2005/06

Knowledge Review

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.

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INTRODUCTION

Dr R Kfir
Chief Executive Officer
Water Research Commission

The WRC continues to face many challenges and the strategic objectives set through the organisational key performance areas are providing the organisation with a strategic framework to face these challenges successfully. All the challenges are directly tied to the Mandate and core business of the WRC as stated in its mission. The challenges include the creation of appropriate new water-centred knowledge, its dissemination and application, building knowledge networks and building the knowledge base by building capacity. During the past few years the WRC has strengthened its national, regional and global profile by building strong water-centred knowledge links. The WRC has both initiated and undertaken key roles in a number of national, African and global initiatives and many staff members have served and are serving in key leadership positions.

Internally, the ongoing challenge is to build a highly effective organisation and therefore the WRC is unceasingly engaged in developing appropriate competencies and skills and implementing a number of key strategic initiatives and measures that will allow it to assess its effectiveness, and to continue striving towards 'business excellence'. Such challenges require an ongoing review of processes and systems that support the undertaking of the WRC and its staff and aim at improving its financial, human resource and fund management systems. A number of drives and initiatives were set against this challenge and are reflected in the set objectives, indicators and measures for the current financial year. These include issues relating to financial processes and performance, business processes and human resource issues. The WRC is striving to meet all set targets, reflecting on its ability to conduct its financial affairs and manage its financial resources in an excellent manner.

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 next financial year. The WRC invested R88.3m. in research funding during 2005/06 and plans to invest approximately R112m. in research funding during the next financial year (2006/07) (including commitment to ongoing projects and VAT). The distribution of research project funds amongst the various types of providers is in general similar to that of the previous year where higher education institutions (universities) are the major recipients. Building capacity in researchers continues to be an important function of research and in many areas of research supported by the WRC it is evident that students that participated in earlier WRC projects are currently leading WRC-funded research projects and serve as members of steering committees as well as reviewers of new proposals. During the current year (2005/06) the WRC has further improved its support to students, with special emphasis on historically disadvantaged students. Currently about 581 students are supported by WRC projects, of whom about 69% are from historically disadvantaged backgrounds. This is a significant increase from last year (about 116 more students). This increase is mainly due to an increase in the numbers of disadvantaged students that grew by 126 students (400 in comparison to 274). This clearly indicates that the WRC's strategy to improve capacity building through its research projects is bearing fruit. Another important capacity-building initiative is the Water Information Network (WIN-SA), an initiative led and coordinated by the WRC (on behalf of the water sector). WIN-SA is a partnership initiative among all bodies concerned with capacity building for local government and information required for instituting water services.

INTRODUCTION (CONTINUED)

Organisation	Number of disadvantaged students	Total number of students
ARC	3	6
Arcus Gibb (Pty) Ltd	4	4
African Water Institute (AWI)	1	1
BKS (Pty) Ltd	1	1
C Swartz Engineering	10	10
Cape Peninsula University of Technology	4	4
Coaltech 2002	4	5
Conningarth Economists	1	
Council for Geoscience	2	3
CPH Water	2	5
CSIR	27	32
Digby Wells and Associates	2	4
Durban Institute of Technology	2	2
Emanti Management (Pty) Ltd	2	3
ERWAT	3	3
Free State Technikon	1	1
Golder Associates Africa (Pty) Ltd	4	6
Human Sciences Research Council	1	1
Mvula Trust	2	2
Nelson Mandela Metropolitan University	4	7
Nemai Consulting	3	3
Partners in Development	2	2
PICWAT	2	2
Proxa (Pty) Ltd	1	2
Pulles, Howard & de Lange	12	18
Rand Water	12	19
Rhodes University	29	41
Rural Integrated Engineering (Pty) Ltd	10	10
SA Institute for Aquatic Biodiversity	2	7
SASRI	2	2
Sigma Beta	1	4
Source Strategic Focus (Pty) Ltd	2	2
SRK (South Africa) (Pty) Ltd	1	1
Sustainable Environmental Technologies	1	1
TBR Project	1	1
Tshwane University of Technology	14	14
Umgeni Water	12	14
University of Cape Town	15	33
University of Fort Hare	17	17
University of the Free State	5	17
University of Johannesburg	6	7
University of KwaZulu-Natal	32	51
University of Pretoria	46	65
University of Stellenbosch	26	50
University of the North-West	3	6
University of the Western Cape	28	38
University of the Witwatersrand	10	26
University of Venda	13	14
University of Zululand	6	7
WRP Consulting Engineers	2	2
Zakhe Training College	3	3
Zitholele Consulting (Pty) Ltd	1	1
	400	581

Another ongoing challenge is the appropriate state-of-the-art dissemination and application of WRC-created knowledge. During 2005/06 the WRC continued to improve on the uptake process of knowledge created via its research activities and maintained its initiatives with regard to public understanding of water science with regular publications such as *Amanzi,* the *Knowledge Review* and *The Water Wheel* which are regarded as highly successful publications. Other successful knowledge dissemination initiatives included Open Days as well as WRC representation at water-related conferences and symposia. In an effort to share knowledge effectively with national policy and decision makers, a series of highly successful briefing notes was created. A recent survey addressing knowledge dissemination indicated a generally high level of satisfaction among stakeholders concerning the relevance and effectiveness of most of the WRC's knowledge dissemination activities, which suggests that the WRC is fulfilling its role as a national hub for water-centred knowledge.

The application of various technologies, processes and/or products developed with the support of the WRC forms another challenge. It requires an understanding of the issues of intellectual property and commercialisation. Although in recent years the understanding of these issues among research providers has been greatly improved, there is a need to actively manage and promote potential applications. By translating needs into research ideas and in turn transferring research results, new technology-based products and processes to the end-users, the WRC is continuing in its drive to provide the country with applied knowledge and water-related innovation. In addition, the WRC is supporting water-related **innovation** and its **commercialisation** where applicable. Often, these technologies, processes and products require commercial involvement in order to make them available for use. The WRC has a widely accepted Intellectual Property (IP) Policy and a Benefit-Sharing Policy which clarifies its contractual requirements for future research projects and improves the level of understanding/knowledge regarding the protection of IP within the water research community. The WRC continues to play an active part in the activities of the South African Research and Innovation Association (SARIMA), and engages with other institutions, such as the Innovation Fund and the Department of Science and Technology on the developments in the IP rights arena. About 88% of the WRC's patent portfolio is licensed out. A number of licensing agreements have been reviewed and some are being re-negotiated with new contracts. In addition, new patents have been through the process of being registered. The licensed WRC patent portfolio includes the Secondary Metabolites, a cluster of 13 patents, currently licensed to Synexa and the product is already being marketed, with the first payment of royalties due shortly. The overall patent portfolio includes the Petro® Process which was licensed to Presario, but since the licence has expired, the WRC has been exploring alternative commercialisation strategies and partners. The Petro® Process is a cluster of 8 patents. Capillary Ultra Filtration (CUF) Technology comprises a cluster of 5 patents and products which are still at various development and piloting stages. This cluster of patents is licensed to FiltRSA and an extension of the licence agreement is currently under negotiation. BioSURE® is a cluster of 36 patents. The products arising from this cluster are under final development and piloting and 27 of the patents are licensed to ERWAT. Possible involvement of the Innovation Fund/IDC in funding commercialisation is being investigated. Acid Mine Drainage (ferrite process) is currently licensed to the Environmental Technologies Agency and the product is still under development. Detection of Fouling of Membranes is a patent registered only in South Africa and the product is still under development. It is licensed to IFU, a German company.

THE WRC RESEARCH PORTFOLIO AND KEY STRATEGIC AREAS (KSAs)

INVESTING IN THE CREATION AND SHARING OF KNOWLEDGE

The research portfolio of the WRC for 2005/06 was developed based on a needs analysis including medium- to short-term as well as explicit and implicit needs. South Africa's water problems/issues are reflected in this portfolio with the aim to scientifically build the required solution and, where possible, the capacity for its use. The process of setting the research portfolio was a result of many interactions at various levels with both the local and the global water sectors. The portfolio was also informed by the latest scientific developments which can be applied to water research so as to provide beneficial solutions.

The WRC continued to invest in the creation of knowledge via its four main key strategic areas (KSAs). These areas include **Water Resource Management, Water-Linked Ecosystems, Water Use**

INTRODUCTION (CONTINUED)

and Waste Management, and Water Utilisation in Agriculture. In general, the portfolio as planned for the year under review was well received by the various stakeholders. The KSA-based structure, with its four water-centred KSAs (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.

During 2005/06 the WRC invested approximately R88.3m. in research funding (including commitment to ongoing projects). This figure includes about R14.7m. of roll-over. In the initial plan, in addition to funds allocated for the KSAs, about R1.6m. were allocated to a central fund. The R500 000 of project funds assigned to the central fund were allocated to WIN. Crosscutting domains were allocated R1.5m. for research activities but not for direct funding of projects as all project funding is catered for by the KSAs. Crosscutting domains fund research projects via the key strategic areas (KSAs). Short-term projects (consultancies) make up to 6% of the research funding. The balance (about 4%) will be used to support direct capacity-building drives (in addition to the support of capacity building which is included in all research projects) and other research sponsorships. The distribution of research project funds to the various types of providers is in general similar to that of the previous year where higher education institutions (universities) are the major recipients. The strategic re-allocation of research project funds between the KSAs for 2005/06 resulted in **Water Resource Management** receiving 32% of the funds, **Water-Linked Ecosystems** 14%, **Water Use and Waste Management** 30% and **Water Utilisation in Agriculture** 24%. The allocation of research funding to water resources (including water-linked ecosystems) was about 48% and for water utilisation (effluent treatment and management, including agriculture) it was 52%. This reflects strategic investment in water sanitation and hygiene and investment in support of local government and emerging farmers. The allocation also indicates an increase in funds for the KSA **Water-Linked Ecosystems.**

During 2005/06, the WRC supported 336 research projects, of which about 73% (245 projects) were active projects (ongoing and new) and about 27% (91 projects) were finalised. The active projects comprised 175 ongoing projects and 70 newly initiated projects that commenced during 2005/06. The various mechanisms of funding included 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 74 solicited projects, which translates to about 30% of active projects. While 44 solicited projects were ongoing, 30 newly solicited projects commenced during the year under review.

In comparison with the previous year, the year under review shows a 26% decrease in the number of projects, i.e. 336 projects in 2005/06 vs. 454 in 2004/05. The number of active projects was reduced by about 30% (from 356 in the previous year to 245 projects during the year under review). This trend of reducing the total number of projects is the result of a drive to improve management of research projects, by emphasising the prompt finalisation of projects, culminating in the high number of projects finalised in the past three years (311 projects). While there is a clear trend of reduction in the total number of projects, the WRC also aims to maintain or even increase the number of new projects as a percentage of the total number of projects. During the year under review new projects formed almost 29% of all active projects and 21% of the total number of projects. This represents a 5% and a 3% increase respectively for similar ratios obtained during the previous year (2004/05). The finalisation of 311 projects and the initiation of 206 new projects during the past three years also illustrate the strong commitment and the emphasis placed on improved management of research projects and the need for the renewal of the research portfolio. The WRC, taking into consideration feedback from its stakeholders and the needs of the water sector, placed emphasis on multidisciplinary projects. Such projects often call for an increased level of investment per project. This means that although the overall number of projects has been reduced, the investment per research project has been increased. The reduction in project numbers is also a result of an increased number of solicited projects. Solicited projects are often large multi-year, multi-provider (consortia-based) projects, frequently with annual budgets in excess of R1m. per annum. During the year under review the WRC supported 74 solicited projects with 40% being newly initiated projects. By using the mechanism of solicited research, the WRC has effectively managed the renewal and relevance of its research portfolio and provided leadership with regard to the creation of new water-centred knowledge. During 2005/06 the WRC almost

doubled the number of solicited projects (from 41 to 74) from the previous year and tripled the number of solicited projects from 2003/04 (from 24 to 74 projects). From 6% of active projects in 2003/04 to about 12% of active projects in 2004/05, the percentage of solicited projects was significantly increased to 30% of active projects in 2005/06.

UTILISATION OF FUNDS BY THE VARIOUS KSAs

The percentage utilisation of research project funds (based on amounts actually paid out) by the KSAs during 2005/06 indicates that about 46% in comparison to about 54.5% (2004/05) was invested in projects that focused on water resources (including water-linked ecosystems) and about 54% compared to 46% (2004/05) in projects that focused on water utilisation (including effluent treatment and management, as well as agriculture). This is based on the actual amount paid out to projects during the current financial year. The allocation of about 50% of the fund to issues related to resource management and 50% to water utilisation is ongoing.

Based on cash paid out, the overall investment in research projects (knowledge creation) was about R63.9m.This amount (paid out for research projects) is 19% higher than that paid out in the previous financial year (R53.7m. during 2004/05). This significant increase is due to the application of effective and rigorous fund management procedures and the improved usage of the deliverables system which has been applied to research projects in recent years.

Investment in the total support of knowledge creation, sharing and dissemination amounted to R80m. (including about R3m. for WIN-SA). 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 almost (1% difference) identical to that of the previous year. The increase in the ratio for research support (from 72% in 2004/05 to 77% in 2005/06) is mainly due to investment in WIN-SA.

KEY STRATEGIC AREAS (KSAs)

During 2005/06 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. The KSAs continued to provide South Africa with leadership and strategic links with the African continent and globally. The KSAs have applied the various funding mechanisms to allow an appropriate balance between solicited and non-solicited research. The balance between solicited and non-solicited research varied for each KSA as a whole or for various research thrusts within each KSA research portfolio. By using solicited research the KSAs directed research into areas of need and either built new capacity and competence or redirected available research capacity into new emerging areas of research. The 2005/06 financial year marks the 4th year of the KSAs operating as the strategic building blocks of the WRC. During the past year the KSAs interacted with both the research providers and the wider sectors and fine-tuned their research portfolio accordingly on a continuous basis.

WATER RESOURCE MANAGEMENT

Scope

No major changes were introduced to the strategic focus of the scope of the research covered by this KSA during the year under review. The focus 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, and guidelines and decision-support systems to support decision-makers in achieving equitable and efficient allocation of water resources among competing needs. The research has placed 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 continued to shift from supporting policy-making to providing guidance for policy implementation and development of policy instruments. The challenge for research in this KSA during the past year was 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 has been extensively addressed through research within this KSA.

During 2005/06 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R20.5m. was invested (paid out) in 105 projects. Of these, 18 projects were initiated while 58 were ongoing. Of the active ongoing and new projects (76 projects) about 43% (33 projects) were solicited projects. During the year 29 projects were finalised and 22 reports published.

WATER-LINKED ECOSYSTEMS

Scope

Research undertaken within this KSA during 2005/06 continued to address the conservation of aquatic ecosystems in order to provide the knowledge for their sustainable functioning in terms of the national commitment to international conventions and the ongoing provision of goods and services which ecosystems deliver. In addition, the National Water Resource Strategy (NWRS) focuses on resource protection as one of its components. The research undertaken in this KSA provides knowledge for protection of the resource, and is therefore central to this aspect of the NWRS. No major changes in strategic direction were envisaged and the research portfolio was found to be sound and applicable. Deviations in programme focus or structure are highlighted below.

Water-linked ecosystems are defined as in-stream (fully aquatic), riparian (dependent on water stored in the river banks and linked to the river) and water table-dependent (dependent on a water table, but not on surface water). This KSA focused on the protection and sustainable utilisation of the aquatic environment and biota (in-stream, riparian and groundwater). This included 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 was 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 were developed within this KSA to support the implementation of the national water policy to ensure sustainable resource use.

During 2005/06 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R8.9m. was invested (paid out) in 37 projects. Of these, 8 projects were initiated while 18 were ongoing. Of the active ongoing and new projects (26 projects) about 11% (3 projects) were solicited projects. During the year 11 projects were finalised and 19 reports published.

WATER USE AND WASTE MANAGEMENT

Scope

The KSA continued to focus mainly on the domestic, industrial and mining water sectors during 2005/06. The aim was 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 the negative effect on human and environmental health.

No major changes were introduced to the general scope of the KSA during the year under review. The primary and secondary objectives of the KSA remained the same. However, the KSA portfolio has undergone some change to accommodate emerging needs and technological trends. A new programme on water services regulation was introduced into the thrust addressing **Water Services: Institutional and Management Issues**. In addition, two new programmes that

address technical sustainability of sanitation services and issues related to financial sustainability were added to the thrust: **Sanitation, Health and Hygiene Education.** The focus was on generating in-depth knowledge of the problem and testing new approaches.

During 2005/06 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R18.8m. was invested (paid out) in 156 projects. Of these, 36 projects were initiated while 79 were ongoing. Of the active ongoing and new projects (115 projects) about 19% (22 projects) were solicited projects. During the year 41 projects were finalised and 37 reports published.

WATER UTILISATION IN AGRICULTURE

Scope

The strategic focus is 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 inter-related sub-sectors of agriculture, namely:

- Irrigated agriculture
- Dry-land agriculture
- Woodlands and forestry
- Grasslands and livestock watering
- Aquaculture

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

During 2005/06 the research portfolio included new initiatives and current projects addressing the scope described above. Overall, about R15.6m. was invested (paid out) in 38 projects. Of these, 8 projects were initiated while 20 were ongoing. Of the active ongoing and new projects (28 projects) about 57% (16 projects) were solicited projects. During the year 10 projects were finalised and 8 reports published.

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 cooperative 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.

INTRODUCTION (CONTINUED)

WATER AND THE ECONOMY

Scope

The scope of research addressed by this domain has remained unchanged from the previous year. In the SA context water is first and foremost treated as a common (social) good. Water is recognised as being essential for sustaining life and is a commodity to which people and the aquatic environment have a legally protected right. However, water is also recognised as an economic good, the use of which has a major impact on the creation of wealth and the well-being of people. Almost without exception, there is an increasing interest in assessing the economic value of water, using water as a catalyst for the generation of wealth and prosperity, and using economic instruments to increase efficiency and effect desired behavioural change among water users. The use of water tariffs to effect changes in water consumption and the use of waste discharge charges to internalise pollution costs and, in so doing, effect pollution reduction and desirable improvements in water quality, are 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.

LEVERAGING INCOME FOR THE CREATION, SHARING AND DISSEMINATION OF WATER-CENTRED KNOWLEDGE

During recent years the WRC has placed emphasis on leveraging levy income by striving to obtain funds for support of water research from sources other than the levy. This drive has been highly successful. The WRC income originating from sources other than the levy has increased by an amount of about R5.7m. from about R4.3m. in 2004/05 to R10m. during 2005/06, reflecting an increase of roughly 132% over the previous year. The budget was set higher in expectation of increased leverage income and this has been met. Income from interest received amounted to R3.5m. Leveraged income included funds allocated to a number of KSAs for direct support to research projects and funds provided for knowledge sharing and dissemination (e.g. the Water Information Network (WIN-SA)). Leveraged income was obtained from both local and international sources, where the main source of income was due to support by various government departments for specific research and other knowledge-sharing projects.

KSA 1

WATER RESOURCE MANAGEMENT

Ms Eiman Karar
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 continues to shift 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 33332005/06 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 consists of a number of strategic thrusts, programmes and projects which directly address the above-mentioned objectives and are summarised as follows (please note that no changes have been introduced since previous the year's plan regarding the scope and objectives of this KSA's thrusts and programmes):

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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

RESEARCH PORTFOLIO FOR 2005/06

The knowledge base generated in this KSA will help South Africa to 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 continue to 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. The current emphasis of the research portfolio continues 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 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.

During the past three years, the KSA has consolidated a number of strategic initiatives in the water resource management research portfolio related to supporting the implementation of the NWRS. In 2005/2006, the opportunity will be given to research community to respond to the water resource management challenges through the non-solicited proposal stream of funding. Further consultation with stakeholders will take place at local and regional level. This will be an important task to identify future research needs and priorities.

BUDGET FOR 2005/06

The approved funding of the research portfolio for 2005/06 leads to a committed funding budget of R 26 578 151. The focus of this portfolio will continue along current trends.

NEEDS ANALYSIS

The KSA aims to be pro-active and responsive to the water resource management needs in South Africa. Therefore, the KSA needs a strong relationship with its stakeholders and needs to adopt several approaches to improve its understanding of the water sector's needs and aspirations. Through this process a number of outcomes are envisaged which include:

- Establish research needs
- Identify diverse perspectives on research issues
- Get or buy-in/ownership of the research portfolio
- Establish legitimacy of the research portfolio
- Achieve balance in the research portfolio
- Identify critical issues
- Profile stakeholders
- Achieve active engagement
- Establish partnerships
- Establish support base for water research.

The methodologies followed in the needs analysis process are varied and include:

- Stakeholder workshops
- Policy documents e.g. National Water Resource Strategy
- Focal group and individual interviews
- Interpretation and reinterpretation of research outcomes
- International/regional forums
- Strategic studies.

During 2005 a series (6 in total) of workshops was held with a number of stakeholders in various provinces. These workshops were a follow-up to national workshops held by KSA 1 and KSA 2. The national workshops contributed to the development of strategic focus issues, research needs and priorities for future research as well as methods of operation. The next stage in the process involved a further participation process to derive input from a wider range of stakeholders to refine the outcomes of the initial workshops and to incorporate local ideas, suggestions, needs and requirements. The participants were drawn from spheres of government, water boards, research institutions and universities. The themes for discussion included: building end-user awareness and capacity, technology transfer to implementers and research needs/issues. Most of the recommendations have implications wider than the WRC. Some of the pertinent issues related to the development of research portfolio are:

- End-user awareness and capacity
  - A deeper understanding of water issues needs to be developed in end-users rather than only a notional understanding
  - Awareness building needs to support the implementation processes
  - Knowledge is required about local

issues, areas and systems
  - The WRC needs to coordinate and engage with partners to promote training in the water sector (including capacity building projects between government departments).

- Technology transfer to implementers
  - The research portfolio need to incorporate tools for transferring and sharing knowledge i.e. training programmes, models and decision support systems, special events, case studies, pilot applications, media etc.
  - Research projects need to define the end at the beginning and involve end-users in the research process.

- Research needs/issues
  - The implications of mine closure to the water environment (groundwater strategy for regional closure, disposal of brine from groundwater desalination plants, apportionment of liabilities with respect to impacts of ground- and surface waters, decanting and abandoned mines)
  - Developing an understanding of ground- and surface interactions
  - Developing equitable mechanisms for allocation of water resources
  - Developing management strategies for development of river and estuarine margins, wetlands, lakes, impoundments, groundwater and catchment areas
  - Developing water information and monitoring systems
  - Groundwater development in primary and dolomitic aquifers
  - Protection of water quality (eutrophication, radioactivity etc.)
  - Understanding of impacts of recreational use on water resources
  - Issues addressing water resource use for recreation purposes
  - Addressing sedimentation issues (brought down by rivers, marine ingress, etc.)
  - Strategic water resource planning (alternative sources, trans-boundary issues etc.).

