steps towards possible industrialization.

Cost: R105 000
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 BioSURE™ process
Pulles, Howard & de Lange Inc.
No 1349

There are two critical steps in the biological removal of sulphates from acid mine drainage and industrial waters. The first step is the reduction of sulphates to sulphides, and the second, the subsequent oxidation of sulphides to elemental sulphur. Significant progress has been made in SA with the first step for both active and passive sulphate reduction processes. The second step is lagging behind. As part of an Innovation Fund Project, Rhodes University with input from Pulles Howard & de Lange Inc. (PHD) developed a basic sulphide oxidation technology in the form of a Sulphide Oxidation Biofilm Reactor (SOBR). This project was undertaken to evaluate and refine this process and to develop operational guidelines for the process for both passive and active applications.

A $1m^3$ bioreactor was constructed based on the original prototype and fed with sulphide wastewaters. During the initial tests the inter-harvest period of the sulphur biofilm was 4 to 5 d, while the biofilm formed was thin and speckled. The overall percentage sulphide removed during this phase was 40% of which 51% was recovered as elemental sulphur biomass. The content of sulphur recovered during this period was 20%. Process development was undertaken in the following four subsequent phases during which the reactor configuration was incrementally adapted as follows based on the outcomes of the previous investigation phase:

- Evaluation of variable sulphide loads
- Enhancing poly-sulphide formation to optimise the oxidation and biofilm formation reactions

- Optimisation of flow and dimensions of the sulphur formation zone
- Optimisation of the harvesting procedure by installing the automated harvesting process

At the completion of the last phase, the sulphide removal efficiency of the reactor increased to 75% with a sulphur recovery of 80% and the inter-harvest harvest period reduced to 12h.

The SOBR concept was thus successfully used for the removal of sulphide and sulphur recovery. Based on the results of the study, preliminary operational guidelines were formulated and this forms a basis for operation of a scale-up SOBR reactor. They are:

- Sulphide concentration of feed greater than 150mg/ℓ
- Redox potential in the SOBR between –150mV and –200mV
- pH of the influent should be greater than 6.5
- Sufficient oxygen diffusion in the upper layer
- Inter-harvest period less than 12h

Cost: R241 400
Term: 2002- 2003

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

Coal mining operations in the Mpumalanga area generate large volumes of high-sulphate acid mine drainage (AMD) effluents which pose a threat to the aquatic environment. These effluents require treatment to acceptable quality standards, which are moreover becoming increasingly stringent in terms of current and future legislation. The search for economical treatment processes to remove sulphate from such effluents is a global problem and is the subject of a large amount of research. Current research is directed mainly at chemical and biological methods. In the former, chemical means are applied to immobilise, concentrate and/or precipitate the sulphate anion. Biological methods are based on the bio-chemical reduction of sulphate by sulphate reducing bacteria.

Electrochemical treatment of AMD effluent is an alternative approach involving the electrochemical reaction of sulphate in an effluent, under specific chemical conditions, to form an insoluble complex which precipitates and can thus be concentrated and separated from the effluent. The core of the process technology is a versatile electrochemical reactor able to dissolve a wide range of different, reactive chemical species. The treatment process combines modern electrical and control technology with traditional electrochemical principles through various engineering disciplines. The objective of this project was to assess and demonstrate the technical and commercial potential of an electrochemical process for removing sulphate from AMD effluents and phosphate from sewage effluents (due to time constraints, the phosphate application was subsequently discontinued by the project steering committee). The research investigation was carried out using a newly-designed electrochemical (EC) reactor on site at Navigation Colliery (Anglo Coal). In the EC reactor (nominal 1 Mℓ/d capacity), Zn was used as a sacrificial anode to complex and precipitate sulphate from the effluent. The effluent was simultaneously neutralised and the base metals were precipitated, while reducing also organics and alkalinity (related to the scaling tendency of the effluent).

The results obtained showed that the effective hydraulic capacity of the plant was directly proportional to the level of contaminants in the effluent. More sulphate could be removed if less calcium and magnesium were present, due to the competition by these alkali metals with the Zn for keeping the sulphate anion in solution. The anodic dissolution of metals in the effluent greatly enhanced the clarification by gravitational settling, filtration and other standard solid/liquid separation techniques, due to the known action of dissolved ions (especially trivalent iron and aluminium) as coagulants and flocculants. Settling velocities in excess of 1m/s were reported. The final waste for disposal consisted of a thick sludge (worst case) or a

moist to dry filter cake (best case), depending on the efficiency of solid/liquid separation achieved. To be economically viable/attractive, it was concluded that the final waste would have to be recycled to the supplier of the initial catalyst (Zn anode), for recovery of the Zn content. A maximum hydraulic treatment capacity for the EC-reactor was estimated at 0.1 Mℓ/d for a mine-water with a sulphate content up to 2 800 mg/ℓ.

A theoretical computer model describing the dynamic performance of the system from start to equilibrium was developed, and was found to simulate the experimental results very closely. A highly accurate response prediction could be made for the process for any known effluent with a known composition. A continuous run over a period of two weeks established the process reliability and operability when monitored and controlled by shift operators at the mine.

Overall the project has demonstrated that electrochemical precipitation of sulphate from AMD effluents is technically viable, but relatively expensive when the operating costs of sacrificial Zn, electrical power, solid-liquid separation and maintenance were taken into account. The unit costs for treatment could, however, be significantly reduced if the Zn used as the sacrificial anode could be cost-effectively recovered and resold. Recommendations made include that further work should be aimed at defining the minimum Zn:sulphate mass ratio more closely, which is in turn dependent on understanding the chemistry of the Zn-hydroxy-sulphate complexes formed

Cost: R670 000
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

Electricity is a basic necessity for economic development in the RSA and water is one of the major resources required for its generation, especially in coal-fired power-generation plants. This project investigated the use of water at power-generating plants and the quality and quantity of the effluents generated, on a per unit (megawatt) basis of electricity generated.

From the survey conducted, at present approximately 192 000 GWh of electricity per annum is produced in South Africa by 29 power stations situated country-wide. The main types of power-generating processes used in the RSA and their percentage contributions to the total national generating capacity are coal-fired (89.2%), nuclear (4.9%), pumped storage (3.5%), hydroelectric (1.5%), and gas turbine (0.9%). Hydroelectric and pumped storage schemes are generally only used during peak diurnal periods (e.g. early morning and evening). Gas-turbine plants are only used during extreme emergencies due to their very high operating costs. To meet demand, the amount of electricity generated increased by almost 30% in the period 1992-2002. In the generation of 192 000 GWh of electricity, approximately 245 000 Mℓ of water of various qualities is consumed, for steam generation and heating, cooling, wet cleaning, ash disposal (wet ashing systems), dust suppression, make-up and regeneration of chemicals, and Irrigation. The effluent produced is much less than this, as up to 80% of this water is lost through evaporation in cooling towers.

The average raw water intake / unit of electricity generated (RWI) was found to depend on the type of power-generating process, whether open or closed loop cycles are used, the type of cooling and ashing processes utilized, as well as the quality of raw water. The average RWI was estimated to be 1.95 ℓ/kWh for recycling wet-cooled coal-fired plants, 6.5 ℓ/kWh for once-through wet-cooled coal-fired plants, 0.09 ℓ/kWh for dry-cooled coal fired plants and 0.198 ℓ/kWh for nuclear plants. No water is consumed for power generation in hydroelectric processes or gas turbine plants. Reductions in the RWI can be achieved through the use of dry-cooled systems and water recycling in the case of municipal plants. It was proposed that target RWIs be set at a maximum of 2.5 ℓ/kWh for wet-cooled coal-fired processes and 0.8 ℓ/kWh for dry-cooled power-generating processes.

The power-generating industry continually assesses the management of water resources and complies with water legislation as determined by the Department of Water Affairs and Forestry. The National Water Act requires all power stations to be registered as water users. In recent years, measures have been taken to reduce the water intake and pollution potential of power-generating stations. These measures include the implementation of zero effluent discharge systems, the installation of dry-cooling and dry-ashing systems, the installation of desalination plants to treat mine-water which can be used as a raw water source, as well as improved management and operation of processes. The report details a number of specific recommendations for reducing raw water intake in the power-generating industry, which could assist the industry in improving its efficiency of water use. The report is expected to be of value not only to the industry, but also to other interested parties such as regulators, researchers and consultants in the water and effluent field.

Cost: R170 000
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 Inc.
No 1215

Large-scale cessation of mining activities at deep underground gold-mines has already occurred and is expected to continue 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 them. 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 data and to apply pollution prevention measures. The premise of this project was, 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 prove that it is hydrologically and geohydrologically isolated from surrounding mines. The project consequently aimed 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.

The project intended to undertake a detailed study on the development of a coherent and integrated closure planning process for a case study region-the Klerksdorp-Orkney-Stilfontein-Hartebeestfontein (KOSH) area. This approach was eventually abandoned due to the unwillingness of the gold-mines in that region (other than Anglogold) to participate in the project. The project methodology was subsequently modified to study the complete South African gold-mining industry and develop a closure planning methodology that would have application throughout the industry. An assessment of the current status of closure planning contained within mine EMPRs, unearthed several misconceptions regarding the pollution potential of various mining facilities and a lack of management of the groundwater regime and the effect of re-watering after mine-closure. Not enough work has been done by the mines to fully understand groundwater flow, contamination and decant potential. As a result the management options to mitigate groundwater contamination after closure are very vague or non-existent. Since closure planning is not being undertaken on an integrated regional basis, those mines that have the longest remaining working life in each region is at the highest risk of being held responsible for dealing with the cumulative regional problem. This situation is not equitable and appropriate procedures need to be developed to ensure that effective closure planning occurs timeously and on an integrated regional basis.

The project team used the principles of risk-based mine-closure planning to develop and implement a regional mine-closure plan. A detailed risk-based closure planning process is presented, together with flow charts aimed at the development of a regional closure planning process. A set of procedures has been developed to address the various elements of regional mine-closure strategies and individual mine-closure plans. The process incorporates the principle that a conceptual mine-closure plan can be developed in the absence of a regional mine-closure

strategy but that no final mine-closure plan can be developed until an approved regional mine-closure strategy is in place. Whereas the focus of a regional mine-closure strategy is to understand interactions between adjacent mines and to find a basis for agreement on how much contamination (waste load allocation) is permitted for each mine, the focus of an individual mine-closure plan is on how to manage the mine-closure process to most optimally comply with the agreed waste load allocation.

It is proposed that when a mine's remaining operational life is in the order of 5 years, the mine will need to undertake a substantial review and overhaul of its conceptual mine-closure plan and will need to significantly upgrade the level of certainty associated with the various assessments. While the process is essentially similar to that employed for the development of a conceptual mine-closure plan, the level of detail and the depth of the assessment will vary. In particular, it is proposed that detailed mine-closure plans should be probabilistic in nature, i.e. they should aim to define the uncertainty associated with the assessment.

Cost: R503 800
Term: 2001-2002

Programme 4: Minimising waste production

Bioremediation and bio-utilisation of pulping and bleaching effluents

Department of Biochemistry and Microbiology, University of the Free State

No 1367

The bio-utilization of pulp and paper wastewaters in the production of high-value products such as enzymes and the use of enzymes in bio-bleaching to reduce the chemical consumption of chlorine-based bleaching agents present new environmentally sound technologies that can significantly minimize the environmental impact of the pulp and paper industry. The project aimed to develop a bioremediation and bio-bleaching technology to minimize the use of hazardous chlorine-based bleaching chemicals which would produce certain economical benefits as well as reduce the environmental impact of the pulp and paper industry. Further, it also aimed to develop a microbial fermentation technology of pulping wastewaters to obtain high-value products such as enzymes to be utilized in a bio-bleaching process for environmental clean-up and upgrading the quality of pulp and paper products. Polyoxometalate (POM) and xylanase-based wastewater bioremediation, as well as the bio-utilisation of wastewater for xylanase production with the fungi *Aspergillus oryzae* and *Aspergillus phoenicis* were performed in bench-scale experiments on various wood types.

The research team succeeded in effecting savings of up to 50% in chlorine-based bleaching agents by using POM while retaining full brightness. Bio-bleaching of bagasse pulp with xylanase (X) afforded reductions in sodium hypochlorite (32%) and sodium hydroxide (20%). Similarly, reductions of chlorine dioxide (30%) and sodium hydroxide (20%) were possible during bio-bleaching of soda-aq pulp. Furthermore, the xylanase enzymes produced on the spent sulphite liquor could be successfully applied in bio-bleaching of pulp. This project has demonstrated that the implementation of the enzyme bleaching technology in the pulp and paper industry could improve the existing technology of pulp and paper manufacture in a cost-effective and environmentally friendly way. The use of enzymes can reduce the amount of chlorine-containing chemicals employed in bleaching. This impacts directly on the levels of toxic effects, chlorides and adsorbable organic halides of the wastewaters. However, economic aspects still need to be fully investigated and quantified under full-scale plant conditions.

Cost: R500 000
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

Mines invariably fill up with water after closure. Because

of different resting water levels within adjacent mines, different hydraulic water pressures are exerted on peripheral areas. Seepage of mine-water from one entity to the next is therefore possible. This flow is commonly referred to as inter-mine flow. The interflow of polluted mine-water between collieries in Mpumalanga is a key issue that needs to be resolved before a holistic mine-water management scheme can be implemented.

This has been an extensive study in terms of its aerial extent and information gathered. The total area investigated constitutes 26 000 km^2 and covers all of the collieries in Mpumalanga from where information could be obtained. A geographic information system, using the WISH software package, was established. It was used throughout this investigation for the processing of the data. The GIS consists of very detailed mining plans for most of the mines in the Mpumalanga area. This is accompanied by mine-specific information on coal-floor contours, water qualities and quantities.

Sufficient connectivity (permeability and/or connections) exists between mines and the surface to allow interflow of mine-water. These connections are in the form of opencast mining, shafts, prospect boreholes and subsidence structures. Interflow of water on coal seam levels is also possible in most of the collieries due to the extensive nature of mining, particularly in the Witbank and Secunda areas. Pathways in mines dictate flow of underground water, rather than natural flow paths. Many critical areas of potential inter-mine flow have been identified, where significant quantities of mine-water will transfer from one mine to the other. The combined impact in terms of anticipated water that will be available for interflow or to decant from the various mines is in the order of 360 Mℓ/d with a sulphate load of 660 t/d. The range of quantities and qualities for individual mines will vary significantly, depending mainly on the mining method employed. Many other site-specific factors also play a role.

Management options to cope with inter-mine flow are applicable on either a mine basis or catchment basis. Those on a catchment basis are:

- The reduction of the number of decanting points through the interconnection of mines.
- The control of decanting positions through interconnection of mine workings.
- The combined treatment of decanting mine-water at convenient locations.

On a mine basis, the following actions will markedly reduce the volume of water or the amount of salt to be discharged:

- Design long-term water management schemes taking cognisance of neighbouring mining activities
- Design the mine lay-out to retain as much of the mine-water as possible in the underground workings whilst mining
- Investigate coal-barrier characteristics and design coal extraction accordingly
- Minimise water ingress into mines to reduce water volumes, if required
- Mix mine-water of various qualities to achieve the best possible quality before flood discharge
- Minimise salt loads by flooding mine workings as soon as possible to limit oxidation reactions, flushing flooded mines and use flushed areas for water storage and utilise the natural neutralisation potential of the coal and rock through proper design

Cost: R897 000
Term: 1999-2000

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 or fine residue deposits (FRDs) 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. 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. This project aimed to 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.

Fieldwork concentrated on supplementing field data that were collected during an earlier study. The approach was to generate additional data and to discover relevant field-related variables that could be used to construct an oxygen diffusion based model for assessing acidification risk. Parameters that were determined in the field and laboratory included sample descriptions, particle sizes, X-ray diffraction mineralogical analyses (XRD) and shake flask tests. Additional parameters, such as ABA analyses, moisture contents, particle size distributions, porosities and sulphur concentrations were obtained from the literature.

Subsurface features that were observed in studying FRD profiles included the presence of a leached zone directly below the surface, a hardpan horizon below this and an oxidation front, where iron-stained sediments contacted grey, apparently un-oxidised tailings. The leached horizon is expected to be the result of rainfall leaching of oxidised products. The hardpan horizon is a result of mobilised iron from pyrite oxidation forming secondary minerals. Evidence of variable oxygen concentrations and preferential flow paths was noted by the presence of mottling and accentuated staining respectively.

A conceptual model was developed to represent the generation of acidity from pyrite oxidisation within a typical Witwatersrand FRD. According to the model, wall sections of a tailings dam will undergo rapid acidification, as a result of horizontal influx of oxygen across the profile. The bulk of an FRD will, however, undergo oxidation through vertical ingress of oxygen by diffusion through the tailings profile. A large store of unreacted material, with associated neutralising potential (NP) occurs below the oxidation zone and potentially provides a means to delay the onset of acidic seepage from the base of the FRD for an extended period.

By making use of the PYROX model, a spreadsheet engineering type model was developed to model the likelihood of acidification from an FRD due to the AMD process. The purpose of the probabilistic spreadsheet model (tailings acidification prediction or TAP model) is to predict the likely rate of acidification of seepage at the base of an FRD. The model consists of two components, i.e. an oxygen diffusion component to predict trends in pyrite oxidation rates and a neutralisation component to predict the rate of consumption of neutralising potential in the FRD. Sensitivity analyses that were run for the model indicated that most FRDs are likely to take more than 1 000 years before acidic seepage will be generated from their bases. Modelling and field observations indicate that weathering in the top of the tailings profile in a typical Witwatersrand FRD is rapid for approximately 10 years after decommissioning and that an oxidised horizon of up to 5m deep will form during this time. Variations in physico-chemical parameters can modify these figures to form shallower or deeper profiles.

Cost: R169 000
Term: 2002-2003

THRUST 5: SANITATION AND HYGIENE EDUCATION

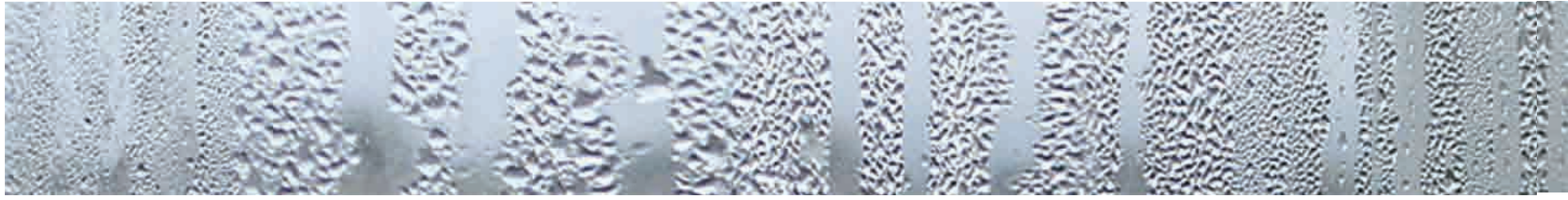
Programme 1: Rural sanitation and hygiene education
Review, consolidation and evaluation of key performance indicators for successful sanitation, health and hygiene promotion programmes
Rural Support Services
No 1378

THIS PROJECT WAS TERMINATED.

Cost: R250 000
Term: 2002-2003

Protocol Manual for the Transfer of Methodology Required to Link Ecosystem and Human Health
Pulles, Howard & de Lange Inc
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 under investigation as they focused on species and tissue differences in contaminant bioaccumulation as well as the spatial and temporal variation in contaminant concentrations. The health risks to humans when consuming contaminated fish are seldom addressed. Furthermore, no standard methodology as for example suggested by the US EPA was followed by the different investigations. This shortcoming limits comparison of data from different studies and prevents accurate determination of risk base fish consumption limits for humans.

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 governmental 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 if 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, the levels of contaminants occurring in the fish and whether the fish can 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 500
Term: 2002-2003

Programme 2: Peri-urban sanitation research

Impacts of storm-water and groundwater ingress on municipal sanitation services

Water Systems Research Group, University of the Witwatersrand

1386

For its functions in conveying residential/industrial wastewater (either in a combined or separate manner with urban stormwater) water-borne pipeline stoppages and collapses take place most commonly due to a combination of roots, corrosion, sedimentation and inadequate construction. Besides stoppages and collapses, stormwater inflows and ongoing groundwater infiltration (or so-called extraneous flows) can reduce the originally designated capacity of a sewer collection system and negatively affect operation of the entire water-borne sanitation system including the wastewater treatment component (i.e. WWTP). Increases in extraneous flows will reduce the effectiveness of the biological process leading to higher pollution loads leaving the WWTP and disposing partially treated urban wastewater into the adjacent river ecosystems.

Urban wastewater quantity and quality management issues and problems are now equally important for either centralized or decentralized disposal of urban wastewater return flows. Both quantity and quality of such water is crucial to the well-being of other water users located downstream of the sources discharging wastewater and stormwater.

The urban water cycle is adversely affected by extraneous flows. If there is ex-filtration, there can be groundwater pollution which also affects the catchment water balance. Water consumption is higher if plumbing leaks and more water are cycled on a macro scale. This increases the overall water supply cost as well as causing pollution. The linkage of water flow between water supply input point and treated effluent output point enables observation of the whole urban water cycle. The evaluation of return flows and consumptive use is a critical component in water resources development studies at various wastewater catchment levels. Stormwater inflows and groundwater infiltration into sewers have costly implications. Although in the past it has been the practice to allow spare sewer capacity, this can increase sewer costs by 10% to 30%, and wastewater treatment by some 10%.

A questionnaire distributed nationally produced alarming data. Little attention is paid to inflows and infiltration and it is customary to allow for up to 50% of sewer capacity and also to design WWTP to cope with this flow. This project identified low awareness about I/I/E problems and remedial/rehabilitation techniques by most South African WSAs/WSPs. Due to the magnitude and complexities inherent to municipal waterborne sewer systems, no WSA/WSP can make an educated decision on developing a new or upgrading/rehabilitating an existing system without a mixture of field and modelled data.

One of the major observations concluded in this project is that maintenance strategies of most WSAs/WSPs in South Africa resort to reactive maintenance, where problems are dealt with on a corrective basis as they arise. Consequently, municipal wastewater system maintenance budgets are commonly low and are based on the previous year's financial expenditure on clogging and collapses. Stoppages and clogging of sewers in South Africa per unit length of sewer are about ten times higher than the international average. In the meantime, the deterioration of municipal water-borne sewers continues to the point of failure and beyond.

In order to determine general awareness about inflow/infiltration (I/I) problems in municipal sanitation systems in South Africa, a nation-wide e-mail survey was conducted under this research project. The survey generated new valuable information and verified several parameters for development/enhancement of urban separated sewer systems. It was established that most municipal sewer systems in South Africa have been in existence for 30 to 50 years and the aging process is taking its toll so that issues related to rehabilitation or replacement are becoming more important to the WSAa/WSPs. The types of materials used in the construction of sewer systems have also changed from formerly clay and concrete to uPVC and AC piping, generating different sets of problems.

The sample survey indicated that the most common causes of stormwater inflows and groundwater infiltration in the South African context are as follows:

- Inadequate design of certain system components
- Illegal house down-pipe connections to the municipal sewers (all surveyed municipalities operate separate instead of combined sewers)
- Open gullies serve primarily as sullage disposal (this typically in most formal and informal townships)
- Gutters/down-pipes linked illegally to sewer gullies
- Unsealed manholes primarily due to theft of the manhole covers
- Faulty pipe joints due to improper construction
- Unwise man-made stormwater channelisation (e.g. road crossings and culverts) and unattended overgrown vegetation in natural channels
- High groundwater table

Next to the common causes generated by this survey, other factors were identified which can contribute locally to inflow/infiltration to sewers:

- The dramatic topography may lead to easy flooding due to marginal changes in stormwater flows
- Re-considered flood lines
- Swimming pools can be a contributing factor if additional stormwater or backwash water is linked directly to the sewers
- Ground movement due to removed mine dumps destroying continuity of sewers
- Thunderstorms of short duration and higher intensities in various locations

The key conclusion this project identified was low awareness about problems and remedial/rehabilitation techniques by most South African WSAs/WSPs. Due to the magnitude and complexities inherent to municipal water-borne sewer systems, only a few WSAs/WSPs can make an educated decision on developing a new or upgrading/rehabilitating an existing system (or its key components). They lack mainly field and modelled data, particularly on inflow/infiltration/ex-filtration events and their consequences.

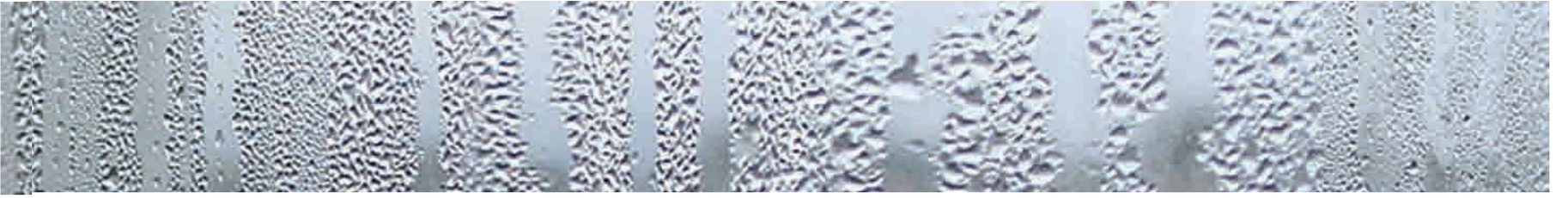
Another major observation from this project is that the maintenance strategy of most WSA/WSPs in South Africa is essentially reactive maintenance, where problems are dealt with on a corrective basis as they arise. Consequently, municipal wastewater system maintenance budgets are commonly low and are based on the previous year's financial expenditure mainly from clogging and collapsing sewers.

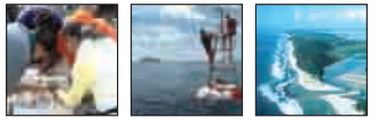
It was also established by this project that the costs associated with maintaining or expanding existing and/or developing new urban wastewater infrastructure appear to be high, but well-invested if allocated on a regular basis. Because there is not yet enough pressure applied from the wastewater services end-users to municipal managers about the economics of alternative solutions, conventional methods therefore prevail and benefits are not highlighted in the cost analysis. Water infiltration in sewer pipelines is common and should be included in the peak design flow.

Due to the magnitude and complexity of the attention required to research, design, construct and manage wastewater sanitation systems, all relevant stakeholders must share responsibility for development and management of these systems. The application of new local and international technologies must be promoted by the WSAs and WSPs through adopting the guidelines in capacity building programmes.

To sustain a reliable municipal wastewater infrastructure and required service to customers, new and improved solutions to existing and emerging problems will have to be researched. Spheres for further research relate to flow monitoring, assessment of structural integrity, operation and maintenance programmes, and new methods in rehabilitation of sewers.

Cost: R340 000
Term: 2002- 2004





CURRENT

THRUST 1: WATER SERVICES-INSTITUTIONAL AND MANAGEMENT ISSUES

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

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Programme 1: Drinking water treatment technology
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

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

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
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

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 O&M of the simple chemical dosing system and the URFL-SSF processes.

Estimated cost: R380 000
Expected term: 2002-2004

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
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

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: R424 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: R236 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
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 KwaZulu-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

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
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

Evaluation of the anaerobic baffled reactor for sanitation in dense peri-urban settlements
Pollution Research Group, University of KwaZulu-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

Material mass balances over and modelling of wastewater treatment plants
Department of Civil Engineering, University of Cape Town
No 1338

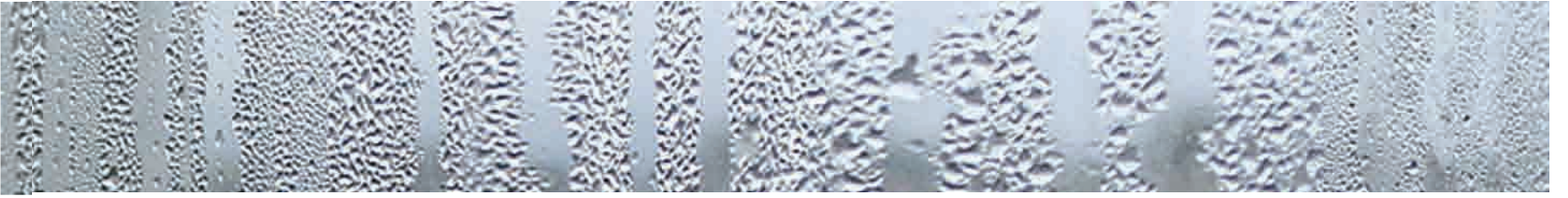
The objectives of this project are to develop a mass balance model for wastewater treatment plants, a model for sequential batch reactors, an integrated anaerobic digester model, and a model for characterising primary and secondary wastewater sludges.

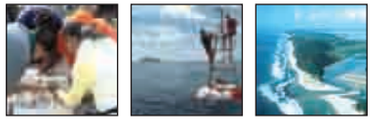
Estimated cost: R429 000
Expected term: 2002-2005

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

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

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

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

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 KwaZulu-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

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 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 KwaZulu-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 KwaZulu-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

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 (attached to the proposal, **Appendix 1**) confirmed this potential and pointed toward the niche application areas to be researched.

The system consists of a membrane impregnated with a novel, conducting, catalytic material. A low-voltage current is sent through this catalytic membrane, thus effecting the oxidation or even complete combustion of micro-organisms and organic compounds in the water. Because only low voltages are required, solar cells may also be used to power the system. From single household to large industrial units may potentially be constructed.

The aims of the project include the following:

- Design and evaluate electrochemical combustion plants for rural water disinfection and industrial organics removal.
- Design a fixed bed electrochemical cell suitable for multi-family usage, and also big enough to be useful for industrial effluent.
- Investigate newer cell designs, fluidised bed, spouting electrode, etc. as alternatives to a fixed bed design.

Estimated cost: R455 000
Expected term: 2001-2002

On-line removal of organic foulants from membranes by use of ultrasonication
Department of Chemical Engineering, University of Stellenbosch
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

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

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.

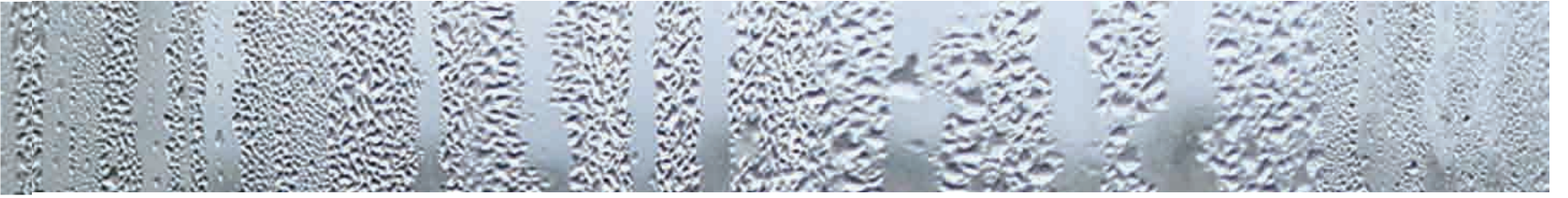
The project entails a new approach to the operation of solid-liquid separation bioreactors for the treatment of effluent containing recalcitrant pollutants. This involves the use of a dual-stage membrane bioreactor, which uses ceramic membranes for cell recycle. Such a reactor can be used for on-site 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.