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

This KSA will support the implementation of the NWRS in the following broad ways:

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

While providing research support to implement the NWA is crucial to the KSA's business, this KSA needs to support water resource management actions at global, regional and local level. In addition to challenges, identified at the 2nd World Water Forum, four further global challenges have been identified for the future:

- **Water and cities:** Acknowledging that urban areas are increasingly the focus of human settlements and economic activities, and that they present distinctive challenges to water managers
- **Water and industry:** Focusing on industry needs and the responsibility to respect water quality and taking account of the needs of competing sectors
- **Water and energy:** Recognising that water is vital for all forms of energy production, and that there is a need to ensure that energy requirements are met in a sustainable manner
- **Ensuring the knowledge base:** Reflecting that good water policies and management depend upon the quality available to decision-makers.

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

The outcomes of the above process were incorporated into the KSA's strategic processes and will assist in identifying future research projects and programmes (including priority-setting). The KSA aims to continue to be pro-active and responsive to the water resource management needs in South Africa.

Overview of technological trends related to needs

Research on water resource management, especially water resource assessment studies, has been characterised by the general trend towards improving the levels of detail and accuracy in water resource observations and modelling techniques. A number of projects have been initiated to address knowledge gaps in water resource processes and how these can be simulated in areas that are deficient in data and information. The knowledge gained through research on hydro-pedology, process hydrology and other water resource processes has made improvements in understanding surface water/groundwater and water quality interactions possible in a number of local environments. Water resource modelling processes and concepts are set to be gained through further improvements which will be based on knowledge documented in recent research projects on water resource processes.

Limited availability and poor quality in data on land surface variables is still a major challenge in water resource management. The installation of additional field gauges such as the recently commissioned rainfall gauges on some mountain tops especially in the coastal regions, the increased access to radar and satellite data sources through better cooperation with international space agencies and institutions that collect satellite data have continued to supplement the much needed resources in water resource management research. The WRC has supported new installations of water resource data recording tools. Most of these installations are targeted at addressing data requirements in specific projects, with provisions to accommodate other projects that will require the same tools in the future. Important recent acquisitions of data observation tools have included surface layer scintillometers (SLS), with a number of researchers benefiting from the use of large aperture scintillometers (LAS) for agrometeorological and hydrological studies.

The WRC and CSIR have collaborated in the acquisition and use of eddy covariance systems for water use monitoring in commercial forests, alien plant forest and various types of natural forests. With increased field instrumentation, especially the use of more demanding equipment that can measure several hydro-climatic and soils variables at very short intervals of a few seconds, our project teams continue to face a number of challenges in their research work. These challenges include the increased data observation costs, shortage of adequately competent human resources to analyse and use observed data, remoteness of most measurement areas, higher security requirements at measurement sites, lack of continuous power supply, difficulty in collecting large volumes of continuous records at short intervals and worst of all, vandalism as well as theft in some areas. The WRC has been involved in addressing most of these challenges on field-based case studies. Of interest to local technological trends, was the establishment of continuous and reliable flow of observed records. The GPRS Direct to Web technology which utilises the GSM cell-phone network to deliver data directly from field sites to a web server was used. Measurements are now consistent and timeously recorded and saved at regular time intervals. This GSM- and internet-based technology has made it possible to use a range of measurement intervals which stretch from a few seconds to several hours or days. This technology, when coupled to high performance data analysis software, the super-fast PCs with processors of several GHz will allow recording analysis and interpretation of large volumes of data that could never be imagined using manual techniques. Security breaches and equipment malfunction are also reported to technicians at their remote locations using the same GPRS Direct to Web technology.

The South African climate is characterised by highly variable rainfall regimes with increasingly higher incidences of drought and flood conditions. In the dry seasons and drought periods many of the rivers are usually meandering low flow or dry channels, while floods bring fast flowing and highly scouring conditions in the river channel and surrounding catchment areas. The design of sediment extraction works is usually dependent on imported guidelines and technology which frequently results in the construction of poorly performing structures. In a recent WRC project researchers have identified the shortcomings of imported sediment abstraction technology and developed hydraulic guidelines for the layout, design and maintenance of river diversion structures in South Africa. The documents which were published from this research are expected to provide further guidance to local design, construction and maintenance of sediment extraction works.

The steady improvement in remote sensing technologies that has taken place in the recent past and is expected to continue into the future is creating opportunities for better water resource assessment and management. Although research has already contributed to realisation of some of these opportunities, great potential exists for further exploitation of these technological trends for the benefit of the water sector.

Examples of value already added by previous WRC research in this connection include the following:

- The use of radar, in conjunction with airborne sensors, to gain an adequate understanding of rainfall processes in clouds and develop the ability to augment rainfall through appropriate in-cloud intervention
- The use of radar and satellite data in conjunction with ground-based observations in an integrated real-time system for measuring and mapping rainfall over South Africa
- The use of integrated rainfall measuring systems in conjunction with real-time river-flow modelling to generate GIS-based flood forecasts.

Improved satellite observation capabilities are constantly opening fresh avenues of investigation into hydro-climatological processes (e.g. heat storage and evaporation) over both land and ocean surfaces. Such investigations are the key to better understanding of climate variability and therefore climate prediction and ongoing water resource assessment. Prospects of continuous monitoring of soil moisture content from space have also been enhanced. Results, used in conjunction with appropriate numerical models, will further enhance accuracy of streamflow and flash flood forecasting.

CORE STRATEGY

STRATEGIC CONTEXT

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

The mean annual runoff is estimated at 50 000 x 10^6 m^3/a which 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
- Supporting policy development, implementation processes and evaluation of policy impacts

STRATEGIC INITIATIVES UNDERTAKEN DURING 2005/06

NATIONAL INITIATIVES

Members of the KSA served on the executive committees of the following learned societies:

- Geological Society of South Africa (Vice-President: Transformation, Education and Conservation)
- Groundwater Division (Secretary)
- South African National Committee for the International Association of Hydrological Sciences (Committee Member).

The WRC through this KSA is partnering (DWAF, WRC, WISA and CSIR partnership) the organisation of a series of water sector colloquia with the purpose of the (a) Identification of new issues, (b) Understanding of emerging trends, (c) Breakdown of organisational & technical barriers, and (d) Fostering of crucial alliances for the sustainable development. To date two colloquia have been held with the following topics:

- Adapt or die: Implementing adaptive approaches to Water Management
- Debunking the capacity myth: Finding, mobilising and growing the capacity for water resource management.

The KSA is also involved in a number of national working groups/project steering committees:

- A working Group focusing on the protection of Karst terrains with emphasis on the Cradle of Humankind World Heritage Site (Kevin Pietersen)
- FETWATER (Kevin Pietersen)
- National Advisory Committee for Water Resource Modelling (Renias Dube)
- Project Steering Committee for the DWAF/DANCED Integrated Water Resource Management (IWRM) Project (Renias Dube)
- Integrated Water Resource Planning Systems User Forum (Renias Dube)
- Working for Water Hydrology Review Panel (Chairman: Renias Dube).

During 2005, a member of **KSA 1** was appointed as a member of the Technical Committee of the Council for Geoscience.

Discussion forums were held with a number of local stakeholders to introduce the KSA research portfolio and strategic intent. This includes a presentation at the University of Venda on the strategic intent of the WRC, in particular KSA 1 research portfolio.

In order to assess public appreciation of KSA functioning, the KSA has participated in the WRC Knowledge Dissemination Survey. The purpose was to request feedback from stakeholders in terms of how well the knowledge dissemination service of the WRC is being rendered and how this service can be improved for the benefit of stakeholders. In general, the response was very positive, with relatively few respondents indicating any levels of disagreement. The respondents' responses peak strongly at a score of between 4, and 5 which is indicative of strong agreement with positive statements about the WRC.

Research conducted by this KSA has been mentioned in the media (including radio interviews):

- Water prize, Pretoria News, Staff Reporter, 17 June, 2005
- SA 'rainmakers' win top award, Sunday Times, 26 June 2005
- Artificial groundwater recharge, IMIESA Vol. 30 (No 7) July 2005
- Groundwater comes of age, Engineering News, 22 July 2005
- PM Live radio interview (AM Live inserts for the water debate).

AFRICAN INITIATIVES

The KSA played a leading role in the preparation of the Freshwater Chapter of the African Environment Outlook 2 (AEO-2). The AEO-2 process and report is used as a tool for monitoring sustainable environmental management in Africa (including monitoring the implementation in New Partnership for Africa's Development (NEPAD).

The KSA is the Coordinator for a UNEP Project on 'Vulnerability of Africa's Water Resources to Environ-mental Change'. The WRC's role is (a) project co-ordination, administration and liaison with project management and other sub-regional teams, and(b) rapid assessments of the following basins: River basins (2): Okavango and Limpopo; Groundwater basins (3): Karoo, basement and coastal areas; Islands: Western Indian Ocean Islands.

During 2005/06 the WRC through KSA 1 continued its involvement in the Water Research Fund of Southern Africa (WARFSA). This involved attendance of Board Meetings and review of research proposals for possible funding.

The WRC participated in the Water Initiative under the auspices of the NEPAD Science & Technology Forum. The purpose is to develop Networks of Water Centres of Excellence in Africa. The WRC is a member of the Water Task Force and has a leading role in the initiative.

The WRC is involved in a WaterNet-led Challenge Programme (Project PN 17) in

the Limpopo Basin: **The Challenge of Integrated Water Resource Management For Improved Rural Livelihoods: Managing Risk, Mitigating Drought and Improving Water Productivity in the Water Scarce Limpopo Basin.**

The WRC prepared an inception proposal on Surface Water Assessment to JICA for the SADC Water Division. This proposal was not supported.

- Meetings/Workshops attended:
  - Attended: NEPAD Workshop on Developing a Network of Centres of Excellence for Water Sciences and Technology. Nairobi, Kenya. 9-12 May 2005. Role: Participant
  - Attended: NEPAD Task Team meeting on Centres of Excellence in Water Sciences and Technologies. Pretoria, South Africa. 27-29th July 2005. Role NEPAD Water Task Force Member
  - Attended: AEO 2 Authors and Editors Meeting. Johannesburg, South Africa 15-23 August 2005. Role: Lead Author for the Freshwater Section
  - Attended: WaterNet Challenge Programme, Executive Committee Meeting. Pretoria, South Africa 9 September 2005. Role: Consortium Member
  - Attended: The 2nd African Ministerial Conference on Science and Technology. Dakar, Senegal 27-30 September 2005. Role: Water Task Force member
  - Attended: WARFSA Board Meeting and WARFSA/WaterNET/GWP symposium. Manzini, Swaziland 29 October - 4 November 2005. Role: WARFSA Board Member
  - Attended: International Workshop on Groundwater Protection In Africa. Cape Town, South Africa 28-30 November 2005. Role: Participant.

INTERNATIONAL INITIATIVES

The WRC together with the University of Witten (Germany) is exploring possible research collaboration on integrated water resource management in the Middle Olifants sub-basin. A workshop was held between German and South African researchers during March 2005 on possible collaboration and to develop a research proposal to the German Federal Ministry of Education and Research. This was followed by a meeting with a delegation of the above Ministry during September 2005. The German Government Delegation was led by Dr U Wahl (Head of Division for Cooperation with Western European Countries, the Mediterranean Region and Africa).

The KSA was involved in the revitalisation of the International Hydrological Programme (IHP) National Committee. The IHP is a programme under the auspices of UNESCO to address water resource management issues. As a result a South African bid for a symposium 2007 was prepared with the title 'Hydrology for the Environment, Life and Policy (HELP) in Action: Local Solutions to Global Water Problems Lessons for the South'.

The KSA is playing a leading role in the preparation of the Freshwater Chapter of the Global Environment Outlook 4 (GEO-4). The GEO process is a tool for the implementation of UNEP's mandate to mobilise scientific expertise to keep the global environment under review. GEO-4 aims to provide an up-to-date, comprehensive, reliable, scientifically credible, policy-relevant and legitimate global assessment and outlook of the interaction between environment and the society. Two expert meetings in Kenya and Switzerland were attended during 2005. The final report will be considered by an inter-governmental and multi-stakeholder consultation in September 2007, before being presented to UNEP's Governing Council/Global Ministerial Environment Forum in early 2008.

During 2005, the WRC supported the preparation of an OECD workshop on Science and Technology Cooperation in Water and Energy. The WRC prepared the background issues paper for water and facilitated participation of international experts. The workshop, held during November 2005, addressed issues related to (OECD 2005):

- Effective science and technology capacity building in the developing countries
- Facilitating knowledge and technology transfer through partnerships with business
- Developing knowledge infrastructure and networks of science and innovation for sustainable development
- Technologies that best meet the needs of the developing countries in the areas of water and efficient use of energy while meeting sustainable development objectives.
- Indicators and criteria of best practices in international science and technology co-operation for sustainable development.

The KSA also played a supporting role in the Safe Water Initiative. This initiative is a collaborative effort between South Africa and France.

GROWING THE KNOWLEDGE BASE

CAPACITY-BUILDING INITIATIVES

In addition to post-graduate students benefiting through WRC research, capacity-building initiatives have been focused also at community level. Notable examples are Project **No 1316: *Community based research on the influence of rehabilitation techniques on the hydrology of degraded catchments*** and **No 1496: *Methods for the cooperative evolution of a catchment management plan, involving stakeholders, government agencies and specialists.***

In total 29 project leaders are female and 12 project leaders are Black. This figure represents approximately 25% and 10%, respectively of total projects.

The table (right) illustrates the number of post-graduate students who benefited from WRC-funded research in this KSA and highlights the institutions which are actively involved in capacity building.

Contractor	Students from disadvantaged backgrounds	Total
Conningarth Economist	1	1
CPH Water	2	3
CSIR	3	5
North-West University	0	3
Rhodes University	1	7
Source Strategic Focus	2	2
SRK	1	1
University of Cape Town	4	9
University of Free State	2	5
University of KwaZulu-Natal	8	17
University of the Western Cape	11	15
University of Pretoria	16	27
University of Venda	4	4
University of Stellenbosch	4	7
University of the Witwatersrand	3	6
University of Zululand	6	7
University of Johannesburg	1	2
Tshwane University of Technology	1	1
Total	**70**	**122**

KNOWLEDGE SHARING AND LEADERSHIP

The KSA participated in a number of initiatives contributing to the water-centred knowledge base in South Africa. These initiatives included participation at open days and arrangement of technology transfer workshops (including participation). During the course of 2005, staff participated in both the WRC Open Days held at the Universities of KwaZulu-Natal and Pretoria. The following workshops were held in support of research outcomes related to:

- Water laws
- Public policy in the water sector
- Water quality modelling (x2)
- Water licensing (esp. integrated water use licences)
- Endocrine disruptor compounds (EDC)
- Climate change (x2)
- Groundwater remediation
- Groundwater protection

This KSA has put great effort into and has successfully disseminated WRC-related knowledge. Knowledge dissemination has also taken place through the publication of the following scientific articles, conference papers, training courses, workshops, software, guidelines and technical reports.

- 32 technical reports were published
- Popular articles (*The Water Wheel*)
  - Groundwater pollution - When Water Turns Deadly - Investigating Nitrate in SA Groundwater
  - Meteorology – Project Provides New Tools for Weather Man's Box
  - Climate Change – Climate Change: The Last Straw for Communities at Risk
  - Catchment Management – Water the Tie that Binds Eastern Cape Community
  - Bio-fuel – Investigations on Track into Impacts of Bio-Diesel Tree
  - Hydropolitics – SA's Rich Water History Unearthed
  - Water Kidz – Groundwater –More Valuable than Gold
  - Upfront – Three Year Water Resources Study Underway
  - Land management - Projects Restoring Land and Water

KEY STAKEHOLDERS

The major stakeholders remain the same and 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 all the key stakeholders.

OTHER 'PLAYERS'

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

PROVIDERS

As in previous years, most of the research supported by this KSA is conducted by universities. Science councils and consulting firms are responsible for most of the balance of the research portfolio. There is limited participation by DWAF and the water boards.

IMPLEMENTATION PLAN

RESEARCH PORTFOLIO FOR 2005/06

The research portfolio has been supported by a needs analysis process to ensure that water resources of South Africa are protected, utilised, developed, conserved and managed to achieve environmental, social and economic sustainability.

The 2005/06 research portfolio addresses this primary objective as reflected by the following aims to:

- mprove 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 for 2005/06 is presented in **Table 1**, which provides an overview and description of research thrusts and programmes.

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

TABLE 1

Overview and description of thrusts and programmes for KSA 1 for 2005

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 hydro-climatic variability	**Scope:** The ultimate goal of this programme is to better forecast 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.

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 cannot be used. This research will seek to develop solutions to maintain high quality flows in river systems that comply with the Water Act of 1998. These low flows and SFR studies will provide clear directions to the licensing of SFRA and the maintenance of high quality flows in rivers. These studies will focus on developing methods or/and equipment for defining and estimating streamflow reduction due to activities such as agriculture, forestry and industry that can be used by the licensing agents. The research will support the current initiatives in the compulsory licensing of streamflow reduction activities. Methods developed should clearly stand out as the preferred solutions in South Africa through how they are proposed, developed and implemented.
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,

THRUST 3 : MANAGEMENT OF NATURAL AND HUMAN-INDUCED IMPACTS ON WATER RESOURCES	
Programme 1: (continued) Predicting the impact of global climate change	ecosystem structure and functions and ecological processes. 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 which point will anthropogenic climate change in the Southern Africa context become detectable and distinguishable from natural climate variability and which 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, hydro-climatic information effectively, to provide information regarding likely inter-related land-use, ecosystem, hydrological (including geohydrological), 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: • 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 by which these pollutants could flow into the environment and the ultimate fate of these pollutants • 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 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 to 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.

EXPECTED OUTCOMES

The knowledge base generated in this KSA will continue to assist South Africa to 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 the national water policy and also provide leadership for the sector at regional and global levels.

RESEARCH PROJECTS FOR 2005/06

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 2005 and 31 March 2006.

COMPLETED

THRUST 1: WATER RESOURCE ASSESSMENT

Programme 1: Groundwater occurrence in fractured rock aquifers

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

Groundwater-resource developments in hard-rock fractured aquifers are generally associated with conductive fractured zones characterised by high transmissivity. Identifying relatively highly productive borehole locations in these fractured-rock environments is an extremely difficult exercise as numerous dry wells are a demonstration of unsuccessful target selection.
A new procedure has been tested to evaluate the potential relationship between known groundwater abstraction locations in fractured-rock environments and geomechanically-modelled sites of high dilatancy. Stress mapping technology (SMT) is a computer-based method, relying on rock mechanic principles and stress-strain relationships, which seeks to transform strain data, in the form of a solid geology map, to stress data.

A modelling technique in which dilatancy (fracture permeability) in the crust is due to variations in mean stress allows for the wide variety of structural settings of fractured-rock localities, as these variations are a consequence of regional deviatoric stress acting on an inhomogeneous rock sequence, and a wide variety of potential sites of mean stress, dependent on variations in rock competency, and patterns of faults, fractures or shear zones. Thus a technique that measures variations in mean rock stress, such as SMT, has potential to generate viable dilatant sites, which could be exploration targets for fractured-rock aquifers.

In areas where the SMT method is applicable, a main advantage over previous lineament-analysis procedures is that once the tectonic history of a given area is determined, it is possible to predict which structural features, or combinations thereof, would likely be targeted for groundwater development. In this way, the siting of new boreholes can more effectively be facilitated, even in areas where no previous borehole information exists. The approach can be applied to other areas where a reasonable understanding of the most recent history of brittle tectonics exists. Through SMT and lineament analysis, therefore, the hydrogeologist can correlate the lineament directions with the various kinds of brittle structures known to be related to extension stresses.

The congruence of stress anomalies and known groundwater abstraction locations, as well as fracture density and fracture frequency in the study area demonstrates the usefulness of the technique as an additional data layer in groundwater exploration.

Cost: R582 000
Term: 2000 -2002

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

This project follows on from previous investigations of deep groundwater potential in the Oudtshoorn area by the Municipality, DWAF and the CSIR in the greater Oudtshoorn area. The purpose of the DAGEOS study itself is to establish the feasibility of augmenting the water supply to the town of Oudtshoorn situated in the Gouritz Water Management Area (WMA) in the Western Cape, South Africa and/or to contribute to a conjunctive surface- and groundwater augmentation scheme. The DAGEOS Project is divided into six phases some of which are overlapping in time: PHASE A - Inception Review and Data Scoping; PHASE B - Regional Hydrogeological Survey; PHASE C - Financial and Business Planning; PHASE D - Target Generation and Borehole/Well-field siting; PHASE E - Exploration Drilling and Resource Assessment; and o PHASE F - Well-field Establishment and Licensing.

The Water Research Commission (WRC) funded project is Phase D of the overall DAGEOS study and focuses mainly on the target generation and borehole / well-field siting. This was done through

digital GIS compilations of topographic, geological and hydroclimatological data. The date sets from the diverse sources were interactively compared and overlaid. As a result 16 potential exploration target sites were generated by remote-sensing analysis and reconnaissance fieldwork. These sites were prioritized and detailed structural and borehole-siting studies at the priority site C1 in the Witkliprug area were complemented by exploration drilling, in order to obtain firm data on aquifer/aquitard thicknesses and aquifer structural properties at depths immediately beneath the target site. This initial exploratory drilling was undertaken by DWAF, with a view to maintaining the exploration boreholes as permanent monitoring sites for both the deep confined aquifers and the shallow stream-related groundwaters. Further intensive remote-sensing analysis and aerial photo interpretation identified a number of hydromechanically significant features to support target generation.

A public participation and information/education programme elicited stakeholder concerns from established agricultural interests in the D3 (Waboomskraal) and D6 (Herold) areas, and Western Cape Nature Conservation Board concerns about the broader ecological-environmental impacts of future groundwater abstraction for municipal bulk supply purposes. Addressing these concerns required an environmental scoping study for the exploration drilling within Target Site Area C1, which proceeded under a formal Record of Decision (issued 04/07/2003) from the provincial regulatory authority.

Cost: R600 000
Term: 2001 - 2003

Programme 3: Understanding and predicting hydroclimatic variability

Regional model development for simulating atmospheric behaviour and rainfall over Southern Africa
Department of Earth Sciences, University of Pretoria
No 1261

Apart from predicting the day-to-day weather, modern numerical models of the atmospheric circulation are used for many purposes, such as climate variability research and development of seasonal forecasting tools and scenarios of climate change linked to enhanced greenhouse gas concentrations. The main objectives of this project were to improve the simulation of water-related variables over South Africa by applying a sophisticated regional-scale atmospheric model and, simultaneously, to equip SA and African scientists with knowledge and skills to develop, maintain and use atmospheric models. The research was conducted in collaboration with model developers at the CSIRO in Australia. Many model runs, interspersed with frequent exchanges of results and progressive improvement of model code, eventually resulted in greatly reduced model biases and much improved simulation of atmospheric circulation and rainfall over South Africa. In the quest for improvement in the model dynamics, a unique non-hydrostatic kernel was developed by the local research team in South Africa. This development was used as guideline for making C-CAM non-hydrostatic at the CSIRO. It also established a sustainable basis for model development in South Africa, both institutional and human related. The achievements of this project, including the building of sustainable bilateral research collaboration, improvements in model dynamics, successful verification of simulations using the improved version of C-CAM and knowledge transfer workshops involving atmospheric scientists from SA, the CSIRO and other African countries, all translate into the region having a greatly enhanced capacity and confidence in its ability with regard to atmospheric modelling. As an additional spinoff and a further capacity-building exercise, the C-CAM model is temporarily being used under license by the project team to produce numerical weather predictions that complement those generated by the SAWS.

Cost: R678 000
Term: 2001 - 2004

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

Numerical weather prediction (NWP) models are very good at simulating atmospheric flow (circulation) fields. Unfortunately the rainfall fields generated by these models are nowhere near as good as these circulation fields, and this had led to a lack of confidence in heavy-rainfall prognoses generated by NWP models. Yet it is important to accurately and timeously predict the geographical extent of widespread and heavy

rainfall, as the accompanying flooding can cause loss of life and severe damage to infrastructure.
The main aim of this project was to develop systems to predict heavy rainfall in an operational weather forecasting environment. Steps taken to achieve this aim included the following:

- Development of methods to isolate heavy rainfall developing in continental tropical and extra-tropical as well as in coastal zone baroclinic weather situations
- Inclusion of topographic effects in the operational coastal zone heavy rainfall forecast system
- Steps towards the modification of NWP rainfall prognoses by incorporating satellite-derived rainfall data
- On-site training of SAWS staff in the use of the operational heavy rainfall forecasting systems.

An additional aim of the project was to develop a statistical validation system for the rainfall fields produced by the heavy-rainfall identification systems.

As a result of the research, two systems which can delineate areas of expected heavy rainfall with a considerable degree of accuracy now exist. The components of these systems are based on well-proven meteorological dynamics but depend also on the accuracy of the prognostic data fields generated by the NWP (Eta) model as used by the SAWS. The first system is the Tropical Heavy Rainfall Identification System (THERIS) and the second, the Coastal Zone Heavy Rainfall Identification System. Variations of the latter were developed for three coastal areas of South Africa: the South West Coast, the South Coast and the East Coast. A thorough investigation into the prognostic fields of the Eta model revealed that the atmospheric flow fields are simulated very well over the South West Coast but the model does not fare as well over the South and East Coasts. However, by identifying appropriate variables in the Eta model prognoses, and incorporating an additional variable (referred to as the topographical upward motion) not directly available from the Eta model output, heavy rainfall identification systems (season and area-dependent) were successfully developed for all three coastal areas. In addition, the research revealed that in order to identify heavy rainfall along the coast, forecasters should be encouraged to investigate variables at the lower 1 000-800hPa pressure levels in the atmosphere and also to be conscious of critical values of vertical motion associated with heavy rainfall. Heavy rainfall forecast systems were verified for the period between September 1999 and March 2002.

Heavy rainfall identification systems are, as a result of this project, available on the SAWS website for use in both central and regional forecasting offices in South Africa. Installation of systems was done in consultation with the weather forecasters, which ensured their active participation in the project. The systems developed are powerful, and provide tools not previously available to the meteorologist. Further research is needed to better exploit the potential benefits of incorporating satellite data and to optimise both the output of the available NWP models and the heavy rainfall prediction systems for specific target areas such as areas of special importance for water resource/disaster management.

Cost: R578 000
Term: 2002 - 2005

Programme 5: Water quality assessment studies and information systems

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 most common source of contamination of surface waters is still human and animal wastes and introduction of water-borne pathogens by these sources are of particular concern. High levels of microbial pollution in source water can lead to breakthrough in the treatment process. The Water Act in 1998, and the publication of the **World Health Organization's** *Drinking-Water Quality Guidelines* in 2004, have placed emphasis on the protection and management of water quality within catchments. A catchment management approach towards microbial pollution will only be successful if it is based on a clear understanding of the origin, fate, survival and transport of pathogens that have been introduced into the water body.

The scope of this project was to investigate the possible sources, survival and clinical relevance of selected water-borne pathogens in a rural and peri-urban area, and to investigate the environmental factors and social determinants that contribute to the transmission of such diseases. The information provided by this study could form the basis for the development of appropriate catchment management and intervention strategies to reduce the health risk to various water users. The project aimed to create a better understanding of the fate and / or clinical relevance of

selected parasites (*Cryptosporidium*) and bacteria (*Salmonella and Vibrio cholerae*) in freshwater environments.

Based on the study it seems unlikely that cryptosporidiosis is commonly transferred from animals to humans in the South African context. The high percentage of the human genotype (80%) observed in the cases investigated suggests the importance of person-to-person contact and human sewage contamination of drinking water, recreational water and food sources, as a means of spreading the parasite. This finding was supported by the prevalence data for *Cryptosporidium* oocyst in calves. The prevalence was found to be lower than what have been reported for other countries. *Cryptosporidium* infection is most prevalent amongst young calves between 1-2 weeks of age. Good management and hygiene practices are however, still required to prevent the spread of *Cryptosporidium* to other animals and the aquatic environment.

The results of the present study have revealed that *Salmonella* was prevalent in environmental and clinical samples examined. *Salmonella* isolates were also isolated from raw vegetables (cabbages, tomatoes and onions) obtained from local rural gardens, which used river water for irrigation. Strains isolated from human stools, water, sediments and food were phenotypically and genetically correlated which provide evidence for the epidemiological link between environmental reservoirs and human infection in an endemic area. This confirms that water and food could be important sources of human salmonellosis in rural areas. *Salmonella typhimurium* is the most commonly isolated serotype from clinical cases in the Venda area and a GFP labelled strain was therefore used to investigate the survival and behaviour of *Salmonella* in freshwater sediments. The study indicated that *Salmonella* survived for extended periods of more than 6 months in sediments at temperatures typically associated with freshwater streams and rivers in South Africa. This is of concern as they could easily be released from the sediment into the water phase at high concentrations during rain events or other disturbances of the sediment.

The *ompW* based PCR identification was found to be ideal for surveillance work and was more reliable than the biochemical identification approach. The identity of *Vibrio cholerae* strains isolated from the Vaal Barage catchment area were confirmed with this PCR technique and thereafter a selection of these strains were typed with AFLP. With the AFLP typing a high level of genetic diversity was seen. It is therefore believed that the *Vibrio cholerae* population in the Vaal Barrage system is not a product of one or two strains that have adapted to local conditions, nor that it consist of diverse clones that only occupy specific niches in the aquatic system. The population in the Vaal Barrage is rather made up of highly diverse clones that constantly compete, resulting in genetic shifts only perceivable within short time frames and localized regions. Using environmental *Vibrio cholerae* as a model, it is suggested that enterotoxigenic strains may exhibit the same degree of persistence and survival in inland aquatic systems, being able to survive for extended periods and posing as potential future health risk.

For the KwaZulu-Natal outbreak, no statistical correlations could be established between the %CIR and the climatic variables of rainfall, temperatures (minimum, maximum and average) and humidity. There may have been correlations within specific months when cholera was at peak but not when the entire dataset was statistically considered. A number of socio-economic factors could be correlated with high CIR percentages in the DCs. They included traditional households, no sanitation or the use of bucket system, the use of river water for household purposes and the lack of refuse removal. This again stresses how the lack of basic services exposes communities to the risk of infectious disease and increases their overall vulnerability.

Cost: R635 000
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 water quality situation in the Umtata River has always been giving cause for concern (DWAF, 1998). The results of a pollution study on Umtata River done between May 1999 and March 2002 (WRC, 2003) indicated high levels of cadmium in the river, which ranged from 0.01 mg/l to 0.08 mg/l for representative data.

The high levels of cadmium in the river have given rise to worries that water supplied from the river will be unfit for domestic use and may also impact on the 'health' of the

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

community that live on the river banks that depend on it primarily for their domestic water supply. Recommendations were then made aimed at preventing or reducing cadmium pollution in the Umtata River one of which was an intervention programme to manage the pollution of the river and a workshop was conducted for all stakeholders in the catchment (DWAF staff, DEAT staff, staff of the local industries in the catchment, municipal staff, councillors and local communities) on actions to take to reduce pollution of the river. The workshop was well attended and the need to implement the recommendations in that report (WRC 2003) was impressed on them.

The major aim of the project was to re-investigate the levels of cadmium in the river catchment. A subsidiary aim of the project was to carry out a risk assessment study of the possible health effect of cadmium in the river on the community who are primary users of water from the river for their domestic supply.

Calibration standards were prepared for cadmium and zinc (zinc has a synergistic interaction with cadmium. The detection limits for cadmium and zinc were determined using the lowest concentrations of each of the elements that gave the least detectable signal by the flame AAS. Quality assurance studies were performed with distilled water samples fortified at levels of 0.005 mg/ℓ for Cd and 10 mg/ℓ for Zn using comparative open beaker digestion technique and extractive concentration method with amino pyrolidine dithiocarbamate (APDC) as complexing agent and methyl isobutyl ketone (MIBK) as the extracting solvent, respectively. Samples for chemical analyses were collected according to standard procedures described in the sampling guide (DWAF, 1992, 1999) and analysed by the open beaker digestion method (DWAF, 1992) as it gave better recoveries and better repeatability than the extractive concentration method (van Loon, 1982). Temperature (determined on site) and pH (with un-acidified water samples) were determined using the Merck (Pty Ltd) 330 pH meter. Risk assessment study was done using the standard USEPA (USEPA, 1989) method to access the potential health risks to community making use of the river water as their primary domestic water source.

The mean (SD) values of Cd in the river water samples ranged from 0.002 (0.001) mg/ℓ to 0.007 (0.002) mg/ℓ. The levels of Zn varied between trace and 0.196 (0.10) mg/ℓ. The levels of cadmium detected in the Umtata River in this study were much lower than the levels detected in previous study between May 1999 and April 2000 (WRC, 2003) and the levels generally fell within the SA guideline of 0.005 mg/ℓ (WRC, 1998). The results for Zn levels in the river also fell within the SA guideline for Zn in water for domestic supply, which is 3 mg/ℓ (WRC, 1998).

The hazard quotients calculated from the data presented in this study varied between 0.35 and 1.22 for adult exposure and between 0.2 and 0.8 for child exposure. The hazard quotients using representative data calculated from the previous study (WRC, 2003) ranged from 1.8 to 14.0 for adult exposure and from 1.2 to 9.3 for child exposure (hazard quotients that exceed 1.0 indicate the possibility of non-cancer toxic risks from exposure). Cadmium concentrations in the Umtata River has substantially reduced compared to the results of the previous study and the levels now fall within the normal safe range expected in river water for domestic uses (WRC, 1998). At these levels of cadmium and zinc in the river the effect of the any synergistic interaction of zinc with cadmium would be negligible.

While for samples taken during May 1999 to March 2000 (WRC, 2003) the risk assessment study showed exceptionally high hazard quotients which indicate that if people were using the water for domestic purposes, adverse health effects would occur, the results of the new study with samples taken between October 2002 and December 2003, indicates that generally the hazard quotients are acceptable. The greater part of the anticipated adverse health effects arise as a result of ingestion of fish or shellfish (approximately 60% of the calculated dose is a result of assuming exposure via ingestion of fish/shell fish). However, if one were to assume that no fish or shellfish were consumed, the anticipated health risks would be significantly reduced. This effect would be most significant for the exposure calculations during the 2nd sampling run between October 2002 and December 2003.

The remedial actions taken following the 1999 to 2000 sampling appear to have been successful in reducing the cadmium levels in the Umtata River water and have therefore resulted in reducing the potential health effects.

Estimated cost: R250 000
Expected term: 2002 - 2003

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

WQ2000 was initially developed as part of Project *No 950 entitled: 'WQ2000: Development of an interactive surface water quality information and evaluation system for South Africa'*. WQ2000 is a monthly time step interactive system that was successfully developed for the Vaal River catchment. It provides a means of rapidly assessing how new developments or changes to present management would change salinity at a quaternary catchment level. Salinity is an important consideration in the planning and development of water resources. Many smaller schemes have to be implemented rapidly, while time and funding constraints often result in scant attention being paid to water quality implications. WQ2000 can facilitate integration of salinity from 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 ability to change default values to reflect planned developments, represents a particularly powerful analysis tool. A wide range of options can be rapidly tested, including changes in effluent flow and quality, introduction of new dams or modification of existing dam capacity and full storage area, changes to the area of opportunistic irrigation and that supplied from farm or major dams, water importation and abstraction.

The aims of the current project were to transfer the WQ2000 technology to potential users, to test and enhance the system and to establish a working and sustainable User Support System (USS). A number of enhancements were identified at the outset, while others were identified and implemented during the course of the study. This led to the establishment of an enhanced WQ2000 system.

Awareness of the value of the system was raised by presenting a series of demonstrations of the system. This was followed with a technology transfer initiative that involved presenting a number of training courses based on the enhanced WQ2000 system. Technology transfer was also built into the project itself. This included mentoring of members of the project team to ensure that knowledge of the system does not reside only with the developer.

Continuity of the modelling system was achieved by incorporating it into DWAF's USS that was first developed for WSAM. This USS provides a centralised source for software and manual updates, user queries, error rectification, ongoing training and a registry of competence. This should lead to further growth in the core of trained practitioners, thereby increasing the degree to which salinity assessment becomes integrated into future studies. This would be further enhanced by extension of the dataset to cover other regions.

The enhanced WQ2000 system provides a means for rapid assessment of the salinity impact of a wide range of developments, including urbanisation, dam construction and irrigation, changes in effluent discharge, water importation and abstraction.

Costs: R328 000
Term: 2004 - 2005

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

At the beginning of 2003 the South African Weather Service (SAWS) website began to offer a set of detailed daily maps of the previous day's rainfall over the whole of RSA and some neighbouring territories. This product was the outcome of the SIMAR (Spatial Interpolation and Mapping of Rainfall) research programme. The regular publication of the maps allowed designers/researchers involved in SIMAR the opportunity of receiving feedback from users with a view to improvement of the product. This follow-on project (Daily Mapping of Rainfall over South Africa: Modelling) and its companion project (Daily Mapping of Rainfall over South Africa: Infrastructure and Capacity Building) together address the various infra-structural, capacity-building and computational issues needed to ensure that the daily rainfall mapping programme of the SAWS is so improved that it meets user needs for high-resolution rainfall data in the best possible way.

In this modelling study, the following six areas of improvement of SIMAR were earmarked for research and all were successfully addressed.

- Effective methods were developed to repair parts of radar rainfall images contaminated by reflectivity values which are not precipitation (e.g. ground clutter, anomalous propagation etc.)

- Precipitation estimates made aloft by radar were successfully extrapolated to ground level and confirmation obtained that the estimates are valid. One of the factors contributing to non-triviality of the extrapolation procedure is the occurrence of bright-band effects due to melting ice at certain levels in stratiform cloud systems. If not successfully addressed, bright band effects lead to gross errors in rainfall estimation.
- A methodology was developed to use instantaneous images of moving rain fields, captured periodically by radar or satellites, to compute meaningful accumulations of rainfall over periods from 5 minutes to 24 hours and longer.
- A new conditional merging algorithm was adopted as the optimal way of combining accumulated radar or satellite rain fields with rain gauge data.
- The methodology developed in SIMAR for rainfall estimation using METEOSAT-7 data was converted to make it appropriate for use with the higher precision data being obtained from MSG (METEOSAT 8).
- The optimal method for forecasting rain fields into the near future (up to 2 hours ahead) was selected from three candidates, which included three candidates, one being a newly developed method using 2-dimensional empirical mode decomposition in combination with adaptive time series forecasting.

The techniques relating to these areas of improvement have been combined in a new improved rainfall merging algorithm for producing optimally estimated rain fields called IRMA.

Cost: R423 800
Term: 2003-2006

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

The efficient operation of large dams is particularly important for the attainment of water use efficiency, in that dams increase the yield of catchments by retaining water during period of water abundance for use during periods of shortage. The main objective of this research project was to assess options with which efficiencies related to the use of water could be improved, and to share with the stakeholders and water resource managers involved in the compulsory licensing process any relevant findings from this research.

The Mhlathuze Catchment was chosen as the research project area, as it is one of the first catchments in the country in which the compulsory licensing process has been initiated, as the catchment is currently deemed to be over-allocated. Furthermore, the catchment is heavily dependent on water stored in a large dam located in the upper reaches of the catchment. The purpose of an audit is to ensure that actual water use by water users at a given point in time (or time range) was compliant with the entitlement to that use for that point of time (or time range). The rationale for auditing water use was to ensure that water was not being over-used, which could improve the efficiency of water use with catchments.

The current adopted water apportionment system is for the purposes of this document referred to as the priority-based river and reservoir operating rule (PRROR) system. As the name suggests, the system discerns between priorities given to different types of authorised water use, while reservoir and river operating rules govern the water restrictions faced by the water users under different conditions of water availability. A review of literature revealed that an alternative water apportionment system exists, referred to as a Fractional Water Allocation and Capacity Sharing System (FWA-CS System) which adopts a 'use-it-or-bank-it' principle with respect to water in dams. Both the PRROR and FWA-CS systems are examples of Institutional Arrangements (IAs). IAs are defined as being 'the rules of the game', and for the purposes of this research project relate to the rules with which water is to be apportioned amongst competing water users, particularly during times of water scarcity.

Given the potential water use efficiency that could be induced by adopting the FWA-CS IA, and the fact that the Water Resources Yield Model (WRYM) and Water Resources Planning Model (WRPM) were unable to support the IA, the Mike Basin water resources planning software, developed by the Danish Hydrological Institute, was used for this project. The Mike Basin software can support both the FWA-CS as well as the PRROR IAs, and the software has been applied extensively around the world. Given

the importance of the planning process in the Compulsory Licensing process, the research team tailored software to integrate with the Mike-Basin model through what is referred to as the COM interface, in order to address this short-coming. The tailored developments included the:

- Coding of an instream flow requirement (IFR) module
- Coding of a yield analysis module, both of which successfully integrate with the Mike Basin Model

The conclusions drawn from this research are that 2004 NWRS and 1998 NWA do not prohibit the adoption of an IA such as FWA-CS. The FWA-CS IA is however a new potential management option, and one which can not be supported by the WRYM and WRPM in their current form. The Mike Basin model was further developed in order to accommodate the FWA-CS in a manner suitable for water resources planning purposes. Without this development the FWA-CS IA would be of little value to stakeholders in the Mhlathuze, as water resources planning is a key component of the compulsory licensing process.

It may be the case that due to the newness of the FWA-CS IA, and also due to the pressure to complete the compulsory licensing process, particularly in stressed catchments in South Africa, that the FWA-CS IA is not initially adopted. However, as monitoring systems are improved, the CMAs become operational and established it is believed that the FWA-CS IA will become increasingly more attractive to implement.

Cost: R902 000
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

The South African climate is characterised by highly variable rainfall regimes with increasingly higher incidences of drought and flood conditions. In the dry seasons and drought periods many of the rivers are usually meandering low flow channels, while floods bring fast flowing and highly scouring conditions in the river channel. Sediment extraction works are frequently poorly designed if their design is dependent solely on foreign guidance. Most of the imported guidelines are based on very different river channels and river morphology as well as less variable flow regimes.

In this study the researchers were set to develop hydraulic guidelines for the layout, design and maintenance of river diversion structures in South Africa.

Laboratory channels were used to investigate sediment deposition and control in different channel sections. These laboratory experiments were also used to provide better understanding of the following:

- Location of maximum velocity in bends
- Sediment deposition in wider South African channels
- Suitable simulation parameters for the 2-D and 3-D hydrodynamic models
- The effect of diversions on bend flow patterns

A number of observations were made in the laboratory work. Some of these included the following:

- The maximum velocity in a flow channel is found near the bend exit on the outside of the bend
- The velocities are higher on the outside of the bend than on the inside and the maximum velocity shifts downwards while moving towards the outside of the bend in the downstream direction. This confirms the presence of a clockwise spiral that develops in the bend as was found in the literature
- The position of the maximum velocity moves in the downstream direction with an increase in the radius of curvature (rc) while the position is not much affected by the varying Froude numbers
- The observed scour patterns have the same tendency with varying radii of curvature to width ratios (rc/w)
- Three main scour holes were identified with the location of the third scour hole being in good agreement with the location of the maximum velocity
- In the vertical velocity distribution, the path of the maximum velocity dives towards the bottom in the downstream direction while moving towards the outside of the bend

The hydrodynamic models DELFT 3D, Mike 21C and Mike 21C (2DH) were used to simulate the channel flow experiments and establish methods for characterising natural flow dynamics in real life waterways.

Cost: R598 000
Term: 2003 -2005

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

In the previous study, WRC **Project No K1144** - (Potential application of genetic algorithms in the water industry), the application of genetic algorithms was reviewed. Findings from that study indicated that:

- GAs are not used to its full potential in the optimisation in the water industry in South Africa,
- Potential applications of the technique within the South African context are:
  - Hydrology and water resources assessment
  - Network optimisation
  - Optimisation of rehabilitation, extension and upgrading of distribution networks during the planning and design phase
- Little formal teaching on GAs is included in the curriculum of civil engineering
- Feedback from Rand Water reflected the need for the development of software utility programs that can be used in practice and stimulate the further exploitation of this technique,
- The pipeline diameter optimisation program that had been developed under this study was well accepted in practice

This study evaluated the application of genetic algorithms in the optimisation of different components of water supply projects and conceptually developed the procedures for the implementation thereof.

Based on the available literature study, as well as the feedback from water supply authorities, the need for the application of GAs as an optimisation technique in the water industry was defined. The potential applications of GAs in the water industry in South Africa were determined as:

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

This study objective was to provide the conceptual development of procedures to implement GAs as an optimisation technique for water resources assessment and network optimisation. The focus of this study was to conceptualise the optimisation problems that were identified and to conceptually develop the required procedures for the implementation of GAs in these areas in a follow-up study. In this study the conceptual procedures for GAs have been developed for:

- Pump optimisation and operational scheduling
- Water resource assessment
- Water distribution networks

Cost: R203 000
Term: 2002 - 2005

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

Programme 1: Predicting the impact of global climate change

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

In this project selected groundwater level and monthly rainfall time series information was analyzed by correlating the groundwater level records with the Standardized Precipitation Index (SPI) values derived for South African rainfall data. SPI is a single numeric index based on the probability of precipitation for any time scale. Analysis of the record period found notable correlation between the groundwater and rainfall datasets. From an analysis of the SPI and long-term groundwater level graphs, the following observations were made about recharge from rainfall to groundwater:

- The SPI value has to be at least positive in order to cause recharge. In the context of this report, recharge is considered to occur when water levels are increasing. In many cases it would appear that the SPI value has to be in excess of +2 to have a meaningful impact on groundwater recharge.
- During a period of positive SPI values, water levels have to show an increasing trend for a period generally at least equivalent in duration to that of the SPI anomaly, otherwise limited or no recharge will take place.

- During periods where SPI values are close to zero or negative, no recharge takes place
- For recharge to occur, the annual rainfall needs to be above the long term MAP

As a result, a methodology has been proposed to calculate a 'Recharge Index'. A number of factors are calculated with each being given a weight. The total weight is then a relative indication of the rate of recharge. The method proposed is still very subjective and a great deal of additional work needs to be done to develop this into a reliable way to turn the 'Recharge Index' into a realistic representation of effective recharge. No attempt was made to express the 'recharge index' value into a percentage of MAP or any other more quantitative way of expressing recharge.