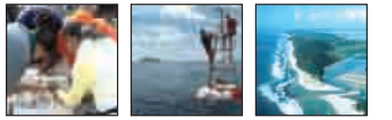
Estimated cost: R885 000
Expected term: 2002-2005

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

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

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

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 bio-desalination 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 bio-desalination 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

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

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

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 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

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

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, Rhodes University

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

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.

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 2: Regulatory mechanisms to improve industrial and mine-water management

An investigation of the specific chemistry and geochemistry of manganese, the bearing that this has on suitable chemical techniques used in the classification of wastes containing manganese, and the determination of alternative characterisation techniques

Pulles, Howard and de Lange Inc.

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

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 1 900 000
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
Further application and development of pinch analysis for water and effluent management
School of Chemical Engineering, Pollution Research Group, University of KwaZulu-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 KwaZulu-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 KwaZulu-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 KwaZulu-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

Water conservation through energy conservation
Pollution Research Group, University of KwaZulu-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

Characterisation of microbial populations and identification of dominant micro-organisms 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

Programme 5: Improved ability to predict and quantify effects

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** and **1264** 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

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

THRUST 5: SANITATION AND HYGIENE EDUCATION

Programme 1: 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

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 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 A and C

Sub-project: The development of risk communication guidelines
Environmentek, CSIR
No 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
No 1400C

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

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 2: 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 not aesthetic 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 re-used 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

NEW

THRUST 1: WATER SERVICES-INSTITUTIONAL AND MANAGEMENT ISSUES

Programme 2: Institutional and management issues-Water services
Sustainable development indicators for urban water systems: Case studies evaluation of the Thohoyandou and Makhado (Louis Trichardt) municipalities (NS)
University of Venda
No 1517

This study aims to apply the concepts and sustainable development indicators developed by the UN and check their relevance in a developing country context. The concepts will be tested on two small towns in the Venda region. From this learning process it aims to improve these indicators such that they will be applicable.

Estimated cost: R150 000
Expected term: 2004-2006

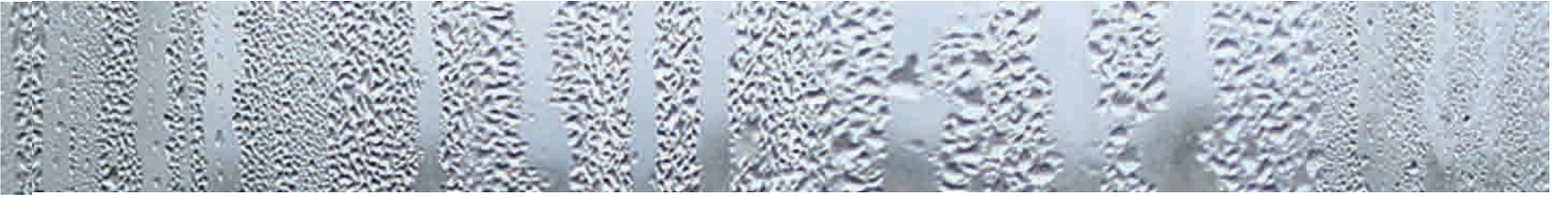
Case study of a district municipality water services authority experience of implementing local government and water services related policy initiatives. An action-oriented research support (NS)
Palmer Development Group
No 1518

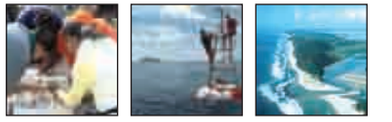
The aim of this study is to design an action-orientated research agenda which will support the activities of District municipalities in implementing water services policy and requirements. The objective is to capture and share experience and lessons and use this as the basis to make improvements in the performance of DMs

Estimated cost: R400 000
Expected term: 2004-2006

Case study on learning by technical water professionals and decision-makers for urban developmental service provision
M van Ryneveld
No 1519

The aim of this study is to determine and identify how dissemination and learning by water professionals in the sector is taking place and its impact on service provision. Using this as the basis recommendations on improvements can be made, as well identify the priority areas requiring attention in terms of skills development. The study is a strategic attempt to understand uptake of water knowledge. It will provide good methodology for future impact studies and assist in planning appropriate





dissemination activities.

Estimated cost: R180 000
Expected term: 2004-2005

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Programme 1: Drinking water treatment technology

An investigation into alternative methods to clean filter media in rapid gravity sand filters to ensure optimal performance and quality of the filtrate (NS)
Umgeni Water
No 1525

The project will establish a reliable procedure and protocol to measure cleanliness of the filter media, the behaviour of filter media, changes in headloss, air and water scour rates and filtrate quality. The nature of deposits on the media will be determined in order to identify the mechanisms that cause media deterioration and extra-cellular microbial compounds present in the deposit on the filter media rendering the medial sticky and difficult to clean will be determined. During the project, a representative survey of the SA water treatment plants will be conducted to benchmark the efficiency of backwash procedures and media cleanliness, to determine the leading causes of media deterioration. It will also be attempted to quantify the potential savings that could be made by implementing the multi-cycle sequential and chemical filter cleaning procedures.

Estimated cost: R413 000
Expected term: 2004-2005

Biological filtration of iron & manganese from groundwater (ns)
Umgeni Water
No 1526

It is aimed to develop criteria for the design of biological filtration systems that will remove iron and manganese from groundwater in rural areas in an economical and sustainable fashion. The effectiveness of such systems will further be demonstrated by the operation of a small water treatment system in a rural area in KwaZulu-Natal.

Estimated cost: R750 000
Expected term: 2004-2007

Development of enhanced floating media separation for drinking water production and pretreatment in rural water supply (NS)
University of Stellenbosch
No 1527

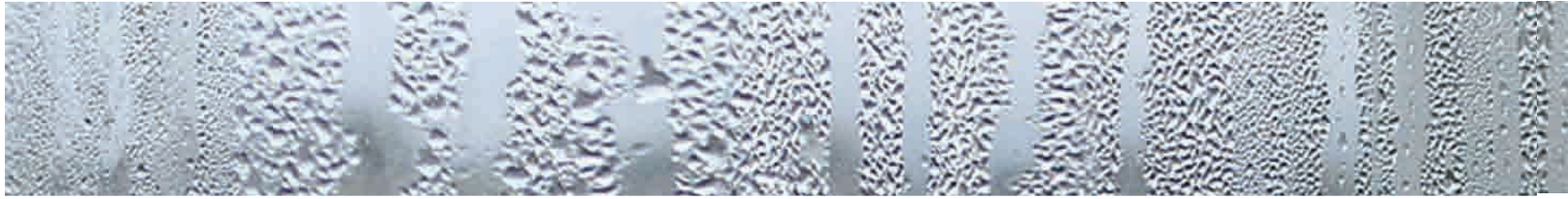
The project proposes to further develop a filter with floating plastic media for the supply of water for rural communities. Performance of the filter both on its own, and as a pretreatment system for ultrafiltration membranes will be evaluated and the operability of the system will be compared to that of a conventional coagulation, sedimentation and sand filtration plant. This system should be a more efficient and cost-effective alternative to sand filters if the research is successfully executed. It is also simple to operate and requires less head for back-washing than conventional sand filters. A successful project can ensure that more small communities will have the benefit of membrane-treated potable water supply.

Estimated cost: R914 000
Expected term: 2004-2007

Polyelectrolyte determination in drinking water (ns)
Umgeni Water
No 1528

The project aims to develop a new analytical technique, or improve on the existing technique, for the determination of residual polyelectrolyte levels remaining in drinking water after treatment of the water.

Estimated cost: R300 000
Expected term: 2004-2006



Programme 2: Water treatment for rural communities

The testing of a membrane technology unit for the removal of nitrate, chloride, phosphate and sulphate pollutants from groundwater (NS)

University of the North West

No 1529

The project aims to evaluate a number of different membranes for the removal of salts and specific pollutants from groundwater sources in the Northwest Province. The project also aims to assist in the training of local people (technicians) to operate and maintain the water processing installation and monitor impurities on-site with field testing equipment. The consumers' understanding of the implementation of a water purification system will further be determined through examining:

- The knowledge of consumers regarding purified water and the purification system
- Their attitudes towards purified water and a purification system

Such membrane systems established in the rural areas will contribute to a healthier life, especially for people living in high nitrate groundwater areas.

Estimated cost: R499 600
Expected term: 2004-2006

Enabling water fluoridation in small drinking water treatment plants

Umgeni Water

No 1530

The project aims to investigate and suggest ways to ensure that the implementation and operation of fluoridation in small and rural plants may be done in a safe and sustainable fashion. Available equipment and instrumentation will be evaluated and guidelines provided for the choice and operation of suitable equipment. Suggestions will be made on the optimal ways to install and operate such equipment and instrumentation. Innovative ways will further be suggested in which to implement and operate such equipment and instrumentation in order to ensure safe and sustainable fluoridation on small and rural water treatment plants.

Estimated cost: R1 200 000
Expected term: 2004-2007

Improving the efficiency of disinfection in small drinking water treatment plants

University of Fort Hare

No 1531

Inefficient disinfection was shown to be a major weak point in the provision of safe water on small and rural drinking water treatment plants. The project aims to investigate the reasons for these existing problems and suggest both technical and social remedies to overcome the problems and to ensure the provision of efficiently disinfected and safe drinking water to these communities.

Estimated cost: R1 000 000
Expected term: 2004-2006

Programme 3: Drinking water quality

Occurrence and fate of EDCs in drinking water (NS)

CSIR

No 1532

It is of high priority that the fate of EDCs be determined to minimize the effect thereof on humans and animals. The project aims to investigate the occurrence and fate of EDCs in raw and treated drinking water using biological/biochemical techniques and chemical tests. Recommendations will be made on the most effective water treatment technologies for the removal of EDCs and the most appropriate combination of tests for the detection of EDCs in drinking water.

Estimated cost: R830 000
Expected term: 2004-2006

Methods manual for monitoring phytoplankton and cyanobacteria (NS)
Rand Water
No 1533

The project will compile a comprehensive methods manual for the analysis of phytoplankton, cyanobacterial toxins, Geosmin and MIB for South African freshwaters Current methods used for phytoplankton identification and enumeration, cyanobacterial toxin analysis, as well as for Geosmin and MIB analysis will be synthesized and a summarized reference document compiled.

Estimated cost: R403 600
Expected term: 2004-2006

New detection methods for EDCs
University of Stellenbosch
No 1534

The project will aim to produce and test an endocrine disrupting compound (EDC) indicator system. This will be achieved by execution of the following objectives:

- Clone cDNA for the human oestrogen receptor ligand binding domain (LBDER) into a suitable yeast (*Pichia pastorus*) expression vector for large-scale expression
- Production of antibodies against LBDER-EDC complexes
- Prepare LBDER by large-scale fermentation expression and protein purification
- Biotynilation of LBDER and preparation of biotynilated pluronic acid needed for non-covalent attachment of LBDER to polysulphone membranes or hydrophobic contactors
- Development of specialised polysulphone contactors for the non-covalent immobilisation of the LBDER via pluronic biotin/avidin technology
- Development of the ELISA indicator system for EDC detection

Estimated cost: R647 500
Expected term: 2004-2007

Programme 4: Water distribution and distribution systems

Country-wide assessment of non-revenue water throughout South Africa using latest international water association methodology
WRP Consulting
No 1535

The study will determine the levels of non-revenue water in the country and develop the methodology to estimate and benchmark between suppliers. The proposal builds on previous innovative work funded by the WRC and will offer innovation in terms of capturing very difficult to obtain data and this to be presented in a plausible manner. Until now the focus of both the national and international sector has been on water leaks and losses. Indications are that in developing countries there are greater opportunities for demand management if the attention is paid to non-revenue water and apparent losses. This study will enhance SA's position as leaders in innovation and knowledge in this topical area.

Estimated cost: R650 000
Expected term: 2004-2006

Benchmarking of domestic water consumption in selected South African cities
Rand Water
No 1536

The study aims to determine water consumption per erf and relate this to erf size, no. of consumers etc. Included is calculation of return flows. This information will be of use for the sector, since the demographics of SA's settlements have been rapidly changing and this will have an impact on water usage and behaviour. Settlement trends, etc. also influence water consumption. The outputs from the study will assist in both national and local planning, as well as provide good figures for future design and demand predictions, leading to more effective demand and water conservation interventions.

Estimated cost: R250 000
Expected term: 2004-2005

THRUST 3: WASTEWATER AND EFFLUENT TREATMENT REUSE TECHNOLOGY

Programme 1: Biological sewage treatment processes

To investigate the performance and kinetics of biological nitrogen and phosphorus removal with ultrafiltration membranes for solid-liquid separation

University Cape Town

No 1537

This project is a follow-on to WRC **Consultancy No. 514** which was specifically commissioned as a one-year feasibility study in 2003 to test whether nutrient removal could be accomplished in this type of robust, low-cost sewage treatment system which is independent of the sludge bulking problems which in turn often compromise the effective performance of activated sludge processes. The low pressure-drop ultrafiltration (UF) membranes being used are supplied and funded for this purpose by the suppliers (MembraTech, UK). Recent information (November 2003) indicates that the process is operating satisfactorily. On the basis that the preliminary promise has been delivered, a fuller investigation is therefore required to provide a rigorous and definitive examination of this type of system. A parallel 'next step', which is already in hand, will be to investigate whether UF membranes of similar or superior performance can be locally sourced, and/or designed and manufactured.

Estimated cost: R1 132 400
Expected term: 2004-2006

Development of a commercially viable implementation model for anaerobic co-digestion of toxic and high strength organic waters

University of KwaZulu-Natal

No 1538

This project builds on two previous WRC projects, namely **No. 762** which assessed the viability of using anaerobic digestion to treat refractory textile wastewater and **No. 1074** which investigated co-digestion of these wastes with domestic sewage on a regional basis. The outcomes of these base studies were positive and the present proposal seeks to extend the technical success achieved into a practical technology-application scheme. In collaboration with Durban Metro (Water and Waste), a commercially-orientated survey will be carried out to quantify specific industrial sources, loads, sewage works capacity and costs (capital and running) for operating the scheme. These results will be drawn together into a multi-stakeholder business plan aimed at meeting the needs of industry, regulators and sewage treatment plant operators. It is significant that previous WRC research, regulator buy-in and progress made with industry with regard to cleaner production have come together to create this window of opportunity.

Estimated cost: R150 000
Expected term: 2004-2005

Evaluation of sewage treatment package plants for rural, peri-urban and community use

Umgeni Water

No 1539

This project is to evaluate package sewage treatment plants for rural and peri-urban community use and addresses a knowledge area that is lacking at present. The resulting guidelines on performance and selection of the units would be valuable to consultants and local authorities, and public health and the environment would also benefit. This is not ground-breaking research, but is practical and should enhance the capacity of local authorities and other service providers in achieving more effective management of package sewage treatment plants, with consequent environmental and social benefits.

Estimated cost: R380 000
Expected term: 2004-2006

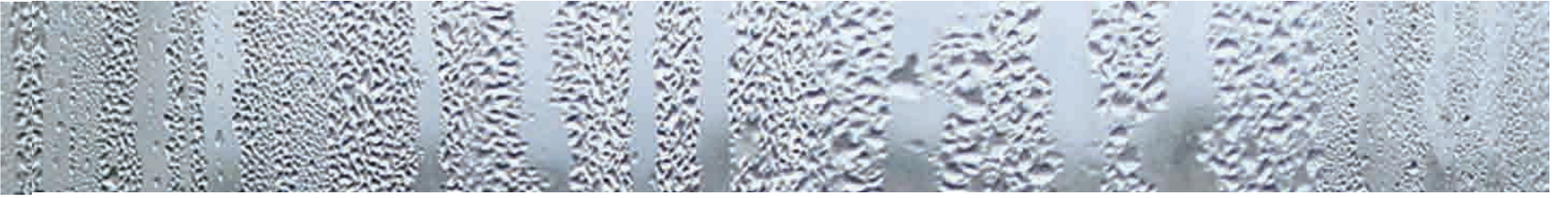
Programme 2: Sludge characterization, treatment, utilization and disposal

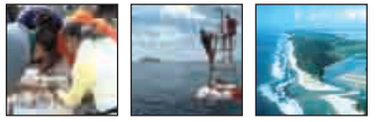
Influence of sludge conditioners on the soil conditioning properties of sewage sludge

University of Pretoria

No 1540

This project aims to determine the influence of sludge conditioners used during sewage treatment processes on the soil conditioning properties of sewage sludge.





Estimated cost: R101 000
Expected term: 2004-2006

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

To investigate and commercialise production of a cocktail of hydrolytic enzymes from anaerobic sulphidogenic bioreactor fed with sulphate reducing bacteria and municipal sewage sludge for the treatment of biological and industrial wastewater

Rhodes University

No 1541

This project for creating enzyme 'cocktails', based initially on a sulphidogenic system and applied then to the treatment of domestic and industrial wastewaters, has novel aspects of technical interest. The concept of generating enzymes to treat wastes is not new but is a relatively fresh approach compared to the conventional biological reactor.

Estimated cost: R216 000
Expected term: 2004-2005

The removal of reactive dyes from dye liquor for the reuse of salt, water and energy

Pollution Research Group, University of KwaZulu-Natal

No 1542

The textile industry needs cost-effective, low environmental-impact processes to remove colour and salt from their effluent. The proposal is for the treatment of concentrated reactive dye effluents from the textile processing industry at source using activated carbon. The high salt concentration shifts the equilibrium towards the carbon, resulting in very high removal efficiencies. The project will combine life cycle assessment (LCA), chemistry and process engineering considerations to develop an important recycle technique for the textile industry, in order to recover and recycle chemicals and consequently reduce the waste loads generated. This is a good reduction-at-source approach towards developing a solution to the problem.

Estimated cost: R272 600
Expected term: 2004-2006

Industrial wastewater remediation via wet air oxidation using immobilised transition metal catalysts

University of the Western Cape

No 1543

Aqueous effluents from the chemical and related industries contain various organic pollutants which are toxic and refractory and occur in concentrations too low for economical recovery but too high for conventional biological treatment. This proposal aims to investigate and develop catalytic wet air oxidation as a technology for treating such effluents.

Estimated cost: R600 000
Expected term: 2004-2006

Integrated research to identify indigenous flora and microflora for use in constructed wetlands for agro-industry effluent treatment, especially winery wastewater

University of Cape Town

No 1544

The wine industry generates problematic wastewaters from cellars and distilleries, particularly when these occur in rural and semi-rural locations. Wetlands are known to be of value and to work, but not particularly well for the high-strength organic wastes. The research programme is to design a constructed wetland for winery effluent treatment based on existing constructed wetland mathematical modelling but optimised by using indigenous effluent-tolerant plants and optimum soil profiles to enhance desirable microbial activity. This application of phylogenetic classification and evaluation of indigenous species for wetlands construction and optimization has innovative aspects.

Estimated cost: R500 000
Expected term: 2004-2006

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

Investigation and development of the biotechnology of sulphur biofilms in the beneficiation and treatment of wastewaters

University of Rhodes

No 1545

The WRC has made a substantial investment in sulphur systems biotechnology for the treatment (active and passive) of acid mine drainage AMD and certain industrial wastewaters. Biodesalination of these wastewaters requires that sulphur-derived TDIS be finally removed from the treated stream, but effective sulphur removal remains a technological bottleneck in these processes. This proposal seeks to further develop a sulphur-removal system based on sulphide bio-oxidation carried out in floating biofilms. This is a core technology in overall AMD bio-treatment processes and the proposal supports and extends current work being carried out in **Project No. 1456**.

Estimated cost: R924 810
Expected term: 2004-2006

Heavy metal removal from water with electrosorption using zeolite adsorbents made from co-disposal residues

University of the Western Cape

No 1546

On a technical level, the aim of this project is to develop a new electrosorption technology for removing heavy metals removal from water using low-cost disposable electrode cartridges containing zeolite adsorbents made from co-disposal mining residues. The potential cost/benefit has not yet been properly identified and a particular question is how electricity consumption in the process will compare to other established processes, a key consideration with regard to the net potential environmental benefits.

Estimated cost: R500 000
Expected term: 2004-2005

THRUST 4: INDUSTRIAL AND MINE-WATER MANAGEMENT

Programme 1: Quantification of water use and waste production

A first-order inventory of water use and waste production by the South African industrial, mining and power generation sectors

Arcus Gibb

No 1547

The aim with this project is to compile a first-order inventory of the amount of water used and waste produced by the South African industrial, mining and power generation sectors, and to assess the impact these have on water quality. Information in this regard is required to judge whether the present investment in research has the right mix and to provide strategic direction to research initiatives. The investigation will make optimal use of existing information such as the NATSURV investigation that provides a benchmark for water use and waste production by major South African industries, the COMRO report on water use by gold-mines, a WRC report on water use by coal-mines, a CSIR report on national waste production and DWAF's Water Resource Strategy on water requirements by different sectors. The available information will where necessary be supplemented by targeted field investigations and compiled into a consolidated overview that presents the total picture. The data on water use and waste production will furthermore be interpreted for the effect they can be expected to have on receiving water quality. In order to ensure credibility of the findings, they will be verified through a workshop with practitioners.

Estimated cost: R600 000
Expected term: 2004-2005

Programme 2: Regulatory mechanisms to improve industrial and mine-water management

Development of guidelines and recommendation towards the classification, rating and disposal of common industrial hazardous waste streams for the purpose of general authorisation for waste disposal

Environmental Business Strategies

No 1548

This project aims (*inter alia*) to identify common waste streams that are of such a nature that they do not need to be regulated and could thus be included in a list of General Authorisations of Waste Disposal, thereby relieving resources to concentrate on those waste streams that do need regulation. There is a big need for studies to help improve the understanding of the Minimum Requirements system and improve its use and reduce confusion. Current initiatives by DEAT to assume responsibility for managing waste sites, has introduced uncertainty about the division of responsibility between DWAF and DEAT. This project will proceed only after obtaining assurance of co-operation with the regulating authorities.

Estimated cost: R325 000
Expected term: 2004-2006

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

Impact of microbiology on fly ash-acid mine drainage co-disposal and remediation systems

University of Cape Town

No 1549

A current WRC/Coaltech project by the University of the Western Cape is investigating the reactions between alkaline fly ash and acid mine drainage and the potential to create value from these two waste products. This project focuses on quantifying the degree to which the microbiological population will be attenuated by the reactions between fly ash and acid mine drainage. This project will collaborate with the present fly ash-AMD study with the aim to:

- Identify the microbial diversity associated with the input and output phases of fly ash/AMD remediation systems
- Determine the survival of micro-organisms contributed by the input phases of fly ash/AMD remediation systems
- Monitor the mobilisation of metal ions (and other toxic ionic species) and gas (H_2S/CH_4) production in FA/AMD sludges.
- Link gas production and ion mobilisation to microbial distribution in sludge systems
- Investigate microbial options for soluble arsenic removal from the clarified water phase in FA/AMD remediation systems

Estimated cost: R559 000
Expected term: 2004-2006

Closure planning in the minerals extraction industry: The role of effective waste characterisation and water-related impact predictions for solid mineral wastes

University of Cape Town

No 1550

The mineral extraction industry is renowned for the contaminants that can emanate from their operations. Despite the fact that the quantitative prediction of environmental impacts associated with solid mineral wastes has been researched over the years, the bounds of uncertainty associated with currently available impact prediction methodologies remain high, and the ultimate fate of contaminants following waste disposal is still largely unknown. This project aims to assist with closure planning for the mineral processing industry by enhancing our ability to predict water related impacts associated with solid mineral waste and integrating that ability with decision making processes concerning water resource management. It is anticipated that a better understanding of the physio-chemical compositions, as well as the kinetic and metabolic behaviour of constituent components, will allow for more effective waste characterisation procedures, better assessment of the time-dependant leachate generation behaviour of waste materials, and ultimately in more realistic quantitative impact predictions.

Estimated cost: R655 000
Expected term: 2004-2006

Development of a first-order decision support system for the sustainable design, operation and closure of metaliferous tailings disposal facilities (S)

Golder Associates Africa (Pty) Ltd

No 1551

The mining of South Africa's gold, platinum and base metal

resources gave rise to hundreds of tailings disposal facilities covering an area of more than 200 km^2. These tailings contain significant proportions of sulphide minerals, which upon weathering give rise to a range of potential pollutants. Seepage to ground or surface water gives rise to various levels of water pollution over large tracts of land. In addition to their potential to degrade water quality chemically, tailings disposal facilities are often physically unstable and susceptible to collapse and erosion. They thus represent a long-term liability to the country. This project will provide a first order decision making tool that can be used by regulators, industry and consultants for the design and construction of tailings facilities that have "surfaces that last" and where the potential for contamination of surface and groundwater resources are practically eliminated. The envisaged decision support system (DSS) will cater for the life cycle of tailings facilities and thus be applicable not only to Greenfield developments but also to the large legacy of existing operational and non-operational tailings facilities. Gaps in our present knowledge base will be identified for potential follow-on projects.

Estimated cost: R600 000
Expected term: 2004-2006

Programme 4: Minimising waste production
Environmental life-cycle impact assessment of water use in selected industrial areas of South Africa
University of Pretoria
No 1552

The Life-Cycle Impact Assessment (LCIA) phase of LCAs evaluates the actual environmental impacts of industrial activities throughout the life cycles of products and processes. The available LCIA methodologies have shown certain limitations in the South African context, especially with respect to the use of water resources. The global Life Cycle Initiative of the United Nations Environmental Programme has addressed these shortcomings and an LCIA framework for South Africa has subsequently been proposed. The framework, and the accurate assessment of impacts of a system, is dependent on a comprehensive Life Cycle Inventory (LCI) of the evaluated system. Water use is included in LCIs, which are incorporated in the LCIA methodology as direct extraction from available resources. However, the environmental burdens associated with water supply extend beyond extraction and includes non-renewable energy use, land use, and pollution of air, soil and water resources. This project will compile a comprehensive LCI of water supply to a specific industrial area. The introduced LCIA framework for South Africa will be used to determine the extent of different environmental impacts, and will include newly developed impact categories for water.

Estimated cost: R160 000
Expected term: 2004-2005

The introduction of cleaner production technologies in the mining industry
Digby Wells & Associates
No 1553

While the mining industry has played a major role in the development of South Africa (and is still continuing to do so) it has also been identified as the largest producer of waste and as a major contributor to water quality degradation in many of our important catchments. It is recognised that the long-term solution to waste management is to minimise waste production and introduce cleaner production technologies. An analysis of the WRC's past and present project portfolio indicated that most of the research effort to address water and waste management in the mining industry was devoted to minimizing the impact of waste on the environment, to improve our ability to predict and quantify effects and to develop technologies to treat polluted waters. No projects devoted specifically to waste minimization and cleaner production technologies were undertaken. Although cleaner production is an essential backdrop against which to do environmental management and the mining industry has launched initiatives such as the mining, minerals and sustainable development project, it does not appear as if the industry has embraced cleaner production, as yet. This project is aimed at introducing cleaner production to the mining industry and entrench its concepts where it is already being practiced. For this purpose multi-facetted initiatives will be undertaken to raise the awareness of the

mining industry concerning the benefits and need for adopting cleaner production approaches. The project will start by assessing the level of awareness in the industry and identifying threats that could be alleviated by cleaner production technologies. Opportunities will be created to implement these and establish waste minimization clubs so that success stories can be generated which, in turn, can be used in an awareness campaign.

Estimated cost: R3 295 000
Expected term: 2004-2007

Programme 5: Improved ability to predict and quantify effects

Study of the kinetic development of oxidation zones of tailings dams with specific reference to the Witwatersrand gold mine tailings dams
Pulles Howard & de Lange
No 1554

The WRC is currently funding (**Project No. 1347**) a one-year study by Golder and Associates to determine and predict the depth and rate of weathering on gold tailings dams, and to develop rapid procedures to assess the risk for a specific tailings dam to produce AMD. This project will complement and extend the present study by building on its findings and extending them. The large-scale reclamation of dams, ranging from 10 to 100 years in age, provides a perfect opportunity to study tailings dam profiles and characterise their oxidation profiles. The project aims to advance our knowledge and ability to practically implement improved prediction capacity in the following areas:

- Establishment of validated kinetic variation of oxidation zones
- Increasing the accuracy of predicting the depth of oxidation zones
- Increasing the accuracy of predicting the phreatic surface
- Applications to any other similar environment, e.g. platinum group metals (PGM) and copper mine tailings

Estimated cost: R360 000
Expected term: 2004-2005

THRUST 5: SANITATION AND HYGIENE EDUCATION

Programme 1: Rural sanitation and hygiene education

Design, testing and documentation of practical methods to move the Archloo VIP toilet to a new pit once the original pit is full
Mvula Trust
No 1520

This is a practical, action-orientated research project, which is of high priority and relevance to the sector. It aims to test the moving of Archloo toilets, looking into their structural integrity, easiness, etc. This will entail investigating design, use of materials and community facilitation of moving toilets.

Estimated cost: R212 000
Expected term: 2004-2005

Involving traditional healers and myths and stories in hand-washing/hygiene education / sanitation promotion initiatives
Sigodi Marah Martin
No 1521

This study will examine the myths and traditional practices around WSS and hygiene, with the intention of developing strategies to involve traditional healers and the practices in promotion of health and hygiene activities and messages. The proposal offers a fresh approach at using local resources and systems to promote good sanitation and hygiene.

Estimated cost: R326 000
Expected term: 2004-2006

Education, awareness and behaviour change requirements to improve safe water practices
CSIR
No 1522

The main aim of this study is to determine or identify the water handling practices and behaviours which have a negative impact on users. Then use this as the basis to develop a framework for action and guidelines on improving hygiene behaviour. The study could break new

ground and lead to new approaches which will lead to benefits in better health and hygiene promotion.

Estimated cost: R650 000
Expected term: 2004-2006

The effectiveness of water and sanitation awareness programmes in informal area
Nemai Consulting
No 1523

This study aims to develop and investigate the criteria for determining the effectiveness of WSS awareness programmes in informal areas; develop a guideline on this information and test this on local case studies. It is then intended to use this info in developing appropriate strategies for effective awareness campaigns.

Estimated cost: R200 000
Expected term: 2004-2006

Programme 2: Peri-urban sanitation research
Understanding the disposal and use of grey-water in the non-sewered areas in South Africa
University of Cape Town
No 1524

There is a strong drive from the South African government to attain basic water and sanitation coverage. The level of service to meet this requirement being applied by the majority of authorities in urban and rural areas relate in most cases to on-site dry latrines (VIPs or equivalent) and 25ℓ/cap.d of drinking water. As water and sanitation services are attained and improved, the potential for problems related to the disposal and management of grey-water will emerge. Solutions are required to circumvent or minimise these problems. The study aims to undertake a complete scoping exercise to identify current and historic grey-water management initiatives in urban and rural areas, and to identify problem areas / challenges. Determine and assess existing management and disposal practices within South Africa.