Cost: R233 000
Term: 2002 -2004

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

Climate change, which is becoming accepted as a reality, will in all probability alter the hydrological landscape in Southern Africa and impact either negatively or positively on water resources in various parts of the country. Since this will have associated impacts on society and the economy, clarification of water-resource related impacts of climate change is imperative. The five main research objectives were as follows:

- The development of plausible climate change scenarios for southern Africa
- Investigation of the potential impacts of climate change on hydrological responses and associated water resources
- Investigation of possible water related socio-economic impacts of climate change in the Thukela catchment (as an example) and factors contributing to future risk
- Recommendations on some strategies to adapt to, and cope with water-related impacts of potential climate change
- Detection of effects of climate change and recommendations on appropriate monitoring systems for detection

A range of empirical and dynamical methodologies to downscale from GCM climate-change predictions were investigated and applied. Outcomes represent a significant advance in our understanding of the regional nature of future climate change. Methodologies have matured to the point where statements about the pattern of climate change at a regional scale can be made with some confidence. However, confidence is still weaker for statements regarding the magnitude of change associated with this pattern. The advances made are, nevertheless, a solid foundation for future development and reveal priorities for future work.

In order to simulate hydrological change, the ACRU model, supported by a quaternary catchments database, was run for the whole of South Africa extending into southern Africa, using one of the several investigated downscaling approaches (specifically, C-CAM modelling, yielding daily climate time series relating to the present and a future climate scenario at appropriate grid points) to provide the necessary input information. Results indicate some hydrological change 'hotspots', which may need to be acted upon by water resources managers. The present winter rainfall region in the Western Cape is one such 'hotspot' of major concern. The credibility of the outcome of this study depends to a large extent on how the downscaled output of daily climate values from C-CAM agree with corresponding outputs from other downscaling approaches. Agreement was generally good for the Western Cape (hotter, with drier winters) and for the eastern escarpment and eastward (warmer, moister), but less consistent for transitional areas elsewhere in the country.

From climate records of the past 50 years, elements of climate change can already be clearly detected in certain regions within Southern Africa, be it for derivatives of rainfall, temperature or for hydrological responses. Not all areas display equal change, and in some areas no change can as yet be detected.

Vulnerable communities in southern Africa already have to cope with multiple stresses, of which climate variability is but one. Climate change will add an additional layer of stress, to which adaptive strategies and adaptation policies will have to be directed.

In identifying adaptation strategies for the region's water-related sector (including both small- and large-scale agriculture and the environment), emphasis will need to be on the 'uniquely South African' situation, with its juxta-positioning of the developed vs. the underdeveloped sectors of the population and economy. Strategies will need to take cognisance of specific local

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

situational contexts, on the one hand, and national level policy and institutional issues, on the other. Successful adaptation strategies will generally be closely aligned with effective integrated water resources management (IWRM).

Cost: R2 240 000
Term: 2003 - 2005

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

Modelling scenarios indicate that climate change impacts are expected to alter the present hydrological resources in South Africa. Despite uncertainties, the majority of the models suggest a decline in rainfall over the western parts of South Africa in the coming decades. Based on these projections, the most severe impacts are likely to occur in this region, where small towns and subsistence farmers are most vulnerable. The available literature suggests that it would be prudent to account for climate change in water resource planning to meet the development objectives of South Africa. With this in mind, this study investigates the adaptive capacity of small towns and communities in the Northern Cape Province to climate variability, specifically drought. By testing these strategies against sustainable development criteria, planning policies for national and water resource planning and management are recommended to ensure water security against the impacts of climate change. A simple multi criteria decision analysis methodology was used to test the long term suitability of the strategies developed was done in consultation with representatives of the various Local Municipalities in the Northern Cape Province and members of the Provincial Drought Task Team.

Based on this study and the responses obtained from the stakeholder group, the following portfolio of strategies should be further investigated when developing a water resource management strategy that takes future climate change impacts into account:

a. Supply side management:
- Reduction of leaks programmes
- Regional water resource planning
- Local water resource management and monitoring
- Conjunctive use of surface and groundwater
- Rainwater harvesting

b. Demand side management:
- Dry sanitation systems
- Education programmes
- Tariff structures
- Water restrictions

Emphasis should be placed on demand side management given the finite amount of water. This is reinforced by the fact that the top three strategies rated by the stakeholders were all on the demand side. However, that is not to reduce the responsibility for better management by the water service providers to reduce wastage and losses in the delivery systems.

Groundwater is likely to be most severely affected, with the groundwater table dropping due to reduced recharge. Strict groundwater management systems should be put in place with early warning mechanisms to report depleted groundwater reserves. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.

Cost: R261 260
Term: 2004 - 2005

Programme 3: Protection and management of surface water quality

Survey of certain persistent organic pollutants (POPS) in major South African waters
School of Environmental Sciences and Development, Potchefstroom University for CHE
No 1213

In 1997 the United Nations Environment Programme (UNEP) initiated a process to develop a global instrument to reduce the risks to human health and the environment caused by the release and long-range distribution of Persistent Organic Pollutants (POPs). This has resulted in the Stockholm Convention on Persistent Organic Pollutants (SC), which is aimed at eliminating or reducing the production or releases of the first 12 identified POPs. The initial group of 12 POPs includes a number of pesticides - aldrin, dieldrin, DDT, endrin, heptachlor, chlordane, hexachlorobenzene, mirex and toxaphene. The other three chemicals are actually classes of compounds that include the dioxins (PCDD), dibenzofurans (PCDF) and polychlorinated biphenyls (PCB). Although much is known about POPs in northern countries, far less is known about problems in other regions.

This project was undertaken with the aim to contribute towards the ability of South Africa to determine and interpret its commitments and obligations under the POPs convention. It was intended to establish for the first time a countrywide assessment of POPs in a selection of major water bodies, and to indicate where more concerted action, management or research, needs to be focused. It would also

investigate cheaper means of analysis through bio-assays, since no accredited lab in SAcould do routine PCDD/PCDF analysis, and establish a network of researchers to serve as focus for leveraging international funding.

This research established the presence and levels of seven PCDD, ten PCDF and 12 PCB congeners in aquatic environments throughout SA. 22 aquatic sites were selected close to or downstream from areas regarded as possible sources of PCDD/PCDF and PCB. The surface layers of sediments were sampled and extracted; and the extracts analysed by an accredited German laboratory. Total concentrations of TEQs (toxic equivalency factor) (based on the instrumental analysis) were calculated as the sum of TEQs from individual compounds, assuming additive responses to chemicals in the mixture. The samples were also extracted for bio-assay analysis. Dioxin-like substances were present at all 22 sites sampled in this investigation. At all sites (except for the Crocodile River site) the contribution of the dioxins and furans were higher than PCB. The highest TEQ value (of almost 22 ng/kg) was determined for the Riet Spruit, which is close to an iron and steel refinery in Vanderbijl Park. Another highly industrialised site, the Modderfontein Spruit, had a TEQ of almost 6 ng/kg. The lowest TEQ was found for the Loskop Dam (0.22 ng/kg) and not the Mooi River (0.34 ng/kg), which was selected because of its expected low impact status.

In general, this study showed that South Africa have detectable levels of PCB and PCDD/PCDF which occur widespread in the aquatic sediment matrix, from freshwater rivers and dams to coastal harbours and river mouths. The concentrations found, displayed the global trend of higher PCB concentrations vs. lower PCDD/PCDF concentrations. The values did not, however, exceed the level of 50 ng/kg sediment, which was the action level determined for the USA.

The values found for the Vaal and Gariep River systems, particularly at the Gariep River mouth, indicate the possibility of long-range riverine transport of these pollutants, and therefore a possible contribution from South Africa, to the global burden. Risk seems not to be restricted to the industrialised areas. Places such as Alexander Bay and the Umgeni River mouth seem to be relatively polluted sites. The harbours' sediments seemed to have rather low PCB and PCDD/PCDF concentrations.

Cost: R410 000
Term: 2001 - 2003

Assessment of current and future water pollution risks due to gold mining in dolomite areas
Council for Geoscience
No 1214

The eastern catchment of the Mooi River, also known as the Wonderfonteinspruit has been the subject of a number of studies, to assess the effect mining activities have on the water resource quantity and quality. A DWAF study into the radioactivity of water found mining activities to be a major contributor to uranium and uranium series radionuclides within the catchment. Radionuclide concentrations were found to decrease downstream of these sources, presumably because of sorption onto sediments. A Tier 1 risk assessment (**Project No 1095**) showed that these radionuclides are distributed in multiple phases within the sediments and that they may be remobilized by environmentally plausible chemical processes. The present study was undertaken to assess the current and future risk to local and downstream water users due to pollution, including heavy metals and radionuclides, and to establish a near real-time continuous monitoring capacity to determine the short-term variations in water chemistry as a guide to future monitoring needs.

A reconnaissance sampling was undertaken to identify contaminated sites as well as to identify the contaminants of concern for the project. Both water samples and sediments were analysed. The mean values for the Wonderfonteinspruit samples were found to significantly exceed not only natural background concentrations but also levels of regulatory concern for cobalt, zinc, arsenic, cadmium and uranium, with uranium and cadmium exhibiting the highest risk coefficients. Owing to the rather isolated occurrence of Cd-peaks in samples and a wide range of possible (not-mining related) sources falling outside the scope of this report, the study focused mainly on uranium. Lead isotope ratios were found to provide a valuable tracer for use in the apportionment of pollution from mining activities. Results suggest that lead isotope studies are able to fingerprint contamination due to different mines or groups of mines which mine the same ore-bodies. Sequential extractions confirmed that contaminant metals are bound to a number of different phases within the sediment, that the processes binding the metals to the sediment are reversible and that plausible changes in the local environment (i.e. from reducing to oxidising conditions) could remobilise a significant portion of these contaminants.

The risk assessment should be viewed as a Tier II risk assessment that benchmarked measured contaminant concentrations against regulatory limits. As such, the current assessment thus still falls short of a public hazard assessment as would normally be commissioned by regulating authorities (such as the National Nuclear Regulator) as part of a full radiological risk assessment. The maximum measured uranium concentrations were used to calculate the risk quotients. The calculated chemical risk quotient associated with drinking river water is 6.39, and the radiological risk quotient is 2.22. Both the numbers are above 1.00, meaning that there is a risk of ill health effects by drinking water from **contaminated** streams in the Wonderfonteinspruit catchment. Although the uranium concentrations of potable water supplied by towns in the study were not determined as part of this study, it is anticipated that their risk quotients would be significantly below 1. While it was determined that the river water in some parts of the Wonderfonteinspruit catchment represents a hazard to residents who may ingest the water, these areas have been identified and warning signs have been put in place by local government.

A continuous monitoring station was established downstream of all major discharge points from gold mines (DWAF weir no. C2H069). The data-logger equipped station ran uninterrupted for a total of about 6 months with 4 different parameters recorded by one multi-purpose probe at 3 and 10 minute intervals respectively. The mobility of dissolved metals is largely controlled by pH and Eh. For both parameters distinct diurnal and seasonal oscillations were found, superimposed by event-related fluctuations. Such variations are likely to impact on the uranium concentration in streams by affecting the rate in which dissolved metals (including uranium) are removed from stream water via adsorption, precipitation or co-precipitation.

Cost: R300 000
Term: 2001 - 2005

Programme 4: Human-induced impacts

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

This research was motivated by the need to improve the understanding of hill-slope hydrological processes using the relationship between soil physics, the pedology and soil hydrology. The hypothesis in this study was that red apedal B horizons are freely drained, yellow-brown apedal B horizons are well drained, and E horizons are poorly drained. This hypothesis conforms to the hypothesis that duration of water saturation determines the quantity and type of iron oxide minerals present and hence the soil colour.

The well-gauged 160Ha Weatherley catchment was used in this study to characterise and quantify the soil water regime and soil profile morphology. The relationship between soil water regime and profile morphology was determined and translated into a model that will be used in assessing the hydrological characteristics of catchments where water measurements are limited or unavailable. Detailed measurements and descriptions of 28 modal profiles located at different sites in the catchment were used in the research. Digital colour photographs of each of the modal profiles and horizons were used in developing a computer aided process for quantifying the colours in an objective manner. Bulk density determinations, piezometric water sampling and soil water content measurements using neutron water meters were assessed against soil profile morphology.

A preliminary assumption was made that the degree of saturation (s) at which anaerobic conditions would be acute enough to cause redox reactions of sufficient intensity to produce visible signs of redox morphology was s>0.7. In accordance with this assumption the daily soil water regime was used to obtain values for the following parameters for the diagnostic horizons for each modal profile:

ADs>0.7 = the average duration in days · year^{-1} that s was above 0.7 of porosity.
Fs>0.7 = the average frequency of s>0.7 events · year^{-1}.
Ds>0.7 = the average duration of s>0.7 events.

Several photograph colour interpretation procedures and equations based on the RGB notation and the diagnostic colour definitions of the Soil Classification Working Group were developed. Relationships between scanned photographs which produced systematic differences to the digital photographs taken with the

Sony MVC-FD83 were also investigated and translated to mathematical relationships.

In the colour indices investigated the following equation yielded the best correlation:

ADs>0.7 (days · year^{-1}) = - 38.6 x Hd + 35.2 x Vd + 1.94 x Cd - 51.3 (9.1)

where:

ADs>0.7 = mean annual duration of water saturation above 0.7 of porosity
Hd = dry colour (numeric) hue
Vd = dry colour value
Cd = dry colour chroma

Chemical and physical analyses as well as mean ADs>0.7 values generally supported the classification of diagnostic horizons in Soil Classification – A Taxonomic System for South Africa. Diagnostic horizons could therefore be used to infer these properties within the current research environment. These relationships could be extrapolated, with caution, to other catchments having similar climate and geology.

In this study it was observed that the soils investigated were mainly those that have developed in the siliceous parent material. The implications of reactions between Fe and other parent material will need further research.

The implications of the climate especially rainfall and temperature in these reactions and resultant soil morphology also need further investigation.

Cost: R925 000
Term: 2002 -2005

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

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

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

South Africa has developed a progressive, far-reaching and technically sophisticated water policy, which reflects an advanced understanding of the principle of sustainable development. However, without appropriate capacity to implement the policy in the long term, little is likely to change for the better on the ground. Effective policy implementation depends on a mix of technical knowledge, social skills, and experience of how things work in the real world. The enormous need for developing the capacity of people in order to effectively respond to the implementation challenge is frequently expressed. This need essentially translates to a need for increasing our capacity to learn. We argue that the water institution will either have to improve its learning capability or yield to sub-critical capacity and inability to master the challenge of sustainable development.

The cycle within which policy undergoes major revision and reform, followed by implementation and review, can be as long as 20-30 years. Few people that are working in a particular field (such as water) of the policy arena are exposed to more than one substantial review during their working lives. Also in terms of the shorter cycles of monitoring and review, continuity is often lost through people shifting their professional focus, moving to other organisations or sectors, or retiring. The natural tendency is for knowledge gained through involvement in policy processes to dissipate to the extent that it is unavailable as a resource for the next generation of policy makers.

The overall aim of this project was to reflect on policy developments that took place over the past 10 years (1994 to 2003) in the water field, and to consolidate and package at least some of the learning in an explicit form for wider sharing or communication as well as retention of such knowledge in the institutional memory. In essence, it was endeavoured to extend the 'paper trail' by capturing the insights, anecdotes and stories related to the policy process that would normally have a small chance of being documented. The formal objectives of the project were to:

- Capture and consolidate knowledge and experience gained in several recent policy developments and R&D processes related to sustainable water resources 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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

The outputs agreed to before commencement of the project were:

- A consolidated report (this report)
- A series of issues papers
- A core group of South Africans who have had their own capacity enhanced
- Guidelines and a framework for training and enhancing the capacity of people in middle and senior management who are involved in policy development and implementation

Project approach

The project focused on two primary activities to achieve its objectives. First, a number of potential issues papers were selected to capture lessons from various policy development and implementation experiences to date. The idea was to contribute to an explicit as well as peer-reviewed record or archive of lessons, to enable wider sharing of lessons amongst current practitioners as well as to ensure that these lessons are available to future generations of practitioners. Through a series of workshops with various specialists and policy practitioners, three priority areas were identified to guide the selection of issues papers (see Chapter 2), namely:

- Analysis of the water policy development process in the context of the generic public policy cycle and principles
- Development and dissemination of technologies and programmes that would enable policy implementation and realisation of policy intent
- Capacity and institutional aspects, including kinds of capacity required to manage policy processes

Second, a training course, later referred to as a professional seminar, was developed and presented to facilitate knowledge sharing in an interactive setting. Four main themes were addressed in these seminars, namely:

- Generic frameworks for public sector policy development, implementation and evaluation
- Application of generic frameworks to water policy
- Effective implementation of policies and programmes: planning, monitoring and evaluation, institutional capabilities, and logistics
- Options for continuous revision and improvement.

Series of issues papers

Six papers were produced as part of this project.

A strong message from these papers is that sustained leadership, sound technical knowledge, the ability to plan (and re-plan) and facilitate a participatory process, good, clear communications and an adaptive, learning culture supported by continuous evaluation and adaptation are the key ingredients which have helped South Africa successfully adapt its water policy to meet the demands of our new democracy. Neglecting any one of these elements will jeopardise success.

Training course/ seminar

The development and presentation of a training course (later referred to as a professional seminar) was seen as a primary vehicle for achieving knowledge transfer and capacity building regarding policy development and implementation. The seminar was developed jointly between the WRC, CSIR Environmentek, Wits University (School of Public Development Management) and DWAF. Two seminars, each running over three days, were presented during the course of the project.

Building a learning capability

The term 'capacity building' is somewhat over-used in South Africa today, yet the importance of ensuring the capacity for implementation of new policy is readily recognised. Several definitions are provided related to the concepts of capacity, capacity building, institutional capacity and organisational capability. In the context of policy development, implementation and review, we view capacity building as a total (structural, functional and cultural) transformation of government in order to mobilise all available resources to achieve policy objectives. We emphasise the importance of the human element in overall capacity, as it is ultimately humans that make decisions, build new relationships and change behaviour. A key outcome of successful capacity improvement is to enhance people's 'capacity for informed action. This human capacity [for informed action] comes about through the integration of information derived from data, plus theory that puts the information in the proper context, plus experience of how things work in the real world. The process of integration is also called learning; hence the need for a strong focus on our ability to learn – we essentially have to learn how to learn as an institution.

An approach is suggested to instituting a learning capability specifically related to policy development, implementation and review. A major intervention is required to cumulatively build a sustainable capability, as opposed to

having sporadic surges and subsequent losses of capabilities as we go through cycles of higher and lower priority. In practice, these considerations can be given affect to in a properly constituted and managed R&D programme, with the aim of developing and maintaining a core capability for policy development and implementation in the water sector. By following a learning-by-doing approach, such a programme should facilitate a partnership between those involved with the development of a theoretical discourse and a community of strategic as well as operational practitioners.

General recommendations and conclusions

It is recommended that two parallel interventions be initiated and maintained within the professional water sector:

- Firstly, an ongoing programme of training and capacity building in generic public policy management, aimed at developing capacity in people entering the water sector in early or mid-career. This should be designed within a framework which addresses the different knowledge needs of line managers, strategic policy centres and specialists. This intervention would be focused more on improving generic policy processes.
- Secondly, a vehicle for stimulating high-level debate and action related to the content and impact of water policy. The institutional 'home' for such a vehicle needs to be identified: there are advantages and disadvantages to locating this either within a government agency or as a less formal network outside an agency. This intervention would be focused on examining policy content, initiating critical review as and when necessary, and generating and analysing appropriate policy options.

In conclusion, it is hoped that the reflective linking of practical experiences with tested theories and the documentation of associated lessons, that were made possible by this project, would be of benefit to the wider policy and water resource management fraternities of the current as well as future generations.

Cost: R720 800
Term: 2002 - 2004

Programme 2: Water policy development and strategic policy support

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

The South African government system is fragmented vertically between three spheres of government, viz. National, Provincial and Local Government as well as horizontally between government departments with different but inter-related mandates. Based on this inter-related nature of South Africa's government system; the constitution, although not prescriptive, provides a chapter that gives a broad framework on how to manage interrelated mandates. Chapter 3 (three) of the constitution provides for Cooperative Government as well as the principles that should guide cooperative government.
Section 41(2) provides that through an act of parliament that government must establish institutions or provide

- Structures and institutions to promote and facilitate cooperative governance
- Mechanisms and procedures to promote and facilitate intergovernmental relations

The implications of this section of the Constitution are the following:

- A need to develop strong appropriate policy, legislation and strategies as the foundation for cooperation;
- A need to create a balance between the technical requirements for interaction between the tiers of governance and political relations; and
- The ability to accommodate the interests of the various tiers of governance while managing the areas of disputes that may arise.

The Constitution therefore becomes the main driver of cooperative governance between institutions of government. The constitution describes the spheres of government as distinctive, independent and interrelated in nature. The distinctive nature of the spheres of government refers to the legislative and executive autonomy that they have while interdependent nature relates to the degree in which each sphere of government depends on another for fulfilment of its constitutional mandates. The inter-related nature relates to the manner in which spheres of government fosters relations between themselves based on mutual trust and good faith for the greater good of the country as whole. The implications are that although the spheres of government are distinct and independent, they cannot function without cooperating with one another as their activities impact on one another. In terms of Section 41(1), cooperation between the

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

spheres of government should be guided by three principles, namely unity, decentralisation and cooperation. These are underlined by:

- Fostering friendly relations between all levels of government
- Assisting and supporting one another
- Informing one another of, and consulting one another on, matters of common interest
- Coordinating their actions and legislation with one another
- Adhering to agreed procedures
- Avoiding legal proceedings against one another

In trying to achieve cooperative governance the South African Government have in the past years developed a number of mechanisms and strategies which, have in certain instances been faced by a number of challenges. These mechanisms have been developed both at political level as well as at executive / administrative levels. At political level structures such as the MINMEC which is a committee between the minister of a specific department and the MEC for the relevant department, the Intergovernmental Forums, which comprised political office bearers from the three spheres of government and the Presidential Coordinating Council aimed at bringing together all Premiers, the state President and DPLG to address issues of common interests were all developed to promote cooperation.

Cooperative governance at planning level is governed by the same principles used at political level; however these are further put into perspective by the policies and strategies that govern planning within the different institutions. Within these policies and strategies cooperative governance is realised through integrated development planning. Policies and strategies such as the Integrated Development Plans and the Municipal Systems Act, NEMA, the National Water Act and the National Water Resource Strategy, etc promotes cooperative governance. Cooperative committees such as the IDP Committees, National Environmental Advisory Forum and Committee for Environmental Coordination, etc. also promote cooperation.

The National Water Act (Act 36 of 1998) enables the establishment of catchment management agencies (CMAs) in the 19 water management areas (WMAs) established in South Africa. These CMAs will ultimately take responsibility for all activities required to enable and support water resources regulation, including authorising the use of water and ensuring that water related activities are performed in accordance with the Catchment Management Strategy (CMS) that is developed in the relevant WMA.

The Local Government 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. In particular, local government has key responsibilities related to water resource management (WRM) including ensuring provision of municipal services, rural development strategies, municipal spatial development and infrastructure planning, environmental management, including pollution control and waste management.

The first paragraphs of the summary referred to the requirements by the Constitution, which states that all organs of state and spheres of government should observe and adhere to the principles and conduct their activities within the parameters of cooperative governance. Although there is general acceptance and support for this requirement, the water sector has not been particularly effective at pragmatically implementing these sentiments nor making them operational. As CMAs are established and local government continues to take on its Constitutional mandates, the need for cooperation between these two institutions will be critical to the effective, efficient and sustainable implementation of WRM.

CMAs are in the process of being established and therefore there is a significant opportunity to ensure that they foster cooperative governance, particularly with local government as a key partner each with their respective mandates in each WMA. This should be the case based on a number of reasons when taking into account the expected functions that local government should perform. As an example the Municipal Systems Act (Act 32 of 2000) gives reference to the role of local government planning in cooperative governance. Section 24(1) stipulates that *'any planning must be aligned with, and complement development plans and strategies of other affected municipalities and other organs of state so as to promote cooperative government contained in section 41 of the Constitution'*. Based on this and the functions that they perform, local government has planning strategies that impact on water resource; these include spatial planning, water services planning (WSDPs) and environmental management planning.

On the other hand the National Water Act requires that CMAs when developing the catchment management strategy take into account the planning by other institutions including local government water services development plans. In relation to water-related activities, local government impact on water resource management is through water use, which permits the institution to abstract or discharge wastewater based on licence granted by DWAF/CMA.

Besides water-related activities and planning imperatives, cooperation between the two institutions is triggered by other roles, which include the role of local government as a stakeholder representing activities at a less binding level, e.g. non-consumptive use of water for recreational purposes as part of tourism initiatives. The second and critical factor is around conservation of water as a scarce resource. Local government as a major water user may need to monitor the efficiency of water use by its clients so as to conserve water. The CMA may provide the techniques for water conservation.

While the areas of cooperation between the two institutions are indicated, based on relevant legislation and policy mandates. Overload of tasks and capacity limitations remains the factor for full local government participation on IWRM. The implications are that the CMAs should take the responsibility for promoting and enabling cooperative governance around WRM between these institutions. The CMAs are therefore faced with a task of developing and driving mechanisms for cooperation with local government. Certain local government institutions have capacity to simultaneously engage with the CMAs on these processes, it is therefore imperative that they become partners in these processes. CMAs and local government should consider the following mechanisms in their engagements.

Governance, accountability and representation

The CMA Governing Board (GB) must have local government representation, although the nature of this representation is not clear. It is clear that the diverse interests of typically 10 to 20 municipalities within a WMA must be represented by a limited number of GB members (probably less than 3). Furthermore, the GB is legally accountable to the Minister of Water Affairs and Forestry and National Parliament (through SCOPA) and has a fiduciary duty to the CMA rather than their individual constituencies. DWAF will oversee the activities of the CMA and the functioning of the GB.

However, the local government representative/s on the GB can promote the interests of local government in policy and strategy decisions that the GB is responsible for. It is therefore in the interests of municipalities to ensure that these members are aware of the WRM issues facing local government and can represent the diversity of municipalities in that particular WMA. ***Municipalities should take the CMA GB Advisory Committee process and subsequent nominations seriously.*** It may even be appropriate for municipalities to develop a caucus / forum to promote their interests through the GB member, but it is more appropriate that this be under the auspices of a formal committee established by the CMA. These committees are discussed in chapter 9 of the document.

Legislative and policy alignment

Local Government may establish bylaws around a range of activities that affect WRM. The CMA has an interest in ensuring that these are aligned with (or at least are not inconsistent with) WRM legislation and approaches. The development of model bylaws may contribute to this, but the ***CMA may take a proactive role in evaluating municipal bylaws in the WMA and advocating changes where these may be inappropriate from a WRM perspective.***

Similarly, it is in the CMA interest that WRM legislation and policy is aligned with the environment in which Local Government operates. Although CMAs do not establish regulations they can advocate that DWAF ensures this alignment, taking account of the specific challenges that that particular CMA faces with the municipalities within the WMA. This may also involve promoting dialogue and alignment with Provincial legislation.

Coordinated strategy development

The NWA requires the catchment management strategy (CMS) to be aligned with other development plans. For local government, this requires alignment with the range of plans developed by local government under the integrated development planning.

Although the principle is clear, operationalising this alignment requires an agreed approach between the CMA and municipality. It may include

- *Participation* / involvement by relevant staff from municipalities in CMS development processes and CMA staff in IDP development process, through the relevant forums
- *Informal meetings* between the

CMA and municipal planning sections to identify and resolve areas of inconsistency
- *Formal review* and commenting on draft CMS or IDPs
- Active process of *joint strategy development,* from initiation to development of relevant parts of the CMS or IDP

Participation in strategy / plan development processes is the minimum level of engagement acceptable, possibly supported by informal meetings or formal review (where problems are identified). Even this requires capacity from both institutions that is often likely to be missing. From the perspective of WRM, ***the CMA must engage with the IDP process.*** Furthermore, the ***CMA should make every effort to engage the municipalities in the CMS process***, possibly through dedicated bi-lateral or multi-lateral local government forums, particularly where the municipality has limited capacity. It should be acknowledged that although ultimately desirable, the likelihood of joint strategy development is limited in the short to medium term, except where there is a real driver for this alignment, possibly related to severe water shortages or water quality problems.

Based on the findings it can be concluded that CMAs and Local Government Institutions do have areas of cooperation, which are critical for realisation of integrated water resources management. While work overload and capacity are recognised limitations of local government and are also anticipated with the CMAs; it is critical that both institutions recognise the importance of cooperative governance therefore playing a proactive role in engaging and driving cooperative processes. CMAs as managers of water resources which other institutions and individuals depend upon should be in the forefront of these cooperative processes.

The manner and level at which local government is involved within the CMA processes and activities should reflect the various roles of local government as an institution, i.e. from integrated planning, water services and being democratically elected institutions representing the interests of all stakeholders within an area of jurisdiction. The implications are that CMAs need to recognise the importance of local government as the driver of local social and economic development, therefore the need to create closer ties for integrated planning and development.

The current approach to CMA establishment processes on local government engagement largely lies at higher political level, therefore excluding certain levels of administration. It is critical that this process engage officials at administrative level particularly for planning alignment purposes.

Cost: R290 000
Term: 2003 - 2004

Programme 3: Institutional arrangements and processes for IWRM

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 defines rivers as a resource that must be sustained in order to safeguard the supply of goods and services to society. To achieve this objective the Act makes provision for reserving a quantity of water of appropriate quality to meet the basic needs people have for water and to sustain aquatic ecosystem functioning. This is known as the Reserve. Implied in the reservation of water to sustain river systems is the assumption that by doing so, rivers will continue to provide for the needs of society. It is well known that rural people rely on the goods and services of rivers to sustain life. This encourages us to perceive the needs rural people have of rivers systems to be defined in material terms such as water, fish and construction materials and we commonly fails to take account of spiritual needs.

As the intention of the environmental component of the Reserve is to sustain ecological processes in rivers, it is established largely through ecological determinations. Consequently, it may be that human dependencies are not adequately taken into account and the patterns of flow defined in the determinations of the Reserve may not meet the requirement of rural people. If they do not, the intentions of promoting collaboration in the management of river systems may be jeopardised.

The premise of this project is that if the needs of rural people are not adequately taken into account in the determination and implementation of the Reserve, the pressures rural people feel in meeting these needs will confound attempts to sustain the resource as defined in the Act.

The project sought to improve our understanding of the nature of the

relationships between the needs of rural households, the rivers system and sustainable use. Since much is already known about material needs, the research was directed at two issues namely, improving our understanding of the role of non-material needs, particularly traditional and contemporary belief systems and values, and how use of river system goods and services is regulated. Since belief systems and values define the norms that in turn direct behaviour, they are strongly connected to regulatory systems.

In order to gain insight into how belief and regulatory systems are changing and how these changes might be harnessed in co-management, the research focused on a community that was in transition from rural to urban.

Notwithstanding their peri-urban situation, the people of Salem make extensive use of the Mlazi River for a variety of uses such as washing, bathing, and watering livestock, but they also use the river frequently for rituals and ceremonies. Some of these relate to traditional beliefs and values whilst others are founded in contemporary Christian religions. The traditional belief systems and values persist, but are weakening whereas the belief systems and values associated with the Zionist Christian Church may be strengthening. Both the traditional and contemporary belief systems show strong connections with the river and therefore offer opportunity for promoting co-management, particularly as respondents indicated concern for river condition.

Respondents in the survey observed that there was not control over access to and use of river resources. The traditional authority whilst having a stronger presence in the area than elected councillors has lost much of its influence. It is suggested that there should still be a role for the Traditional Authorities in co-management. It is also suggested that constituencies such as the Zionist Christian Church that have spiritual connections with river systems should be encouraged to participate in co-management. All parties would however need to be empowered to do so. This requires that there are opportunities to participate. At present a structure and processes for co-management do not exist in the area and people have no opportunity to participate. It is also clear that they have neither the self-confidence nor the competencies for effective participation. Suggestions are made for a structure, the characteristics of constituencies that might participate and for agreements that would define roles and accountability of participants in co-management.

Cost: R315 000
Term: 2000 - 2002

Developing and trialling guidelines for participatory water resource management at catchment and water management area scales
Geography Department, Rhodes University
No 1233

South Africa's National Water Act of 1998 makes the management of any water resource a partnership between local water users, regional catchment managers, and DWAF. The Act encourages communities to become actively involved in developing and managing their water resources.

The three sets of guidelines – *Participatory Guidelines, Environmental Guidelines, Planning and Economic Guidelines* – are aimed at IWRM practitioners who work with stakeholder communities. The guidelines help practitioners make participatory water resource management a reality. They introduce the necessary social tools and scientific knowledge to enable communities to participate as envisioned by the legislative framework.

The *Participatory Guidelines* are concerned with good Integrated Water Resource Management (IWRM) practice, applying the philosophy of participatory IWRM and describing methodologies and case studies for community participation. Good IWRM entails capacity building, networking and conflict resolution, all of which require consistent work over time. The practitioner's responsibility is to help participating stakeholders to become knowledgeable about catchment issues and to build well-organised groups who can sustain the IWRM work when the project comes to an end.

The *Environmental Guidelines* describe the legislative and ecological context within which integrated water resource management practice takes place. They give the reader/ practitioner guidance in three ways - they outline national policy for water resource protection, they describe the environmental principles that inform good catchment management and IWRM, and they list some of the IWRM procedures and partnerships currently in operation.

The *Planning and Economic Guidelines* present tools and conceptual models for participatory financial planning and decision-making, and outline the economics of IWRM. The tools allow

project priorities to be quantified and rationally assessed. This is the first time that many of these tools have been introduced in South Africa, but they have been tried and tested elsewhere in the world and constitute international best practice.

Cost: R1 000 000
Term: 2001 - 2003

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 report presents the findings of an action research project aimed at developing understanding related to the governance of shared, scarce natural resources. Worldwide there is increasing pressure on society to achieve equitable, efficient and sustainable use of ecosystem goods and services. The challenge we face is to reconcile the distribution of costs and benefits for society as a whole. The process that should underpin this reconciliation must be founded on trade-offs that have continually to be achieved through democratic processes. Only if these trade-offs are made democratically can we hope for the popular support that leads to compliance. In this way, attainment of equitable, efficient and sustainable use of ecosystem goods and services will reflect the extent to which democracy is institutionalised in society and the agencies that act on its behalf.

South Africa provides compelling opportunities to improve understanding of the complex nature of democracy in the context of decision-making around trade-offs in the use of the goods and services derived from ecosystems. Prominent amongst these opportunities are the trade-offs that determine the allocation of rights to use river system goods and services and the distribution of costs and benefits resulting from their use. This provides motivation to research the institutionalisation of democracy in water resources management.

The research was conducted in the Sabie-Sand catchment in Mpumalanga Province, South Africa. The project was divided into three phases. The objective of Phase I was to develop familiarity with relevant underlying theories and to describe the social-ecological system in the Sabie-Sand catchment with respect to decision-making structures, processes and behaviours. From this, issues were selected to focus the action research phase of the project (Phase II). The objective of Phase III was to draw lessons from the research experience and to highlight the implications for the development of appropriate relationships and cultures for sharing a common property resource.

Phase I identified three models, or frameworks, that would be particularly useful in guiding the research. These were Senge's process for profound change, a form of action research known as appreciative enquiry, and Cook's model for understanding empowerment.

Senge's process for profound change provided a process-oriented framework of the components of change and the reality of delays inherent in the change process. One of the striking aspects of Senge's process is the focus on the need to build social capital (aspects such as confidence and trust) long before tangible results are realized.

Appreciative inquiry is based on the principles of empathy and respect. It encourages groups to expand their collective vision by amplifying the strengths of a group; an appreciative and inquiring attitude promotes the co-evolution of values as opposed to a rights- and conflict-based approach to resource-sharing. Appreciative inquiry concepts are based on the organisational sciences, which confirm that future-building is a more appropriate approach to problem-solving than focusing on current problems.

Cook's empowerment model recognises the need for capacity enhancement in three distinct areas: Subjective empowerment (relating to confidence); Objective empowerment (relating to responsibility and opportunity); and competence (relating to skills, knowledge and attitudes). People tend to often focus on skills development in empowerment efforts, and tend to be unaware that building confidence and an ability to see and use opportunities also form an important part of the overall empowerment process.

Phase I also identified a number of issues around river resource governance in the Sabie-Sand catchment. These were:

- Large discrepancies between organizations and individuals
- Very little co-ordinated decision-making between organisations, which tend to engage government to resolve resource issues, rather than each other:
- A lack of formal representation of the interests of many resource users
- A predominance of decision-making structures that were not necessarily geared to address their constituency's resource-related issues

Apart from the issues identified, a number of opportunities were also identified:

- The Sabie River Irrigation Board had a vision (and matching enthusiasm) to expand its scope to include a number of downstream users. In this way, the board would enhance its representation and empower others. This offered a significant opportunity to the research project.
- The private forestry sector (Global Forest Products) and the Kruger National Park stood out as organisations that are outward-looking, well-resourced and able to seek, engage and drive cooperative processes. They are at opposite ends of the catchment, again providing an opportunity for focus and for integrating upstream/downstream concerns.

At the end of project Phase I, differentials in levels and types of empowerment emerged as a major obstacle to stakeholders' collective capability to develop shared understanding and make wise trade-offs. Learning about what constitutes empowerment and cooperative empowerment therefore became a focus area for Phase II of the project. The Cook Model of empowerment was used to guide the research team and resource stakeholders.

Phase II focused on action research. It applied strategic adaptive management (SAM) concepts in its approach. SAM is based on the acceptance of the uncertainty and variability inherent in social-ecological systems and the need to proceed with incomplete information. Thus, management should be experimental, adaptive and learning-oriented, so that learning from each round of implementation informs the next. This approach moves away from the balance of nature theory to a concept of nature as a system of hierarchical patches that are changing and diverse over space and time. SAM introduced an emphasis on being strategic, or future-focused. The future orientation of SAM was extremely important to the project discussed here. Phase II had the following aims:

- To determine the potential of well-resourced interest groups to own and drive a cooperative empowerment process for the collective benefit of a broader group with shared interests in the same resource
- To apply the strategic adaptive management and future-building processes as a vehicle for cooperative empowerment
- To draw lessons from the action research experience relevant to catchment stakeholders and water policy implementers

Phase II of the research project proceeded, in the first place, as a series of individual consultations with the 'well resourced' stakeholders. Once their agreement to participate further in the process was obtained, a joint workshop between the stakeholders, the research team, and DWAF was held. This was followed by a further by a further meeting.

There were a number of outcomes arising from the above process. Well-resourced stakeholders were willing to engage and invest in local-level informal processes, but they felt that they would benefit greatly from explicit acknowledgment and endorsement of their endeavours by DWAF. Related this, there is a question about where the responsibility of an informal process ends, and where that of more statutory processes begin. There was also a perceived need for adequate and appropriate representation when people strive to make decisions together. There is a tension between being representative (i.e. having all groups present, but perhaps not participating equally) and building relationships, perhaps more slowly but more thoroughly and meaningfully, to achieve full representation.

The research conducted during this project has allowed the team to identify a number of important lessons regarding cooperative resource governance. These include the following:

- Relationship-building cannot be rushed (as predicted by Senge's Model)
- Repeated reinforcement is important for sustaining relationships
- Stakeholders can learn to value relationships as much as the decisions they support
- Informal resource governance processes require support from formal processes, and there is a risk of failure if they are not supported
- There is a need to balance the requirements for empowerment (which takes time), and representation (which can be achieved relatively rapidly, but does not necessarily lead to voluntary compliance and truly empowered resource sharing)
- Individual champions, or catalysts, play a critical role in sustaining and fostering relationships in informal resource sharing processes.

This report provides a broad overview of the outcomes of the research. However, the main products of this research are in the form of papers that have been submitted for publication in the open literature. These papers are contained in the appendices to this report.

Cost: R1 416 000
Term: 2002-2005

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

The North-West Dolomitic aquifer (also known as the North-West Dolomitic Water Area (NWDA)) is shared between three water management areas (WMAs). These are Crocodile West-Marico, Middle Vaal and Lower Vaal WMAs. This presents a number of institutional challenges to manage the NWDA as a common resource.

A study was conducted to identify and analyze resource management issues through a situational assessment. The situational assessment involved a description of the ecological as well as the social and institutional contexts. The ecological context primarily includes a geohydrological assessment. The social and institutional context includes a water demand/use assessment, institutional assessment and legal review.

Geohydrological assessment
The geohydrological assessment, which was a continuation from Phase 1 (WRC Report KV 140/02), concluded with a conceptual model. This forms a sound basis for a hydrodynamic (numeric) model as well as an educational tool to hone a wide range of stakeholders' knowledge of the NWDWA. Information on the resource was adapted for a handbook to be circulated to local water managers and users.

Water demand assessment
A water demand assessment was done structured according to main water uses, namely agriculture (irrigation and stock), industrial, domestic, and environment. Good results were generated for the domestic demand but there were concerns about the quality of data for the remainder of the uses. Of greatest concern was the data for irrigation as this use consumes three-quarters of the resource. The problem of quantifying and projecting irrigation demand requires high-level attention and co-ordination.

Institutional assessment
An array of organizations influences the use and management of groundwater. This assessment concentrated on the local and regional players and found that overall there was extremely limited capacity for sustained and intensive contributions in the process of groundwater management. This would be less of a problem if the designated organizations, namely CMAs and water user associations (WUAs) were in place. But since they are not and there are problems with legal compliance, the study concluded that the regional offices should be better resourced, there should be stronger lines of communication between all the main role-players and that a campaign is required that will stimulate the formation of WUAs.

As a result, of the above management alternatives were recognized which was developed through a process of scenario building. Four scenarios were developed, and from these a range of coping measures was identified. These coping measures allow for both interim and long-term options. An interim option, while intense institution building is underway, is to appoint an NWDWA coordinator who can act in the interests of the aquifer, ensuring that it is represented in the plethora of organizations that exist and affect the management of and demand for this resource. In the long term, the institutional arrangements that govern the resource may be a dolomitic water management committee, which will pull the different role-players together into one committee and serve to centralize decision-making around the aquifer. However, for this approach to be effective, the participating organizations need to be strong and their strength will depend largely on how they are set up and to what extent stakeholders are capacitated to play a meaningful role in water management.

Cost: R762 906
Term: 2002-2004

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

A particular governance system should be matched to and aligned with the biophysical and ecological processes occurring within the ecological system that supports a society or community. Recognising these linkages, the WRC formulated this above-mentioned project as part of the **Environmental Governance Systems** thrust as part of the water and environment cross-cutting domain. This is the final report from the project consisting of the review and evaluation of governance elements and the strategic direction for research to support governance systems around water in the hydrological cycle.

Interpreting water governance: The complete system of governance for

water may be represented as a three-dimensional system of:

- *Elements*, including principles & mandate, policies & legislation, regulatory framework, institutional arrangements and practice
- *Levels*, from international, national, regional, local to neighbourhood levels
- *Responsibilities* of government, non-government organisations and civil society

International Context: Defining what constitutes international water law is simple due to the preponderance of customary international law at this level. For governance of water in the hydrological cycle, the most relevant initiatives are those related to climate change, management of transboundary water resources and environmental management. These initiatives and law are taken as context for the national governance evaluation.

National policy and legislation: Conclusions about the broad legislative environment are relevant for water governance in South Africa such as:

- The Constitution sets the parameters for good water governance.
- The legislated governance system for water has several elements, with the National Water Act and Water Services Act administered by DWAF at its core.

Evaluation of the governance systems: While the policy and legal environment has been generally well developed in South Africa in accordance with government policy since 1994, the implementation of this policy and legislation has been generally uneven, inconsistent and often inadequate to meet the challenges facing the country. Therefore the key focus of the evaluation is on the regulatory environment and practice. It does this specifically from the perspective of the water governance, and prioritisation is primarily based on the associated impact on the water environment. For practical reasons, the synthesis takes a physical media approach, focusing on governance of air, land and water.

Air governance: Specific issues that may benefit from further investigation include:

- Opportunities and institutional arrangements for joint planning, management and regulation of air and water quality (linked to land quality) at a catchment basin scale, through the catchment management strategy process
- The technical, procedural and institutional considerations for addressing water resource impacts as part of the air emissions licensing process

Land governance: From the wide-ranging review and evaluation of land governance from a water-hydrological perspective, the following are examples of the priority issues identified:

- The opportunities for effective coordination of land use governance through catchment management processes, and appropriate mechanisms to institutionalise the required cooperative governance
- The institutional capacity of local government to effectively perform its functions related to management of the hydrological cycle, particularly around integrated development planning, municipal service delivery, waste management and land use authorisation

Water governance: In addition to the water related issues associated with land governance, specific governance issues related to the water environment include as examples:

- Governance of catchment management agencies at all levels, within a paradigm of cooperative, integrated, developmental and participatory management
- Governance considerations and mechanisms for the development of catchment management strategies through a consultative process and their alignment with local development planning (IDP, WSDP) and provincial planning processes (PDGS)

Challenges to good water governance: There are a number of fundamental challenges to improving water governance in South Africa such as:

- Change and maturity in the governance systems
- Institutional change and decentralisation

Given the magnitude of these strategic challenges, it is remarkable that there is a relatively effective governance system in the water and related sectors. From this synthesis and evaluation, it is apparent that an institutional champion is required for promoting coherent and harmonised implementation of water governance related to the entire hydrological cycle. While DWAF must continue to play this role at a national policy level, it is proposed that catchment management agencies provide a focus point for improving governance of water in the hydrological cycle at a catchment level.