Estimated cost: R800 000
Expected term: 2004-2006

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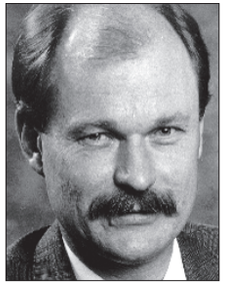
KSA 4

WATER UTILISATION IN AGRICULTURE

Making the Difference - Improving Agricultural Water Management



Dr Gerhard Backeberg
Director

Scope

The strategic focus in this KSA is on increasing the efficient use of water for the production of food, fibre, fuelwood and timber; ensuring sustainable water resource use; reducing poverty and increasing 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.

This thrust includes two programmes:

- 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 specialisa-tion, 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.

This thrust includes one programme:

- 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.

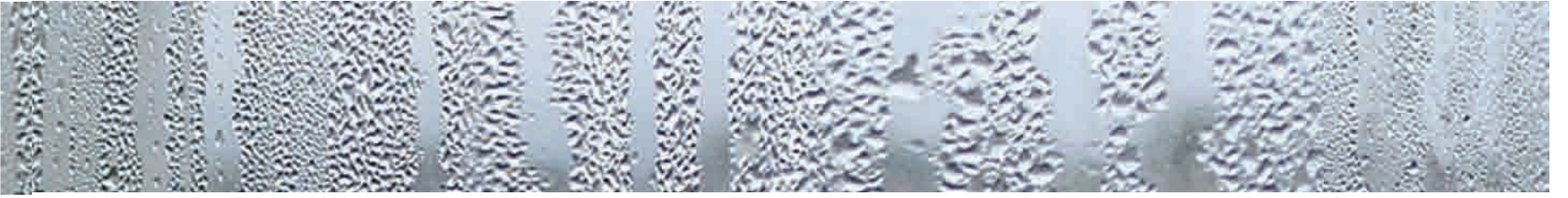
Commercial farming is a major user of water resources and faces a particular challenge to ensure that this share of water is used effectively and efficiently. There is invariably a close link between efficient use and allocation of water and whole-farming profitability. Water management on farms is also 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

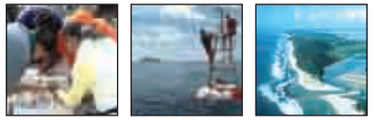
This thrust includes two programmes:

- 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 processes of production of field, horticultural and industrial crops. With cultivation and irrigation, larger quantities of salts present in the soil and lower strata could be mobilised. Increasing salinity levels and higher water tables threaten the sustainable use of soil and water. Knowledge and tools to manage the quantity and quality of water resources for agricultural production are therefore required. The focus of research is





on developing methods and models to manage water distribution and prevent water resource degradation.

Agricultural decisions to use land and to conserve rainfall or to withdraw water from rivers, dams and boreholes, has wide-ranging impacts on the natural environment. 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. 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. This thrust includes two programmes:

- Sustainable water resource use on irrigation schemes and within river catchments
- Impact assessment and environmental management of agricultural production

Budget for 2004/05

The approved funding of the research portfolio for 2004/05 leads to a committed funding budget of R11.1m. The focus of this portfolio will be along the current trends.

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.

As in previous years, water utilisation can best be quantified as rainfall-dependent, surface water- and groundwater-dependent use. Approximately 12% and 62% of rainwater in South Africa is used annually for respectively dry-land cropping and by natural grasslands, woodlands and forests. Rainwater runoff and deep percolation become available as surface- and groundwater 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 13.8m. people in South Africa, at least 35% are directly or indirectly dependent on agriculture. This consists of small-, medium- and large-scale enterprises, which provide employment opportunities for 11% of formal labour. Furthermore, 59.9% of all households live in urban areas and 40.1% of households live in rural areas. In these rural areas, 64.2% of households or at least 10.5m. people are poor and are living below the 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, waterlogging 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.

With 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:

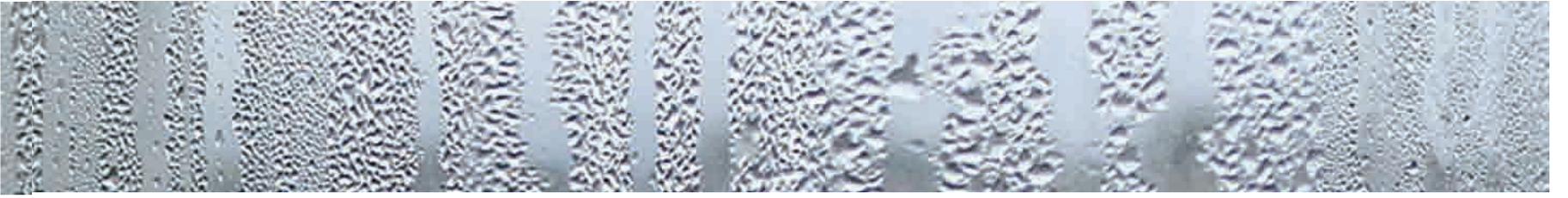
- Fair reward for effort, risk and innovation
- Security of tenure for present and future participants
- The sustainable use of natural and biological resources
- Sound research, science, knowledge and technology systems
- Market forces which direct business activity and resource allocation

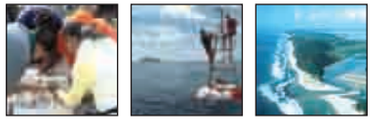
The outcomes which are envisaged to flow from successful implementation of programmes include:

- 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 are still relevant and as in previous years, highlight the key issues which must be addressed in the WRC research portfolio.





Technological trends

With growing demand for water in the domestic and industrial water-use sectors, the competition for water currently used for agricultural production will increase in future. Technologies, models and methods are available to improve the efficiency of 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-Sahara 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. These trends have been re-enforced by the Comprehensive Africa Agriculture Development Programme of NEPAD, published in July 2003.

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, the National Department of Agriculture and the Department of Water Affairs and Forestry. These individuals, groups and organisations remain the key stakeholders with which the WRC has to engage.

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 largely have stayed the same as in previous years and are the Provincial Departments of Agriculture (PDAs), the National Department of Agriculture (NDA) through its Directorate: Water Use and Irrigation Development and the Department of Water Affairs and Forestry (DWAF) through its Directorate: Water Use Efficiency. 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 Inter-Departmental Co-ordinating Committee on support for small-scale irrigation has also been formed, and as part of this action a task team is revising guidelines for project evaluation.

Locally the Human Sciences Research Council (HSRC) has reorganised its research activities and regrouped its projects into interdisciplinary new priority areas (NPAs). The NPA of Integrated Development is to undertake research which is designed to promote sustainable development in rural and urban areas. In addition various Institutes of the Agricultural Research Council (ARC) obtain funding and undertake research on water-related subjects. Of particular relevance is water research in relation to soils and climate, engineering, field, horticultural and forage crops.

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 resources management for food, livelihoods and nature. Research is as before 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 are universities and technikons/colleges (currently Universities of Pretoria, Natal, Free State, Stellenbosch, Rhodes 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.

STRATEGIC INITIATIVES UNDERTAKEN DURING 2004/05

The KSA was involved in a number of key national, Africa-focused and international initiatives:

National initiatives

- The WRC played a leading role in presenting the national symposium of the South African National Committee on Irrigation and Drainage (SANCID) in November 2004, during which 40% of the 32 papers presented were based on WRC-funded research projects
- The WRC organised a workshop on cooperation with the ARC on the up-scaling of water harvesting from homestead food gardens to communal croplands. Particular attention was given to mechanisation of cultivation with 30 participants from private and public organisations present.
- Concerted efforts were made to improve the public understanding of water-related issues by means of a series of articles with the title "Irrigation talk" in *The Water Wheel* and providing brief summaries of recently published WRC reports in the magazine *Agri*, which is distributed nationally to farmers and agricultural interest groups
- Consultation with stakeholders in AgriSA and NAFU was started, to obtain support for the collection strategy of WRC water-research charges. During two open days organised by the WRC, posters were displayed to show-case some key research results achieved in KSA 4.

African leadership

- An invitation was received from IWMI, and the WRC participated in an African Training Hub meeting at the Blyderiver Resort, Mpumalanga Province in December 2004 organised by IWMI and the World Bank, by displaying posters and WRC reports and making two presentations on WRC-funded projects.

- Within Africa the membership of the Southern African Regional Irrigation Association (SARIA) was re-activated through a WRC initiative and representatives from Botswana, Lesotho and South Africa met in the Eastern Cape Province to discuss future activities

International initiatives

During the September 2004 congress of ICID in Moscow, Russia, the WRC participated in two workshops:

- The workshop on *Water Harvesting and Sustainable Agriculture* was co-chaired with three papers on biophysical and socio-economic aspects of water harvesting presented by WRC researchers
- A session was chaired and a paper presented during the workshop on *Management of Poor Quality Water for Irrigation*

An initiative was taken to present a South African case study on the "Economics of Water Harvesting" during the FAO/Netherlands organised international conference on *Water for Food and Ecosystems* in The Hague, January/February 2005.

The international workshop on "Water Resource Management for Local Development" held at Loskop Dam Resort in November 2004 was co-sponsored and organised by CIRAD, French Embassy, WRC and DWAF. Out of 50 papers, one keynote paper and six contributed papers were on WRC projects.

IMPLEMENTATION PLAN

Research portfolio for 2004/05

As in previous years, the primary objective is to increase national food security, improve livelihoods of people and to increase efficient growth and equitable distribution of wealth on a farming, community and regional level through efficient and sustainable utilisation and development of water resources in agriculture.

The secondary objectives are to:

- Increase biological, technical and economic efficiency of water use
- Reduce poverty through water-based agricultural activities
- Increase profitability of water-based farming systems
- Ensure sustainable water resource use through protection and reclamation practices.

An overview of KSA 4 research thrusts and programmes is presented 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 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 resource use on irrigation schemes and within river catchments	**Scope:** With cultivation and irrigation, larger quantities of salts present in the soil and lower strata could be mobilised. Increasing salinity levels and higher water tables threaten the sustainable use of soil and water. Knowledge and tools to manage the quantity and quality of water resources for agricultural production are therefore required. The focus of research 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 use land and to conserve rainfall or to withdraw water from rivers, dams and boreholes, has wide-ranging impacts on the natural environment. 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. 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 FOR 2004/05

The findings for research 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 1 April 2004 and 31 March 2005.

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

The factors influencing the performance of subsurface drip irrigation systems

Institute of Agricultural Engineering, Agricultural Research Council

No 1189

Drip irrigation is considered to be the most efficient irrigation system, but there is evidence in the literature that this system can also be inefficient due to bad water quality, mismanagement and poor maintenance. Clogging of the emitters is one of the most serious problems associated with sub-surface drip irrigation. As a result of this project, guidelines were developed to enable irrigators with sub-surface drip irrigation systems to apply good management and maintenance schedules to enable them to adhere to the conditions of the National Water Act (Act 36 of 1998) regarding the efficient and beneficial use of water in the public interest. Currently, sub-surface drip systems account for ± 7 500 ha of the total of 140 000 ha of drip irrigation in South Africa.

Drip irrigation equipment from three companies was evaluated in laboratory tests and field analyses. The performance of five new emitters was assessed under controlled conditions in the hydro laboratory of the ARC-Institute for Agricultural Engineering. In field evaluations, two areas in southern Africa with a total of five systems were identified in the Mpumalanga Lowveld and Swaziland. Apart from the performance evaluations, data were also collected on the maintenance schedules. Water samples were taken for water quality analysis and farmer questionnaires were completed, which supplied most of the background information.

The results of the tests on the retrieved emitters are discussed in terms of clogged and functional emitters. The clogged emitters are discussed in terms of root clogged and other clogged emitters. The functional emitters are divided into three discharge categories namely the

reduced discharge, the *average discharge* and the *increased discharge* categories. As anticipated, emitters with smaller flow paths were more likely to clog than emitters with larger flow paths. The emitters with the larger flow paths were thus inclined to perform better when using water that has a severe clogging potential, especially where irrigators did not make use of reliable maintenance schedules. In the root growth inhibitor (Treflan) treated blocks, the emitters showed 74% less root intrusion than the untreated blocks. The untreated blocks were 29.3% root intruded against the 7.5% of treated block and there was also a significant increase of root intrusion of 505% over the 42-month period in the untreated blocks. The impact of clogging in the untreated blocks was evident with the 16% decrease in emitter delivery rate and the worsening of the coefficient of variation (CV) from an excellent 3.04% to a very poor 56.36%. An average 34% of the emitters were no longer functional after the 42-month testing period. With the treated blocks, root intrusion could not be prevented completely and after the 42-month period, 16% drippers were not functional (27% better than the untreated blocks). The impact of the clogged drippers in treated blocks was that the CV dropped from an excellent 3.04% to a poor 32.30% which was still 43% better than the untreated blocks. However, the average emitter delivery rate stayed fairly constant.

Appropriate installation and maintenance are of utmost importance for the successful long-term operation of any sub-surface drip irrigation system. It is recommended that water quality analysis be carried out to identify the potential clogging problems due to water quality. This will assist in emitter type and filter selection and help in developing proper preventative measures. The use of a root growth inhibitor is also of critical importance with a sub-surface drip system to prevent root intrusion. Solutions to specific clogging problems and the choice and management of equipment to help ensure effective water utilisation are provided in the report. Information on design principles and operation and maintenance for best management practices is also presented. The importance of a complete design report with details of the system's specifications, maintenance requirements and installation guidelines is emphasized.

Cost: R343 000
Term: 2000-2004

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

The majority of small-scale farmers are located in less favoured agro-ecological conditions, with poor soils, and low and erratic rainfall. The development and transfer to farmers of production practices and techniques that encourage water and soil conservation, and increased water use efficiency can provide small-scale farmers with an opportunity to increase agricultural production. However, before these water conservation techniques and other new production technologies can be transferred to farmers, analyses to assess their economic viability, social acceptability and environmental sustainability are required.

The main aim of the study is to carry out economic viability and social acceptability analyses, and an assessment of the environmental sustainability of in-field rainwater harvesting techniques.

The study employs participatory research techniques, such as Participatory Rural Appraisal (PRA) and Participatory Action Research (PAR), to facilitate involvement of smallholder farmers in the diagnosis of constraints they face in their production activities and the formulation of technological interventions that can be employed to help overcome these constraints. The report discusses the essential features of the PRA and PAR methods, and the procedures followed in conducting PRAs and PAR in the study villages are described.

The new technologies should provide significant

economic returns if farmers are to be persuaded to undertake the required investments. Profitability analyses using enterprise budgets show that there is a significant increase in farm income when farmers adopt rainwater harvesting compared to the income levels achieved under conventional crop cultivation. By adopting the simplest form of in-field rainwater harvesting-without the use of mulches in the basins and the runoff area, farmers can increase their income by about R800.00 per hectare in the case of maize production.

The results reported in this study suggest that farmers are willing to apply IRWH techniques in their production activities, and that these techniques are not only economically viable but also environmentally sustainable. Based on these findings it can be recommended that extension efforts should be undertaken to encourage adoption and adaptation by farmers.

While the preliminary results reported here suggest that the use of IRWH techniques provides social, economic and environmental benefits, these findings come from assessment of the techniques in a short period. There is a need for continued monitoring of the impacts (environmental, economic and social) of these techniques. In this regard it would be necessary to conduct an impact assessment study in three to four seasons from now. This will allow a better understanding of the role that IRWH can play in the farming systems in semi-arid areas.

Cost: R425 800
Term: 2001-2003

Programme 2: Integrated water management for profitable farming systems

Water markets in irrigation areas of the Lower Orange and Crocodile rivers of South Africa

Prof WL Nieuwoudt

Consultancy No 552

Irrigation farmers in the Lower Orange and Lower Crocodile rivers of South Africa were surveyed during 2003/04 in order to study the impacts of water transfers and risk and risk aversion on resource use. Irrigation farmers in both areas appear highly risk averse as measured by the Arrow/Pratt risk aversion coefficient (especially for down-side risk). In the Lower Orange River, where water supply is fairly stable, income per cubic meter of water was an important variable in explaining water transfers. In contrast, water supply in the Lower Crocodile River is highly irregular. In the latter river, risk reduction appears to be more important in water reallocation. Results provide support for transfer of water licences from lower valued to higher valued uses through water markets. Survey data were analysed using principal components, logit and ridge regression. A theoretical contribution of the study is to standardise the Arrow/Pratt absolute risk aversion coefficient for scale and range of data. Policy risk and risk aversion also appear to be important in explaining expected future investment in irrigation farming in the Lower Orange River. Results show that farmers, who view water use rights as not secure, expect to invest less. The latter effect is thus amplified as farmers appear to be highly risk averse. Important policy implications are that farmers should be better informed about the practical implications of the new National Water Act and specifically water licences.

Cost: R157 500
Term: 2003-2004

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

Irrigation farmers need to consider many technical, economic and financial factors when choosing or evaluating different irrigation systems. This research project proposes methods to estimate costs for various combinations of irrigation systems in the Onderberg and Nkomazi areas of the Mpumalanga Province. The research further demonstrates methods to analyse the profitability and financial feasibility of the various irrigation systems on a whole farming level.

The goal of the research was to analyse the most important irrigation systems in the Onderberg/Nkomazi areas on a whole farming level for both large-scale and small-scale

farms economically and financially.

This research focuses on both large-scale and small-scale irrigation farming. The small-scale irrigation farming includes five independent case-study farmers in the region, as well as 24 project farmers on three irrigation projects, namely Madadeni (7 ha plots under dragline irrigation), Mbongozi (5 ha plots with centre pivots), and Walda (10 ha plots under floppy irrigation). The data for the large-scale irrigation farming were collected from 74 farmers.

The output of the research is, firstly, the cost-estimating procedures which were developed for drip-, micro-and furrow-irrigation systems; secondly, that the cost of any combination of the above-mentioned irrigation systems together with centre pivot- and dragline-irrigation systems can be analysed; thirdly, that the economic analyses were done on a whole farm level, taking risk into account, for small-scale farmers on irrigation schemes, independent small-scale farmers as well as large-scale farmers. The universal result was that cash flow is the biggest problem for all the farmers to different degrees. For the small-scale farmers the challenge is to survive financially and for large-scale farmers is to finance expensive irrigation systems and long-term crops such as orchards.

The cost-estimating procedures should be used to estimate the total fixed and operating costs of the major irrigation systems. These procedures are suitable for on-farm use by irrigators and advisors. They can be used to decide over the long run which irrigation systems to buy, and in the short run how to manage the operating costs which are directly linked to the decisions of how much, how and what to produce.

It is recommended that business plans of irrigation farming should include the effects of business and financial risks on survival. Reliable crop enterprise budgets for all the relevant crops under irrigation should be developed and maintained for small-scale irrigators.

Policy-makers should ensure that sound financial incentives are adequately put in place to help small-scale farmers. New projects should take cognizance of the crucial financial effects of plot size and reliable product markets. A land tenure reform policy in tribal areas is needed to encourage investment and development on these farms. An efficient land market should be supported based on security of property rights and low transaction costs.

Cost: R750 000
Term: 1998-2004

Sustainable local management of smallholder irrigation
Department of Agricultural & Environmental Sciences, University of the North
No 1050

The Government of South Africa has invested substantially in smallholder irrigation over several decades, particularly in the former homeland areas. In Limpopo Province alone, there are 171 irrigation schemes with assets valued at R4 billion. However, most of these irrigation schemes are not performing optimally. As a result, the original purpose of generating employment and reducing rural poverty through the establishment of these schemes has not been achieved in many instances.
This study was undertaken with the objective of contributing to rural poverty alleviation by improving productivity, profitability, gender equity and environmental sustainability of smallholder irrigation. Investigations were conducted at six irrigation schemes in the Olifants River Basin of Limpopo Province with plot sizes ranging from less than 0.1ha to 5ha and where a variety of crops are cultivated, including maize, wheat, cotton, and vegetables. A multidisciplinary approach was adopted to achieve the objectives of the study. Participatory approaches and questionnaire surveys were used to collect data on socio-economic aspects while agronomic experiments and other tools of measurement were used to collect data of a technical nature.

As anticipated, the study found that agricultural productivity in the irrigation schemes investigated is generally low. This is particularly so in maize production where most farmers producing maize were incurring losses. The most profitable enterprises included high-value crops such vegetables and wheat. Contrary to the findings of other studies that have reported that smallholder farmers

depend mainly on pensions and remittances for their income, this research revealed that farming at the six irrigation schemes investigated constituted the major source of household income. However, while farming plays a dominant role in poverty alleviation and food security, generally, it does not generate sufficient income. Naturally, there was a positive relationship between food security and land size. Farmers with smaller plots tended to experience food insecurity while those with larger plots did not. Most farmers, irrespective of their land size, apply excessive amounts of water when it is their turn to irrigate their plots resulting in low water productivity. Despite these practices, salinity levels in all the irrigation schemes are within acceptable levels. Although smallholder farmers practise crop rotation, leguminous crops which enhance nitrogen cycling within the plant-soil system are generally not included in the rotation.

Government withdrawal from support service provision in the irrigation schemes has severely hampered the productivity of smallholder farmers. Some of the schemes have almost collapsed and access to support services has been severely curtailed resulting in low productivity and food insecurity. Despite the minimal support service provision from Government, for the majority of farmers the extension agent remains the main source of production and marketing information. However, extension officers themselves are not equipped to provide the required information due to inadequate training. Although smallholder irrigation farmers aspire to remain in farming, access to support services and irrigation water remains a major concern. Unfortunately, the scope of water user associations (WUAs) is limited to irrigation-related issues and does not extend to provision of support services.

The current organizational arrangements in the irrigation schemes are characterized by major shortcomings in terms of meeting gender equity objectives and ensuring adequate participation of disadvantaged groups. Organizations such as irrigation committees and WUAs are dominated by men with little participation of women. Notwithstanding these shortcomings, the committees are highly rated and enjoy the support of farmers. The study concluded that the irrigation management transfer process in Limpopo Province is proceeding before the necessary success factors are in place and this may result in failures. The emphasis in the transfer process seems to be on rehabilitation of the irrigation schemes with little attention paid to other factors which are necessary for raising productivity and making farming profitable. The main recommendations of the report consist of suggested improvements to various institutional and organisational arrangements of the irrigation schemes.

Cost: R863 500
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

Irrigation scheduling is accepted as the process to decide when to irrigate crops and how much water to apply and is assumed to play an important role in the general improvement of water use efficiency on the farm. However, the idea that there is a single key to the adoption of irrigation scheduling as a component of efficient water use on the farm is simplistic. It implies that science has all the answers, and scientists just need to convince the farmers of its value.

The adoption of irrigation scheduling amongst commercial and small-scale farmers was investigated with the purpose of identifying the possible human and socio-economic factors that may influence the adoption thereof. This investigation was done on macro (scheme) level as well as micro (on-farm) level.

By combining the quantitative assessment on 332 irrigation schemes and the insights gained from the semi-structured interviews conducted with key individuals in the irrigation fraternity, a more focused approach was followed in the identification of human factors and constraints that impact on the adoption of irrigation scheduling practices of commercial and small-scale farmers. The quantitative survey amongst a random sample of 134 commercial farmers from eight different provinces

represented the micro level of the study. This also comprised the investigation and description of the irrigation practices and scheduling methods used by small-scale farmers as well as their perceptions and possible reasons for adopting or rejecting the use of irrigation scheduling methods. Interviewing key informants on several of the small-scale irrigation schemes formed the second phase of this investigation. Four small-scale irrigation projects were selected for more detail investigations and assessments, to illustrate the different approaches followed in the training and development of small-scale irrigation farmers in the use of irrigation scheduling practices.

Farmers generally perceived the efficient use of irrigation water on the farm as being the major reason for the adoption of irrigation scheduling practices, and not just the conservation of irrigation water *per se*. Perceived indicators of efficient use of irrigation water on the farm include the improvement of the quality of high value crops, increasing of production yields, decreasing of energy (diesel and electricity) operational costs and improvement of the management efficiency of nitrogen and other nutrients. Accuracy, reliability, ease of implementation and affordability are some of the important technological characteristics of scheduling methods and devices that were identified by the farmers.
The majority of small-scale farmers do not perceive irrigation scheduling as an important production constraint. They are preoccupied with the persisting barriers to progress, which include lack of credit, infrastructure, and access to markets, land tenure, vandalism and theft and extension support. Many of the extension officers involved in the survey admitted that they lack the necessary knowledge and skills in irrigation management, and are consequently not in a position to render an effective service to farmers.

The study found that commercial irrigation farmers rely mainly on information from the local co-operative, private consultants, industry experts and fellow farmers, while the majority of the small-scale irrigators depend more on information from the departmental extension officers. A significant relationship exists between the number of information sources used and the implementation of the type of irrigation scheduling methods which implies that farmers involved in the use of objective scheduling methods are more willing and prepared to seek additional information sources outside the irrigation area than the farmers involved in subjective scheduling methods.

One of the most valuable insights derived from this project was the identification of the vast difference in perception regarding irrigation scheduling and what it involves. Some of the farmers perceive irrigation scheduling as a means of finding solutions to their problems, and will therefore make use of the most scientific and sophisticated methods that are available, while the majority of irrigation farmers are more interested in the use of irrigation scheduling to identify "troubles or problems" (trouble shooting) experienced with irrigation. These farmers are therefore not always interested in absolute accuracy and sophisticated equipment, because no relative advantages could be perceived from the use of it. Therefore, it is inevitable that farmers will differ in their selection of the most appropriate scheduling method and technique, as their needs will be based on the relative technology level of operation required on the farm.

Cost: R586 000
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

Most commercial farmers recognise that effective irrigation scheduling is a prerequisite to save on irrigation water and to improve on water-use efficiency. However, only a small percentage of irrigation farmers currently use any scientific irrigation scheduling aid. One important reason may have been the lack of quick, simple and reliable irrigation scheduling techniques. This aspect has been addressed to a large extent by the development of the Soil Water Balance (SWB) Model. Although the model follows a scientifically based mechanistic approach, a user-friendly interface makes it accessible to any person with basic

computer training.

It became clear that in order to make SWB usable and accessible to all potential users, firstly changes to the computer software and secondly the training of potential users on a national scale had to be done, to enable them to use the model on their own.

The same course outline was used for the three course levels, although the emphasis was different for the student, consultant and farmer. The course material consisted of theoretical background of the soil-plant-atmosphere continuum, followed by an introduction of the SWB model. Practical demonstrations and exercise sessions formed an integral part of all three courses.

Irrigation calendars were developed as an alternative to real-time irrigation scheduling with SWB. The SWB model was modified to enable the generation of site-specific recommendations of seasonal irrigation requirements, which is printed out and handed to the farmer. Irrigation calendars should be especially useful to farmers without computers and access to real-time weather data, but commercial farmers could also benefit from this simpler management option.

It can be concluded that the first objective of this project, namely to further develop the SWB model as a user-friendly irrigation-scheduling tool, has been achieved to a great extent, as most of the concerns raised by users and course attendees have been attended to. However, some feedback suggested that certain aspects, such as required model inputs, could be simplified even further. This aspect should receive attention during further model development.

The second objective, which focused on the transfer of developed technology to potential users by establishing the SWB model as a user-friendly irrigation-scheduling tool through training sessions, has only partly been met. Although training sessions were presented and may people were exposed to SWB, it cannot be stated categorically that SWB has now been accepted as a scheduling tool on a broad basis. However, the training sessions were a good capacity building experience for most attendees, which should result in a positive impact on the management of irrigation water in the long term.

A backup service to individual users should be provided by the establishment of call centres manned by trained staff in key areas. Such call centres could, for example, be established with staff of WUAs or Irrigation Boards, or it could be run by consultants as a business venture. Centres like these could handle all SWB related enquiries and problems of users. It could also generate irrigation calendars for farmers who cannot be serviced by SWB consultants.

Cost: R587 200
Term: 2001-2005

THRUST 4: WATER RESOURCE PROTECTION AND RECLAMATION IN AGRICULTURE

Programme 1: Sustainable water resource use on irrigation schemes and within river catchments

Development of guidelines for treatment of scale in assessing the streamflow reduction impacts of alien infestations

Ninham Shand (Pty) Ltd

No 1221

Increased water demand, coupled with the continuously dwindling water resources and the impacts of years of water management under South Africa's 1956 Water Act as well as its replacement in 1998, have called for drastic a shift of focus and principles behind the licensing and management of water use. Water uses that require licensing now include other land-based activities which reduce streamflows. Section 36 of the National Water Act (NWA) of 1998 provides for the Minister of Water Affairs and Forestry to declare certain land uses as streamflow reduction activities (SFRAs). After an SFRA declaration, the water use will now be regulated by licensing and water use charges. At present forestry is currently the only declared SFRA where licensing and charging of water use is required. Ongoing initiatives are looking at the declaration of other land use practices such as dry land sugar and bamboo plantations as SFRAs.

This project investigated the existing streamflow reduction

(SFR) estimation techniques in different catchments, at a number of varied scales. In this research weakness in the different SFR estimation approaches, especially model inputs, model algorithm and outputs are identified and recommendations made to improve the accuracy and reliability of future SFR estimates. The SHELL model (a version of the Pitman Model modified by Ninham Shand to include afforestation and alien vegetation routines) and ACRU model (which incorporates the SFR curves (after Scott and Smith, 1997; Gush et al, 2001)) were used to simulate the reduction in flows due to alien vegetation and afforestation. Field-based measurements and estimates of streamflow reduction were analysed and included as sources of additional estimates of streamflow reduction. The outputs from the hydrological models were then applied to the yield model (WRYM) to determine the impacts of the different streamflow reduction regimes on overall catchment yield.

The absence of uniformly fine or high-resolution data on vegetation mapping, soils, and rainfall were noted to have significant negative impacts on the higher resolution ACRU daily model simulations. As a result ACRU model gave significantly lower estimates of streamflow reduction. The method used in ACRU, which is currently used nationally was also noted to be very sensitive to a number of different physical processes that are usually poorly represented at large scale and in national hydrological considerations. The method applied in SHELL was noted to provide more predictable outputs and to be more suitable for the larger area simulations that were investigated. This study is expected to influence the selection and refinement of suitable SFR estimation techniques used for licensing afforestation and other land-use practices that will be declared SFRA in the future.

Cost: R599 700
Term: 2001-2003

Irrigation water measurement: The application of flow meters in irrigation water management
Department of Agricultural Food Engineering, University of Pretoria
No 1265

The WRC initiated a research project in 2000 in order to review the current situation and needs in the field of irrigation water measurement in South Africa. The main objective of the project was to develop guidelines for the correct choice, installation and management of water measuring devices by Water User Associations (WUAs) for canal, pipeline and river distribution systems.

A series of field visits to important irrigation areas in South Africa as well as visits to a number of measurement equipment manufacturers and the relevant government departments were undertaken. A comprehensive literature study of flow measurement in irrigation was also conducted. A considerable amount of time was spent on the activities for the installation of various flow measurement devices at irrigation schemes. Different types of flow meters as well as water level sensors were installed at a number of WUAs, and monitored for extended periods of time. Shorter evaluations were conducted under laboratory conditions. Surveys were conducted amongst water users from 6 different WUAs with different water distribution systems, irrigation systems and farming conditions. The areas covered were the Lower Riet River, Umlaas River, Loskop, Vaalharts, Hartbeespoort and Dendron. The water measuring guidelines included in this report were compiled and a computer based database of commercially available measuring devices for irrigation water (KBS) was developed.

The process of planning and installing measurement devices in the field exposed the project team to some of the constraints that WUAs have to face when implementing water measurement as required by legislation. The contact with specific WUAs helped to create a better understanding of the day-to-day activities on the schemes, and assisted in developing practical guidelines for water measurement, which was the main objective of this project.

The contact with water management staff and users showed that irrigation water measuring cannot be considered in isolation but is rather one of the tools that can be used by WUAs and of which greater awareness is necessary, especially as far as new technological development is concerned. This, together with the interest

that was shown in the Discussion Forum of stakeholders, definitely points to a need for the transfer of information to WUAs and water users.

It was found that suitable measuring devices are available, but in order for them to be used successfully, they need to be installed correctly, well maintained, and read accurately. In other words, a WUA's water measuring system has to be managed. This approach of managed implementation consists of at least the following components:

- A reason for measuring ("trigger")
- Acceptance and support by the water users
- Assessment of the current situation and planning the system
- Choosing appropriate technologies
- Correct installation by skilled technicians
- Sound operation and maintenance policies
- A system for data retrieval and management
- Comprehensive financial planning
- Procedures for handling disputes and tampering

The guidelines that were compiled are aimed at implementing this approach successfully in practice, and give a detail description of the actions that need to be taken under each component listed above. There is currently no policy to guide WUAs in this and it is hoped that this report will provide some guidance to policy makers with regard to the issues that have to be addressed.

Cost: R1 234 300
Term: 2001-005

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. The new vegetation extracted a smaller portion of the stored, infiltrated water 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 was 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 project aimed to test this hypothesis 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.

Remote sensing through aerial photography indicated that there is widespread patchiness in croplands, especially in wheat fields that dominate land use in the catchment. Ground-truthing by soil sampling and analysis of transects through the barren patches confirmed that they are associated with soil salinity which is of sufficient magnitude to explain the poor wheat growth. Use of a soil salinity sensor (EM 38) in the field proved to be a successful substitute for detailed soil sampling to quantify soil salinity and to subject its distribution to geostatistical analysis and interpretation in relation to land use and topography. Spectral manipulation of new colour ortho-photos that are available for a portion of the catchment has demonstrated that the bare patches in wheat fields can readily be demarcated, allowing their aerial extent to be quantified.

Despite the fact that a new, comprehensive database has been assembled by regional water specialists on ground-water quality, the records for the drier, more saline sub-catchments of the Berg River remain sparse and are inadequate for establishing a connection between soil or regolith salinity and groundwater salinity.

Long-term salinity records of selected tributaries of the Berg River indicate that some trends are discernible, although masked by freshening releases of Theewaterskloof water into the Berg River since the early 1990s. The data seem to confirm the importance of climatic (as opposed to palaeo-geologic) factors in determining the development of dry-land salinity.

Modelling of likely runoff under different vegetation

scenarios (winter wheat vs. renosterveld) using the ACRU model, suggested strongly that land-use changes potentially have a major impact on salt release from the regolith into surface waters. This supported the hypothesis that a switch from perennial deep-rooted renosterveld to annual shallow-rooted wheat would result in less water use and therefore enhanced discharge of salts into the river system, similar to what has been found to have occurred (and is still occurring) in wheat lands of Australia which have replaced *Eucalyptus* scrub over the past century.

This pilot study has confirmed that dry-land salinity is extensive and is likely to have a significant impact on water quality in the river. It has also provided the justification and the basis sought for planning a follow-on study aimed at fully understanding and quantifying the problem.

Cost: R449 000
Term: 2002-2004

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

Agriculture has been implicated as a major source of non-point source (NPS) pollution because most of the land area is utilised for agricultural activities. It is therefore 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 to reduce NPS pollution. This project aimed to involve major players active in this field in a scoping exercise and knowledge gap analysis in order to develop the terms of reference for a longer term project that would establish an integrated model for the prediction of agricultural NPS pollution from field to catchment scales for the major agricultural NPS pollutants.

The methodology that was followed was primarily strategic in nature, with carefully selected detail investigations. Selected specialists conducted detail work according to circumscribed briefs. Strategic and scientific overview inputs were made by a small core team. One or more colleagues with complimentary skills and capacity supported the specialists where necessary. A series of scientific assessments were conducted on individual pollutants (each by a different specialist) to prepare position papers for the five key NPS water quality concerns. These individual assessments were integrated by a core team to yield the Terms of Reference for a long-term research programme by the WRC. Position papers were prepared for pesticides, nutrients, sediments and metals, pathogens and economic instruments. The main components of the position papers were:

- Brief overviews of the extent of each problem within a national context and statements on data and information constraints
- Description of the origins and sources of each problem in which the main sources of the specific agricultural NPS problem was identified
- Description of the transfer/transport/transformation processes and mechanisms, with an assessment of the level of understanding concerning the processes operating at various scales from microscopic level up to catchment level and an identification of the knowledge gaps
- Description of models that simulate the production, transport and fate of the pollutants, with an assessment of the predictive (modelling) ability that is available to address each of the specific agricultural NPS problems and identification of knowledge gaps
- Mitigation measures/best management practices to address the problem, with an assessment of the state of mitigation measures to address the specific agricultural NPS problem and identification of knowledge gaps

The project also compiled a first-order estimate of the contribution of agricultural activities towards NPS pollution in South Africa. The large-scale national databases of point discharges, return flows and agricultural land and water use that underlie DWAF's National Water Resources Strategy and the Internal Strategic Perspective Projects were used to partition aggregated observed water quality loadings into point and non-point components for selected constituents at selected sites in three representative river systems.

The terms of reference (TOR) for the long-term research project were based on a conceptual framework formulated jointly by the project team in a workshop setting.

Cost: R 644 400
Term: 2003-2004

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

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: 2000-2005

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

Assessment of the interaction between aquaculture and water quality in on-farm irrigation dams
Division 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 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: 1999-2005

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
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: 2002-2005

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

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, Limpopo Province
Tshwane University of Technology
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 in the KwaZulu-Natal Province
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

Programme 2: Integrated water management for profitable farming systems

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
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.

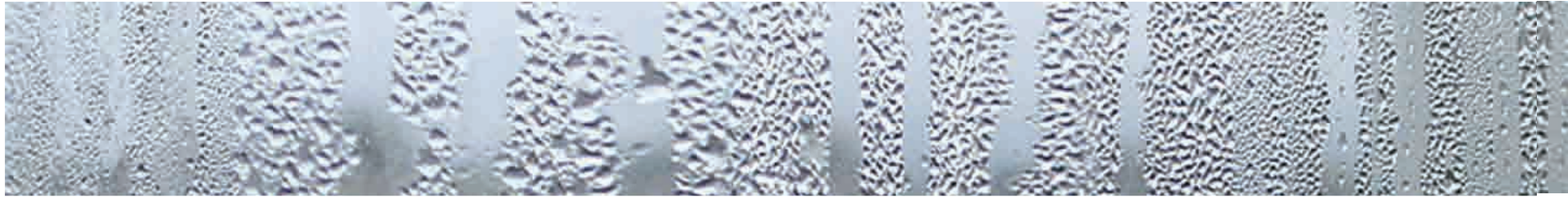
The aim of this research project will be to investigate the links among vegetation, saturated zone dynamics, and runoff generation for the different classes of riparian zone, and to test the hypothesis that riparian zone vegetation has a significantly variable effect on catchment water yields.

Estimated cost: R727 500
Expected term: 2001-2006

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 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: 2002-2004

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

NEW

THRUST 1: WATER UTILISATION FOR FOOD AND FIBRE PRODUCTION

Programme 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture

Standards and guidelines for improved efficiency of irrigation water use from dam-wall release to root zone application

ARC/IAE

No 1482

Irrigated agriculture is the single largest user of water in South Africa. With expansion of domestic and industrial water use, competition for the existing lawful use in irrigation will increase. The levels of efficiency of water use which are currently attained will be scrutinised and particular attention will have to be given to the management of water use. Broadly defined, management of water use starts at dam wall releases, through river or canal conveyance, on-farm storage and distribution, in-field application up to root zone storage. However, the problem is that at present there is no standardised terminology, comparable benchmarks or generally acceptable guidelines to improve water use and irrigation efficiency. These issues must be urgently addressed in order to provide consistent management advice and comply with the requirements of the National Water Act of 1998 regarding compulsory licensing and periodic review of licences. For the purpose of planning, design and operation of water supply systems, definitions of various efficiency terms need to be clearly stated, understood and accepted by all stakeholders. The site-specific criteria and tools which will be used to measure efficiency and practically achievable bench-marks need to be established. In order to achieve this, the proposed research project must be undertaken on a representative member of irrigation schemes which should include but are not limited to the following: Loskop: Tabina; Middle Letaba; Crocodile/Komati; Pongola; Makhatini; Gamtoos; Sundays; Orange-Riet; Vaalharts; Breede; Hex; Hartbeespoort.

Estimated cost: R4 500 000
Expected term: 2004-2009

Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture

A scoping study to evaluate the fitness-for-use of grey-water in urban and peri-urban agriculture

Environmentek, CSIR

No 1479

The White Paper on Agriculture emphasises food security. Household and urban food gardens are part of the spectrum of production systems and processes that can contribute to food security and are therefore supported by government. One of the factors that limit the application potential of these systems is a shortage of water to supplement rainfall. Grey-water may help to overcome this limitation by providing a dependable source of water that is under the control of the household gardener. Grey-water is the untreated household effluent that is produced from baths, showers, kitchen and hand-wash basins as well as washing machines. More than half of the indoor household water use is normally used for these purposes and can thus potentially be intercepted by the householder for additional uses. Grey-water is often used for the watering of gardens in times of drought or restrictions on water use. However, as the quality of the different household sources can differ significantly, there is considerable uncertainty about the risks associated with, and the acceptability of, the practice. It is thus uncertain

whether grey-water use should be promoted or discouraged as a source of water for urban and peri-urban agriculture. Potential risks associated with the use of grey-water include:

- Health risks such as transmission of infectious diseases and bioaccumulation of potentially toxic elements in plants
- Reduced crop yield as a result of salinity and specific ion effects (e.g. boron, sodium and chloride)
- Soil degradation because of high sodium, salinity or other substances
- Groundwater contamination
- Reduced return flow from wastewater treatment works may cause a significant reduction in the volume of recirculation that is assumed in present water resource planning scenarios
- Reduced flow and higher solids content may cause blockages in sewerage systems and treatment problems in wastewater treatment works

Potential benefits that can be derived from the use of grey-water in urban and peri-urban agriculture, are:

- Reduced (or no) cost of water for gardening in urban and peri-urban areas
- Reduced demand for high quality potable water and thus new treatment facilities and water supply schemes
- Reduced agricultural requirement for application of plant nutrients.
- Reduced flow to septic tanks and water treatment facilities, that result in reduced pumping costs
- Reduced flow from wastewater treatment works which are closer to natural environmental flows, especially in winter rainfall areas

In view of the opportunity that the use of grey-water presents for agriculture in urban and peri-urban areas and the risks this may hold, it is deemed necessary to conduct a scoping investigation that will present a balanced evaluation of the opportunities and threats presented by grey-water use in peri-urban agriculture and the research needs that will have to be addressed in this research project to address the problem

Estimated cost: R500 000
Expected term: 2004-2005

THRUST 2: WATER UTILISATION FOR FUELWOOD AND TIMBER PRODUCTION

Programme 1: Water-efficient production methods and systems in agro-forestry, woodlands and forestry plantations

Agro-forestry systems for improved food production through the efficient use of water

Environmentek, CSIR

No 1480

Less than 15% of land area in South Africa is arable. This implies that there is very limited scope for conventional food production, both on irrigated and dry-land. In addition to limited arable land, South Africa is a water-scarce country. Its rainfall is below the world average, and its distribution is somewhat unreliable.

The relatively low rainfall and limited arable land make it imperative to effectively and efficiently use these natural resources for food and fibre production. This is even more important for emerging and subsistence farmers who often lack access to information and use of production technologies.

Small-holder agriculture, particularly in Africa, has been faced with land degradation. This is due to a number of factors, including poor management and limited production factors. In order to improve the status of land resources and sustain their productivity, there is a need for a "shift" from the current production practices. Agro-forestry (AF) systems (whereby there is a deliberate planting of trees in combination with food/forage crops for the benefit of people and the environment) have been reported to be potentially productive in degraded and marginal soils. Agro-forestry is also perceived to have potential for the rehabilitation of such degraded and/or marginal lands.

In South Africa, however, AF systems are relatively unpopular, yet the majority of the subsistence farmers are dependent on degraded lands for their agricultural production. A major challenge is to enable such farmers

and poor communities to produce optimally under such constraints, simultaneously rehabilitating and improving the land resource. This will ensure both sustainable production and food security, while improving the livelihoods of the poor.

This project aims to address a number of questions that need to be answered in order for agro-forestry to be adopted locally.

Questions exist as to which AF systems are suitable, given the bio-climatic zones/specific ecosystems within South Africa; what spatial and/or temporal agro-forestry systems will be appropriate for emerging/subsistence farmers within the current resource confines; what are tangible benefits of agro-forestry in relation to:

- End users
- Environment
- Soil health
- Agricultural potential
- Specifically, the impacts (positive/negative) of agro-forestry on natural water resources for specific bio-climates in South Africa

The key to some terminology used is specified below:

- Soil health - all physical, chemical and biological components that are important to agriculture.
- Efficient use of water-water consumed in relation to dry matter produced
- Water balance-water applied, infiltration, retention, runoff, percolation, etc.
- Production-quantity, quality, commercial value of food/fuel/forage products
- End users-farmers (local, small-scale), incorporating local knowledge through participative assessment.

Estimated cost: R3 250 000
Expected term: 2004-2009

THRUST 3: WATER UTILISATION FOR POVERTY REDUCTION AND WEALTH CREATION IN AGRICULTURE

Programme 1: Sustainable water-based agricultural activities in rural communities

Best management practices for smallholder farming on two irrigation schemes and surrounding areas in the Eastern Cape and KwaZulu-Natal through participatory adaptive research

University of Fort Hare

No 1477

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 had been 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. It is acknowledged that research results available for water management in commercial farming are applicable to subsistence farming, and need not be repeated. The aim of this project is to make existing knowledge, indigenous and new technologies, useful for the particular circumstances of subsistence farming. The research project on "best management practices for small-scale subsistence farming" therefore requires commitment and co-operation amongst researchers, farmers and the community. This will be done through participatory action research which combines research, education and action to the direct benefit of farmers and surrounding communities.

Estimated cost: R4 500 000
Expected term: 2004-2009

Sustainable techniques and practices for water harvesting and conservation and their effective application in resource-poor agricultural production in the Eastern Cape Province
University of Fort Hare
No 1478

Approximately 74% of South Africa's rain-water 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 exert 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 will 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 will be analysed.

Estimated cost: R5 000 000
Expected term: 2004-2009

Programme 2: Integrated water management for profitable farming systems
Technology transfer and integrated implementation of water management models in commercial farming
CPH Water
No 1481

Large investments have been made by the WRC in developing models for water management from field to catchment scale. These models are the following:

SWB: Generic, mechanistic model for real-time irrigation scheduling at field scale
SAPWAT: Planning tool for determining crop water requirements at field, farm or irrigation scheme level
RiskMan: Simulation model of net cash-flow for water use and crop combination at specified risk levels at farming scale
WAS: Integrated water requests, water distribution and accounts system at irrigation-scheme scale
ACRU: Hydrological modelling at catchment scale

All of these models are already being implemented or are undergoing technology transfer. A stage has now been reached where the integrated implementation of the models can be demonstrated. At the same time there are many changes in the environment in which farm management takes place, which emphasise the need for decision-support. The target groups who can potentially benefit through decision support include staff of regional offices of DWAF or CMAs, staff of WUAs, agricultural advisors or extension officers and leading farmers on irrigation schemes.

A major hurdle which has been experienced in practice is setting up the models for implementation. This hurdle can be overcome by actually installing a GIS, collecting data and demonstrating the use of the models. The pre-requisite is to engage with end-users in order to determine and respond to real needs. In order to achieve this, a framework must be presented which illustrates flexibility of choice in the linking of different models, the opportunity for common databases generation and exchange of data

This project is based on consultation between the WRC and DWAF, and technology transfer of the specified water management models will be undertaken on selected irrigation schemes in the following river catchments: Crocodile (east); Olifants (east); Pongola or Mhlatuze; Sundays or Gamtoos; Breede; Orange-Riet; Orange-Vaal; Crocodile (west); Great Letaba in order to promote integrated implementation.

Estimated cost: R2 250 000
Expected term: 2004-2007

THRUST 4: WATER RESOURCE PROTECTION AND RECLAMATION IN AGRICULTURE

Programme 2: Impact assessment and environmental management of agricultural production
Modelling non-point source (NPS) pollution in agriculture from field to catchment scale
Sigma Beta Consulting
No 1516

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 therefore 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 to reduce NPS pollution. 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 will enhance the usefulness of the existing guidelines 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, the present level of knowledge concerning them is not as advanced as for irrigation-induced salinisation of water resources. The project will address those issues that require priority attention, with regard to NPS pollution.

Estimated cost: R5 000 000
Expected term: 2004-2009

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KSA 5

WATER-CENTRED KNOWLEDGE

Creating Value for the WRC and its Stakeholders

Dr Innocent Msibi
Director

Scope

The KSA will continue to focus on knowledge management during the next financial year (2004/05) in a similar mode and direction as described in the previous year's review, while there will 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.

During 2005/06 this KSA will continue to focus on developing the practice of knowledge-sharing to a new level, paving the way for the rest of the water sector to follow. This will coincide with a strong drive to improve information management tools and other supporting systems.

Objectives

Knowledge management in a knowledge-intensive organisation like the WRC is both a core business activity as well as a support function, while information and communication technology (ICT) plays a major role as an enabler. The objectives of the KSA have been reviewed based on the previous year's experience and can be grouped as follows:

Internally focused objectives:

- To enhance the core processes of research support and management by improving access to relevant knowledge.
- To create the necessary culture of knowledge management.
- To develop and maintain consistent data architecture to enable the flow of content through a knowledge management system and support the core business of the organisation.
- To support innovation and commercialisation through proper management and protection of the WRC's patent portfolio

Externally focused objectives:

- To develop a system of user-focused knowledge through information networks
- To participate and or lead knowledge-dissemination initiatives including sharing and networking supported by functional, user-friendly research and

water information systems
- To continuously improve knowledge transfer and dissemination through information networks, dissemination of reports, guides, scientific and non-scientific journals, and by providing support to other technology transfer initiatives
- To develop a strategic advice capability supporting studies regarding water-centred knowledge, innovation and commercialisation

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) as described in the previous year was 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. Thus there needs to be a clear link between this KSA and the other water KSAs, who will be at the core of the knowledge management 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 2004/05 will be built on the solid foundation that has already been established.

THRUST 3: PUBLICATIONS AND DOCUMENT MANAGEMENT (PDM)

Key focus is on driving the handling and storage of documents, archiving, and maintaining library and information services. Another aim is the 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 focuses 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 2004/05

The approved funding of fixed costs, running costs, printing and publishing costs and human resource costs leads to committed funding of R5 302 091.

CORE STRATEGY

Strategic context

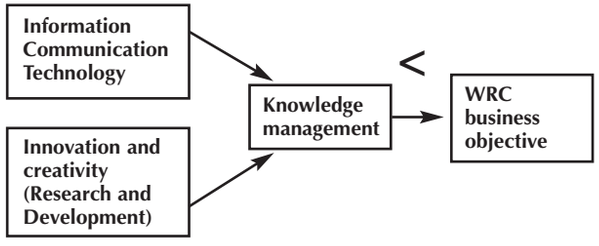
The strategic context as presented in the previous years has been reviewed and it was concluded that no major external or internal strategic issues have emerged and that there is no need to change the context as described previously.

Given the dangerous perception about knowledge management as seamlessly entwined with technology, the KSA has to continue to clearly 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.

The KSA will also continue to 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 will continue to be 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". The shift from information processing to knowledge creation will be defined by reconciling knowledge management and the WRC core strategy.

Following progress already achieved during the last financial year, this KSA will dynamically redefine itself while addressing the critical issues of organisational adaptation, relevance, and competence in face of increasing discontinuous environmental change. Essentially, this KSA will continue to 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 following diagram 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 sharing knowledge. Through this, and continually supporting the core processes of the WRC, the WRC business objectives will be achieved.

Having implemented the above, this KSA will continue to assist 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. Both internal and external customers as identified previously are the same as described before.

- Internal customers

Research managers and staff of the WRC
Appropriate information is required for planning activities and decision-making. Staff members need to be able to access the information base of 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, be it 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 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 emerging technological environment will affect the priorities of any organisation which is a hub for any sort of knowledge. Despite the ever-changing operating system environment, capacity requirements, speed and uptime, there is also the emerging situation where the national government has given the go-ahead for the use of the Linux operating environment and Open Office. Given what happened when WordPerfect was replaced with Microsoft Office following a decision by government, it can be expected that within a period of four years the Linux operating system will be the most dominant system used by our stakeholders. Further systems development needs to be guided by these emerging issues. This places further pressure on our human resources.

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 (AWWRF)
- International Water Association (IWA)
- Water Research Foundation (WRF)
- International Water Management Institute (IWMI)
- Water and Sanitation Collaborative Council (WSSCC)

Scope

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 in dynamic and non-linear changes in the WRC/external environment, there is an increasing interest in designing information systems that can take dynamic and diverse interpretations of changing information into account. Hence in the short term the KSA will look at institutionalisation of "best practice" by embedding 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 give people canoes and compasses

Progress against set KPAs for 2004/05

The following examples are used to present the progress to date:

- Participation in more than two initiatives for the improvement of public understanding of science (*Youth Water Prize*, Sasolburg Scifest and WRC-Rhodes University open day)
- Production of a special publication for the Global Wash Forum, (December, 2004, Dakar, Senegal) entitled *Global WASH Forum: Water, Sanitation and Hygiene for All Solutions and Actions; Local and National*
- An Internal Editorial Board was appointed to give guidance, support and advice on the presentation and content of *The Water Wheel*
- WIN was successfully initiated as a water sector program managed by the WRC and its business plan was completed
- Sales of special publications increased by more than 20%. Postage costs for bulk items have been shifted to the customer. Revenue from advertising (*The Water Wheel*) has increased slightly (5%)
- *Water SA*:
  - Circulation has been reviewed, and a new system will be effective as from April 2005, which will save about R100 000 annually
  - A fresh new way of distributing the journal has been structured and will be implemented early 2005/06
- A draft Knowledge Management Policy was presented to research managers
- IT tools such as publications database (piloted), critical databases, (identified and being redesigned into the new Fund Management System), WRC webpage (redesigned and improved), Intranet (redesigned), Helpdesk (running), extra security (implemented)
- Patent management and commercialisation structure, strategy, income, etc. being sorted out and being managed
- Open day and Knowledge Management Workshop held
- The Information Technology Use Policy has been completed and submitted for approval by the Executive
- Publications database, ready for full access by external users
- Increased high level of Internet security-second firewall implemented internally (highly effective for both internal and external customers)

HIGHLIGHTS FOR THE 2004/05 FINANCIAL YEAR IN TERMS OF THRUSTS

THRUST 1: KNOWLEDGE MANAGEMENT

Water Information Network (WIN)

The WRC strongly supports and houses the Water Information Network (WIN) and provides leadership and management. WIN is a network of organisations (both governmental and non-governmental) in the water services sector that works to ensure that this body of knowledge is well-managed, readily accessible and applicable, and leads to improved decision-making and performance in the areas of water and sanitation.

The collective aim of these organizations is to enhance sector knowledge management initiatives. It was set up by the Water Services Sector Leadership Group in 2002, which identified knowledge management, best practice promotion and information dissemination as strategic priorities for the sector. Between February and July 2004, an information needs analysis was conducted by DFID-funded consultants. This important study identified critical sector challenges which WIN had to address. In July 2004 WIN was physically set up at the WRC, and a programme coordinator was appointed. The WIN Business Plan was completed in October 2004, after a consultative process had been followed. The WIN Business Plan focuses on:

- Strengthening the knowledge networks
- Creating a user-friendly information portal
- Supporting sector lesson learning and sharing

It is through these three focal areas that WIN is adding value to knowledge management initiatives across the water services sector. In November 2004, WIN participated in the African Regional Training of RCD Facilitators organized by the IRC, as part of its global Resource Centre Development Programme. In November 2004 WIN undertook a six-month project known as the Sector Collaboration Review, which aims at documenting the success/failures of sector collaboration in South Africa, and to disseminate the good lessons. This will be finalised at the end of July 2005. WIN is also preparing to launch its information portal on the 22nd of July at the **National Section 78 Lesson Learning Workshop**, organized by DWAF. Although WIN is housed by the WRC, its ownership is with the broader water services sector. It is the ultimate goal of WIN to reach out to the broader sector and particularly to local government. One hopes that this will also be an initiative that enhances the work of the WRC as it becomes a recognized knowledge-sharing tool.

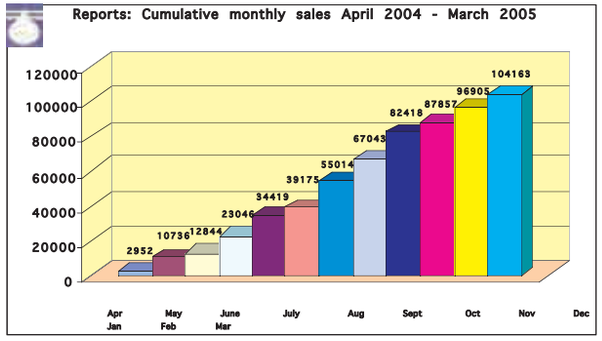
THRUST 3: PUBLICATIONS AND DOCUMENT MANAGEMENT

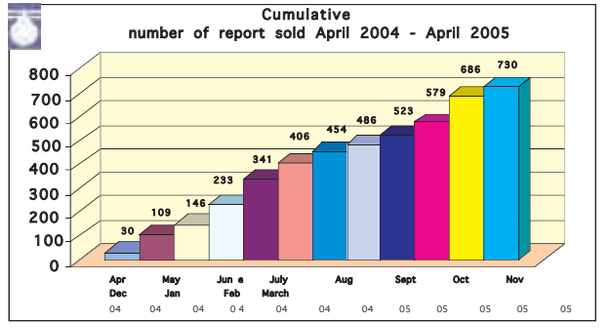
At the conclusion of a project and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof.

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 127 new reports were published (30 000 copies printed) and approximately 28 000 reports were dispatched upon request from stakeholders; some of these were sold and the income generated in this way came to R104 163.

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. In addition roughly 350 WRC reports, previously available in hard copy only, have now been scanned in and are available to stakeholders in PDF format. About 10 000 copies of *Water @ Work-A Career Guide* were distributed on request from the WRC offices.

The following graphs illustrate the cumulative figures for the number of reports sold during the year under review (730) and the income generated (R104 163).





Number of reports sold April 2004 -April 2005

List of WRC publications

A continuously updated list of WRC publications is posted on our Website (www.wrc.org.za) for perusal by users and orders for reports may be placed either electronically, telephonically or by fax.

The Water Wheel

The WRC's public understanding of science magazine, *The Water Wheel*, made its first appearance in December 2002 when it replaced the *SA Waterbulletin*. The magazine, which is published six times a year, is aimed at popularising water science and research issues, while informing the public about the application of science and scientific processes, methods and research in the water field. Features do not only report on WRC projects, but also on the positive contribution of water research to society and the improvement of life of South Africans in general.

The publication covers a range of topics, ranging from catchment management and mine-water treatment to the conservation of ecosystems and artificial groundwater recharge. Around 7 000 copies are distributed bi-monthly throughout South Africa and the SADC countries to individuals, private companies, institutions with an interest in water, state departments, local authorities, non-governmental organisations, water boards, mines, and institutions of learning.

While the publication is still available free of charge, advertising space is sold in *The Water Wheel* in an attempt to defray the continuously escalating production costs and postage. Advertising rates are available from the editor at the WRC.

At the start of 2005 the publication underwent a complete makeover, resulting in a fresh new design aimed at attracting a wider audience. A number of new features were also introduced, including a regular water education section aimed at teaching learners about the wonders of water. These pages have since been extended to a water education page on the WRC website.

A special edition of *The Water Wheel* was published in March 2005 to commemorate National Water Week. This edition, which featured articles of interest to learners and included a water quiz, was distributed at the SABC Career Fair, SciTech and delivered to schools in the Gauteng area.

Water SA

In 1975 it was decided to establish a peer-reviewed scientific water journal which would appear quarterly. *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. Its appearance 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 China, 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 2004/05 *Water SA* published 97 articles written by 279 authors and reviewed by 170 international and Southern African reviewers. *Water SA* has an extensive local as well as overseas readership. At the time of writing there are 2 962 subscribers to *Water SA* of whom 837 are abroad. By April 2005 these subscribers will receive their copies electronically free of charge. 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 has also been available free of charge on the

Internet via the WRC website (http://www.wrc.org.za) and from April 2005 onwards it is to be published free of charge as an e-journal only with print copies available on request at a nominal fee.

THRUST 4: INTELLECTUAL PROPERTY RIGHTS AND COMMERCIALISATION

A series of workshops were conducted in September and October last year (Pretoria, Durban, Bloemfontein and Cape Town) at which we explained the rationale behind WRC IP Policy and IP provisions in our research contract, as well as various other queries on the contract. The workshops were successful in that stakeholders gained a better understanding of our position, and we managed to iron out most of the difficulties.

A new internal filing system for patents was implemented; an electronic database of WRC patents and trademarks is being designed, which will include a reminder system, a provision for estimated costs, as well as actual costs and the usual bibliographic information.

Commercialisation:

BioSURE™

A licence agreement with ERWAT was signed in January 2005 in terms of which we licensed our BioSURE™ series of patents and trademarks to ERWAT. The technology is currently being used at Grootvlei Mine. We also concluded a benefit-sharing agreement with Rhodes University (where the technology was developed with our funding) in respect of which we share the benefits we receive from the licence agreement with them.

PETRO™

We renegotiated the licence agreement for this technology, and received our first royalty income from this licence in March/April 2005.

FILTERSA Licence

We are currently renegotiating the licence agreement with FILTERSA to make it more workable to all parties.