Costs: R500 000
Term: 2004-2005

Programme 4: Transboundary water resource management

International freshwater agreements
CSIR
No 1515

South Africa shares four rivers with its six neighbours – the Incomati, Orange, Limpopo and Maputo. The water in these rivers is increasingly under pressure due to increased water demands in South Africa as well as in the neighbouring states. South Africa has ratified the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (United Nations, 1997), which calls for the exchange of data and information, the protection and preservation of shared water bodies, the creation of joint management mechanisms, and the early settlement of disputes (UNEP, 2002).

Essential tools for achieving the objectives of the UN Convention are the various treaties, protocols, memoranda and agreements entered into between basin states (collectively referred to as agreements). South Africa is party to a range of bilateral, multilateral and regional agreements on 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 to with neighbouring states.

The overall goal of this research project was to contribute to the good governance of South Africa's shared watercourses, by making available copies of the agreements the country is party to and analysing selected treaties. To achieve this, the project had four objectives:

- Compile a list of all freshwater agreements to which South Africa is a signatory
- Update the Transboundary Freshwater Dispute Database (TFDD)
- Store the agreements in a database, and make it available in CD-Rom format
- Using the Legal Assessment Model (LAM) of the International Water Law Research Institute (IWLRI) to determine how effective current agreements are

The initial challenge for the project team was to develop a methodology for the inclusion of agreements in the final list and the database. After consultation with the project steering committee and the Department of Foreign Affairs (DFA), it was decided to include all agreements that the Government of South Africa had entered into with another *sovereign state* since 1910 with a direct impact on the *management* of freshwater resources.

These agreements cover a variety of issues and were sourced principally from DWAF and DFA archives. The final list of agreements contains 59 entries that were included in the database entitled *International Freshwater Agreements Database*.tba and distributed with this report. The database is fully searchable using a variety of fields. The hard copy agreements were then scanned and saved as PDF files, viewable from the database. The final list of agreements was used to update the TFDD, housed on an Oregon State University website, once permission was granted by the WRC. This is important as the TFDD is used extensively as an authoritative source of data and information on global freshwater agreements.
The database analysis showed that the rate at which South Africa enters into agreements with other countries is increasing. This is linked partly to the normalisation of South Africa's relationship with the international community and partly to the global trend of concluding more multilateral treaties on water resources and management. There are indications that this will continue, making it important to keep the database up to date.

The original project proposal would have used the Legal Assessment Model (LAM) to analyse a selection of agreements. However, once the LAM became available, it became clear that it is more useful for determining if a proposed water use is permissible, rather than as an overall analytical tool. International agreements tend to have an evolutionary aspect, increasing their range, scope and complexity over time. In order to draft agreements that will work effectively in practice, and to support that evolutionary process by bringing in scientific processes to support future negotiating teams, it is necessary to understand which components to include in such agreements, and which matters should be regulated by such agreements.

The project analysed two key agreements of regional importance to which South Africa is a party: the 'Tripartite Interim Agreement Between the Republic of Mozambique and the Republic Of South Africa and the Kingdom Of Swaziland for Co-operation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses', signed on 29 August 2002 (hereafter called the Incomaputo Agreement), and the 'Treaty on the Lesotho Highlands Water Project between the Government of the Republic of South Africa and the Government of the Kingdom of

Lesotho', signed on 24 October 1986 (hereafter called the LHWP-Treaty).

The analysis showed that these two agreements meet the requirements for effective operation. While the LHWP-Treaty contains important elements of 'modern' international water law, the Incomaputo Agreement reflects the developments of international water law to a higher degree. With its comprehensive basin-wide management regime, the Incomaputo Agreement is well suited to function as a model agreement for other, future basin-wide water agreements that may be considered in the SADC region. Importantly, the analysis has shown that certain improvements to the Incomaputo Agreement are desirable and indeed possible.

This study revealed the intricacy of international agreements - both in terms of the domestic ratification process that must be followed, and on an international level with other states. Importantly, older agreements that were entered into while South Africa was still a British colony or with other colonial powers prior to those territories gaining independence, are still valid, and their provisions – both rights and responsibilities – are still in place, unless they had been specifically revoked by the country concerned after independence.

The degree of legal predictability that agreements provide contributes to a spirit of cooperation and collaboration over shared water resources. However, the long-term effectiveness of these agreements depends on their regular upkeep; in this case ensuring that they are readily accessible to present day decision-makers, planners and managers.

Two key recommendations are made. The first is to distribute the database widely to a broad range of stakeholders, and ensure that it is maintained regularly to include the latest agreements. The second recommendation is that a similar project should be conducted for the entire SADC region – to provide a centralised register of all the international freshwater agreements to which SADC states are party.

Costs: R270 000
Term: 2004-2005

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

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, DWAF
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.

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

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 -200

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: R560 000
Expected term: 2003-2004

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

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 nationwide water resource assessment in 1990, WR90, became essential tools for water resources management, planning and operational practitioners, researchers and decision makers. The 1990 study which basically focused on surface water resources has become less and less useful over the years as the water sector evolved with new legislation coming in (Water Act of 1998), changing land uses, improved knowledge and data, technological advances, and the need to answer new questions in a changing water sector. The WR2005 study seeks to quantify and assess national water resources in an integrated manner that takes into account the new water environment and addresses the shortcomings of the previous nationwide studies.

The objectives are to:

- Evaluate the WR90 project and its use. Critically review the outcomes of the WR90 project with regard to

- Project implementation
- Uses and users
- Project impact on the water sector
- Shortcomings and strengths
- Develop WR2005 project framework
- Develop WR2005 tools
- *Develop WR2005 database*
- Investigate and build a user support system for WR2005 products
- Document the project work and package products efficiently and cost effectively
- Introduce and build PDI capacity

Estimated costs: R6 700 000
Expected term: 2004 - 2007

Programme 3: Understanding and predicting hydroclimatic variability

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 is 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

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

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 inter-annual rainfall and its extremes over Southern Africa through the use of multimodel ensembles
- Investigate the operational predictability of seasonal to inter-annual 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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

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

The development of a prototype 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: R1 000 000
Expected term: 2003-2007

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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.

Water quality is often ignored in resource assessment. This project will provide a strategic framework for research investment by identifying research gaps and priorities. The project aims to:

- Review research needs and priorities for water quality assessment, with a focus on water quality assessment studies and water quality information systems, arising from recent South African water quality policy development and implementation initiatives associated with resource-directed measures as well as source-directed measures
- Provide strategic guidance to the WRC for future research in this area

Estimated cost: R200 000
Expected term: 2004/05

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

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

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: R1 214 000
Expected term: 2003-2005

THRUST 2: INTEGRATED WATER RESOURCE DEVELOPMENT

Programme 1: Integrated catchment management

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

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 Weatherley 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 cooperative 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

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: R900 000
Expected term: 2004-2005

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: 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

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: R900 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: R3 500 000
Expected term: 2003-2005

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

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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

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

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 4ha 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 hill-slope 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

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-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

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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

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: R1 349 800
Expected term: 2003-2006

National flood now-casting 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: R1 314 000
Expected term: 2003-2005

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

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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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 cooperative 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 2: Water policy development and strategic policy support

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 cooperative associations of individual water users, who wish to undertake water-related activities for their mutual benefit. This study is aimed at clarifying the roles of WUAs, evaluating the functioning of a number of established WUAs against this framework and the particular needs of the local conditions, and formulating guidelines for the institutional and management arrangements.

Estimated cost: R380 000
Expected term: 2000 -2001

Programme 3: Institutional arrangements for IWRM

Human resource needs assessment - tertiary level: South African Water Sector up to 2015
Department of Civil Engineering, University of the Witwatersrand
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

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: R1 000 000
Expected term: 2003-2005

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

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

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

NEW

THRUST 1: WATER RESOURCE ASSESSMENT

Programme 1: Groundwater occurrence in fractured-rock aquifers

Flow conceptualisation, recharge and storativity determination in Karoo aquifers (with special emphasis on the Eastern Cape (Mzimvubu) to Keiskamma Water Management Area)
SRK (CE)
No 1565

The Karoo rocks outcrop over almost three quarters of South Africa and act as a host for an important groundwater resources. Hundreds of villages in the rural areas of the Eastern Cape and KwaZulu-Natal Provinces obtain their water supplies from boreholes adjacent to or within the area of influence of dolerite dykes and sills, which have intruded the Karoo sediments. These conditions produce unique and complex hydrogeological system, which complicates the study and development of groundwater. This project aims:

- Conceptualise flow dynamics and groundwater flow paths
- Determine recharge-discharge and storativity and generate target maps for groundwater exploitation

Estimated cost: R3 400 000
Expected term: 2005 - 2009

Programme 3: Understanding and predicting hydroclimatic variability

Using enhanced knowledge of climate variability for the benefit of water resource management
University of Cape Town
No 1566

Research into climate variability over the past 15 years has enhanced knowledge substantially with regard to the Southern African region. Because of the sensitivity of water resources in the region to climate variability, it is imperative that this knowledge be utilised optimally for water resource management.
Consequently, this project will focus on:

- Identifying the strengths and weaknesses in current climate prediction tools from the water resource management perspective
- Assessing whether recently gained knowledge of climate variability (including knowledge resulting from locally-conducted research) and new insights from current research on climate variability related to climate change can be used to improve tools, and/or the effectiveness with which tools can be used, by water resource managers.
- Demonstrating beneficial use of best available tools or tools specifically improved for water resource management applications and transferring knowledge in this regard.
- Filling crucial knowledge gaps which are known to still exist, in as far as this is possible in the short term
- Identifying longer-term research, capacity-building and/or educational initiatives to enable water resource managers derive maximum benefit from climate modelling and forecasting tools.

Estimated cost: R1 478 000
Expected term: 2005 - 2008

Programme 4: Development of appropriate techniques for evaporation monitoring

Refining tools for evaporation monitoring in support of water resource management
CSIR
No 1567

Evaporation, after precipitation, is the largest component of the hydrological cycle at the land surface. It includes evaporation from open water surfaces, moist soil and wet foliage, as well as the transpiration of plants. There are many compelling water-resource related reasons (among them demands created by recent water legislation) for being able to measure/estimate and monitor evaporation with sufficient accuracy and precision. While many potentially suitable techniques and methods exist, there is a lack of knowledge regarding their appropriate use and capacity in applying them.
Consequently, this project will aim to:

- Classify and characterise land uses/units and water-resource management applications for which evaporation measurements/estimates are needed
- Assess accuracy and precision requirements relating to evaporation measurement/estimation for various water-resource management applications
- Assess appropriateness of evaporation measurement/estimation techniques for addressing a range of key water-resource management needs
- Develop guidelines for the complementary use of measurement and estimation techniques
- Develop/refine evaporation measurement/estimation techniques, where necessary, for key water-resource management applications
- Establish a sound basis for capacity building and skills development relating to evaporation measurement and estimation

Estimated cost: R1 600 000
Expected term: 2005-2008

KSA 1 WATER RESOURCE MANAGEMENT (CONTINUED)

THRUST 2: INTEGRATED WATER RESOURCE DEVELOPMENT

Programme 2: Integrated catchment management

Water resource management in rainwater harvesting (RwH): An integrated system
Source Strategic Focus (Pty) Ltd
No 1563

Rainwater harvesting (RwH), an old technology that dates back thousands of years, is gaining popularity in a new way. The global trend towards cheap and less ecologically disruptive water supply systems has tended to favour the development and application of cheap, environmentally friendly and readily available techniques that are decentralized as opposed to huge centralized water infrastructure. RwH, one of the cheaper and decentralized water provision techniques, is set to expand nationally to cater for South Africa's unserviced population in rural and agricultural communities which currently exceeds half the population. Larger-scale implementation of RwH will require improved management to enhance benefits and mitigate negative impacts. Increased understanding and a better synthesis of RwH techniques to be achieved in this project will lead to the development of a model-based decision support tool as well as a policy document on the RwH practice. The RwH decision support tool and the policy document are set to guide and direct the RwH practice within the boundaries of integrated water resource management in accordance with the provisions of the National Water Act and other related legislation such as the Environmental Conservation Act. As part of the RwH decision support tools, methodologies for quantifying socio-economic, hydrological, ecological and environmental impacts of RwH are expected to be developed and refined for packaging as standalone applications or for incorporation into existing water resource management and water systems analysis models.

Estimated cost: R2 800 000
Expected term: 2005-2008

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

Programme 1: Predicting the impact of global climate change

Secondary impacts on water resources due to primary changes in precipitation and temperature associated with climate change
University of Cape Town
No 1562

The WRC is currently funding a project to investigate the potential impact of global and regional changes in climate and climate variability on water resources, but this focuses only on hydrology at present. There are likely to be secondary effects on water resources arising through changes in flow regimes and ambient temperature - these include changes in nutrient cycling, changes in processes affecting sequestration of toxic substances such as metals, changes in chemical and biochemical oxidation and reduction processes, and changes in background concentrations of dissolved salts. The complex changes in water quality, water quality and temperature due to climate change will in turn have effects on aquatic ecosystem structure and function, with further implications for the quantity, quality, reliability and availability of water resources. This project will build on recent and current research within the WRC and other organisations, to generate potential scenarios for the secondary and tertiary impacts of climate change on water resources, with the aim of supporting the development of policy responses and coping mechanisms.

Estimated cost: R2 500 000
Expected term: 2005 - 2008

Programme 4: Human-induced impacts

Persistent organic pollutants (POPs) in the environment
North-West University
1561

South Africa is a signatory to the recent Stockholm Convention, which is intended to minimise and prevent the release of harmful persistent toxic substances in the environment. Although the WRC has recently funded work on persistent organic pollutants (POPs) in the water environment, this research now needs to be taken further in order to:

- Assess with higher confidence the scale and significance of the occurrence of POPs in the water environment in South Africa, the potential short-term and long-term impacts on water resources and water-linked ecosystems and the associated threats to sustainability of water resources and water use;
- Better identify and quantify the fate and effect of selected POPs in the water environment;
- Guide and inform the development of appropriate policy and regulatory measures that will:
  - Support implementation of the requirements of the Stockholm Convention
  - Substantially contribute to the protection of water resources and water-linked ecosystems with regard to POPs

Estimated cost: R1 500 000
Expected term: 2005 -2008

Development of a model to assess the cost associated with eutrophication
Umgeni Water
No 1568

Eutrophication and its accompanying effects is one off the intractable symptoms of water pollution associated with modern society. It diminishes the quality of our water resources for many uses and costly treatment is often required to overcome its negative effects. In the prevention vs. cure debate, it is important to not only know the cost of prevention, but also the cost associated with eutrophication when it occurs at various levels, in order to justify often expensive preventative measures. Knowledge of the cost associated with eutrophication will also help in determining and justifying the introduction of waste discharge charges. Similar to a study that assessed the cost to users that can be associated with water salinity, a multidisciplinary team will conduct this project to determine the costs associated with eutrophication that are experienced by different water users, such as those associated with water purification, recreation, irrigation and the aquatic environment.

Estimated cost: R2 000 000
Expected term: 2005 -2008

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

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

Econometric model to predict the effect that various water resource management scenarios would have on South Africa's economic development
Conningarth Economist
No 1570

Water being a limited resource, it is accepted that its availability will constrain the economic development of South Africa. At present it is very difficult to predict which unforeseen negative effects well-intended management decisions may have on development. Australia developed a model of the Australian economy that relates the present and future water demands to potential growth in production in 55 industry groups across 18 regions. This model is used to predict how the Australian economy would be affected under different scenarios of water resource management. The model that will be developed under this project will do the same for the South African situation.

Estimated cost: R2 000 000
Expected term: 2005 -2008

Programme 2: Water policy development and strategic policy support

Implications of South Africa's trade policies for water policy and water resource management
University of Pretoria
No 1564

This project is to develop a 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, as well as to identify points or issues for future related research to support policy development, analysis and implementation in the water sector and linked economic sectors.

Estimated cost: R 530 000
Expected term: 2005 -2007

Towards the establishment of water market institutions for effective and efficient water allocation
CPH Water
No 1569

The NWA provides for the transfer of water use licences through a water market. A recent WRC review of the value of water to different sectors of the economy has revealed that the market mechanism has proved to be an efficient tool to effect the transfer of water to more efficient users and improve water use efficiency under South African conditions. However, due to high transaction costs, this mechanism is under-utilised. In order to utilise the efficiency of market mechanisms, it would thus be necessary to institute institutions that facilitate transfer and reduce transaction costs. On the other hand, safeguards also need to be instituted to prevent potential negative externalities associated with transfers. This project will investigate three case studies to determine which steps and institutions are required to balance these requirements.

Estimated cost: R1 500 000
Expected term: 2005 -2008

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KSA 2

WATER-LINKED ECOSYSTEMS

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 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
- Impoundments

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION

Scope: This thrust includes research which specifically addresses the management of ecosystems for sustainable utilisation. Central to this is the need to manage the social and economic requirements of society from ecosystems and the implementation of policy and legislation. Capacity will be built to implement the research findings. Current programmes are:

- Ecological Reserve
- Estuary management
- Ecosystem health
- Environmental water quality
- Endocrine disrupting compounds (EDCs) in water sources

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 2005/06

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.

Research will be solicited in the following areas in 2005/06:
Wetland health and integrity: The knowledge underlying the management of the country's wetlands is less well-developed than that for rivers, due at least in part to their complexity. However, there is now an urgent need for this knowledge, as management decisions are being made. This will form a component of the overall wetlands research programme. The other components of this programme are the rehabilitation of wetlands (currently co-funded by WRC and *Working for Wetlands*) and the *Wise Use of Wetlands* (not yet started).

The effect of managed river flow on vectors of human diseases: An increase in vector populations is a potential effect of managed flow which is not currently considered when designing the Ecological Reserve. It is known that changing flow in a river will change the habitat and so cause a shift in the numbers and diversity of taxa (some of which are disease vectors) that live there, but knowledge needs to be generated to quantify, predict and manage this effect.

It is anticipated that research will be solicited in the following areas starting during the next financial year:

Impoundments: Research will be conducted into the management of biological processes in impoundments with the management of the problems resulting from eutrophication (e.g. algal blooms) as an anticipated outcome.

Socio-economic considerations: Framework for the valuation of goods and services from aquatic ecosystems for the Resource Directed Measures (RDM)

Non-solicited research: Research projects which enhance the understanding of ecosystems will be given prominence.

BUDGET FOR 2005/06

The approved funding of the research portfolio for 2005/06 leads to a committed funding budget of R11 890 230. The focus of this portfolio will continue along current trends.

NEEDS ANALYSIS

There is still, as identified in previous years, 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 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

Several important new trends in inland water research have been emerging internationally, and these are briefly discussed below. These trends are being picked up into the medium- to long-term planning within the KSA where they are relevant to the country.

- Climate change. There is an increasing body of knowledge on the effects of climate change from the temperate latitudes, but this deals largely with increasing temperature. More relevant to Southern Africa is the predicted change in rainfall, with the dry west becoming drier. The ramifications of this for management of the resource could be substantial.
- Impoundment management. Toxic blue-green algal blooms resulting from the eutrophication of impoundments is a problem world-wide. Recent work internationally is addressing the possibility of managing the natural ecological processes within these impoundments in order to reduce the impact of these blooms. The ability to do this would not only protect the natural environment, but would also assist in keeping the cost of water treatment down.
- Conservation planning is being used increasingly internationally as a holistic and reliable tool for making decisions on how to most effectively conserve representative ecosystems
- Natural resource accounting is becoming widely accepted as a way to bring environmental values into the macro-economy of countries.
- In Europe there is a current surge of interest in the development of environmental water quality indices based on diatoms. These appear to be more successful than previous attempts at correlation as it appears that new methods of data analysis are being used.

PORTFOLIO PLANNING

As indicated previously, national research drivers in ecosystem research continue to be aligned with international trends, although the emphasis is on the local situation. This past year the process of redesigning the portfolio was started and the results are briefly presented here. The process will be developed further before the next call for proposals. Current research drivers continue to include:

- Ecosystem processes and functions. Research into these aspects is important for the sustainable management of ecosystems and it is anticipated that this will remain a priority research driver for the foreseeable future. Research in this area provides the basic understanding on which management decisions may be based.
- The Ecological Reserve provides a tool which enables managers to balance resource use with sustainability. *Version II* of the *Resource Directed Measures* (RDM) *Manual* is in the early stages of development, and it is anticipated that the process to determine the Reserve will become a lot more stable once this is out. As this happens the need for new research in this field should decline sharply. Projections for this research topic are that within 5 to 6 years it will require considerably less funding than it has at the moment, and in about 10 years it will be phased out. A possible exception to this may be wetlands, as methods for determining the Reserve in these complex systems have not yet been finalised.
- cooperative environmental management and governance is being developed within the context of estuarine management, and is developing the capability to integrate ecosystem management with the social and economic requirements of the stakeholders. The current phase of this work is concentrating on making the science accessible to communities living beside estuaries, concentrating on organs of local government. This will empower people to take management decisions based on the state of the art ecological, economic and social research which has been done in the previous phase. This initiative is being piloted at the moment, and in its present form will probably not be funded beyond another 4 to 5 years.
- The current wetlands programme will be run in 3 phases. The first phase (rehabilitation) is underway, and a start has been made on the second phase (health and integrity). The third phase (wise use) will probably start

between 2008 and 2010. The second and third phases have strong social and economic components which include the management for, and use of, the ecological goods and services. The third phase, entitled *Wise Use of Wetlands*, will deal almost exclusively with social and economic issues. It is anticipated that this programme (as currently envisaged) will be complete before 2015.

- Conservation planning is a tool for making decisions on how to most effectively conserve representative ecosystems. The WRC is co-funding a programme which is piloting this process on rivers (elsewhere it has only been used in terrestrial situations until now).
- Ecosystem health and environmental water quality provide knowledge to balance the use of the resource and the discharge of effluents with the ecological health and sustainability of the resource as well as human health related issues. It is anticipated that research into this topic will continue for the foreseeable future.
- Rehabilitation research in its present form has a finite duration. It is becoming linked to wetland rehabilitation within the Working for Water programme as well as within DWAF, and will probably cease to exist as a research initiative within 10 years.
- The research initiative into the need for and provision of fish-ways is going well and the current level of funding will probably be reduced substantially after 2008.