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CROSSCUTTING DOMAINS

INTRODUCTION

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 (XDs) address the following key issues:

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

WATER AND SOCIETY

Dr Andrew Sanewe
Head

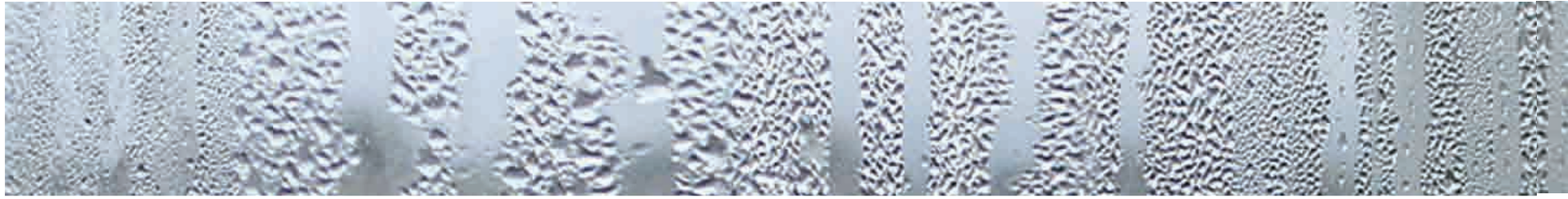
Scope

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 derives 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.

Objectives

The aims of this domain are 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
- Empowered communities able 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 will continue to focus on investigating hydro-political issues within South Africa and the SADC region. Issues include the inter-sectoral 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 remains on analysing and understanding society's needs for water services. This 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 continue to 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

The focus of research within this thrust remains 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 9.6m. for 2004/05.

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 1 April 2004 and 31 March 2005.

COMPLETED

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

Devastating floods occur in South Africa, causing serious loss of life and damage to infrastructure. Despite recent advances in numerical weather prediction models, tools available to the weather forecaster are at present still unable to provide accurate predictions of exactly where heavy rainfall will be concentrated and how much will be recorded. This project set out to improve heavy rain forecasting techniques by focusing separately on tropical and baroclinic systems, evaluating their predictability and developing a forecast verification system for operational use. The project succeeded in developing a system which delineates areas where heavy rain can be expected with a good degree of accuracy. The system is made up of three distinct subsystems: A model for identification of tropical weather systems (MITS); a tropical heavy rainfall identification system (THERIS) and a baroclinic rainfall system for the coastal zone (BARCOZ). While the system proved very successful in isolating areas of heavy rain at the synoptic scale, data limitations still cause some difficulties in resolving local scale severe rainfall events, such as may occur in the vicinity of the escarpment, and

in making significant progress towards truly quantitative precipitation forecasts. Despite this, the research has made a significant contribution to severe storm forecasting through the provision of user-friendly recognition and verification tools not previously available to forecasters.

Cost: R239 000
Cerm: 1999-2002

Principles and processes for supporting stakeholder participation in integrated river management
Division of Water, Environment and Forestry Technology, CSIR
No 1062

The study was based in the Sabie-Sand catchment, which was chosen as a study site for this project for a number of reasons. These include the fact that much research had been done there, providing a solid basis for understanding of the ecosystem, and that there was an existing and active catchment working group (the Sabie River working Group) representing all major players that could act as a "surrogate client" for this work.

The report is structured into three parts. Part 1 addresses the question of how best to support stakeholder participation in integrated river management an it provides details on the constitutional and legal context underpinning stakeholder participation. It discusses the principles that arise from this context, as well as the processes that would be needed to achieve sustainable and equitable outcomes through integrated management. The lessons learnt from this project are also outlined. Part 2 provides an overview of the detailed findings of the project. These findings are based on a range of papers and reports that were produced as the project progressed. Part 3 focuses on the issue of capacity building. Capacity building is a vitally important aspect of research investment. As the project sought ways of empowering people to participate in the management of water resources, particular attention was paid to this issue. The theoretical understanding of capacity building is documented and a list of people in whom capacity has been built as well as a list of products (outputs from capacity building) that have been produced by the project is provided.

Scientists, especially those engaged in natural resource management in support of sustainable development, should strive to adapt (where appropriate) their approaches to implementation projects. It seems that by encouraging a structured "bottom-up" approach, the benefits of stakeholder wisdom and empowerment will be brought to the fore. This will require a mind-shift, from one of "telling" or "teaching" to one of sharing knowledge, influencing wise decision-making, and facilitating the identification of problems as well as solutions. This seems to be the most important lesson arising from this study and it should go some way towards directing the way forward. This project has also shown that it is indeed possible for people to modify their own perceptions and behaviour willingly in support of a cooperative process that is likely to deliver equity, sustainability and efficiency in the water resource management process. The willingness of participants in this process to learn (and change) together, combined with the fact that water issues are likely to organise people around the debate for years to come, suggest that these interactions can form a platform to promote the principles, values and ethics that underpin democratic behaviour.

Cost: R1 500 000
Term: 1999-2002

An evaluation of the role of water user associations in water management in South Africa
Pula Strategic Resource Management
No 1140

In 1995 a legislative review process was initiated for water resource management in South Africa, culminating in the 1997 *White Paper on a National Water Policy for South Africa* and the National Water Act (Act 36 of 1998). These provide the imperatives for water resource management (WRM), by defining the purpose and objectives of WRM, as well as certain requirements for performing WRM. The Act creates the framework for fundamental institutional transformation of the water resource management sector, which includes the establishment of water user

associations (WUAs).

The legal framework within which WUAs perform their functions is specified within the National Water Act (and in some cases the Water Services Act), which provide significant flexibility in their implementation. However, WUAs are faced by a number of challenges in relation to the policy environment, particularly in relation to their organisation and functions. The WRC project: **An evaluation of the role of water user associations in water management in South Africa** was commissioned to highlight some of these challenges. The objective of this report is to present the findings of the study. This includes an overview of the policy and legal environment within which WUAs operate, a review of the international experience, lessons synthesised through the analysis of a number of South African case studies, and recommendations and proposed guidelines for the management of WUAs.

On the local case studies done there was an indication that water use entitlement and secure land tenure are the determinants of being an elected member. The nominated members mostly consist of the emerging farmers, local government, industries, etc. This scenario somehow gives an indication that unless emerging farmers and other groups form their own associations they will not be able to influence decisions taken at higher level. At the same time there is need to understand and create a balance between commercial farmers who have investments in farming and the emerging farmers who do not have that level of investment.

The associations may perform the role of water services provider on behalf of the Water Services Authority, e.g. a municipality. Again the rule is that this function may only be performed if it is not going to jeopardise the performance of the principal functions. In terms of this function the Water Services Act states that any agreement between the WSP and WSA should be in a form of a contract understood and agreed between them. The WSP should understand all the costs and other implications of being a service provider, e.g. in cases where there is no water supply, the WSP should find an alternative to bring water to communities. The role of water services also come with the requirement providing a Water Services Development Plan and Water Services Charter to be provided by the WSP.

In reality this places much responsibility on the side of the WUA who in most cases are struggling to meet some of the functions for its members. Secondly some of these associations have not grown to the stage of performing such functions. The suggestion would be that associations should move away from taking the role of water services until they have capacity to do so.

The main conclusion of the research is that there are a number of ways in which WUAs can be established and operated, in response to the needs of water users in South Africa. However, DWAF needs to develop policy and guidance on the preferred approaches, rather than this study proposing such guidelines.

This study has indicated that:

- WUAs may play a role in water services, but as water services providers contracted by the relevant water services authority. Furthermore, it is recommended that WUAs should address bulk water services, and should avoid becoming involved in water services provision to individual customers (or households).
- Although it is not the model that is recommended by this study, the concept of umbrella WUAs needs to be engaged and a policy position developed
- Clarity is needed on the requirements for representation (or membership) by all water users using water resources within an area
- More research leading to a policy position is needed on the potential role of WUAs in managing local water allocation and water markets between members
- Although a policy process has been initiated on the role of agricultural WUAs as vehicles for rural development and poverty eradication, a number of issues remain. In particular, innovative approaches need to be developed (either in the context of WUA or other bodies) to enable integrated departmental initiatives. This may require DWAF to allow water use subsidies (particularly support to emerging farmers) to be channelled through local bodies other than WUAs.

Cost: R380 000
Term: 2000-2001

Umgeni flood now-casting using radar-An integrated pilot study

Department of Civil Engineering, University of Natal

No 1217

This project aimed, firstly, to pull together, for flood forecasting in a real world application, the outcome of previous research funded by the WRC in the areas of radar estimation of rainfall, space-time modelling and forecasting of rainfall, linear catchment modelling and river-flow modelling, and, secondly, to provide decision makers in Umgeni Water and Durban Metro (and eventually the Umgeni Catchment Management Authority) with the tools to be proactive rather reactive in the context of flood warning. The components of the project are meteorological, hydrological and hydraulic. The meteorological component comprised utilising telemetering rain-gauges and a radar feed from Durban radar via the SA Weather Service METSYS branch in Bethlehem. The reliability of the Durban radar was ensured and software written to handle the data stream (MDV format) directly in real-time. The hydrologic component comprised the modelling of the rainfall-runoff response of river basins from the small to the large, interpreted in a transfer function framework using a linear model developed in a previous WRC contract **(No. 1050: A linear catchment model for real time flood forecasting)**. A forecasting version of the rainfall-runoff model was set up. The hydraulic component (reported in Volume 2 of the final report on this project) comprised the work done in the linked investigation (current consultancy **No. 456: Mlazi River nowcasting to include levels of inundation**).

Some of the innovations relating to the flood forecasting system and its components include the following:

- Development of algorithms for merging of rain-gauge and weather radar estimates of rainfall over large areas this provides good information in detail about where it is raining and is essential input to the decision making system
- Employment of GIS to capture real-time rainfall over sub-catchments as input to the rainfall/runoff model by integrating the optimal spatial rain-fields
- Derivation of a short-term rain-field nowcasting method to advect possible future rain-fields in real time in order to anticipate where it will rain up to an hour ahead. This makes use of a space-time model of rain-fields (the 'String-of Beads' Model or SBM) developed under a previously completed WRC project **(No. 1010)**
- Exploitation of the speed and efficiency of a linear transfer function rainfall/runoff model developed under a previous WRC project **(No. 1005)** to make flood now-casts also in the parallel study, which developed and applied a flood water-inundation model for the industrialised Mlazi River flood plain
- Establishment of a GIS-based information base in the eThekwini Metro Disaster Management Centre, giving instantaneous visual displays of real-time information on whereabouts of storms (and their now-casts) relative to suburbs, townships, rivers, roads, etc.

The forecasting of rain-fields in real time gives good forecasts up to an hour ahead over a large area; the improved estimation comes from the merging of information from rain-gauges with that from radar. Validation of streamflow forecasts on "unseen" historical streamflow data (offline) was successfully accomplished, although testing in real-time (online) could not be completed because the real-time flow data did not become available until after completion of the project.

At the commencement of the project the Durban Metro Disaster Management Centre did not have any facility for anticipating floods except from emergency weather reports and forecasts. They typically found themselves reacting to information phoned in by people who had either experienced damage or who had noticed that flooding was occurring. As a result of the project, people living near rivers now have both the potential for receiving warnings about impending floods and the knowledge that the Disaster Management Group is working towards mitigating floods in their area in a proactive rather than reactive way. Furthermore, with the new flood forecasting capability, 6 to 12 hour warning of an impending flood will enable industries to evacuate staff and perform controlled shut downs or take steps to reduce the damage to sensitive plants. This is a far cry from September 1987 when the SAPREF Refinery and the Mondi Paper Mill were closed for 10 days with serious economic consequences.

Cost: R350 000
Term: 2001-2003

Hydropolitical history of South Africa's major international river basins
Centre for International Political Studies,
University of Pretoria
No 1220

The hydropolitical histories of South Africa's four international river basins - the Orange, Limpopo, Incomati, and Maputo-are complex and fascinating. They show similarities as well as disparities in their development trajectories. Where the hydropolitical histories are similar, is where the rivers' development follows the general socio-economic and political progression of South African society. This project has provided, in a single source for ease of reference, a detailed history of all known water development and allocation initiatives in the four above-mentioned basins since pre-colonial times. This can be used as the basis for understanding current patterns of water use and social development linked to water, as well as for indicating potential areas of tension around water in the future, notably as part of the forthcoming water allocation reform process.

Cost: R398 100
Term: 2001-2002

Multicriteria decision support for Reserve determination and other catchment management activities
Dept of Statistical Sciences, University of Cape Town
No 1298

This project considered the role of multiple criteria decision analysis (MCDA) in water resource planning, particularly in the light of the requirements of the National Water Act, Act No. 36 of 1998. The report is subdivided into two main parts. Part 1 provides guidelines for the use of MCDA methods, and is organised to reflect the key stages of the water management cycle. The intention is to provide potential users of the approach with understanding of the underlying assumptions and methodologies and the potential they offer for facilitating different stages of the management cycle. The activities in the water management cycle are resource directed measures, water resource planning and management strategies and water use authorisations. Part II describes a number of case studies in which these approaches were used. The case studies are:

- Thukela project
- City of Cape Town
- DRIFT and DRIFTSOLVER
- Usutu-Mhlatuze GIS-based DSS

Cost: R262 000
Term: 2002-2003

Decision support for water policy making
University of Stellenbosch
No 1509

This project was terminated during 2004/05 at the request of the project leader. No deliverables were completed, and no report is available.

Cost: R122 000
Term: 2004-2006

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

In many municipalities prepayment water meter technology has become a prominent instrument of water management contributing, with other measures, to the sustainability of water provision. This study aimed at providing an understanding of the social and institutional context in which the technology fails or succeeds. This understanding is derived from an examination of the available literature, the analysis of surveys and by examining case studies. Specifically, the objective was to understand how the technology could best be used to

ensure sustainable water provision by local authorities. Key objectives were to determine how the changing institutional environment impacted on the uptake of the technology and, similarly, how socio-economic contexts affected its adoption.

The information from the National Postal Survey (NPS) and the Labour Force Survey (LFS) was combined with data on water charges to unpick the attitudes and perceptions of current users. Aspects considered include perceptions of satisfaction with the technology in general and with cost effectiveness and technical reliability in particular. Prepayment meters in private houses, instead of communal taps, were viewed more critically by their users.

Among service providers there was a strong correlation between technical reliability and general satisfaction with the technology. The role of on-going support for the technology was highlighted by the correlation between support levels and high satisfaction levels regarding the meters in general and their technical reliability in particular. Contrary to popular perception vandalism was not cited by service providers as a particularly serious problem. Somewhat surprisingly service providers indicated that the FBW policy would have a minor impact on anticipated uptake of the technology.

Case studies on eight municipalities were conducted to ensure a cross-section of experiences with the technology. This exercise revealed that:

- The drive to introduce prepayment water technology was motivated by a need to combat institutionalisation of non-payment
- Planning, installation and operation were characterised by many technical problems. However, instrument suppliers were initially willing to provide strong technical support
- In many cases there was an initial lack of public participation. This situation has since improved
- The Free Basic Water Policy has had an important influence on municipalities' installing the technology. The FBW, *inter alia*, altered their perceptions as to where the technology was most appropriately placed
- Expected future trends were highly varied. Some municipalities planned to expand coverage, while others planned to replace their prepayment meters with conventional ones. The last were generally motivated by high maintenance costs or the unreliability of the instruments.

In general the study concludes that prepayment water meter technology has a valuable role to play in sustainable water service delivery. The major recommendations arising from the study were:

- Water policy (including free basic water provision and the use of equitable share grant) should be packaged in a manner that enables municipalities to better interpret and apply it.
- Municipal structures and their agents need assistance to understand and address social conflicts relating to service payment. The impact of indigent policy and the insights gained from case studies need to be more widely shared.
- A working partnership between stakeholders such as DWAF, SALGA, DPLG as well as WRC, must be generated. This partnership should be used to ensure that policy measures and interventions blend. The resulting shared understanding and application of policy should be communicated to municipalities in an accessible and easily understood manner.
- Municipal water service providers should be equipped to see the differences between community resistance to payment and the means by which payment is effected. Similarly consumers have to be informed that free-riding is no longer an option-irrespective of the means by which consumers are called to account.
- Municipal structures must actively educate constituencies as to the implications of "free-riding". This education should highlight the cost of "free-riding" in terms of reduced service delivery in other service sectors. Political representatives should play a more prominent role in articulating the grievances of their constituencies while promoting the decisions of the elected local government.

Cost: R375 500
Term 2001-2002

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

Research reports have been completed on payment strategies for low-income water consumers in the then Pretoria, Durban, Johannesburg and Cape Town Metropolitan Areas and on determination of the price elasticity of demand for water amongst low-, medium- and high-income groups in Alberton and Thokoza. As a consequence of the interest engendered by these studies from local government departments and private companies such as consulting engineers, the WRC commissioned a more in-depth study with the following objectives:

- To compare different water payment strategies and investigate the attitudes and behaviour of low, mid and high-income level residential water users as a consequence of these payment strategies
- To determine the price elasticity of demand for water of low, mid and high-income groups, to enable effective water demand management to be put in place in the selected areas

Both the participative payment strategy testing (PPST) and contingent valuation (CV) methodologies required a systematic process of interaction between researchers and water consumers, which culminates in data being gathered by means of two surveys (called Survey No 1 and Survey No 2) for each methodology. For the CV experiment, these surveys record the different ways consumers use water, i.e., for indoor/outdoor usage, cooking, washing, etc. and changes to the amount of water used for these different purposes as the price charged for water changes. For the PPST experiment, these surveys record data about household water consumption, their water bills, their perceptions about the quantity of the water used and other related perceptions regarding their payment behaviour.

Surveys were conducted by face-to-face interviews among samples of low-, medium- and high-income population groups of residential water users in three newly created metropoles, namely Tshwane, Ethekwini and the city of Cape Town.

From the PPST experiment three issues emerged as being important with respect to water payment strategy policy formulation. These issues are the water account, payment options, consumer's water usage and their estimation of that water usage. Because of the lack of understanding with water accounts in the three metropoles, particularly amongst the low income group, it is recommended that water accounts be made simpler and more user friendly than the present ones. It is also recommended that more suitable payment points be provided particularly for the low income group. With regard to understanding water usage and the economic value of water which would aid in the implementation of payment strategies, it is recommended that an educational programme be implemented, and in addition each household should be encouraged to record its water usage so that a greater understanding of the value of water in South Africa (where water is a scarce resource) may be engendered. In formulating payment strategies it is also recommended that any help that can be given to low income consumers with respect to the cost of water should receive careful attention, for example, discounts for early payment.

From the results of the CV experiment certain tariff policies were suggested and also some advice was offered on water system design and the tariff of water. With respect to tariff design, it was suggested that tariffs should cover all costs, they should be made as simple as possible, that they should be collected regularly, emphasising that a sound tariff policy should promote the efficient use of the resource and provide an adequate service to all its consumers. The question of cross-subsidisation and tariff design was considered and it was pointed out that cross-subsidies can create serious distortions that affect the efficient use of water and they require a considerable administration structure for them to be effectively managed.

With respect to the design of water resource developments, the price elasticities of demand found from the CV experiment could be used by designers to use investment funds efficiently by means of staged system

design, thus using the funds available in the most efficient manner.

Cost: R 700 000
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

The Free Basic Water Policy was officially implemented in July 2001. The policy was rolled out in most urban areas on or near this date. However, in rural areas it was much more difficult, and there are many areas that have not yet seen the implementation of free basic water (FBW). This is due to varying financial, technical, political and logistical problems at the local and district municipality level.

This research investigated the current situation in rural municipalities, looking specifically at FBW policy, institutional arrangements, operation and maintenance costs, cost per capita and affordability in relation to the equitable share allocations. Five case study areas were chosen: the uThukela Water Partnership (KwaZulu-Natal); the Alfred Nzo District Municipality (Eastern Cape); the Ngqushwa Local Municipality (Eastern Cape); the Vulindlela Water Scheme (KwaZulu-Natal) and the Nlhungwane Community Scheme (KwaZulu-Natal).

From this research it is clear that Water Service Authorities (WSAs) are at varying levels of implementation, with few having a fully operational policy that is reaching the rural areas. Some communities have not been informed about FBW and are still paying for all their water. The institutional arrangements for FBW implementation are unique to each WSA, but a common factor in efficient, cost effective provision was noted to be the contracting of an organisation with the expertise and capacity to successfully manage water provision within a budget.

For each case study area the operation and maintenance costs were determined (as far as possible), and from this, the cost *per capita* per month for water provision. One recurring cause for concern was the lack of asset replacement costs in WSA budgeting. This will cause a major problem in the future when infrastructure needs to be replaced. It was noted where a WSA had not developed a FBW policy an ad hoc, unreliable operations and maintenance system tended to be in place, with higher costs than encountered where a reliable, comprehensive service was provided. This highlights the need for WSAs to prioritise FBW, regardless of their budget restraints, as FBW-by-default could result in greater expenditure than if the time, resources and budget are allocated for the development of a sound FBW policy and implementation strategy.

For poor rural areas the affordability of FBW is primarily determined by the equitable share (ES) allocations. The study investigated these allocations, when compared with the median cost , and found that the ES allocations are insufficient to cover the operation and maintenance costs in all but one of these rural areas. Using the portion of the ES that is allocated by National Treasury for the supply of water and dividing this grant money (at R5.84 *per capita* per month) by the population served by the water service provider for the case study areas, within the percentage cover that is currently required at reported indigence levels and service levels, it was found that even if it is taken into account that, for example, only 80% of the population should qualify for FBW, and that only 55% of the population currently have access to potable water, the ES is insufficient to supply for this portion of the population. The issue of affordability highlights the need for WSAs to have effective and efficient cost-recovery systems that ensure payment for water by those that are not poor, and by all users who consume more than the free basic allowance. Cost-recovery was a noted problem in each of the case study areas and needs practical and politically acceptable solutions if FBW is to be sustainable.

Free basic water in the rural areas of South Africa is difficult, but possible. With good management FBW could be sustainable in the long term as long as national government provides sufficient levels of equitable share revenue to municipalities. From the lessons learnt in this research, the key factors in successful implementation are:

- Good planning
- Honest assessment of the WSA capacity and the consequential contracting of experts to fulfil the roles and responsibilities they cannot
- Political support for FBW policy
- Accountability

Cost: R 500 000
Term: 2002-2005

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

Sanitation includes not just toilets, but a range of elements, which are inter-related and of equal importance, such as physical infrastructure, hygiene-related behaviour, disposal of wastewater, excreta and other solid wastes, community participation in decision-making, improved health of millions, safer living environments, greater knowledge of sanitation-related health practices and improved hygiene. Rural areas present unique challenges to sanitation improvement activities and in some situations, technical solutions are not the answer. Rural areas are characterised by inferior infrastructure, low incomes, poor site conditions, unreliable water availability, high population density, and lack of legal land tenure and lack of recognition by formal governments.

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 could be made on the development of a marketing plan for sanitation promotion. It is in the light of this, the current study was conducted with the aims of:

- Identifying critical success factors that motivate people to adopt safe hygiene practices
- Making recommendations for the development of a village-level participatory marketing plan for sanitation promotion

Based on a methodology of participatory evaluation the following key findings were generated:

- **Socio-economic status**
  The communities were characterised by inferior infrastructure (e.g. poorly constructed houses, lack of electricity and poor road conditions), poor site conditions, unemployment, low incomes, poor living conditions, low literacy levels and lack of recreational facilities. There was a general lack of human, physical, organisational and natural resources in the communities. The lack of basic services affected the sanitation status of the communities. The health of the communities was generally poor because of poor diet, dirty surroundings and unavailability of water. Consequently, community members suffered from diseases such as worms, eye infections, diarrhoea, cholera, bilharzia, malaria, and typhoid.
- **Water supply status**
  Clean water supply was irregular, inadequate and inaccessible because existing natural water supply sources (such as perennial rivers, springs, fountains, dams) and manufactured water supply sources (such as street taps, yard taps, and tanks) were limited and some did not produce water which was safe for human consumption. Inadequate water supply was also attributed to bursting pipes, lack of money to fix broken taps, taps being closed and drought. Water sources were poorly maintained. Without regular water supply and proper maintenance of water sources, it is almost impossible for people to adopt safe hygiene practices. The communities identified inadequate water supply as a de-motivating factor for adoption of safe hygiene practices.
- **Sanitation status**
  There was a lack of essential services for safe disposal of water and other domestic waste. Rivers, streams, canals, gullies and ditches were often destinations of most untreated human excreta and household waste. Such waste accumulated on streets, in open spaces,

between houses, in stagnant pools and on waste land. Sewerage oxidation ponds, septic tanks and water reticulation, all forms of toilet structures were generally poor to non-existent. Schools were built with no latrines and a number of communities used the bush for defecation. Toilets were not properly maintained, poorly designed and in certain instances toilets could not be shared due to cultural beliefs.

- **Hygiene practices**
  To a large extent communities did not practise safe hygiene practices. Some of the community members did not practise personal hygiene such as washing hands before handling food, before eating, after a visit to the toilet, after cleaning house and after work or rubbish disposal because of lack of hand-washing facilities and irregular water supply. It was particularly indicated that men do not wash their hands after passing urine. Household hygiene was to a greater extent not practised because there were households without toilets or with poor toilet facilities, which resulted in poor disposal of children's faeces and some families using the "bush" for defecation. Some households left their water containers uncovered or half covered to "capture" rain water. The containers were not washed regularly, drinking water was generally untreated due to lack of money to buy disinfectants and lack of knowledge and dirty water was thrown in front of the house due to the lack of drainage systems. Uncovered drinking water encouraged animals to drink from the water containers since there were no demarcation areas around households
- **Hygiene perceptions**
  Sanitation was narrowly viewed as a toilet issue. Communities generally did not perceive urinating on open spaces, behind the house or on the roads among males as bad hygiene practice. Some communities perceived covering food *for visitors only*, boiling drinking water *for children only*, cleaning a toilet *without detergents*, touching children's faeces, as safe hygiene practices. The communities perceived safe hygiene practices as "rich people's affair". They believed that only rich people can afford toilets - toilets were associated with dignity, privacy and status. Some preferred to defecate in the "bush" because they perceived toilets, especially inside ones as "Western culture". Encouraging children to defecate behind the house was not perceived as unsafe hygiene practice because it was safer for children. The viewpoints of the participants show the importance of understanding perceptual problems and dealing with them; as sanitation marketing largely concerns altering perceptions and practices of users and providers.

While the key findings discussed above implicitly highlighted the factors that played a role in the communities' inability to adopt safe hygiene practices, this sub-section highlights the factors that the communities thought could motivate them to adopt safe hygiene practices. The study showed that the motivating factors for adoption of safe hygiene 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: 2002-2003

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

TERMINATED

Cost: R150 000
Term: 1999-2001

CURRENT

THRUST 1: WATER AS A SHARED RESOURCE

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

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 multi-disciplinary, collaborative, action research. This project will provide a model for how human interactions in water resource management can be facilitated to promote behaviour changes that are in line with the principles and values of democracy. The project will also show what the role and opportunities are for research in this process and how collaborative research teams need to operate to fulfil those opportunities within the resource management context.

Estimated cost: R1 416 700
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

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

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

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 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

Raising community awareness for the provision of potable water and empowerment of 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

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 participation in decision making within water management and water services institutions.

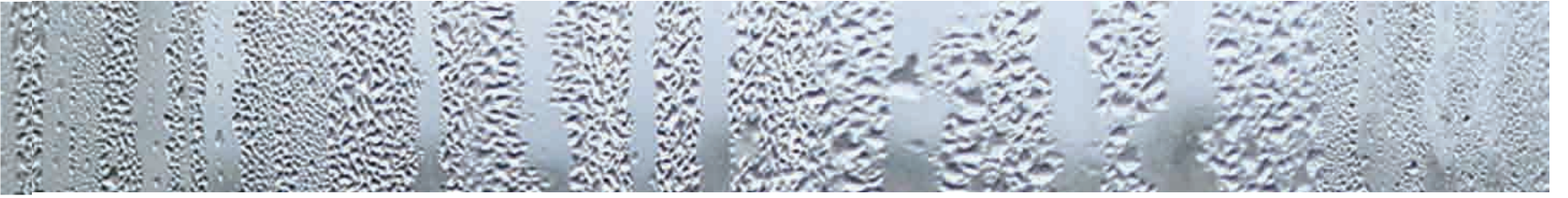
Estimated cost: R298 800
Expected term: 2003-2004

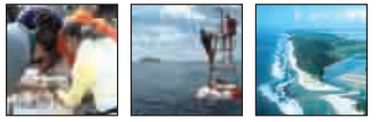
THRUST 4: POVERTY ALLEVIATION

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

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 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
- Determine the effect of agroforestry practices on soil water availability to traditional crops (e.g. maize)
- Determine whether the inclusion of trees in traditional cropping systems can enhance the infiltration of rainfall and prevent soil loss
- 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

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

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

NEW

THRUST 1: WATER AS A SHARED RESOURCE

Guidelines for river management and rehabilitation in South Africa
Laughing Waters
No 1412

Internationally, the science of river rehabilitation is active and gaining support. South Africa has started work on river rehabilitation and related facets such as urban drainage (funded through local authorities) and the removal of alien plants (funded through the *Working for Water Programme*). There are many projects, current or completed, in the country which have been designed and implemented based on the individual experience of a number of organisations or individuals. But there is no common, shared bank of this experience, which would result in people working together across sectoral boundaries to rehabilitate degraded rivers. This project will develop the network to link all the experience in the country and establish relevant guidelines.

Estimated cost: R700 000 (KSA 2)
Expected term: 2004-2007

Integrated development planning for estuaries
Institute for Natural Resources
No 1485

This project adds a new dimension to the ***Eastern Cape Estuaries Research and Management Programme*** which was initiated in the late 1990s. The original vision of this programme was to empower the communities living beside these estuaries to manage the resource sustainably. The work undertaken has had a big impact in the area, and has resolved some long-standing problems both between national government policy and communities as well as between communities themselves. The integration of knowledge generated so far into the integrated development planning (IDP) process is a necessary step towards sustainable management of the estuaries. The IDP is required of local government, but the capacity to include environmental matters in the IDP is not available in the smaller local authorities, CMAs, new provincial environmental affairs structures, and so building the capacity here will entrench it for the future.

Estimated cost: R1 200 000 (KSA 2)
Expected term: 2004-2007

A catchment management strategy for the Kat River
Rhodes University
No 1496

For the past 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). This project will pilot the development and application of methods of establishing a co-operative catchment management strategy, address water allocations, Reserve requirements and Resource Quality Objectives, and support a monitoring programme.

Estimated cost: R2 100 000 (KSA 1)
Expected term: 2004-2007

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

Currently, granting approval for groundwater development and use falls within the area of responsibility of two government departments and their delegated regional and local authorities. Unfortunately, current procedures for granting approval for groundwater use are unnecessarily restricting groundwater's development because the two Departments follow different procedures with respect to assessing groundwater use applications. A multidisciplinary research project is needed to develop an appropriate solution, supported by efficient and effective cooperative governance. Resulting documentation will be the industry standard for exploring, developing and using groundwater supplies in South Africa.

Estimated cost: R200 00 000 (KSA 1)
Expected term: 2004-2006

International freshwater agreements
CSIR
No 1515

The quantity and quality of the water in SA's international rivers is increasingly under pressure due to increased water demands in South Africa as well as in the neighbouring states. South Africa has signed and ratified the UN Convention on the Law of the Non-Navigational Uses of International Watercourses, which promotes the principles of equitable and reasonable utilisation and imposes 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. 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. 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, including 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. This project will access, review and reconcile these various agreements.

Estimated cost: R270 000 (KSA 1)
Expected term: 2004-2005

THRUST 2: SOCIAL NEEDS FOR WATER SERVICES

Protocols for 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: Developing a protocol for defining spring-flow sustainability index; assessing the value of isotopes in characterising the sustainability of springs with the isotopic signature; and developing a weighting system to assess the sustainability of spring flow.

Estimated cost: R734 100 (KSA 1)
Expected term: 2004-2007

Climate change and small town water resources
University of Cape Town
No 1500

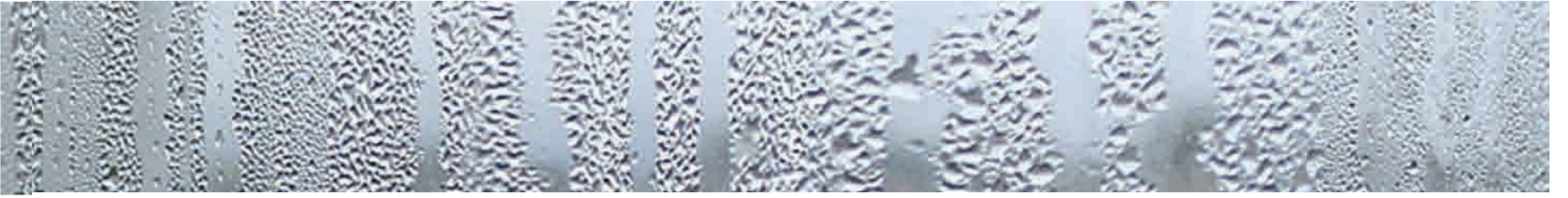
The most severe impacts of climate change are likely to occur along the western parts of South Africa, were small towns and subsistence farmers are most vulnerable. This study intends to investigate the adaptive capacity of small towns and communities in the Western and Northern Provinces to climate variability, specifically drought. By extrapolation of successful adaptive strategies, national water resource planning and management will be assisted to safeguard water security against the impacts of climate change. The emphases on local authorities and providing them with the necessary tools/knowledge to address the possible impacts of climate change are considered critical.

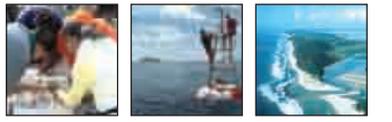
Estimated cost: R261 260 (KSA 1)
Expected term: 2004-2005

Sustainable development indicators for urban water systems: case study for the Thohoyandou and Makhado Municipalities
University of Venda
No 1517

This study aims to test the concept of using sustainable development indicators developed by the UN and to check their validity in two small towns in the Venda region of Limpopo Province.

Estimated cost: R150 000 (KSA 1)
Expected term: 2004-2006





First-order assessment of the level and distribution of water poverty in South Africa using a water poverty map at municipal level
University of the Western Cape
No K8/561

This study aims to investigate the feasibility of using water poverty maps to define and study the nature of water poverty in South Africa as well as providing a clear decision tool for the allocation of scarce resources to development initiatives that will be most effective and as a way of measuring the impact of these initiatives.

Estimated cost: R100 000 (KSA 3)
Expected term: 2004-2005

Case study on learning by technical water professionals and decision-makers for urban developmental service provision
Dr BM van Ryneveld
No 1519

The aim of this study is to identify how skills dissemination and learning by water professionals in the urban services sector is taking place and its impact on service provision, and to suggest possible improvements.

Estimated cost: R180 000 (KSA 3)
Expected term: 2004-2005

Involving traditional healers and myths and stories in hand-washing/ hygiene education/ sanitation promotion initiatives
Sigodi Marah Martin
No 1521

This study will examine the myths and traditional practices around water supply, sanitation and hygiene, with the intention of incorporating these, and involving traditional healers, in the promotion of health and hygiene practices.

Estimated cost: R326 000 (KSA 3)
Expected term: 2004-2006

Education awareness and behavioural change requirements to improve safe water practices
Environmentek, CSIR
No 1522

The aim of this study is to review water handling practices which impact negatively on users and to use results as the basis for a framework for actions to improve hygiene behaviour.

Estimated cost: R650 000 (KSA 3)
Expected term: 2004-2006

The effectiveness of water and sanitation awareness programmes in informal areas
Nemai Consulting
No 1523

This study aims to determine criteria for effective water and sanitation awareness programmes in informal areas and to test criteria in local case studies, with a view to developing appropriate strategies for effective awareness campaigns.

Estimated cost: R200 000 (KSA 3)
Expected term: 2004-2006

THRUST 3: GENDER AND OTHER LIMITATIONS REGARDING ACCESS TO WATER

Human rights and equitable access to water
AWARD
No 1512

The constitutional commitment to providing water for basic human needs is captured by the National Water Act (1998) in the concept of the "Basic Human Needs Reserve" (BHNR). 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-local government. This project seeks to find ways of remedying this situation.

Estimated cost: R173 100 (KSA 1)
Expected term: 2004-2005

THRUST 4: POVERTY ALLEVIATION

Best management practices for small-scale subsistence farming on selected irrigation schemes and surrounding areas through participatory adaptive research
University of Fort Hare
No 1477

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 will be an objective of this research project to make the benefits of better management practices apparent to the farmers as early as possible. The intention is also to build upon existing knowledge, indigenous and new technologies, which are useful for the particular circumstances of subsistence farming. This will be done through participatory action research which combines research, education and action to the direct benefit of farmers and surrounding communities.

Estimated cost: R4 500 000 (KSA 4)
Expected term: 2004-2009

Sustainable techniques and practices for water harvesting and conservation and their effective application in resource-poor agricultural production
University of Fort Hare
No 1478

A critical issue in the near future will be the increasing pressure on water for agriculture, in particular for food and fuel-wood production, due to population growth. At the same time, there is increasing dependence on agriculture in rural areas, which exert even more pressure on the rain-water 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. 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. This research project promotes techniques and knowledge that improve the agricultural productivity of water at farming level. Attention is to be given to production methods for crop cultivation in combination with livestock husbandry (and where possible utilising indigenous products). Social, economic and environmental factors will be taken into account. The perceptions of rural households and possible adjustments to water harvesting and conservation practices in order to improve food security and rural livelihoods will be analysed.

Estimated cost: R5 000 000 (KSA 4)
Expected term: 2004-2009

Agro-forestry systems for improved food production through the efficient use of water
CSIR/ Environmentek
No 1480

The relatively low rainfall and limited arable land make it imperative to effectively and efficiently use these natural resources for food and fibre production. This is even more important for emerging and subsistence farmers whose practices often lack access to information and use of production technologies. Small-holder agriculture, particularly in Africa, has been faced with land degradation. In order to improve the status of land resources and sustain their productivity, there is a need for a "shift" from the current production practices. Agro-forestry (AF) systems, (whereby there is a deliberate planting of trees in combination with food/forage crops for the benefit of people and the environment) have been reported to be potentially productive in degraded and marginal soils and also to have potential for land rehabilitation. In South Africa, however, AF systems are relatively unpopular, yet the majority of the subsistence farmers are dependent on degraded lands for their

agricultural production. A major challenge is to enable such farmers and poor communities to produce optimally under such constraints, simultaneously rehabilitating and improving the land resource. This will ensure both sustainable production and food security-while improving the livelihoods of the poor. This research project addresses a number of questions that need to be answered in order for agro-forestry to be adopted locally.

Estimated cost: R3 250 000 (KSA 4)
Expected term: 2004-2009

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WATER AND THE ECONOMY

Mr Meiring du Plessis
Head

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, 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

As in the previous year, 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

All thrusts in this domain remain unchanged from the previous year.

THRUST 1: THE VALUE OF WATER TO DIFFERENT SECTORS OF THE ECONOMY

The value of water, which continues to be addressed in this thrust, 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 continues to focus 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

This thrust is based on the rationale that 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

The funding for research projects supported by the various KSAs and focusing on this domain, is estimated at about R3.3m. for 2004/05.

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 1 April 2004 and 31 March 2005.

COMPLETED

THRUST 1: THE VALUE OF WATER TO DIFFERENT SECTORS OF THE ECONOMY

Valuation of changes to estuary services in South Africa as a result of reductions in freshwater inflows
Department of Economics, UPE
No 1304

There are just over 250 functioning estuaries in South Africa and of these an increasing number are subject to river inflow deprivation. River water is abstracted upstream of the estuaries for urban and agricultural use, and runoff into rivers is affected by forestry and the spread of high water consuming alien vegetation. As a result of the reductions in river water inflow, the services rendered by these estuaries are eroded.

The main purpose of this study was to develop a method of valuing changes in freshwater inflow that would better inform estuary managers on economic issues relating to the problem of freshwater deprivation.

The Contingent Valuation Method (CVM) was selected for the purpose of estimating the marginal social values because it is highly suited to quantifying the benefits to the public of environmental goods and attributes. It serves as an alternative to indirect techniques (the travel cost and hedonic pricing methods) for quantifying these benefits. These values may be used in decision-making with respect to the management of the environment and, if desired, incorporated into cost benefit analyses. For most of the estuaries both high and low forecasts are generated of the impacts of changes in freshwater inflow into estuaries. For proposed increases in freshwater inflow the former relate to optimistic scenarios and the latter to pessimistic scenarios, but for proposed decreases in freshwater inflow, the former relates to pessimistic scenarios and the latter to optimistic scenarios. The forecasts of impacts on estuary services of changes in freshwater inflows were generated on the basis of expert opinion.

The main findings of this report with respect to values, are measured in the form of the total willingness to pay (TWTP) in Rand for freshwater inflow into the estuary-the product of the median willingness to pay (WTP) bid per annum per household and the total number of user households per estuary.

The CVs reflect a wide range of values-from 1.1 c/m^3 in the case of the Klein Brak low estimate scenario, to 10.5 c/m^3 in the case of the Groot Brak high estimate scenario. The median estimate of the 11 valuations reported 4.9 c/m^3 of water and the mean estimate is 4.78 c/m^3 of water.

It was expected that the estuaries most prone to high change in services from changes in freshwater inflow would yield the highest values per cubic metre, for example, temporary open/closed estuaries. The results corresponded with this expectation. The Groot Brak Estuary heads the value list and it is particularly affected by freshwater inflow reductions. The Knysna Estuarine Bay, on the other hand, is only marginally affected by freshwater inflow reductions from the Knysna River and is near the foot of the value list.

Relating to river flow management the main argument of this study is that efficient management of freshwater allocations to South African estuaries can only be accomplished if it is informed by current estimates of marginal social costs and marginal social values of this inflow. Based on findings with respect to the estimated bid functions and observations made in this study, it is also recommended that resources continue to be committed to educating the public affected by estuary services on the link between these services and the quantity of freshwater flowing into the estuaries.

Cost: R336 000
Term: 2002-2004

THRUST 2: THE ECONOMIC ADVANTAGES AND DISADVANTAGES OF WATER RESOURCE DEVELOPMENT

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

The majority of small-scale farmers are located in less favoured agro-ecological conditions, with poor soils, and low and erratic rainfall. The development and transfer to farmers of production practices and techniques that encourage water and soil conservation, and increased water use efficiency can provide small-scale farmers with an opportunity to increase agricultural production. However, before these water conservation techniques and other new production technologies can be transferred to farmers, analyses to assess their economic viability, social acceptability and environmental sustainability are required.

The main aim of the study is to carry out economic viability and social acceptability analyses, and an assessment of the environmental sustainability of in-field rainwater harvesting techniques.

The study employs participatory research techniques, such as Participatory Rural Appraisal (PRA) and Participatory Action Research (PAR), to facilitate involvement of smallholder farmers in the diagnosis of constraints they face in their production activities and the formulation of technological interventions that can be employed to help overcome these constraints. The report discusses the essential features of the PRA and PAR methods, and the procedures followed in conducting PRAs and PAR in the study villages are described.

The new technologies should provide significant economic returns if farmers are to be persuaded to undertake the required investments. Profitability analyses using enterprise budgets show that there is a significant increase in farm income when farmers adopt rainwater harvesting compared to the income levels achieved under conventional crop cultivation. By adopting the simplest form of in-field rainwater harvesting-without the use of mulches in the basins and the runoff area, farmers can increase their income by about R800.00/ha in the case of maize production.

The results reported in this study suggest that farmers are willing to apply IRWH techniques in their production activities, and that these techniques are not only economically viable but also environmentally sustainable. Based on these findings it can be recommended that extension efforts should be undertaken to encourage adoption and adaptation by farmers.

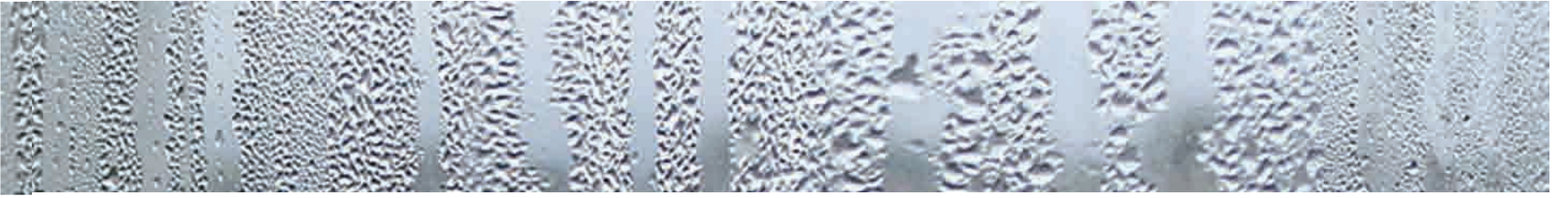
While the preliminary results reported here suggest that the use of IRWH techniques provides social, economic and environmental benefits, these findings come from assessment of the techniques in a short period. There is a need for continued monitoring of the impacts (environmental, economic and social) of these techniques. In this regard it would be necessary to conduct an impact assessment study in three to four seasons from now. This will allow a better understanding of the role that IRWH can play in the farming systems in semi-arid areas.

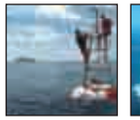
Cost: R425 800
Term: 2001-2003

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

A previous study in the Crocodile River catchment analysed water use efficiency based on direct economic benefits generated in specific primary production activities (forestry, irrigated sugarcane and five irrigated sub-tropical fruits), i.e. at the farm level. Accordingly, indirect economic benefits realized upstream or downstream from the primary sector in question were not accounted for. The social costs and benefits of the major environmental impacts of the studied activities were also not investigated. The aims of the present study were therefore to account for




total economic benefits (direct and indirect) of water use in the catchment, and to investigate the environmental (natural) and social costs and benefits of the above production activities.

The point of departure of the study was the mapping and quantification of the value chains of each of the three land-use types analysed: forestry, irrigated sugar-cane and five irrigated sub-tropical fruit types. This was done in a two-stage process where, firstly, the product flows of the relevant land uses were mapped through the identification of forward and backward linkages. Secondly, each value added, through extensive survey and primary data collection in each of the three value chains in Mpumalanga.

Economic, social and environmental impact analyses were then completed for each value chain. Direct impacts were defined as the economic, social and environmental impacts occurring within each of the land uses (i.e. at farm level) as the result of water-based production activities. Indirect impacts were defined as the resultant impacts occurring in the forward and backward linkages of the respective value chains. The economic impact analysis set out to measure and compare total economic benefits (direct and indirect) from water use by plantation forestry, irrigated sugarcane and five types of irrigated subtropical fruit (oranges, grapefruit, bananas, avocadoes, mangoes) in the Crocodile River catchment. The environmental impact analysis identified the value chain of direct and indirect product flows within each sector. This was used as a basis from which to build a hybrid life-cycle assessment of the respective sectors and focused on the environmental aspects of the life-cycle analysis. The social impact analysis set out to measure the impact of the respective value chains on households and individuals. This part of the study examined direct and indirect employment and enterprise linkages, and assessed the external social benefit and costs on households that result from these three land uses.

Water apportionment decisions remain, for the largest part, dependent on accurate water use information. This study has shown for instance how estimates of forestry water use figures changed with the adoption of new forest hydrology modelling data. The measurement of irrigation water use remains an important issue in the determination of actual on farm water use, and prediction models for this are currently not adequate. Comparative analysis of forestry and irrigation water use must be done carefully, as the terminology and definitions used in forest hydrology and irrigation planning are different. Water use per ton of product in the respective value chains, defined as indirect water use for the purposes of this study, are very small in comparison to the direct crop water use.

The study revealed the importance of considering indirect economic benefits in comparing the social worthiness of alternative productive uses of water and other economic resources. This was especially evident from the value added (VAD) and employment multiplier effects, which were between 2- and 20-fold larger than the direct benefits. The multiplier effects were more pronounced for the longer value chains, i.e. those that comprised of more intermediate value adding activities between the farm and the final consumer.

Cost: R558 000
Term: 1999-2001

THRUST 3: THE USE OF ECONOMIC INSTRUMENTS TO EFFECT BEHAVIOURAL CHANGE REGARDING WATER UTILISATION

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

In many municipalities prepayment water meter technology has become a prominent instrument of water management contributing, with other measures, to the sustainability of water provision. This study aimed at providing an understanding of the social and institutional context in which the technology fails or succeeds. This understanding is derived from an examination of the available literature, the analysis of surveys and by examining case studies. Specifically, the objective was to

understand how the technology could best be used to ensure sustainable water provision by local authorities. Key objectives were to determine how the changing institutional environment impacted on the uptake of the technology and, similarly, how socio-economic contexts affected its adoption.

The information from the National Postal Survey (NPS) and the Labour Force Survey (LFS) was combined with data on water charges to unpick the attitudes and perceptions of current users. Aspects considered include perceptions of satisfaction with the technology in general and with cost effectiveness and technical reliability in particular. Prepayment meters in private houses, instead of communal taps, were viewed more critically by their users.

Among service providers there was a strong correlation between technical reliability and general satisfaction with the technology. The role of on-going support for the technology was highlighted by the correlation between support levels and high satisfaction levels regarding the meters in general and their technical reliability in particular. Contrary to popular perception vandalism was not cited by service providers as a particularly serious problem. Somewhat surprisingly service providers indicated that the FBW policy would have a minor impact on anticipated uptake of the technology.

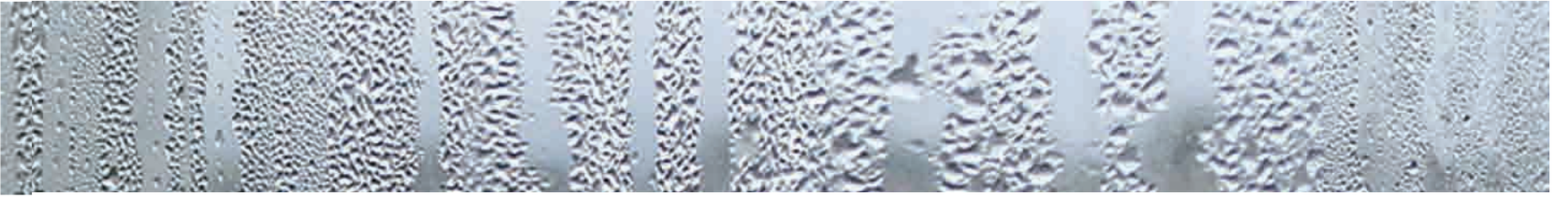
Case studies on eight municipalities were conducted to ensure a cross-section of experiences with the technology. This exercise revealed that:

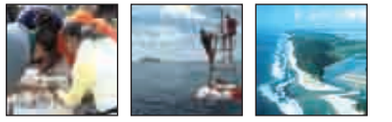
- The drive to introduce prepayment water technology was motivated by a need to combat institutionalisation of non-payment
- Planning, installation and operation were characterised by many technical problems. However instrument suppliers were initially willing to provide strong technical support
- In many cases there was an initial lack of public participation. This situation has since improved
- The Free Basic Water Policy has had an important influence on municipalities' installing the technology. The FBW, *inter alia*, altered their perceptions as to where the technology was most appropriately placed
- Expected future trends were highly varied. Some municipalities planned to expand coverage, while others planned to replace their prepayment meters with conventional ones. The last were generally motivated by high maintenance costs or the unreliability of the instruments.

In general the study concludes that prepayment water meter technology has a valuable role to play in sustainable water service delivery. The major recommendations arising from the study were:

- Water policy (including free basic water provision and the use of equitable share grant) should be packaged in a manner that enables municipalities to better interpret and apply it.
- Municipal structures and their agents need assistance to understand and address social conflicts relating to service payment. The impact of indigent policy and the insights gained from case studies need to be more widely shared.
- A working partnership between stakeholders such as DWAF, SALGA, DPLG as well as WRC, must be generated. This partnership should be used to ensure that policy measures and interventions blend. The resulting shared understanding and application of policy should be communicated to municipalities in an accessible and easily understood manner.
- Municipal water service providers should be equipped to see the differences between community resistance to payment and the means by which payment is effected. Similarly consumers have to be informed that free-riding is no longer an option-irrespective of the means by which consumers are called to account.
- Municipal structures must actively educate constituencies as to the implications of "free-riding". This education should highlight the cost of "free-riding" in terms of reduced service delivery in other service sectors. Political representatives should play a more prominent role in articulating the grievances of their constituencies while promoting the decisions of the elected local government.

Cost: R375 500
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

Research reports have been completed on payment strategies for low-income water consumers in the then Pretoria, Durban, Johannesburg and Cape Town Metropolitan areas and on determination of the price elasticity of demand for water amongst low-, medium- and high-income groups in Alberton and Thokoza. As a consequence of the interest engendered by these studies from local government departments and private companies such as consulting engineers, the WRC commissioned a more in-depth study with the following objectives:

- To compare different water payment strategies and investigate the attitudes and behaviour of low, mid and high-income level residential water users as a consequence of these payment strategies;
- To determine the price elasticity of demand for water of low, mid and high-income groups, to enable effective water demand management to be put in place in the selected areas.

Both the participative payment strategy testing (PPST) and contingent valuation (CV) methodologies required a systematic process of interaction between researchers and water consumers, which culminates in data being gathered by means of two surveys (called Survey No 1 and Survey No 2) for each methodology. For the CV experiment, these surveys record the different ways consumers use water, i.e., for indoor/outdoor usage, cooking, washing, etc. and changes to the amount of water used for these different purposes as the price charged for water changes. For the PPST experiment, these surveys record data about household water consumption, their water bills, their perceptions about the quantity of the water used and other related perceptions regarding their payment behaviour.

Surveys were conducted by face-to-face interviews among samples of low-, medium- and high-income population groups of residential water users in three newly created metropoles, namely Tshwane, Ethekwini and the city of Cape Town.

From the PPST experiment three issues emerged as being important with respect to water payment strategy policy formulation. These issues are the water account, payment options, consumer's water usage and their estimation of that water usage. Because of the lack of understanding with water accounts in the three metropoles, particularly amongst the low income group, it is recommended that water accounts be made simpler and more user friendly than the present ones. It is also recommended that more suitable payment points be provided particularly for the low income group. With regard to understanding water usage and the economic value of water which would aid in the implementation of payment strategies, it is recommended that an educational programme be implemented, and in addition each household should be encouraged to record its water usage so that a greater understanding of the value of water in South Africa (where water is a scarce resource) may be engendered. In formulating payment strategies it is also recommended that any help that can be given to low income consumers with respect to the cost of water should receive careful attention, for example, discounts for early payment.

From the results of the CV experiment certain tariff policies were suggested and also some advice was offered on water system design and the tariff of water. With respect to tariff design, it was suggested that tariffs should cover all costs, they should be made as simple as possible, that they should be collected regularly emphasising that a sound tariff policy should promote the efficient use of the resource and provide an adequate service to all its consumers. The question of cross subsidisation and tariff design was considered and it was pointed out that cross subsidies can create serious distortions that affect the efficient use of water and they require a considerable administration structure for them to be effectively managed.

With respect the design of water resource developments, the price elasticities of demand found from the CV experiment could be used by designers to use investment funds efficiently by means of staged system design, thus using the funds available in the most efficient manner.

Cost: R 700 000
Term: 2002-2004

THRUST 4: THE USE OF ECONOMIC INSTRUMENTS TO PROMOTE EQUITABLE AND EFFICIENT WATER ALLOCATION AND DISTRIBUTION

An investigation of the supportive role of the market mechanism in implementing the provision of the New Water Act (NWA) in order to achieve efficient and equitable water utilisation
Conningarth Consultants
No 1297

The demand for water in South Africa is steadily increasing while the opportunity for developing new sources of water supply becomes scarcer and the remaining potential sources are becoming increasingly more expensive to develop. In the face of this potential imbalance between supply and demand it is logical to emphasize ways in which the existing supply can be used more efficiently. It requires a shift from the previous philosophy that water is a free good that can be used without regard to its scarcity value to one where water is considered to be an economic good.
The point of departure for this study is, therefore, to determine to what extent the NWA reflects this philosophy as far it relates to the use of the market mechanism for allocating water use. The principles that inform South Africa's new approach to water management and specifically the provisions contained in the NWA that facilitates a water market must be assessed. A detailed evaluation of the legal issues contained in the NWA as it relates to a water market is made. It is concluded that although reference is never made in the NWA to a water market, it contains no provision that prevents its functioning.

The ways in which trade is taking place at present and in which it is supposed to unfold in the future are subsequently investigated. The approach to water management as outlined in the NWA cannot be implemented immediately. The reality is that the transformation from the old to the new approach involves a large number of time-consuming steps.

In addition, the NWA provides for a number of new administrative structures such as catchment management agencies (CMAs) at the regional level, water user associations (WUAs) at the local level and various advisory bodies to be created as needed.

The draft National Water Resource Strategy (NWRS) 2002 contains a plan as to how and when these required procedures and structures will be instituted. It will take considerable time before all the structures are in place and fully operational. For instance, according to the NWRS it will take up to 20 years for the licensing procedure to be completed.

Although all the structures are not in place, trade is at present taking place reasonably satisfactorily judged on the basis of the time it takes to approve an application. Implementation problems, many of which are caused by the newness of the system and others caused by processes that must at present be followed to provide for the licensing of water use, will decline as the new approach becomes more familiar. Once water use entitlements are licensed the time needed to consider routine applications to trade should not be a factor that inhibits trade.

The recommendations relate to considerations about the unease about some of the consequences of trade. It is argued that reliance must be placed on evaluation procedures to take both private and social costs and benefits into account. Administrative aspects are influenced by the fact that all the structures provided for in the NWA are not yet in place and it is, therefore, recommended that it be evaluated periodically as the process unfolds. For water markets to function properly all the relevant information is needed, and more could be done to provide such information.

Lastly, the new decentralized process of dealing with water management, which includes trade, is dependent on the availability of skilled personnel. It is proposed that a human resource development strategy be implemented to deal with this potential bottleneck.

Cost: R622 100
Term: 2002-2004

Development of models to facilitate the provision of free basic water in rural areas

Mvula Trust

No 1379

The Free Basic Water Policy was officially implemented in July 2001. The policy was rolled out in most urban areas on or near this date. However, in rural areas it was much more difficult, and there are many areas that have not yet seen the implementation of free basic water (FBW). This is due to varying financial, technical, political and logistical problems at the local and district municipality level.

This research investigated the current situation in rural municipalities, looking specifically at FBW policy, institutional arrangements, operation and maintenance costs, cost per capita and affordability in relation to the equitable share allocations. Five case study areas were chosen: the uThukela Water Partnership (KwaZulu-Natal); the Alfred Nzo District Municipality (Eastern Cape); the Ngqushwa Local Municipality (Eastern Cape); the Vulindlela Water Scheme (KwaZulu-Natal) and the Nlhungwane Community Scheme (KwaZulu-Natal).

From this research it is clear that Water Service Authorities (WSAs) are at varying levels of implementation, with few having a fully operational policy that is reaching the rural areas. Some communities have not been informed about FBW and are still paying for all their water. The institutional arrangements for FBW implementation are unique to each WSA, but a common factor in efficient, cost effective provision was noted to be the contracting of an organisation with the expertise and capacity to successfully manage water provision within a budget.

For each case study area the operation and maintenance costs were determined (as far as possible), and from this, the cost *per capita* per month for water provision. One recurring cause for concern was the lack of asset replacement costs in WSA budgeting. This will cause a major problem in the future when infrastructure needs to be replaced. It was noted where a WSA had not developed a FBW policy an ad hoc, unreliable operations and maintenance system tended to be in place, with higher costs than encountered where a reliable, comprehensive service was provided. This highlights the need for WSAs to prioritise FBW, regardless of their budget restraints, as FBW-by-default could result in greater expenditure than if the time, resources and budget are allocated for the development of a sound FBW policy and implementation strategy.

For poor rural areas the affordability of FBW is primarily determined by the equitable share (ES) allocations. The study investigated these allocations, when compared with the median cost, and found that the ES allocations are insufficient to cover the operation and maintenance costs in all but one of these rural areas. Using the portion of the ES that is allocated by National Treasury for the supply of water and dividing this grant money (at R5.84 *per capita* per month) by the population served by the water service provider for the case study areas, within the percentage cover that is currently required at reported indigence levels and service levels, it was found that even if it is taken into account that, for example, only 80% of the population should qualify for FBW, and that only 55% of the population currently have access to potable water, the ES is insufficient to supply for this portion of the population. The issue of affordability highlights the need for WSAs to have effective and efficient cost-recovery systems that ensure payment for water by those that are not poor, and by all users who consume more than the free basic allowance. Cost-recovery was a noted problem in each of the case study areas and needs practical and politically acceptable solutions if FBW is to be sustainable.

Free basic water in the rural areas of South Africa is difficult, but possible. With good management FBW could be sustainable in the long term as long as national government provides sufficient levels of equitable share revenue to municipalities. From the lessons learnt in this research, the key factors in successful implementation are:

- Good planning
- Honest assessment of the WSA capacity and the consequential contracting of experts to fulfil the roles and responsibilities they cannot
- Political support for FBW policy
- Accountability

Cost: R 500 000
Term: 2002-2003

Decision support for water policy making
University of Stellenbosch
No 1509

This project was terminated during 2004/05 at the request of the project leader. No deliverables were completed, and no report is available.