A number of new research initiatives have been identified and are being piloted. It is anticipated that some of these will become large programmes which will run for longer than a decade. These are discussed briefly below:

- Knowledge of the socio-economic aspects of sustainable ecosystem management lags behind knowledge of the ecosystem functions and processes. Knowledge of this aspect needs to be improved if we are to ensure long-term sustainability of the resource. It is anticipated that research in this area will continue for the foreseeable future. Some work may be done within the KSA that addresses water resource management (KSA 1), but KSA 2 will make a substantial contribution to this topic. This will need to include research into natural resource accounting.
- 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. The complexity, as perceived form the standpoint of present knowledge, indicates that this research area will be active for a long time to come.
- Research has been initiated on the Reserve determination for non-perennial rivers. Perennial rivers are largely limited to the well-watered east and the main stems in the arid west of South Africa. However, many of the tributaries, even in the well-watered east, are non-perennial. Although this programme is planned to be complete by 2009, it is certain that a number of research questions will be raised during the research, and will require a decision as to which should be addressed.
- Since the closure of the FRD Inland Water Ecosystems Programme in the mid 1980s there has been very little research done on impoundments, and this has been largely limited to that funded by the water boards to address their own pressing needs. Impoundments are integral to both South Africa's water resource management strategy and to the linear ecosystems of the rivers that they impound. They also have specific characteristics of their own. For instance, they are the first part of the resource to be affected by eutrophication, they break the connectivity of the river which affects biodiversity, alter the sediment characteristics of the river and a number of other effects. There are new ideas emerging from elsewhere in the world that have the potential to improve our management of impoundments, and these need to be examined. It is anticipated that research in this area will continue for the foreseeable future.
- South Africa has a very rich history of diatomology. Recently developed indices using diatoms as indicators of water quality appear to be promising as both present indicators of water quality which are both robust and easy to use, but will also be able to give insight into historical water quality for areas where early collections exist. It appears that these indices may be successfully applied to both historical collections and to recently collected diatoms. It is anticipated that this research topic will not receive special attention beyond about 2009, but by this time will either be incorporated into the suite of indices available for use or laid to rest.
- Conservation planning for aquatic ecosystems is a new area of research which is being piloted in South Africa through an initiative co-funded by DWAF, CSIR and the WRC. It offers a quantitative method for planning conservation and utilisation of the resource. While this initial phase may not last longer than 8 to 10 years, the needs identified during this phase will continue for the foreseeable future and are likely to address the management of biodiversity and the resource.
- Research into the management of biodiversity (in terms of the recent legislation) has started with a small

KSA 2 WATER-LINKED ECOSYSTEMS (CONTINUED)

project on fish biodiversity. It is likely that this field will expand substantially once the outcome of the conservation planning programme (above) becomes known.

There are a number of research areas which have not yet been addressed, and these need attention for the reasons given below. These are listed briefly:

- Climate variability and change. The effects of these on biota and the influence on long-term resource management need to be better understood if we are to plan successfully in the long term. Of particular importance to the Southern African situation is the predicted decrease in rainfall in the drier western parts of the country.
- The contribution of river flow to the near-shore environment needs to be better understood. We estimate the contribution of estuaries to the marine commercial fishery (through species that either breed or spend part of their life cycle in estuaries) at R950 million per year (1997 value; WRC **Report No 756/2/03)**. We know qualitatively that the prawn fisheries off the river mouths improve after a season in which there have been good floods. We do not know the extent of the effect of management interventions on rivers on the near-shore marine environment, so are unable to include this effect in any natural resource accounting on new developments. Land-based developments may prove to be less economically attractive when viewed against the larger picture.
- There is a need to develop the ability to effectively manage the integration of ecological, economic and sociological knowledge to enable IWRM. This will synergistically add value to the knowledge available in each of the disciplines.

CORE STRATEGY

The core strategy is fundamentally unchanged from 2004/05. 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 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, current thinking is 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 from research funded during 2004/04 are the funding of research on environmental water requirements (now the basis of the Ecological Reserve in the NWA which continues to be used to refine the implementation of the Reserve), and research on the sustainable management of estuaries is being used to empower local authorities to better manage their natural resources.

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

term to longer-term strategic needs of the country, and ranges from more fundamental to highly applied work within the area defined by the mandate.

STRATEGIC INITIATIVES UNDERTAKEN DURING 2005/06

NATIONAL INITIATIVES

- Participation in national committees related to this KSA

Steering Committees (National)

- The River Health Programme. The WRC is one of three national custodians of this programme
- 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
- Researchers funded through this KSA were well represented and participated actively in the WRC Open Day held in Durban.

Leadership positions: (within South Africa)

- Chairperson of the Board of the National Community Water and Sanitation Training Institute, University of the North (SA Mitchell)
- Institute for Environmental and Coastal Management, UPE (vice-Chairperson) (SA Mitchell)
- Institute of Water Research, Rhodes University (SA Mitchell)
- National Science and Technology Foundation - Executive Committee representing the Science Council sector (MS Liphadzi)
- Consortium for Estuarine Research and Management (CERM) - Co-ordinate for the WRC – WRC the lead organisation (SA Mitchell)

- Interview on *Morning Live* in support of groundwater research funded by the WRC - June 2005
- SA Mitchell was external reviewer for the chapter on Freshwater Biodiversity of the *National State of the Environment Report,* DEAT.

- **Workshops**
  A series of 6 1-day workshops was held at centres around the country (during April and May 2005) to give input into the strategic planning for both KSA 1 and 2. The venues were selected to cover the country's 9 provinces and to get input from as wide a range of stakeholders as possible. These workshops have provided valuable data on research needs and the priorities in the various parts of the country.

INTERNATIONAL AND AFRICAN INITIATIVES

- Delivered a paper entitled 'South and East African experience of managing for water and ecosystems'. RAMSAR COP 9, Kampala. 7- 15 November 2005 (SA Mitchell)
- Delivered a poster entitled 'Keeping Up with Clean Water Demand while Maintaining Ecological Integrity: A Challenge in South Africa'. Ecological Society of America. January 2006 (MS Liphadzi). The KSA is strongly involved (SA Mitchell is the co-chairperson of the Executive Committee) in the activities of the Framework for Education and Training in Water (FETWater), a joint UNESCO, Belgian and South African programme aimed at building more capacity in integrated water resource management. The WRC is managing the FETWater funds and the proposal for funding for Phase 2 has been submitted to UNESCO for consideration.
- This KSA is involved in the GWRC initiative on cyanobacterial research.
- SA Mitchell attended the RAMSAR conference of Contracting Parties and a member of the South African Government delegation.
- RAMSAR Conference of Parties - organised and chaired a side-event workshop entitled 'Environmental flows in Africa, their determination and use in water resource management' with speakers from Mali, Tanzania and South Africa. Chaired a second side event entitled 'Implementing the Precautionary Approach in Conservation and Wise Use - Why, When and How?' (SA Mitchell).
- SA Mitchell has been proposed to represent Africa on the RAMSAR Scientific and Technical Review Panel for the triennium 2006 - 2008.
- Delivered a paper entitled 'Heavy metal displacement in EDTA-assisted phytoremediation of biosolids soil'. IWA-WISA conference, Cape Town. 10-12 August 2005 (MS Liphadzi)
- Delivered a paper entitled 'The role of research in informing the governance process'. International Symposium on Ecosystem Governance, Kwa-Maritane, Pilansberg. 10-13 October 2005 (SA Mitchell).
- Delivered a paper entitled 'The legislative framework to protect the water environment in South Africa: Moving from policy to implementation' to the *First Jiuzhai Paradise International Environment* Forum, All China Environment Federation, Jiuzhai, Sichuan Province, China. 27-31 October 2005 (SA Mitchell).
- Delivered a poster entitled 'Keeping Up with Clean Water Demand while Maintaining Ecological Integrity: A Challenge in South Africa'. Ecological Society of America. January 2006 (MS Liphadzi)

GROWING THE KNOWLEDGE BASE

CAPACITY-BUILDING INITIATIVES

This KSA strongly supports capacity building, competence development and improved communication of research findings at the individual, organisational and community levels, as an ongoing priority. Capacity building and competence development are central to the work funded in this KSA as, apart from natural attrition, the implementation of the NWA and all the changes that that implies to the management structures requires that water management will be devolved to lower levels of government, requiring greater numbers of people able to fulfil the function.

Continual effort is made to maintain contact with relevant government departments and other potential end-users of research, firstly to enable them to make input into the identification of research needs, and also to ensure that they are aware of and able to use the products of research.

Progress to date on ongoing projects indicates that the number of students undergoing post-graduate training at tertiary institutions under WRC-funded projects in this KSA was estimated as 113 in total, of which 52 students (about 46%) are from previously disadvantaged groupings.

The table below gives a breakdown of the students employed by each of the agencies with which KSA 2 has research contracts for the year 2005/06 and highlights the institutions which are actively involved in capacity building:

Organisation	Previously dis-advantaged students	Total no of students
CSIR Environmentek	4	6
Palmer Environmental Consultants	0	0
Pulles, Howard and de Lange (see note)	6	12
SA Institute for Aquatic Biodiversity	2	7
Rhodes University	6	9
University of Cape Town	4	10
University of the Free State	1	6
University of KwaZulu-Natal Dbn & Pmb	9	15
Nelson Mandela Metropolitan University	4	7
University of Stellenbosch	4	16
University of the Western Cape	4	4
University of the Witwatersrand	7	20
Free State Technikon	1	1
TOTAL STUDENTS	**52**	**113**

Note: The students employed by Pulles, Howard and de Lange are accommodated at the Universities of Johannesburg and Venda.

KNOWLEDGE-SHARING AND LEADERSHIP

The KSA led, participated in and/or supported 10 technical workshops including:

- A series of 5 1-day workshops was held at centres around the country that are easily accessible to DWAF staff (during April and May 2005) to give training in the assessment of the Ecostatus of rivers, a measure now being used in the DWAF Reserve determination
- A 1-day workshop was held in Pretoria (June 2005) to develop a strategic plan for the EDC programme
- A 2-day workshop was held at the University of the North-West (Potchefstroom Campus) (during August 2005) to train scientists and technicians in the use of diatom-based water quality indices
- A 4-day workshop was held at the University of Johannesburg field station on the Vaal River (during October 2005) to train resource managers in procedures for human health risk assessment associated with consumption of freshwater fish and in the application of fish health assessment index
- A 1-day workshop was held in conjunction with *Working for Wetlands* in Pretoria (during December) to develop the most suitable procedures for wetland classification and inventory in South Africa for use in the national programme
- A 1-day workshop was held in Pretoria (during December) to strategically identify the key effects of climate change on biota in order to develop indices for measuring this

Staff of the KSA attended the following conferences:

- Delivered a paper entitled 'South and East African experience of managing for water and ecosystems'. RAMSAR COP 9. Kampala, 7- 15 November 2005 (SA Mitchell).

Publications emanating from projects and consultancies 2005
The number of final reports published at the end of 2005/06 amounted to 21, of which 3 were technology transfer documents

	Reports	TT Documents	To be published before March 2006	TOTAL
THRUST 1: Ecosystem processes	2	1	2	5
THRUST 2: Ecosystem management and utilisation	6	2	7	15
THRUST 3: Ecosystem rehabilitation	1			1
TOTAL for KSA	**9**	**3**	**9**	**21**

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. Both the IUCN and Wetlands International, (international NGOs) fund specific projects within their mandates in this field, and the latter is becoming increasingly active in Africa. Funding may also be available from industry for specific projects. The relationship between the WRC and the Secretariat of the RAMSAR Convention is becoming closer.

OTHER 'PLAYERS'

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

IMPLEMENTATION PLAN

RESEARCH PORTFOLIO FOR 2005/06

In essence, the implementation plan follows that of previous years 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 continue to be achieved through the following:

- Develop an understanding of the ecological processes underlying the delivery of goods and services.

KSA 2 WATER-LINKED ECOSYSTEMS (CONTINUED)

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

An additional programme on **Impoundments** has been added to Thrust 1 to accommodate research scheduled to start.

The ***Endocrine disrupting compounds*** programme has been split from **Programme 4** (was **Toxicology** Programme, now **Environmental water quality**) to become **Programme 5**. Each programme within each thrust is designed to deliver products which are needed by specific end-users in the short-, medium- and long- term. In the case of the thrusts on ecosystem management and utilisation as well as ecosystem rehabilitation the end-users will largely be managers and policy makers, while in the case of that on ecosystem processes the end users may be the same as above, the research will also provide the basis on which the more applied research would be based. Each programme is designed with the input of the relevant stakeholders, taking global trends into account, and so is able specifically to address the needs expressed, and benefit the country.

The research portfolio for 2005/06 is presented in **Table 1** which provides an overview and description of research thrusts and programmes.

TABLE 1

Overview and description of KSA 2 thrusts and programmes for 2005/06

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.
Programme 5: Impoundments	**Scope:** Research within this programme will cover ecological functions and processes within impoundments with a view to improving our ability to manage these.
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.

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION	
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. Research on the environmental health of wetlands, estuaries and impoundments is also included in this programme. This programme links with the crosscutting domain **Water and Health** and includes resource management actions which may affect human health.
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	**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 cost-effective treatment and control strategies. Further emphasis is on the development of simple, rapid and cost- effective detection techniques. This programme will be done in three phases, of which the first phase is already completed.
THRUST 3: ECOSYSTEM REHABILITATION	
Scope: This thrust addresses the rehabilitation of the aquatic environment (including both the abiotic and the biotic components) which 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 2005/06

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 2005 and 31 March 2006.

COMPLETED

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

Approximately 70% of South Africa's estuaries are intermittently open, and the period of closure varies between estuaries and seasons. These estuaries are subject to the same development pressures as those which are permanently open, but are more susceptible to impacts because there is no regular tidal flushing. Up to now, most of our knowledge has been based on work done on the permanently open estuaries, but this is not always directly transferable to those which are not permanently open. The estuaries selected for study in this project are both small and closed most of the time.

The objectives of the study were to:
- Determine variations in phytoplankton chlorophyll *a* concentration in relation to changes in nutrient input following increased river inflow
- Determine spatio-temporal distribution of the phytoplankton chlorophyll *a* concentration and relate this to water level fluctuations
- Examine the influence of fluctuating water level on phytoplankton community structure particularly during periods of mouth closure
- Determine shifts in phytoplankton community structure following changes in nutrient loading brought about by increased water flow
- Link the information from this study to ongoing regional research on estuarine reserve determinations and other regional, national, and international related research on temporarily closed/open estuaries

The two estuaries selected for study were the Maitlands and the Van Stadens. The Maitlands River catchment (area approximately 60km^2) is primarily farmland with a relatively small portion of land covered by shrub-thicket vegetation near the coastline designated as nature reserve. The Van Stadens River catchment (area approximately 90km^2) is largely covered by shrub-thicket vegetation with some areas covered with forests, however some areas of the catchment are used as farmland primarily for dairy and chicken rearing.

Results indicate that both estuaries are oligotrophic, and that the rivers are the sources of nutrients for the systems, with the Maitlands River contributing significantly higher levels than the Van Stadens River. The phytoplankton communities reflect this difference.

The study showed that the nanophytoplankton size-fraction was responsible for driving water column production, and the contribution of groundwater to the nutrient budget varied.

Cost: R597 000
Term: 2001-2004

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

A previous project (**No 754**) had shown that individual rivers had unique assemblages of fauna. This project aimed to investigate these results in greater depth in order to develop understanding of the observed phenomenon termed catchment and river signatures.

Several permutations of the data set were, therefore, analysed in an attempt to detect whether the observed catchment signatures were the result of sampling bias. The catchment was shown to be the landscape feature that best explained invertebrate species distributions. This conclusion supports the findings of Wishart et al. (WRC **Project No 975**), who reported that the genetic structure and flow of selected invertebrates and fish revealed that catchments in the Fynbos bioregions of the Western Cape were unique entities and that catchments are the best functional units for conservation of instream biota.

Investigation of the characteristics of the invertebrate data that produced catchment signatures revealed that there was no one over-riding cause. It was concluded that the signatures were not caused by unique species within each catchment, nor by a unique mix of taxa in each catchment, nor by unique proportions of the same set of taxa within each catchment. Instead, the signatures were caused by subtle changes of species within each major taxon group from catchment to catchment. The only analysis which eradicated the catchment signatures was that using functional feeding groups. Of the disturbed sites analysed, the greatest disturbances were caused by release of very cold water from the hypolimnion of a dam and infestation of grey poplar. The signatures, however, appear to be the result of complex interactions of many variables over long geological time.

River and catchment signatures are real biotic fingerprints of upper rivers and catchments in the Western Cape, distinguishing each from the others. There is no reason to believe that they do not exist in other parts of South Africa and, indeed, elsewhere although this remains to be shown.

Cost: R478 000
Term: 2002-2004

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 on habitat requirements
University of Venda, Department of Zoology
No 1197

In recognition of the close dependence of the rural poor on a wide range of ecosystem services, this project determined the influence of anthropogenic factors on the biodiversity which underlies the provision of these services which people obtain from rivers and wetlands and provides indicators on how to assess the state of the resource. It also builds towards decision-making capacity towards the management of the resource.

The approach adopted was to compare two geomorphologically similar sites, one situated below a village on the Luvhuvhu River where there was a lot of activity and the other from the smaller, more remote Mutale River.

The recovery of the river from the 2000 floods could be seen in the changes in the macro-invertebrate fauna in both rivers. At both sites the feeding guild of collectors was dominant, predators and scrapers occurred in smaller quantities and shredders were absent. *Leptophlebeid* mayflies were the dominant group of macroinvertebrates. The fish fauna (numbers and diversity) also changed steadily throughout the period of fieldwork and this was attributed to the recovery of the rivers after the flood. The change was less marked in the Mutale River than it was in the Luvhuvhu River, possibly because the flood disturbance was cushioned by Lake Fundudzi just upstream of the sampling site. While the fish assemblages as a whole showed a greater overall response to water quality, the *Leptophlebeid* mayflies were the single most responsive group to water quality.

Preliminary results indicate that a neural network approach could be used to predict the influence of human disturbance on biodiversity in ecosystems, although this needs further development.

Cost: R95 975.08
Term: 2000-2005

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION

Programme 1: Ecological Reserve

Refinement of aspects of the Reserve determination methodology for water quality, including the assessment of potential impacts on aquatic biota
Freshwater Research Unit, University of Cape Town
No 1311

This project addressed the determination of water quality for the Ecological Reserve for wetlands as well as refining the existing Reserve protocol for nutrients. A DSS was developed to present a method for estimating water quality of wetlands, but wetland variability is such that in all cases it is recommended that a monitoring programme is implemented.

It is recommended that the TWQR for total phosphorus (0.005mg/ℓ) is too conservative; the 75%ile of DWAF monitoring data would indicate that 0.02 mg/ℓ would be better. However, that for soluble reactive phosphate and total inorganic nitrogen should be maintained until detection limits can be improved.

For effective protection of water quality in wetlands it is essential that reasonably stringent pollution limits be set. At the same time, to enable optimum utilization of those systems for economic development, the water quality objectives should not be too

conservative. A method to help determine suitable water quality objectives was developed in this project. In a similar vein eutrophication of all types of aquatic resources (not just wetlands, but also rivers and lakes), is an increasing problem both in South Africa and world-wide. The two major thrusts of this project are very different, the one directed at setting the water quality Reserve for wetlands, and the other for assessing nutrient levels (primarily in rivers). Nevertheless they are both concerned with managing water quality in aquatic resources. As water becomes even scarcer in this country, and pollution loads increase, managing water quality will become an ever-challenging concern. Sophisticated tools and new ways of tackling the problem will need to be engaged.

Cost: R320 000
Term: 2002-2005

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

DRIFT (Downstream Response to Imposed Flow Transformations) comprises four modules (biophysical, subsistence use, scenario development and compensation economics). The *DRIFT User Manual: Geophysical Model for Predicting Overall River Conditions in Small-To-Medium Sized Rivers with Relatively Predictable Flow Regimes* developed in this project provides instruction for the implementation of the biophysical aspects of DRIFT, namely Modules 1 and 3.
The activities required for these two modules are dealt with sequentially as follows:

- Preparation of DRIFT hydrological data (covers preparation of the DRIFT hydrological data, the DRIFT-HYDRO© software, the format of the input data files and the output summary data as presented to the specialists involved in the process)
- Work with specialists – consequence of flow changes (covers obtaining the data for the DRIFT biophysical database)
- Populate DRIFT database and generate initial scenarios (population of the DRIFT biophysical database, generate scenarios linking modified flow regimes to ecological conditions)
- Generating the modified flow regime for each scenario (generate modified flow regime for each DRIFT scenario, summaries included in this section are examples of the hydrological data presented to specialists and the calculations used in DRIFT-SOLVER©).

This Manual was developed because the DRIFT method of environmental flow determination has been in use for some years, and is now increasingly being used outside South Africa. It has become necessary to provide back-up to the method which does not depend on there being an expert present. This manual has undergone extensive review, initially from specialists and a draft of the final manual served as the resource document for the implementation of DRIFT during a comprehensive reserve process funded by DWAF. The DRIFT methodology and associated software will continue to be upgraded and developed. The worksheets and programs provided with this manual are beta versions, and are freely available for use in determining environmental flows. The authors do not accept any responsibility for any errors or bugs they may contain, and will welcome any comments on the methodology and software.

Cost: R287 500
Term: 2003-2004

Environmental water requirements in non-perennial systems
University of the Free State
No 1414

The South African National Water Act (NWA) (Act 36 of 1998) requires that the environmental reserve be determined for each significant water body before water licenses may be issued. Methods currently available for the determination of environmental water requirements for South Africa's rivers are based on perennial rivers, but about two-thirds of South Africa has non-perennial rivers. Non-perennial rivers are more variable than perennial rivers, and may function differently. The non-perenniality makes them ecologically more fragile and so alterations to their hydrology may have far reaching effects. It is, therefore, important that methods are developed to assess the environmental water requirements for non-perennial rivers with acceptable confidence.

Three case studies, at desk top level, (Limpopo, Nylsvley and Kuiseb Rivers) were done to assess the suitability of existing methods for the estimation of environmental water requirements for use on non-perennial rivers. The case studies chosen were among the more data-rich of the non-perennial rivers in Southern Africa.

The categories of non-perenniality proposed are semi permanent (flow for at least 9 months p.a.), ephemeral (flows for between 3 and 9 months p.a.) and episodic (flows briefly after rainfall events). This categorisation enabled the country to be divided into ecotypes, with the episodic area centring on Namaqualand and the Kalahari.

The data, both availability and quality, are discussed in detail for each of the case studies. Hydrology was not available for the Kuiseb (an episodic river), so the full desktop assessment could not be made. However, the Default Ecological Management Class (DEMC) and the Default Ecological Status Class (DESC) were determined, and this was compared with the Present Ecological Status (PESC). This enabled the Attainable Ecological Management Class (AEMC) to be determined and this was used as an input into the hydrological model of Hughes and Munster (1999) and to DRIFT, where appropriate. A number of existing feasibility studies were also reviewed to identify areas where current methods may be refined. The relationship between ground and surface water needs further clarification, as do water quality, and the indicators of ecosystem health, as those used on perennial rivers are not directly applicable. Methods for the estimation of the socio-economic importance of non-perennial rivers to people who depend on them are not well developed.

Cost: R600 000
Term: 2004-2005

Programme 4: Environmental Water Quality

Enteric pathogens in water sources and stools of residents in the Venda region of the Limpopo Province
Dept. of Microbiology, University of Venda
No 1126

A significant proportion of residents in rural communities in South Africa are exposed to water-borne diseases and their complications mainly due to poverty, and lack of access to treated potable water supplies and have to rely mainly on water sources.

The study aimed to determine and document the microbial quality of various water sources in the Venda region, Limpopo Province. The prevalence of various enteropathogens in water sources and stool samples as well as antibiograms of isolates were determined. The frequency or extent of isolation of enteric bacterial pathogens in diarrhoeal cases among infants and adults was also established. Seasonal distributions of the various enteropathogens are reported. Indicator organisms such as total and faecal coliforms, faecal enterococci and somatic coliphage counts were used to determine the microbiological quality of the water sources.