Cost: R122 000
Term: 2004-2006

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

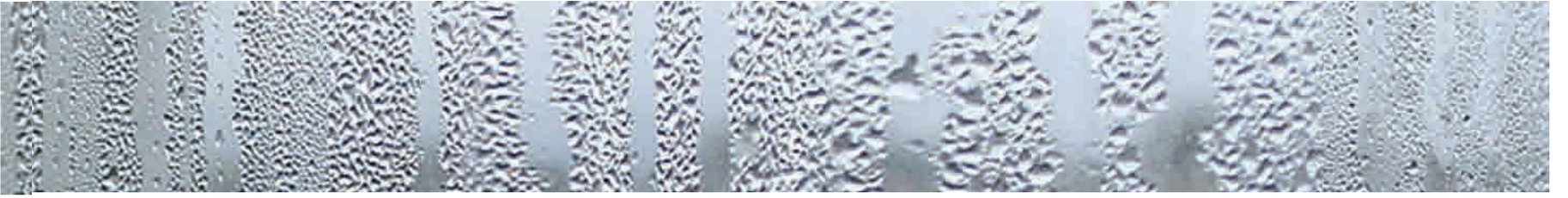
Integrated socio-economic and cultural values as additional components of the criteria for estimating and managing the Reserve
Institute for Natural Resources, University of Natal, Pietermaritzburg
No 1195

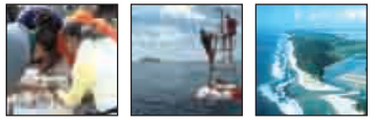
The National Water Act of 1998 aims to achieve sustainable use of water for the benefit of all users. It also guarantees the protection of aquatic ecosystems. Historically, the evaluation of the importance of river systems has been largely based on ecological importance, while ignoring social and cultural 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

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

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

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

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

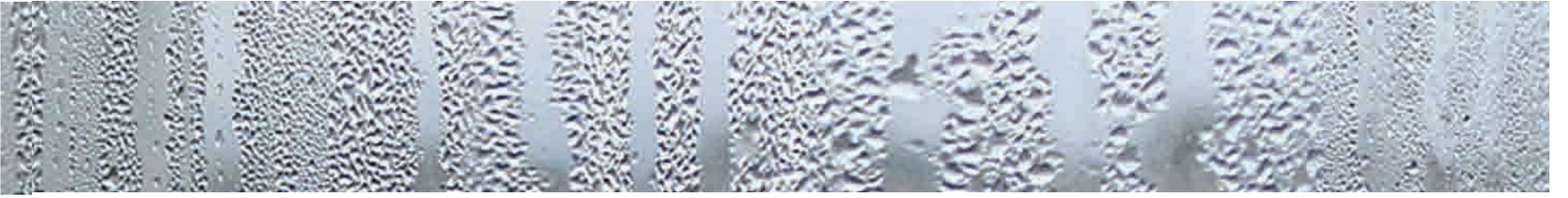
There has been ongoing debate in the water and sanitation sector regarding the importance of viewing water services projects as part of an integrated development programme rather than as one-off projects that are seen as an end in themselves. One of the main issues related to this is the importance of, 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.

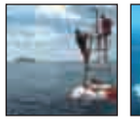
Estimated cost: R 300 000
Expected term: 2003-2005

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

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

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.

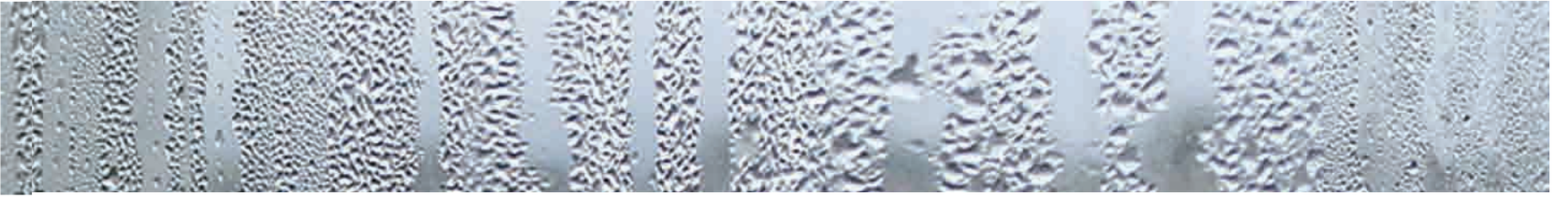
Sub-aims are to:

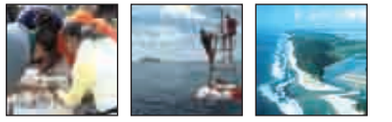
- Develop an appropriate land tenure system for small-scale farmers
- Develop an appropriate marketing arrangement for inputs and outputs for small-scale farmers
- Develop a suitable financial arrangement for loan and credit acquisition to facilitate successful establishment of small-scale farmers
- 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

NEW

THRUST 1: ASSESSING THE VALUE OF WATER FOR THE DIFFERENT SECTORS OF THE ECONOMY

Valuation of estuary services in South Africa
Nelson Mandela Metropolitan University
No 1413

Estuaries are delicate systems that are not only in high demand for development, but also deliver important goods and services with a value out of proportion to the geographical area occupied. The continued delivery of these goods and services is dependent on adequate freshwater inflow, and with the high rates of abstraction this is decreasing. The Reserve determination process takes into account ecological process and functions, but does not adequately account for the values placed on estuaries by people.

This follow-up project will build a database of the value of freshwater inflow into estuaries using the contingent valuation method to value the goods and services provided by the freshwater inflow and based on the value attributed to the freshwater inflow by estuary users.

Estimated cost: R2 160 000 (KSA 2)
Expected term: 2004-2007

THRUST 4: THE USE OF ECONOMIC INSTRUMENTS TO PROMOTE EQUITABLE AND EFFICIENT WATER UTILISATION

Human rights and equitable access to water
AWARD
No 1512

The constitutional commitment to providing water for basic human needs is captured by the National Water Act (1998) in the concept of the "Basic Human Needs Reserve" (BHNR). 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-local government, for whom the economic implications carry much weight. This project seeks to find ways of addressing this situation.

Estimated cost: R 173 000 (KSA 1)
Expected term: 2004-2005

Country-wide assessment of non-revenue water throughout South Africa using latest international water association methodology
WRP Consulting
No 6242230

This study will determine the levels of non-revenue water throughout the country and develop the methodology to estimate and benchmark between suppliers. The study will fill an information gap and will be of strategic importance to the water sector. It builds on previous innovative work on leakage benchmarking funded by the WRC and will offer further innovation in terms of capturing and presenting data which is very difficult to obtain.

Estimated cost: R 650 000 (KSA 3)
Expected term: 2004 2006

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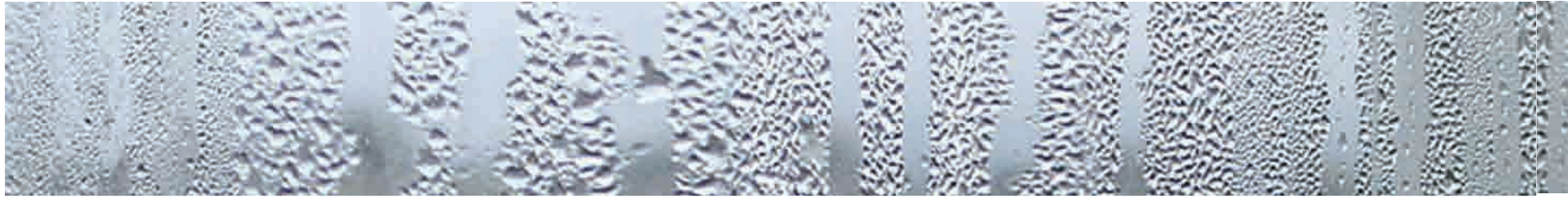

WATER AND THE ENVIRONMENT

Dr Heather MacKay
Head

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 the environmental components (atmospheric, marine, terrestrial, aquatic, subterranean) within the hydrological cycle, and between the hydrological cycle and governance systems, hinder sustainable water resources 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 resources 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, 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.

Objectives

The revised objective of the domain is to contribute to achieving a situation where our governance systems and our understanding of environmental processes and functioning within the hydrological cycle are aligned, to support sustainable water management that meets the needs of society.

Thrusts

The redefining of the scope of this domain has necessitated the reformulation of thrusts. The new thrusts, as listed and described below, **replace** the three thrusts (i.e. **Governance Systems for Water in the Environment, Biodiversity Protection and Environmental Functioning**) which applied in the previous year.

THRUST 1: ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE

All environmental components and processes within the hydrological cycle depend on and are regulated by the structural, functional and compositional aspects of biodiversity. Environmental components and processes also respond to and impact on society's decisions and actions. Historically, research has been narrowly focused on separate environmental components within the hydrological cycle rather than the processes and relationships between them. This thrust focuses on understanding these relationships within the hydrological cycle, their role in maintaining flows of water-related

goods and services to society, and their vulnerability to change in the broader environment.

THRUST 2: ENVIRONMENTAL GOVERNANCE SYSTEMS

Internationally, good governance is based on principles such as inclusivity, representivity, accountability, efficiency and effectiveness, as well as social equity and justice. In turn, good environmental governance should reflect our best understanding of the structure, functions, processes and variability that typify natural systems. Although there has been considerable development within the field of public, corporate and natural resource governance, little attention has been paid to the development of good environmental governance systems. This thrust focuses on water-related governance within society and the design of systems that better anticipate, reflect and respond to changes in environmental components and processes within the hydrological cycle.

THRUST 3: INTEGRATIVE KNOWLEDGE FOR ECOSYSTEM-BASED WATER RESOURCE MANAGEMENT

This thrust focuses on the generation, application and communication of higher-level knowledge and understanding of ecosystem approaches to water resource management, which can recognise and account for natural processes and human-induced impacts that affect water resources. This is achieved by stimulating the generation of new insights and information, through:

- Synthesising outputs from relevant programmes and projects within the WRC's research portfolio
- Combining these with the findings of other relevant national and international research initiatives
- Influencing and initiating appropriate new research to address gaps in current knowledge and deal with emerging new issues.

In order to strengthen the capacity to develop and apply ecosystem approaches to water resource management, the thrust will need to facilitate collaboration with other funding agencies and encourage partnerships between different research initiatives and with resource managers.

The desired outcomes of this thrust are:

- The development of mechanisms and communities of practice that integrate within and between the different disciplines and knowledge bases related to both the biophysical environment and environmental governance systems
- Co-operation between relevant governance sectors, helping to develop and harmonise environmental governance systems related to water
- Interactions between these groups, in support of good environmental governance practices.

Research portfolio

The funding for research projects relevant to this domain and supported by the various KSAs is estimated at R6.7m. for 2004/05.

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 1 April 2004 and 31 March 2005.

COMPLETED

THRUST 1: ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE

The development of a classification system for rivers in the KNP and a model for analysing trends in the condition of these rivers
Rhodes University
No 881

The background to this work is that most of the research during Phases 1 and 2 of the Kruger National Park Rivers Research Programme was undertaken on the Sabie River which is the smallest of the 5 major rivers flowing through the Kruger National Park. The question was, how applicable is this research to the other 4 rivers? And, can it be extrapolated to the other rivers in the Park?

Four types of data were used in the classification of the rivers in question. These were catchment information, river flow data, water quality data and biological data. Although many data exist for the Sabie River, most of these were not

used in this project because the data filter used was that there should be information at the equivalent level of detail for each of the 5 rivers to enable valid comparisons. Each data set was subjected to principal component analysis. River flow was not found to be useful in the analysis of similarities and differences even although two of the rivers, the Letaba and the Luvuvhu, have changed from perennial to seasonal flow in the last few decades. This was not taken further. The most important factors in water quality were salinity (cations accounted for 51% of the variability and anions 15%) and nutrients (10% of the variability). Analysis if the macroinvertebrates and fish showed that natural biodiversity accounted for the main differences between the rivers in terms of these biota. However, while the fish data were collected at the species level, the invertebrate data were collected at the family level (using SASS5 methods) and so the definition provided by the latter was insufficient to show any differences that may have existed.

In conclusion, this approach should not be taken further. It would be better to use the freshwater biodiversity conservation planning tool that is currently being developed in the jointly funded (CSIR, DWAF & WRC) project being led by the CSIR.

Cost: 116 662
Term: 1997-2001

Aerosols, recirculation and rainfall experiment
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 influence cloud formation over Southern Africa and to quantify the relative contributions of natural and anthropogenic aerosols to effective (rain-producing) CCN. For the first time it was possible to characterise the nature and availability of CCN in relation to the production and transport of anthropogenic aerosols over South 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. The industrialised Highveld is a major continuous source of industrial aerosols which may act as fine-sized cloud condensation nuclei (CCN). Depending on concentration, size distribution and chemical composition (especially hygroscopicity) relative to natural CCN, these anthropogenic CCN could impact either negatively or positively on raindrop formation. Large numbers of fine-sized CCN with a narrow particle spectrum, common in industrial emissions, were found compete for available cloud water and inhibit raindrop growth. By contrast, relatively fewer but on average larger particles, such as naturally found in cleaner air or air typical of coastal areas, resulted in reduced cloud droplet concentrations with a broader size spectra, faster drop growth rates and thus higher possibilities of rainfall. The processes are, however, extremely complex and dynamic and only with further study will it would become possible to predict and properly manage specific impacts of air pollution on the hydrological cycle.

Cost: R1 390 000
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

High variability and short instrumental records conspire to limit understanding of longer-term climate patterns and variability (decadal and centennial scales) in South Africa. Proxy data series from continuous cave speleothems presented significant new opportunities for addressing this gap. Accordingly, this project originally aimed to construct a regional, sub-decadal scale record of precipitation, temperature and vegetation response in the north-eastern, summer rainfall region using such data. High resolution dating methods were used to establish sound age models congruent with the high resolution of the proxy data sampling, and to allow comparisons with other high

resolution series such as ice cores. The proxy data concern mainly the oxygen and carbon isotope series. The rapid shifts observed in the stalagmite records provide a strong indication of the rapidity of changes in rainfall and vegetation patterns, which are on the order of years to decades. Whereas overall trends and variability at low frequencies (longer time scales) are more stable and to some extent even predictable, variability is noisy at higher frequencies (multi-decadal and, to a lesser extent, centennial scales). This means that, while most objectives of the project were achieved, the goal of achieving greater clarity regarding subdecadal climate variations could not be immediately met.

Cost: R375 000
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

The aims of this project were:

1. Apply the concepts of desired future state (DFS) (Rogers and Bestbier, 1997) to ensure that the models developed are in line with management needs. In particular:

   (a) Develop a conceptual framework of problems pertaining to fish biodiversity (Sensu Noss, 1990) for the Sabie River in the context of established "agents of change"
   (b) Evaluate and refine the thresholds of probable concern (TPC) prescribed for both fish and geomorphology as defined in the DFS report of Rogers and Bestbier (1997)
   (c) Reassess the existing BLINKS models and develop further conceptual models to address the "problem world"
   (d) Conversion of existing biotic-abiotic links models (BLINKS)
   (e) Construction of other QRBM modules if necessary to address the conceptual "problem world"

2. Transfer and implementation of prototype QRBMs to KNP management
3. Design and implementation of monitoring programmes for the auditing of each fish QRBM
4. Design and implementation of monitoring programmes for the auditing of each fish QRBM as well as the calibration requirement needs for the abiotic models
5. Refinement/calibration of final QRBMs

Aims 1 and 2 were addressed by the development of a qualitative rule-based model (RBM) based on a selected indicator to monitor conditions in the Sabie River. Successful indicators of ecosystem health provide the required information in a robust way at minimal investment of resources. The process of strategic adaptive management relies on indicators to identify when changes beyond the envelope of variability occur to alert management to the fact that action needs to be considered. This envelope of variability is defined by a threshold of probable concern (TPC) which is set at a level of change that is considered unacceptable for the indicator being monitored. During the Kruger National Park Rivers Research Programme river water temperature was identified as an indicator of change in flow, as the river water warms up more quickly at low flow. This would indicate reduced flow, in the short term caused by changes in the pattern of water abstraction from the river upstream of the Kruger National Park. The first part of the Sabie River's course has a steep gradient as it descends the escarpment, and at Hazyview the gradient decreases as the river flows into the Lowveld, at which point the water temperature increases.

Amongst the rich diversity of fish species in the river are two species of sucker-mouth catfish (*Chiloglanis* spp.), one cold-water tolerant and the other warm-water tolerant. The cold-tolerant species is the only species occurring to just downstream of Hazyview where the upstream limit of the warm-water tolerant species occurs. The cold-water tolerant species disappears from the river quite quickly below this point, although there are pockets of this species in well-shaded and cooler areas downstream.

Water temperature was regarded as being the agent of

change, and so the TPC selected to monitor conditions in the river was the point where the dominance of the two species of catfish changes. This addressed Aims 1 and 2, although Aim 1(a) was not addressed as it needed a fishery biologist to do this properly.

A water temperature-monitoring network was established in the Sabie River that monitored temperature at hourly intervals for over a year (the extent of the field sampling programme) at a number of stations outside and inside the Park. This addresses Aim 4. The model was transferred to the KNP management, but it is not being used at the moment. Thus Aim 3 was addressed in principle, but the technology transfer is not complete. The other RBMs represent, at this stage, hypotheses only. Refinement and calibration will only be achieved through ongoing monitoring and data collection.

In the longer term, this may also be used to monitor temperature-related climate change in the Lowveld.

Cost: R552 000
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

This project on the dynamical modelling of the climate system built on an earlier project, thereby consolidating recently developed capacity to undertake climate simulations and at the same time addressing key questions about the regional climate system of Southern Africa, of concern to the water and other sectors. The research questions addressed with atmospheric models focused on those aspects of the climate system for which there remains poor understanding. Central among these is the climate sensitivity to feedback mechanisms and the dynamic responses to external forcing-especially land-surface feedbacks to the atmosphere. The modelling studies showed that the land-surface may play a notably more important role than has been previously thought in governing intraseasonal variability, extreme events, and possibly the strength of the regional climate response to global climate change. During the course of these studies, characteristics of the models were tailored to optimise performance over the southern Africa domain. As a consequence of this, modelling tools are now well understood in terms of their skill and error. Building on this, the models have been stretched to understand the limits of their performance, and in one application, successfully simulated local scale weather systems down to 500m resolution, and in doing so provided valuable insight on extreme events in the Western Cape.

Cost: R1 655 000
Term: 2000-2004

Improving the basis for predicting evapotranspiration from dry-land crops and veld types in South African hydrological models
Environmentek, CSIR
No 1219

After rainfall, evaporation is the second most important variable in hydrological modelling and other water resource management methods which use water balance techniques. While rainfall has been widely recorded over most of South Africa over the past decades evaporation measurements and measurement points are still very sparsely distributed. The measurement of evaporation is a difficult process which involves the measurement of a number of other parameters and then applying these parameters in equations and theories such as the Penman-Monteith theory to give total evaporation estimates. Water resources management modelling techniques require measured physical variables to calibrate modelling processes and to improve the methods used to estimate the model variables. This study involved the measurements of physical variables in different vegetation covers and then applying the recorded variables to the improvement of evaporation simulations in locally used models. Existing records were compiled and further physical measurements were done in selected sights where measurements had not been done before. These sites consisted of a coastal bushveld, valley thickets and moist upland grasslands.

The Bowen Ratio Energy Balance technique was used to

estimate total evaporation. In this technique, the available energy flux density, the air temperature and water vapour pressure profile differences above a surface were measurement and used to generate total evaporation in millimetres. Measurements were taken in the selected sites over the period 2002 to 2003. The ACRU, SWAT and SWAP models were used to simulate evaporation in the areas where the measurements had been taken. The outputs from the models were compared with the physical measurement results and the model performance evaluated in the light of the measurements and the assessments of prevailing conditions as observed by the researchers.

The study revealed several weaknesses in the inputs and simulation procedures of three models used in this study, that is the SWAP, SWAT and ACRU models. It was concluded that the models investigated in this study were oversimplified such that they could not adequately cope with most real life catchments where vegetation exist in complicated mixes of different vegetation compositions and stages of succession. The models used average vegetation parameters which lacked in representing the normal vegetation variability in the study areas. A shift towards mechanistic modelling approaches rather than conceptual modelling to relate evaporation routines more closely to the actual physical processes was recommended. In this project the researchers identified that better results in evaporation simulations were possible if the models used more representative reference evaporation, crop growth routines that relate more accurately to the physical processes. The research provided a basis for the proposed revision of total evaporation simulations in water resources models, especially the ACRU model.

Cost: R530 600
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

Sediment flux in estuaries is in a dynamic balance between that brought in from the land and that from the sea. While the ingress of non-cohesive marine sediment is dependent on long shore transport and tides, cohesive land derived sediment is dependant on river flow. Floods are important in the removal of both cohesive and non-cohesive sediment, and the natural flood cycle is influenced by upstream impoundment and abstraction of the water. The philosophy behind Ecological Reserve is that sufficient water should remain in the system to enable the natural processes to continue.

The aims of this project were to:

- Formulate a hydraulic description of sediment transport processes through the estuary during tidal cycles as well as during floods
- Formulate a hydraulic description of flushing efficiency of estuaries with or without mechanical breaching of the mouth
- Develop guidelines to determine and manage the estuarine water Reserve to ensure a long-term equilibrium estuarine morphology

The process of marine sediment ingress is both complex and slow, and the accurate physical measurement of the process has proved impossible with instruments currently available. Indirect methods such as bathymetric surveys and water level measurements are recommended for the determination of sediment ingress. Sediment flushing occurs during floods, and the opportunity to take measurements during a flood did not occur during the course of the project. However, it was shown that mathematical modelling does predict sediment movement, and the modelling of marine sediment ingress was verified by field measurements. Predictions on flood-induced sediment movement could not be verified due to the absence of floods during the study period.

Scouring of an estuary mouth during breaching was both measured in the field and modelled. It was shown that the effectiveness of the process increases considerably with the amount of water in the estuary at the time of breaching, with the higher water levels before breaching creating a wider, deeper mouth and the mouth to remain open for

longer.

The following recommendations come out of this project:

- The role and modelling of cohesive sediment dynamics, including during floods and in tidal currents, needs to be better understood
- The effects of man-made obstructions such as causeways, bridges, marinas, weirs, to the flow in an estuary needs to be better understood and this understanding incorporated into management at the national, provincial and local level
- The interrelationship between vegetation, hydrodynamics and sediment transport needs to better understood before it can be fully incorporated into management decisions
- The interrelationship between abiotic and biotic components in an estuary need to be better understood
- Our knowledge of the relationship between off–shore freshwater and sediment requirements for prawn banks and the near-shore fishing industry, particularly related to floods, needs to be understood before it can be meaningfully managed
- We need guidelines for the management of dredging in estuaries

Cost: R950 500
Term: 2001-2004

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

The problem of sedimentation in estuaries is increasing for several reasons, amongst which the increase in the sediment load of rivers resulting from poor land husbandry combined with decreased flows entering estuaries resulting from water abstraction are important. A secondary effect of the latter reason is the increased ingress of marine sediments into estuary mouths. The overall result is that there is a declining trend in the capability of estuaries to deliver the goods and services required of them. The economic impact may be substantial, as in the case of the Kowie Estuary at Port Alfred where the estuary has become less navigable resulting in both dissatisfied civilians as well as the commercial fishermen being unable to operate effectively.

The Guide produced supplements some of the more technical WRC publications such as *Towards the Management of Marine Sedimentation in South Africa* (WRC **Report No.1109/1/03**) and *Towards the Conservation and Sustainable Use of Eastern Cape Estuaries* (WRC **TT Report No. 237/04**) and complements the handbook on *Managing Estuaries in South Africa: A Step by Step Guide* (WRC **TT Report No. 243/04**).

The handbook is written in layman's language and covers the importance of estuaries, adaptive management and why it is important, the causes and symptoms of problems in estuaries and the relation of these to human activities both in the estuary as well as in the catchment. There is a chapter on the prevention of problems which includes a summary of the legislation dealing with estuaries and a chapter on solving problems. The final chapter guides the breaching of closed estuaries, a controversial topic which, if managed badly, will lead to increasing future problems.

Cost: R160 000
Term: 2002-2003

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. The new vegetation extracted a smaller portion of the stored, infiltrated water 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 was 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 project aimed to test this hypothesis 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.

Remote sensing through aerial photography indicated that there is widespread patchiness in croplands, especially in wheat fields that dominate land use in the catchment. Ground-truthing by soil sampling and analysis of transects through the barren patches confirmed that they are associated with soil salinity which is of sufficient magnitude to explain the poor wheat growth. Use of a soil salinity sensor (EM 38) in the field proved to be a successful substitute for detailed soil sampling to quantify soil salinity and to subject its distribution to geostatistical analysis and interpretation in relation to land use and topography. Spectral manipulation of new colour ortho-photos that are available for a portion of the catchment has demonstrated that the bare patches in wheat fields can readily be demarcated, allowing their aerial extent to be quantified.

Despite the fact that a new, comprehensive database has been assembled by regional water specialists on ground water quality, the records for the drier, more saline sub-catchments of the Berg River remain sparse and are inadequate for establishing a connection between soil or regolith salinity and groundwater salinity.

Long-term salinity records of selected tributaries of the Berg River indicate that some trends are discernible, although masked by freshening releases of Theewaterskloof water into the Berg River since the early 1990s. The data seem to confirm the importance of climatic (as opposed to palaeo-geologic) factors in determining the development of dry-land salinity.

Modelling of likely runoff under different vegetation scenarios (winter wheat vs. renosterveld) using the ACRU model, suggested strongly that land-use changes potentially have a major impact on salt release from the regolith into surface waters. This supported the hypothesis that a switch from perennial deep-rooted renosterveld to annual shallow-rooted wheat would result in less water use and therefore enhanced discharge of salts into the river system, similar to what has been found to have occurred (and is still occurring) in wheat lands of Australia which have replaced Eucalyptus scrub over the last century.

This pilot study has confirmed that dry-land salinity is extensive and is likely to have a significant impact on water quality in the river. It has also provided the justification and the basis sought for planning a follow-on study aimed at fully understanding and quantifying the problem.

Cost: R449 000
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 or fine residue deposits (FRDs) 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. 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. This project aimed to 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.

Fieldwork concentrated on supplementing field data that were collected during an earlier study. The approach was to generate additional data and to discover relevant field-related variables that could be used to construct an oxygen diffusion based model for assessing acidification risk. Parameters that were determined in the field and

laboratory included sample descriptions, particle sizes, X-ray diffraction mineralogical analyses (XRD) and shake flask tests. Additional parameters, such as ABA analyses, moisture contents, particle size distributions, porosities and sulphur concentrations were obtained from the literature.

Subsurface features that were observed in studying FRD profiles included the presence of a leached zone directly below the surface, a hardpan horizon below this and an oxidation front, where iron- stained sediments contacted grey, apparently un-oxidised tailings. The leached horizon is expected to be the result of rainfall leaching of oxidised products. The hardpan horizon is a result of mobilised iron from pyrite oxidation forming secondary minerals. Evidence of variable oxygen concentrations and preferential flow paths was noted by the presence of mottling and accentuated staining respectively.

A conceptual model was developed to represent the generation of acidity from pyrite oxidisation within a typical Witwatersrand FRD. According to the model, wall sections of a tailings dam will undergo rapid acidification, as a result of horizontal influx of oxygen across the profile. The bulk of an FRD will, however, undergo oxidation through vertical ingress of oxygen by diffusion through the tailings profile. A large store of unreacted material, with associated neutralising potential (NP) occurs below the oxidation zone and potentially provides a means to delay the onset of acidic seepage from the base of the FRD for an extended period.

By making use of the PYROX model, a spreadsheet engineering type model was developed to model the likelihood of acidification from an FRD due to the AMD process. The purpose of the probabilistic spreadsheet model (tailings acidification prediction or TAP model) is to predict the likely rate of acidification of seepage at the base of an FRD. The model consists of two components, i.e. an oxygen diffusion component to predict trends in pyrite oxidation rates and a neutralisation component to predict the rate of consumption of neutralising potential in the FRD. Sensitivity analyses that were run for the model indicated that most FRDs are likely to take more than 1 000 years before acidic seepage will be generated from their bases. Modelling and field observations indicate that weathering in the top of the tailings profile in a typical Witwatersrand FRD is rapid for approximately 10 years after decommissioning and that an oxidised horizon of up to 5m deep will form during this time. Variations in physico-chemical parameters can modify these figures to form shallower or deeper profiles.

Cost: R169 000
Term: 2002-2003

THRUST 2: ENVIRONMENTAL GOVERNANCE SYSTEMS

Development of guidelines for the disposal of water treatment sludges to land

School of Applied Environmental Sciences,
University of Natal
No 1148

In order to produce potable water from turbid primary sources it is necessary to remove suspended and dissolved solids, organic matter and other contaminants. Although slight variability exists between the actual methods used in the water treatment process, the underlying principles remain the same. The ever-increasing demand for clean water has led to an increase in the number and size of water treatment facilities around the world. A consequence of this is an increase in the production of water treatment residue (WTR), which requires suitable disposal methods. In many parts of the world, including South Africa, WTR has conventionally been disposed of in landfill but due to increased costs land application is becoming the preferred disposal method.

Land disposal is based upon a 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. The aim with this project was thus to produce research data which will assist in the development of environmentally acceptable guidelines for South African conditions for the disposal of water treatment residues to land, and to study the effect of land disposal of water treatment residue on the physical, chemical and fertility properties of soils and on the chemistry of the local

groundwater and nearby surface waters. For this purpose a number of WTRs were subjected to laboratory analysis and their interaction with soils evaluated in pot and field trials.

This investigation has produced a considerable amount of data on the Midmar WTR and by extension on all similarly produced polymer WTRs. However, knowledge of the other WTRs investigated is restricted to the reported laboratory and glasshouse studies. The dangers of extrapolation from these to the field situation are indicated by the differences in phosphate and nitrate behaviour of the Midmar WTR in laboratory and field studies, problems experienced with Faure WTR in glasshouse studies due to high Mn levels and the high EC measured in the pot experiment using the Rand Water WTR. The problems with extrapolation to field situations are compounded for WTRs because they vary both spatially and temporally from the same treatment works. However, it is clear that the laboratory and glasshouse experiments exaggerate the problems and reflect worst-case conditions.

Despite this, it is also clear that all aspects of the work reported reveal a highly consistent result, i.e. that land application of WTR is safe and is likely to have no negative impacts on soils, vegetation or groundwater even at very high disposal rates that are unlikely to occur in the field. Indeed, it appears that the land application of WTR can have positive effects such as improving water retention in especially coarse-textured soils and increasing hydraulic conductivity in fine-textured soils, reducing P sorption in high P sorbing soils and increasing P sorption in sandy soils, increasing the sorption of heavy metals (thereby reducing their pollution threat) and increasing properties such as cation exchange capacity and plant-available Ca and Mg.

Notwithstanding the above, there are some aspects that require further investigation before formalised guidelines for the land disposal of WTR can be fully produced. However, the positive effects of land disposal of WTR clearly outweigh the assumed negative impacts that were the impetus behind this investigation. Thus, even without formalised guidelines, the results given in this report offer compelling evidence for DWAF to consider declassifying WTR in order that land disposal, with minimal regulatory control of the site, may be an approved option for water treatment authorities.

Cost: R650 000
Term: 2000-2003

An evaluation of dedicated land-disposal practices for sewage sludge
Institute for Soil, Climate and Water, ARC
No 1209

Most of the wastewater treatment facilities in South Africa dispose of their sewage sludge on dedicated land disposal (DLD) sites (sacrificial lands), since this is the quickest and cheapest way to get rid of the waste. The sludge is regularly applied at high rates to the surface soils. No crops are grown and the land is only used for the disposal of sewage sludge. The practice is not viewed as sustainable and its impact on the environment is believed to be negative. This project was undertaken to evaluate the extent of the current practice and its potential present and future pollution risk it poses to the water environment.

A survey was undertaken in conjunction with **Project No. 1283** to determine the current extent of sacrificial land disposal. Stockpiling is used by most of the sewage treatment facilities (40%), either as the only disposal method or a means to store the dried sludge until it is utilized by farmers and municipalities, disposed of in landfills or composted. Another 40% apply liquid sludge to soils through practices such as irrigation, flooding, sludge ponds, instant lawn irrigation and paddies; 30% of the DLD sites were on sandy soils with a high leaching potential and only 11% on soils with sufficient adsorption capacity to impede groundwater pollution. The majority of topsoil samples had above-average macronutrient and organic carbon contents, and 65% of samples had pH-water values <6.5; 88% of the topsoil samples had at least one element that exceeded the Dept of Health's maximum permissible level (MPL) for beneficial use of soils (It should be kept in mind that no MPCs exist in SA for dedicated land disposal practices). Nickel was too high in most of the samples, followed by Zn and Pb. Other elements present in high concentrations were Cd, Cr and Cu.

Of 40 representative sites selected for further detailed studies, 23 had a P-content that was above average for normal soils, none had above average N-content (but of the 9 sites monitoring groundwater, 7 had nitrate levels exceeding DWAF water quality guidelines), while 60% had an organic C-content exceeding 1.2%. Of the 40 sites, 30 had at least one heavy metal that exceeded the MPL for beneficial use of soils. The topsoil Cr-level exceeded the concentration in 50% of sites, Ni in 45%, Zn in 40%, Pb in 35%, Cu in 30%, and Co and Cd in 25% of sites. The NH_4EDTA extractable metal fraction, which provides a measure of potentially bio-availability, indicated a small medium term risk of metals entering the environment. On the other hand, the exchangeable (NH_4NO_3 extractable) Ni, Zn and Cd concentrations are reason for concern because 23-45% of the sites had concentrations above the NH_4NO_3 guidelines Germany set for groundwater protection, indicating a short term risk for groundwater pollution.

A geochemical contaminant fate-and-transport model that was used to simulate the risk of dedicated land disposal on the water environment indicated that sludge-derived humic and fulvic acids can mobilise metals down the soil column and into the groundwater and that hydrous ferric oxides, on their own, will not suffice to immobilise metals. A further finding with potentially far reaching implications is that only when the soil has an appreciable amount of particulate organic matter in it, does the metal ions remain attenuated in the upper soil layers.

Cost: R959 000
Term: 2001-2004

Development of an appropriate procedure for the closure of deep underground gold mines
Pulles, Howard & de Lange Inc.
No 1215

Large-scale cessation of mining activities at deep underground gold-mines has already occurred and is expected to continue 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 them. 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 data and to apply pollution prevention measures. The premise of this project was, 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 prove that it is hydrologically and geohydrologically isolated from surrounding mines. The project consequently aimed 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.

The project intended to undertake a detailed study on the development of a coherent and integrated closure planning process for a case study region-the Klerksdorp-Orkney-Stilfontein-Hartebeestfontein (KOSH) area. This approach was eventually abandoned due to the unwillingness of the gold-mines in that region (other than Anglogold) to participate in the project. The project methodology was subsequently modified to study the complete South African gold-mining industry and develop a closure planning methodology that would have application throughout the industry. An assessment of the current status of closure planning contained within mine EMPRs, unearthed several misconceptions regarding the pollution potential of various mining facilities and a lack of management of the groundwater regime and the effect of re-watering after mine-closure. Not enough work has been done by the mines to fully understand groundwater flow, contamination and decant potential. As a result the management options to mitigate groundwater contamination after closure are very vague or non-existent. Since closure planning is not being undertaken on an integrated regional basis, those mines that have the longest remaining working life in each region are at the highest risk of being held responsible for dealing with the cumulative regional problem. This situation is not equitable and appropriate procedures need to be developed to ensure that effective closure planning occurs timeously and on an integrated regional basis.

The project team used the principles of risk-based mine-closure planning to develop and implement a regional

mine-closure plan. A detailed risk-based closure planning process is presented, together with flow charts aimed at the development of a regional closure planning process. A set of procedures have been developed to address the various elements of regional mine-closure strategies and individual mine-closure plans. The process incorporates the principle that a conceptual mine-closure plan can be developed in the absence of a regional mine-closure strategy but that no final mine-closure plan can be developed until an approved regional mine-closure strategy is in place. Whereas the focus of a regional mine-closure strategy is to understand interactions between adjacent mines and to find a basis for agreement on how much contamination (waste load allocation) is permitted for each mine, the focus of an individual mine-closure plan is on how to manage the mine-closure process to most optimally comply with the agreed waste load allocation.

It is proposed that when a mine's remaining operational life is in the order of 5 years, the mine will need to undertake a substantial review and overhaul of its conceptual mine-closure plan and will need to significantly upgrade the level of certainty associated with the various assessments. While the process is essentially similar to that employed for the development of a conceptual mine-closure plan, the level of detail and the depth of the assessment will vary. In particular, it is proposed that detailed mine-closure plans should be probabilistic in nature, i.e. they should aim to define the uncertainty associated with the assessment.

Cost: R503 800
Term: 2001-2003

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

The aims of this project were as follows:

1. Situation/anchoring of river rehabilitation in a South African context and establishment of links with relevant current water initiatives
2. Consultatively developed plan for a long-term program for the development and implementation of river rehabilitation in SA
3. Trialling of Australian river rehabilitation procedures on a small degraded urban river in South Africa

Aims 1 and 2 are addressed in **Volume 1**, and Aim 3 is addressed in **Volume 2**.

Volume 1 begins by defining the meaning of river rehabilitation and other related terms to foster the correct general understanding amongst people in the field. This part of the project began with 6 regional workshops which were attended by a total of 150 people. At each of these workshops a number of presentations were made followed by a facilitated discussion. As each of the workshops had a different mix of practitioners, managers, decision makers, consultants and researchers, each of these discussions developed differently. These discussions highlighted a number of areas requiring research, development or application, and these are detailed in the report. In addition, the identified needs were distilled into the terms of reference for a solicited project on the topic.

Volume 2 covers a case study of the rehabilitation of the Ihlanza River, East London. The Ihlanza River runs through the suburbs of East London and discharges into the sea on the city's top surfing beach. It was highly degraded and polluted.

Through an extensive process of public participation, funds were mobilized (largely through Buffalo City Metro) to rehabilitate the river. The 12 steps of the process followed are detailed in the report in such a way that they can be followed by others wanting to achieve the same outcome, and include everything from planning and public participation to supervision, monitoring and maintenance on the ground.

Cost: R372 650
Term: 2002-2004

CURRENT

THRUST 1: ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE

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

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

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 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 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

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

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 & 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 learnt 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

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, indigenous and alien, existing in South Africa.

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

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 3000 years) in Southern Africa and Africa.

The research aims to:

- Determine whether the long-term declining trends observed in SA groundwater level data are indicative of a current and/or longer-term groundwater drought cycle(s) or whether other factors are contributing to this trend
- Collate and develop new methods if required, that can be used to correlate long-term water level fluctuations with rainfall and climatic cycles
- Document the analytical techniques available and used to analyse relevant geohydrological information to assist planners in the long-term planning of groundwater utilisation as part of integrated water resource management

Estimated cost: R233 000
Expected term: 2002-2003

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

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

Expected term: 2002-2005
Estimated cost: R450 000

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

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 fishways, will be used to develop cost-effective designs for local biota.

Estimated cost: R 2 000 100
Expected term: 2003-2007

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

THRUST 2: ENVIRONMENTAL GOVERNANCE SYSTEMS

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: 2004-2006

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 how this knowledge can be integrated into current systems to enhance sustainable management.

Estimated cost: R 300 000
Expected term: 2003-2004

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 3: INTEGRATIVE KNOWLEDGE FOR ECOSYSTEM-BASED WATER RESOURCE MANAGEMENT

Investment strategy for the crosscutting domain: Water and the Environment
CSIR Environmentek
No K8/546 (consultancy project)

The outcomes of this project provided the basis for design of the medium-term investment strategy for the crosscutting domain. The primary theme of the strategy is the need to develop water governance systems which are better matched to the ecosystems within which water is found in the hydrological cycle. In accordance with the principles of sustainable development, we need to ensure that: *"Our governance systems are aligned with our understanding of environmental processes and functioning, in order to support sustainable water resource management that meets the needs of society"*.

To support this process, research in this crosscutting domain is planned to address three key aspects:

- Understanding the ecological system, and the role of biodiversity in that system, to enable prediction of the impacts of society's actions or the likely endpoints of observed trajectories of change
- Understanding the forward and backward linkages between the ecological and governance / social systems
- Understanding the environmental governance structures and processes within society, and how to design a system for good governance, that better reflects and can respond to changes in the ecological system

Estimated cost: R200 000
Expected term: 2004

NEW

THRUST 1: ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE

Environmental water requirements in non-perennial systems
University of the Free State
No 1414

Methods for the determination of environmental flows for the reserve have been developed and used for rivers with permanent flow. However, many rivers in the semi-arid west of the country are ephemeral. The NWA requires that the Reserve be determined before licences may be issued, and currently used methods have not been verified for ephemeral rivers. Verification needs to be done and, where necessary, new methods developed.

Estimated cost: R2 000 000 (KSA 2)
Expected term: 2004-2007

Habitat use and movement of freshwater fish
Freshwater Research Unit, University of Cape Town
No 1483

This project presents a unique opportunity to investigate the movements of large fish in an un-impounded river, the Doring River in the Western Cape. This is knowledge which cannot be obtained from elsewhere in the country as there are so few un-impounded rivers remaining. The two things making this opportunity unique are that the Doring River, which is one of the last un-impounded rivers in the country, will be impounded within the next decade or so, and that we have a researcher capable of the task. DWAF have asked for information on the movements of fish in a river system for use in their planning of fish-ways, and this research will complement the existing projects researching fish-ways by providing additional information that these projects will not be able to provide.

This work has previously been funded as a consultancy, and progress has been made both in the initial aims of the project, as well as in the sourcing of funds for the radio telemetry tracking of the fish.

Estimated cost: R688 000 (KSA 2)
Expected term: 2004-2007

Conservation planning for river biodiversity
CSIR
No 1486

Conservation planning was developed for use on terrestrial systems. Using it on river biodiversity is a new application which started during the planning of the Greater Addo National Park. It worked well, but areas needing refinement were identified. Currently both DWAF and the CSIR are funding some of this refinement, and this proposal will further develop what promises to be a useful method for river prioritisation.

Estimated cost: R352 300 (KSA 2)
Expected term: 2004-2005

Integrated management of water hyacinth in SA
University of the Witwatersrand
No 1487

Water hyacinth is difficult to control and is a problem world-wide. Chemical control is expensive and ineffective in the long term. Biological control has provided a sustainable and cost-effective control in certain conditions, but the harsh South African winters are more detrimental to the control agents than the weed, allowing the weed to regenerate in spring of each year. This project will refine earlier work (WRC **Project No. K5/915**) to control this problem weed by low-dose levels of certain herbicides without unduly damaging the populations of the control agents.

Estimated cost: R1 655 600 (KSA 2)
Expected term: 2004-2007

Climate change and small town water resources
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 formers 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.

Estimated cost: R261 260 (KSA 1)
Expected term: 2004-2005

Field investigations to study the fate and transport of dense-aqueous liquids (DNAPLs) in groundwater
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. DNAPLs 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.

Estimated cost: R3 058 000 (KSA 1)
Expected term: 2004-2007

Land-use impacts on salinity in Western Cape Waters
University of Stellenbosch
No 1503

Dry-land salinity is widespread throughout semi-arid regions of the world and its occurrence in some of the major catchments of the Western Cape is therefore not surprising. Wheat lands in the Swartland and Overberg

regions are widely known to contain "brak kolle" (saline scalds) where the wheat will not germinate. Such saline soils are already recognised as a source of some of the salts affecting the quality of water in major Cape waterways such as the Berg River, where tributaries draining Malmesbury shale-derived soils are known to contribute

disproportionately to the salt load. What does not seem to have been addressed yet in the numerous studies of salinisation of major South African rivers is the possibility 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 as that which is so widespread in Australia. This is particularly likely in the semi-arid wheat lands of the Western Cape, which receive most of their rain during the winter months. The key question: is the dry-land salinity in catchments such as that of the Berg River more intense now than it was several decades ago and is it still intensifying? There is already substantial evidence of soil and groundwater salinity in the catchment but more systematic quantification is still needed.

Estimated cost: R1 995 880 (KSA 1)
Expected term: 2004-2009

Mine-water irrigation return flow
University of the Free State
No 1507

Irrigation with mine water is one of the most promising uses of excess mine water. Currently sufficient detail regarding the subsurface behaviour and long-term impact of this practice does not exist to the satisfaction of the regulators. Consequently this project will quantify the effects of irrigating with mine water on the surrounding groundwater resources.

Estimated cost: R455 650 (KSA 1)
Expected term: 2004-2007

THRUST 2: ENVIRONMENTAL GOVERNANCE SYSTEMS

Integrated development planning for estuaries
Institute for Natural Resources
No 1485

This project adds a new dimension to the Eastern Cape estuaries research and management programme which was initiated in the late 1990s. The original vision of this programme was to empower the communities living beside these estuaries to manage the resource sustainably. The work undertaken has had a big impact in the area, and has resolved some long-standing problems both between national government policy and communities as well as between communities themselves. The integration of knowledge generated so far into the Integrated Development Planning (IDP) process is a necessary step towards sustainable management of the estuaries. The IDP is required of local government, but the capacity to include environmental matters in the IDP is not available in the smaller local authorities, CMAs, new provincial environmental affairs structures, and so building the capacity here will entrench it for the future.

Estimated cost: R1 200 000 (KSA 2)
Expected term: 2004-2007

Industry-government partnerships for development and implementation of sector-based standards for the water environment
Karin Bowler Enterprises
No 1511

The aim of this project is 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 NWA 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 is 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: R400 000 (KSA 1)
Expected term: 2004-2005

Strategic review of governance systems
Pegasus Strategic Management
No 1514

This project will review and evaluate 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 (KSA 1)
Expected term: 2004-2005

International freshwater agreements
CSIR
No 1515

South Africa shares four rivers with its five neighbours-the Incomati, Orange, Limpopo and Maputo. The quantity and quality of the water in these international rivers is 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 project). 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.

Estimated cost: R370 000 (KSA 1)
Expected term: 2004-2005

Trade policies and water management
University of Pretoria
K5/1564

The primary aims of this project are:

- To develop strategic understanding of the linkages between trade policies and water policy in South Africa, and the implications of trade policies for water resources and water management
- To identify points or issues for future related research to support policy development, analysis and implementation in the water sector and linked economic sectors.

The outcomes of this research will be used to guide South Africa's position in regional and international trade negotiations, and to guide future research which supports improved quantitative understanding of linkages between trade and water policies.

Estimated cost: R500 000 (KSA 1)
Expected term: 2004-2005

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WATER AND HEALTH

Dr Gerhard Offringa
Head

Scope

This domain continues to play an essential role 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.

Objectives

The objectives of this domain remain unchanged. The primary objective 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

The thrusts which define the structure of this domain's research portfolio are the same as presented in the previous year's *Knowledge Review*. However, the content

has been refined and extended, especially in the case of Thrust 1 where a number of new programmes and sub-programmes, such as one focusing on HIV/AIDS-water linkages, have been introduced.

THRUST 1: MICROBIAL WATER QUALITY AND ASSOCIATED DISEASES

This thrust continues to focus on improving knowledge, both of the micro-organisms responsible for water-borne diseases and of the epidemiology of such diseases; assessing associated health risks, especially in communities at risk and immuno-compromised individuals; 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 (water-vectored and other water-related), with emphasis on simple, rapid and cost-effective analytical detection techniques.

THRUST 2: CHEMICAL QUALITY OF WATER AND ASSOCIATED DISEASES

The overall objective of this thrust is to characterise, and acquire information for assessing the 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 development and implementation of cost-effective treatment and control strategies. Special emphasis is given to studies on endocrine disrupting contaminants (EDCs) and toxicants, 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 continues to focus on ways of anticipating conditions conducive to the outbreak of water-linked diseases and on 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, toxicant and EDC monitoring programmes, and the development of public awareness and educational materials.

Research portfolio

The funding for research projects supported by the various KSAs and focusing on this domain, is estimated at about R8.82m.for 2004/05.

In **Thrust 1: Microbial Water Quality and Associated Diseases**, a number of new programmes and sub-programmes are being introduced. The programme: **HIV/AIDS water-related linkages and impact on water use and waste**, replaces the previous Programme 1 **(Development and application of analytical techniques for the detection of viruses)**. Subprogrammes being developed in the reformulated Programme 2 now titled **Known and emerging water-borne, water vector and water-related pathogens causing diseases**, are: **Management of environmental flows to keep incidence of aquatic vector diseases to a minimum, Water linkages to agriculture pesticide use and malaria**, and **Influence of pollutants on multiple antibiotic resistances of bacterial populations in water sources**.

An audit of South African research related to water and health during the period 1993-2003, due to be completed in 2004, will be useful in giving further direction to this thrust.

In **Thrust 2: Chemical Water Quality and Associated Diseases**, Phase 1 of the EDC (endocrine disruptor contaminant) programme has been completed. Phase 2 will start in 2004 and Phase 3 in 2006. The terms of reference (ToRs) of several of the projects in these phases will be developed in 2004. Several workshops which were held during 2003 to transfer EDC-related knowledge have enhanced co-operation between researchers and some stakeholders in the water sector. Such co-operation now needs to be extended to the industrial sector. Collaboration with the GWRC (Global Water Research Coalition) on EDC research will continue in 2004.

DWAF has an obligation to implement the National Toxin Monitoring Programme (NTMP) in 2008. The WRC will continue to participate in the NTMP's development, which started in 2003, by funding 2 of the 10 projects in Phase 2 of the development programme. One of these projects will provide support for implementation by developing a capacity building plan and assessing laboratory needs. The other will provide sampling guidelines and a model for predicting the fate of the toxins in the environment.

Two new sub-programmes will be initiated in this thrust, and appropriate ToRs developed. These subprogrammes will provide for investigations into health effects relating to the fluoridation of potable water and into bio-control methods for toxic cyanobacteria.

In **Thrust 3: Safeguarding Public Health**, the emphasis will be on developing educational material such as the new series on *Management of Microbial Diseases*, the first volume of which was published in 2003, with three others due to follow in 2004/05. ToRs for research, due to start in 2005, in support of education and awareness-building programmes address the following:

- Detrimental effects on health of pollutants in water resources
- Safe use of pesticides will be developed in 2004. Provisional attention will also be given to early warning systems concerning water-associated microbial disease outbreaks.

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 1 April 2004 and 31 March 2005.

COMPLETED

THRUST 1: MICROBIAL WATER QUALITY AND ASSOCIATED DISEASES

Programme 2: Known and emerging water-borne, water vector and water related pathogens causing diseases

A study of microbial communities and related water quality of the Mhlathuze River

Dept of Biochemistry and Microbiology,
University of Zululand

No 1282

The increasing demands on water resources and contamination from industrial waste and human activities, constant monitoring of the water quality and proper resource management are crucial to ensure public health. The aims of this project were to monitor the microbial quality and the related physical and chemical variables of the Mhlathuze River, study the microbial population and diversity in the river and therefore accumulate data on the survival and transmission of water-borne pathogens and through this assisting to create capacity and infrastructure for the implementation of the National Microbial Monitoring Programme (NMMP).

This project monitored the microbial and some physical-chemical aspects of the water in the Mhlathuze River for the period of March 2001 and November 2002. The conventional and molecular methodologies were used to study the survival and transmission of indicator micro-organisms as well as the microbial population structure and diversity of the Mhlathuze River.

The results show that most of the physical-chemical values obtained were within South African standards. The bacteriological quality of the water posed a risk of infectious disease transmission to the communities. The following environmental factors observed influenced the elevated levels of faecal and total coliform bacteria:

- Activities (domestic, recreational, agricultural, industrial) along the river
- Rainfall
- Surface water temperatures. The resuscitation results also demonstrate strongly that the faecal coliform contamination level on its own, could not present a clear picture of the water quality in this water system

The study also suggests that the Mhlathuze River has become a major reservoir for antibiotic resistant microbes and that the sustained presence of antibiotics and/or industrial effluents enhances the ability of microbes to resist the presence of antibiotics/drugs. There existed a wide pool of antibiotic resistance genes within the

environmental isolates in the Mhlathuze River.

Cost: R316 000
Term: 2001-2003

THRUST 2: CHEMICAL QUALITY OF WATER 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 1467

Agriculture has been implicated as a major source of non-point source (NPS) pollution because most of the land area is utilised for agricultural activities. It is therefore 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 to reduce NPS pollution. This project aimed to involve major players active in this field in a scoping exercise and knowledge gap analysis in order to develop the terms of reference for a longer term project that would establish an integrated model for the prediction of agricultural NPS pollution from field to catchment scales for the major agricultural NPS pollutants.

The methodology that was followed was primarily strategic in nature, with carefully selected detail investigations. Selected specialists conducted detail work according to circumscribed briefs. Strategic and scientific overview inputs were made by a small core team. One or more colleagues with complimentary skills and capacity supported the specialists where necessary. A series of scientific assessments were conducted on individual pollutants (each by a different specialist) to prepare position papers for the five key NPS water quality concerns. These individual assessments were integrated by a core team to yield the terms of reference for a long-term research programme by the WRC. Position papers were prepared for pesticides, nutrients, sediments and metals, pathogens and economic instruments. The main components of the position papers were:

- Brief overviews of the extent of each problem within a national context and statements on data and information constraints
- Description of the origins and sources of each problem in which the main sources of the specific agricultural NPS problem was identified
- Description of the transfer/transport/transformation processes and mechanisms, with an assessment of the level of understanding concerning the processes operating at various scales from microscopic level up to catchment level and an identification of the knowledge gaps
- Description of models that simulate the production, transport and fate of the pollutants, with an assessment of the predictive (modelling) ability that is available to address each of the specific agricultural NPS problems and identification of knowledge gaps
- Mitigation measures/best management practices to address the problem, with an assessment of the state of mitigation measures to address the specific agricultural NPS problem and identification of knowledge gaps

The project also compiled a first-order estimate of the contribution of agricultural activities towards NPS pollution in South Africa. The large-scale national databases of point discharges, return flows and agricultural land and water use that underlie DWAF's National Water Resources Strategy and the Internal Strategic Perspective Projects were used to partition aggregated observed water quality loadings into point and non-point components for selected constituents at selected sites in three representative river systems.

The terms of reference for the long-term research project were based on a conceptual framework formulated jointly by the project team in a workshop setting.

Cost: R 644 400
Term: 2003-2004

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

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. 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 conclusions of this study indicated 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 18ºC. 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

THRUST 3: SAFEGUARDING PUBLIC HEALTH

Programme 1: Monitoring systems

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

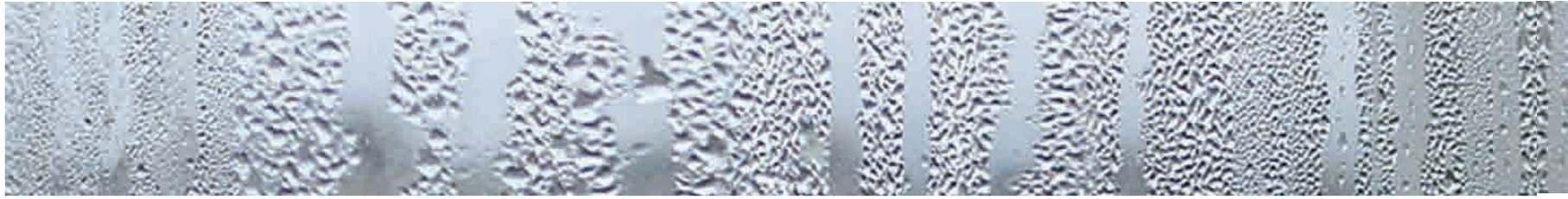
Division of Water, Environment and Forestry Technology, CSIR

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 two 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 learnt 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 of this project that was published and is used by DWAF.

Cost: R303 000
Term: 2000-2001



Programme 2: Public awareness and education material
Protocol Manual for the Transfer of Methodology Required to Link Ecosystem and Human Health
Pulles, Howard & de Lange Inc
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 under investigation as they focused on species and tissue differences in contaminant bioaccumulation as well as the spatial and temporal variation in contaminant concentrations. The health risks to humans when consuming contaminated fish are seldom addressed. Furthermore, no standard methodology as for example suggested by the US EPA was followed by the different investigations. This shortcoming limits comparison of data from different studies and prevents accurate determination of risk base fish consumption limits for humans.

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 governmental 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 if 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, the levels of contaminants occurring in the fish and

whether the fish can 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 500
Term: 2002-2003

CURRENT

THRUST 1: MICROBIAL WATER QUALITY AND RISK ASSESSMENT

Programme 2: Known and emerging water-borne, 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

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

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 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 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 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

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

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

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

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

Sub-project: Management of water- related microbial diseases series:
The development of risk communication guidelines
Environmentek, CSIR
No 1400 A

Sub-project: Development of a child-centred course for teachers to promote basic health and hygiene awareness in rural communities
Lenehan Engineering and Environmental Consulting
No 1400 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

NEW

THRUST 2: CHEMICAL WATER QUALITY AND ASSOCIATED DISEASES

Programme 1: Detection, prevention and management of EDCs in water sources
Chemical and biological assays and sentinel species for EDCs
University of Pretoria / Consortium
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 chemicals (EDCs) in mixtures. The crucial question is whether sufficiently high levels of EDC 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.

Estimated cost: R2 000 000 (KSA1)
Expected term: 2004-2007

Occurrence and fate of EDCs in drinking water
CSIR
No 1532

It is of high priority that the fate of EDCs be determined to minimize the effect thereof on humans and animals. The project aims to investigate the occurrence and fate of EDCs in raw and treated drinking water using biological/biochemical techniques and chemical tests. Recommendations will be made on the most effective water treatment technologies for the removal of EDCs and the most appropriate combination of tests for the detection of EDCs in drinking water.

Estimated cost: R830 000 (KSA3)
Expected term: 2004-2006

An investigation into the occurrence of endocrine disrupting chemicals; organochlorine pesticides and heavy metals (Cd, Zn, Ca and Pb) in surface waters of the Northern Province
University of Venda
No 1557

Organochlorine pesticides (OCPs) and heavy metals have been implicated in endocrine disrupting activities. In studies done in the Northern Province DDT was detected in the streams and rivers, thus pointing to pesticide pollution of water sources. It is important to widen the scope of the studies done to get a clearer picture of the pollution profile of the source waters that could be detrimental to human, animal and ecosystem health.

Estimated cost: R60 000
Expected term: 2004-05

Programme 4: Eutrophication and associated toxic algal blooms: Detection and management of algal toxins in water sources

PCR-based marker for identification of toxic cyanobacteria strains
University of Pretoria
No 1502

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 and 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. This 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.

Estimated cost: R668 500 (KSA 1)
Expected term: 2004-2007

Methods manual for monitoring phytoplankton and cyanobacteria
Rand Water
No 1533

There is no uniformity in the manner in which water suppliers approach the monitoring of phytoplankton and algal blooms, with the result that incompatibility of data makes it difficult to draw conclusions regarding the extent of the problem. The aims of the proposed project are to:

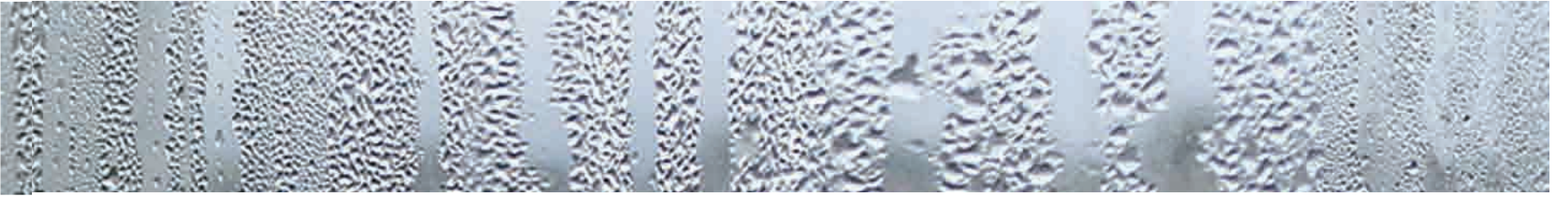
- Synthesise current methods used for phytoplankton identification and enumeration, cyanobacterial toxin analysis and geosmin and MIB analysis nationally and internationally
- Compile a comprehensive methods manual for the analysis of phytoplankton, cyanobacterial toxins and geosmin and MIB for South African freshwaters
- Compile a summarised reference document

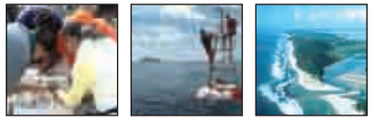
Estimated cost: R403 600 (KSA 3)
Expected term: 2004-2006

Development of a strategic research programme for toxic algal blooms
Targeted consultancy
No K8/576/7

There are various possible products on the market that could potentially be used to control toxic algae blooms. The aims of this consultancy will be to conduct a literature study on existing and possibly available methods and develop a ToR of a research programme, for using these methods in SA conditions to evaluate their performance under field conditions; and determine the economic viability and commercialisation of the product(s).

Estimated cost: R200 000 (XD-HEALTH)
Expected term: 2004-2005





THRUST 3: SAFEGUARDING PUBLIC HEALTH

Programme 1: Monitoring systems

Application of the CHEMPROP Model for South African conditions to predict the environmental fate of toxic organic chemicals in the aquatic environment (as a contribution to the National Toxicant Monitoring Programme (NTMP)

Rand Water

No 1475

The software CHEMPROP was developed in Germany and facilitates the prediction of physiochemical properties and associated environmental fate of organic compounds, as well as the baseline toxicity to aquatic organisms and is based on the structural composition of compounds. It was designed as a research tool for developers and experts. It will be tailored as a specific prediction tool for the local conditions that could be used to govern the selection and optimization of subsequent analytical procedures.

The aims of this project are to:

- Develop and evaluate a specific fate prediction tool that is tailored for the local geographical conditions in South Africa
- Train students in the application of CHEMPROP and ensure that this technology is transferred to South Africa
- Use CHEMPROP to assist in determining sampling strategies and frequencies for the NTMP

Estimated cost: R254 820 (KSA 1)
Expected term: 2004-2006

Refinement of protocols for the *National Microbial Monitoring Programme for Groundwater*

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 (KSA 1)
Expected term: 2004-2006

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