Results obtained showed that the minimum and maximum counts of all the sampling points investigated with regard to indicator organisms ranged substantially and the results for the indicator organisms were higher than the guideline values for safe drinking water stipulated by the Department of Water Affairs and Forestry of South Africa. Enteric pathogens isolated from the studied water sources included *Escherichia coli, Plesiomonas shigelloides, Vibrio, Enterobacter cloacae, Shigella, Salmonella, Aeromonas hydrophila, Aeromonas caviae* and *Campylobacter.* Antibiotic susceptibility results of water isolates revealed marked susceptibilities to nalidixic acid, ciprofloxacin and amikacin. Multi-resistance patterns of various isolates to tetracycline, ampicillin, erythromycin and chloramphenicol were noted.

Antibiotic susceptibility profiles of bacterial isolates from human sources showed that the majority of isolates (over 85%) were sensitive to ciprofloxacin, gentamicin amikacin and nalidixic acid. Multi-resistance patterns of virtually all the human isolates to tetracycline, ampicillin, erythromycin and chloramphenicol were observed.

The untreated water sources used for drinking and other domestic purposes and the multi-antibiotic resistance profiles of the enteric bacteria from these sources are potential threats to the health of residents and therefore call for urgent intervention strategies by government, the community and other relevant role players. The detection of rotaviruses was significantly higher in the winter season and this finding may be strategic for vaccination against rotaviruses. The study further indicated that ciprofloxacin, amikacin and gentamicin are the recommended antibiotics to be used for the treatment of diarrhoea cases requiring antibiotic therapy. Feedback to communities on findings and implications regarding microbiological quality has been initiated and is ongoing.

Cost: R365 000
Term: 2004-2005

Development of a water quality index

for estuarine water quality management in South Africa
University of Johannesburg, Department of Zoology
No 1163

The need for the development of a classification system for estuaries based on water quality has been raised a number of times (Van Driel, 1999) and as a result this study was initiated. The study was focused on choosing appropriate variables that can be used to determine water quality for estuaries, which in this study was referred to as the Estuary Water Quality Integrity Index (EWQII). The main aims of the project were to:

- Develop a water quality index for estuaries that interprets water quality variables in terms of ecological/biological resource protection
- Incorporate the index into a DSS using ARCVIEW as a platform to link to other meta-databases
- Develop the index in such a way that it will contribute towards the classification in terms of the Ecological Reserve requirement
- To integrate the water quality index with existing estuarine index scores through the DSS

The final EWQII, which currently consists of 28 variables, has been developed in conjunction with an EWQII Assessment Category classification scheme that interprets the index value in terms of RDM classification. This objective was successfully met. The products from this project have not been tested outside the project team on other estuarine projects, e.g. EFRs or Reserve studies. The DSS approach to setting water resource management objectives has been applied to the Elands River in Mpumalanga with great success and has drawn expression of interest from SAPPI and CSIR (Pretoria). Presentations have been given to individuals from these two organizations. The theoretical concepts and application of mass balance models to calculate nutrient fluxes, water quality indices and the DSS approach to ecological risk assessment formed part of theoretical models in the B.Sc. Honours (Aquatic Health) and the tutored M.Sc. in Aquatic Health during 2003 and 2004. A total of 35 Honours and 6 M.Sc. students completed the modules successfully.

Recommendations for further research from the project leader
The implementation of the concept of 'optimum' assemblages that represent particular types of estuaries particularly in relation to responses to natural variable parameters such as salinity: Implementation of this function in a management context will entail:

- Classification of morphologically distinct estuaries (which is already available)
- Determination of assemblage status (in terms of proportions of species or functional groups) in these estuaries
- Determining the 'keystoneness' of the species or functional groups
- Assigning classes based on $\Delta_{assemblage}$ calculated from:

$$\Delta_{assemblage} = \sum_i a_i \left| z_i - z_{ref,i} \right|$$

Cost: R515 000
Term: 2000 - 2002

Programme 5: Endocrine disrupting compounds (EDCs) in water sources

The development and validation of bioassays to detect oestrogenic and anti-androgenic activity using selected wildlife species
University of Stellenbosch, Department of Zoology
No 926 and 1253

This report incorporates the results of the following WRC projects:
No 926: An assessment of the extent of oestrogenic activity in Western Cape water resources

Cost: R463 000
Term: 1998 - 2000

and

No 1253: Endocrine disrupting contaminants (EDCs) in South African water resources: Development and validation of *in vitro* and *in vivo* bioassays to detect endocrine interaction and characterize physiological disruption in non-mammalian animals

Cost: R400 0000
Term: 2001 - 2002

During the nineties, after several keystone papers had been published on the potentially adverse effects on human and wildlife health by various environmental contaminants, the endocrine disruption hypotheses soon emerged, stating that: 'Synthetic, and some naturally occurring, chemical substances in the environment are disrupting the normal functions of the endocrine system and its hormones in humans and wildlife'. The first WRC funded project, mainly a literature

review, regarding oestrogen and oestrogen mimicking substances in the water environment was published in 2000 and recommended that screening and testing methodology being developed or optimized, *in vitro* and *in vivo* bioassays, as well as analytical methods for the specific detection of suspected EDCs in the aquatic environment and consumer products.

It was against this background that the WRC was approached to fund basic research on biomarker characterization followed by the development of bioassays using the local animal modes, e.g. the African clawed frog, *Xenopus laevis*, as bio-indicators.
The aims of the two projects were to study the normal reproductive cycles of *X. laevis* and the turtle species, *Pelomedusa subrufa* in order to gain baseline information for comparative eco-toxicological studies as well as to identify potential biomarkers for use in bioassays; the vitellogenin response in the frog, *X. laevis* when exposed to natural and selected xenobiotic oestrogens; to investigate the practical implementation of vitellogenin as a biomarker for xenobiotic oestrogens using either fish, amphibian or turtle model systems; and to develop and validate bioassays to eventually be employed in a battery of bioassays for hazard and risk assessment of EDCs in water resources:

The local aquatic amphibian species, the African clawed frog, *X. laevis* and the widespread local aquatic turtle species, *P. subrufa* was used in a seasonal reproductive biology study. This research programme represents a first attempt to utilize local endemic vertebrate species as bio-indicators investigating the potential of specific biomarkers such as the hepatic produced yolk precursor, vitellogenin (Vtg) to determine environmental oestrogenic activity. It successfully highlighted the use of biomarkers related to the male androgenic system as well as the sex determination and differentiation developmental systems. In addition, the potential of using the functional involvement of the thyroid endocrine gland in the early developmental and metamorphosis programme in amphibians as biomarker system for studying the interaction with the thyroid systems proved valuable.

The bioassays developed and validated through these projects using endemic animal species contribute towards the greater objective to eventually establish a batter of EDC screening bioassays.

THRUST 3: ECOSYSTEM REHABILITATION

Programme 2: River rehabilitation

Development of criteria for the design of fish ladders for South African rivers and estuaries
Pulles,Howard and de Lange Inc.
No 1310

There has been an increase in interest world-wide on promoting the free passage of migratory aquatic organisms. In South Africa there is a growing body of evidence indicating that many fish species migrate various distances both upstream and downstream into more favourable habitats, both as adults and juveniles, at various times of the year for a variety of reasons. Impassable barriers are amongst the causes identified for certain fish species becoming threatened or endangered.

This is the second of three projects addressing very specific questions on the need for fish-ways, their design and location. This report covers the situation assessment of fish-ways (provision, enabling legislation, effectiveness and design). This report has a detailed assessment of design criteria based on the needs of the non-salmonid fish indigenous in the country.

This report also presents an inventory of the known fish-ways in the country, and found 42 of the existing 57 in the country to be functional to some degree.

Monitoring results are described for two fish-ways, the Nhlabane fish-way KwaZulu-Natal) and the Xikundu Weir fish-way on the Luvhuvhu River. A generic monitoring programme has been designed from the work done on these two weirs.

A website has been created (http://www.fishways.co.za/) to ensure that up-to-date information is accessible during this development phase of the work on fish-ways.

Cost: R553 000
Term: 2002-2005

CURRENT

THRUST 1: ECOSYSTEM PROCESSES

Programme 1: Estuarine processes

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

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: 2002-2006

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: R352 300
Expected term: 2004-2005

Programme 3: Wetland processes

A biophysical framework for the sustainable management of wetlands in the Northern Province with Nylsvley 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; Nylsvley 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 Nylsvley 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: 2001-2005

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: R660 000
Expected term: 2002-2005

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: 2002-2005

KSA 2 WATER-LINKED ECOSYSTEMS (CONTINUED)

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

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

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

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

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

Estimated cost: R904 000
Expected term: 2003-2006

Programme 2: Estuary management

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: 2004-2008

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

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 representivity 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: 2001-2005

Programme 4: Environmental water quality

Application of biosensors for eco-toxicity testing of water resources
Department of Microbiology, University of Durban-Westville
No 1286

Microbial biosensors offer advantages over other methods of eco-toxicity 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 eco-toxicity 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: R700 000
Expected term: 2001-2004

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

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

Programme 5: Endocrine disrupting compounds (EDC) in water sources

WRC Programme for endocrine disrupting contaminants (EDC)
Consortium Members: US; UFH; 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 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

An investigation into the occurrence of steroidal hormones (oestrogens) in sewage effluent using biological/biochemical and chemical techniques
CSIR Environmentek
No 1555

Chemicals with endocrine disrupting potential find their way into the environment via use and disposal. A large number of structurally diverse chemicals are suspected to act as endocrine disrupting chemicals (EDCs). One of the groups of EDC contaminants found in the environment is the steroidal hormones (oestrogens). Studies have shown that sewage effluent and surface waters contain the oestrogenic chemicals 17ß-estradiol, estrone, estriol (metabolites of human hormones) and 17a-ethynylestradiol (synthetic oestrogen). Several *in vivo* and *in vitro* biological/biochemical techniques have also demonstrated significant oestrogenic activity in South African sewage effluent and receiving surface waters. As oestrogens may pose a risk to human health and aquatic life, it is essential to screen local sewage effluent for oestrogens, to ensure useful results for risk assessment and management.

The objective of this project is to determine the oestrogenic activity (biological/biochemical tests) and oestrogen concentrations (chemical analysis) in the effluent of selected sewage treatment works.

Estimated cost: R120 000
Estimated term: 2004 -2005

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 cadmium (Cd), a heavy metal, have been implicated in endocrine disrupting activities. Lead (Pb) though not classified as endocrine disruptor is equally toxic. In malarious regions residual spraying of DDT for malaria control purposes is common and allowed by government. OCP residues could get into freshwater systems via storm water erosion (both urban and from agricultural lands). OCPs have been of great concern due to their persistent nature and chronic adverse effect on wildlife and humans. These substances including Cd may affect the normal function of the endocrine systems and can adversely affect the bio-diversity of ecosystem and also have serious implications for human health. Cadmium is also implicated in endocrine disrupting activities. Lead is also shown to be toxic. Zink (Zn) and calcium (Ca) have synergistic and antagonistic interactions with Cd, respectively. Their presence in large amounts could affect the toxic effects of Cd one way or the other.

Water quality criteria for Cd, Zn and Ca, have been set, but have not been established for other EDCs. DDT was detected in streams and some at levels marginally higher than the WHO guideline levels. It is important to widen the scope of the study to get a clearer picture of the pollution profile of waters in the Venda Province.
The objectives of the project are to:

- Establish the use pattern of pesticides in the region
- Compile a list of endocrine disrupting pesticides in use and other potential EDCs and heavy metals (Cd)
- Determine the levels of OCPs and heavy metals - Cd, Pb, Zn, Ca (Ca & Zn because of their synergistic and antagonistic effects on Cd) in major freshwater systems in the region

Estimated cost: R60 000
Estimated term: 2004 -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: 2003-2007

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

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

Development of management guidelines for controlling pest blackflies along the Orange River
Nepid Environmental Consultants
No 1558

The overall objective of this study is to develop practical management guidelines for integrated blackfly control along the Orange River, based on a combination of chemical and biological control methods, and flow manipulation. The specific objectives of this study are to:

- Review the current Blackfly Control Programme in order to identify problems and information needs and to revise the project plan to address the key aspects that are needed to improve the efficacy of the control programme
- Assess the technical and practical feasibility of integrating flow manipulation back into the Blackfly Control Programme.
- Liaise with agro-chemical companies to identify a potential new larvicide to compliment *Bti*
- Screen formulations of the larvicide(s) in small-scale laboratory trials
- To Initiate and undertake a large-scale field trial to assess the selected larvicide's efficacy and impacts on target and non-target organisms
- Present the results as part of an application to register the selected product for blackfly control, should a suitable product be identified
- Quantify the overall costs and benefits of alternative methods of blackfly control, so as to provide a rational framework for a cost-effective and integrated control programme
- Train a selected member of the local community (Mr McPherson) to undertake small-scale laboratory trials of potential larvicides, and to monitor larval populations during large-scale river trials.

Estimated cost: R428 000
Expected term: 2004-2006

Programme 3: Influence of instream-constructed barriers

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

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

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

NEW

THRUST 1: ECOSYSTEM PROCESSES

Programme 3: Wetland processes

National Wetland Rehabilitation Programme Phase II: Wetland Health and Integrity
University of Cape Town, Freshwater Research Unit
No 1584

This is a solicited project, the second of three phases in the National Wetland Rehabilitation Programme, and focuses on the development of methods to assess the health and integrity of wetlands, as this assessment lags behind the assessment of rivers and estuaries, which poses a problem in the environmental water determination process.
There is growing recognition of the important role of ecosystem services provided by wetlands. This project will develop a suite of assessment techniques not only to assess the ecological condition of the wetland, but also the state of the services delivered, in addition to a protocol by which the loss of wetland function through degradation can be measured. Training courses and a communication programme will assist in the transfer of the technologies developed.

Estimated cost: R3 450 000
Expected term: 2005 -2009

Programme 4: Groundwater-dependent ecosystems

Framework development for the sampling, classification and geographical occurrences of stygobiont amphipods in South Africa
University of North West, Potchefstroom, Zoology Department
No 1586

97% of the world's freshwater is subterranean, and there is an increasing demand for the development of this resource to meet the increasing needs of the population. Little is known about the stygobiont fauna or the interaction between underground and surface water. During this project the following aims will be addressed:

- Formulate a framework to characterize the geological occurrences and geographical distribution of the subterranean amphipods using GIS techniques
- Discussion on the applicability of the sampling protocol
- Identifying microbial composition in association with stygobiont amphipods
- Trace of inorganic macro-elements for water quality
- A primary framework development for the characterization

Estimated cost: R1 350 000
Expected term: 2005 -2010

THRUST 2: ECOSYSTEM MANAGEMENT AND UTILISATION

Programme 1: Ecological Reserve

Environmental water requirements in non-perennial systems
Centre for Environmental Management, University of the Free State
No 1587

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.

Estimated cost: R2 737 000
Expected term: 2005 -2008

Development, testing and installation of a real-time Ecological Reserve implementation method for the Thukela River
Institute for Water Research, Rhodes University
No 1582

Previous work on implementing the Reserve has identified the need for suitable hydrological triggers to be used to specify the Reserve flows required in real time. It has also identified some of the limitations of the Regional Offices of DWAF to deal with, and make use of, the Reserve information supplied by the DWAF RDM Office. During the recent Reserve determination on the Thukela River some concepts were developed on how this could be done.

During the project the researchers will develop and test a real time Reserve implementation method, and install the system in the KZN DWAF Regional Office, for application to the Thukela River A manual for the method and training of KZN DWAF Regional Office staff will also be developed. The model will be based on a standard model for which initial calibrations are available for all the quaternary catchments country-wide, so the model will be widely applicable.

The development and application of a real-time Reserve implementation method will assist in the implementation of the NWA on the ground.

Estimated cost: R681 800
Expected term: 2005 -2008

Programme 2: Estuary management

The freshwater requirements of temporarily open / closed estuaries on the South Eastern and South Western Cape coasts
South African Institute for Aquatic Biodiversity (SAIAB)
No 1581

This project is the result of recommendations of a CERM strategic planning meeting held in March 2004 and is a multi-faceted project in order to answer the generic questions routinely posed during DWAF RDM workshops.

The outcome of the research will deepen the knowledge on the functioning of temporarily open and closed estuaries. The results will be worked into estuary management as the work progresses as the team are involved with DWAF and MCM initiatives in estuary management, including determination of the Reserve.

Estimated cost: R1 753 000
Expected term: 2005 -2008

Programme 3: Ecosystem health

Osmoregulation in freshwater invertebrates in response to salt pollution
Institute for Water Research, Rhodes
No 1585

Salinisation is a major cause of water quality deterioration. Current methods for water quality assessment include boundary values for specific salts. Biological data is scarce for most of these salts, and what exists is based on acute toxicity data. This research aims to provide chronic toxicity test data for selected indigenous stream organisms which is biologically relevant for the country. This will be done through physiological experimental research (oxygen consumption and osmolarity) using samples generated during acute and chronic toxicity testing, and evaluating the salt boundary values in the setting of resource quality objectives.

Estimated cost: R2 01 160
Expected term: 2005 -2007

The effects of streamflow manipulation on the intermediate hosts and vector populations of disease and the transmission of associated parasites
Environmental Assessment and Reporting, Institute of Natural Resources
No 1589

An effect of manipulating the flow of a river is that the changes in habitat will result in changes in the occurrence, population dynamics and dominance of organisms in the ecosystem. While many of the effects brought about by these changes are known, one effect which needs more attention is the influence of flow manipulation on the aquatic intermediate hosts / vectors of the diseases. The diseases caused by bilharzia, liver fluke and malaria are prevalent in certain areas of South Africa and within these areas are considered to have important economic consequences, which are manifest in sectors of the economy other than the water sector. The implication of the Reserve process determination on human health has hitherto not been realised or researched. The need to understand the relationships between the environmental Reserve and epidemiology is critical for community household health and regional economic growth. This project will define the intermediate hosts / vectors and routes of parasite transmission in the natural environment for bilharzia, liver flukes, and malaria; describe those streamflow interventions that enable or enhance the intermediate hosts /vector life cycle and parasite transmission; it will assess the low manipulation options for control of the Intermediate hosts / vectors and associated parasites. The project will develop the capability to predict the effect of flow manipulations on the intermediate hosts / vectors and associated parasites and will make recommendations on how stream flow manipulation could be used to manage the incidence of the identified diseases.
The project will be carried out mainly as a desktop study and available data from the regulated and unregulated rivers will be considered. Relevant case studies that illustrate the implications of stream flow regulation for regulation of intermediate host / vector populations and the transmission of associated diseases will be identified for use in this study.

Estimated cost: R400 000
Expected term: 2006 -2008

Programme 4: Environmental water quality

Development of a diatom protocol for river health assessment (continuation of K8/508)
DH Environmental Consulting
No 1588

Increasingly, diatoms are finding their place in the suit of water quality assessment tools available elsewhere in the world. The collection on which this project will be based spans a half-century, and the information that may be gleaned is potentially very valuable. A diatom assessment protocol (DAP) for river health assessment will be developed during this project, and this process will happen in three distinct phases.

In Phase 1 a South African diatom taxonomic identification key will be developed, and diatom images will be transferred from the SA Diatom Collection onto electronic format. In Phase II the DAP protocol will be comprehensively tested to compare it with SASS indices within the River Health Programme, and there will be user training. It will also be linked to a central reporting database by means of a software resource data and information system on ecosystem conditions from the SA Diatom Collection.

Estimated cost: R292 000
Expected term: 2005 -2006

Programme 5: Endocrine Disrupting Compounds (EDCs) in water sources

A seasonal study of the endocrine disruptors in effluent coming from the Kuils River Sewage Treatment Plant, Western Cape, South Africa
University of the Western Cape
No 1590

Sewage effluents have a major impact on aquatic ecosystem health. Several xenobiotics occurring in the environment are known to interact with the development and functioning of endocrine systems in wildlife and humans. Many of these xenobiotics have been known to exhibit oestrogen-like activity in fish, amphibians, reptiles, birds and mammals. One of the most widely used approaches for assessing oestrogenic activity in non-mammalian oviparous species is the development of bioassays for detecting vitellogenin in the plasma of animals. *In vitro* assays have been developed using vitellogenin as biomarker. Vitellogenin induction by *Xenopus laevis* liver cultures and the recombinant yeast assay could be used to detect oestrogen activity in environmental waters. Recently ELISA kits that detect estrone, estradiol and estriol have become commercially available.

The aim of the study is to do a seasonal study to monitor EDCs (oestrogenic contaminants) in sewage treatment plant effluents ending up in the Eerste-Kuils River water catchment system by using the locally produced UniVtg kit for the detection of tissue culture synthesised *Xenopus laevis* vitellogenin and this study will test its reproducibility and reliability for use with the *Xenopus* liver culture assay system.

Estimated cost: R200 000
Estimated term: 2005 -2006

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KSA 3 WATER USE AND WASTE MANAGEMENT

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.

It remains a continuous challenge to provide and supply water of adequate quality and quantity for economic and public health purposes. 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 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 (stormwater, sewerage and on-site sanitation), water-related competencies and capacity

KSA 3 WATER USE AND WASTE MANAGEMENT

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
- Water services regulation

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 and new 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 to commence from 2005/06 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 (incl. sulphate and metals) in industrial and mining effluents
- Training in wastewater treatment plant operation
- Biotechnological co-treatment of industrial / mining effluents with sewage wastewaters

THRUST 4: INDUSTRIAL AND MINE-WATER MANAGEMENT

Scope: The usage of water in the mining and industrial sectors produces high concentrations of wastes and effluents. Some mining activities produce wastes that act as non-point sources of water quality degradation and acid mine drainage. This thrust aims to provide appropriate, innovative and integrated solutions to water use and waste management in the industrial and mining sectors.

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

THRUST 5: SANITATION AND HYGIENE EDUCATION

Scope: This is a new thrust which includes some programmes which were previously 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.

RESEARCH PORTFOLIO FOR 2005/06

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. There is ongoing emphasis in this area 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 grey-water 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

Strategic initiatives of the previous years, together with the consolidation of research and project activities in the year 2004/05, have provided the path for 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. In the year 2005/06 the KSA plans to introduce two new programme areas in the **Wastewater and Treatment** thrust to cover aspects related to stormwater and sewerage, as well as a new thrust area dedicated to sanitation issues. Of these, the KSA has only managed to set up the **Sanitation** thrust. Setting up the stormwater and sewerage programme was hampered due to the lack of the timing in the progress of identifying the research needs in this area. This resulted in no new programmes being initiated in 2005/06.

The plan for 2005/06 will put greater emphasis on technology transfer and consultations with the sector role-players towards further identifying research needs and creating awareness of the strategic research portfolio for the KSA and its thrusts. With regard to the research portfolio the following changes to programmes have been incorporated:

- In the thrust area of **Water Services and Institutional Management Issues** one new programme is being introduced. This emanates as a direct result of the Water Service Research Strategy which identified the following area as priority:
  - **Water services regulation**
- In the thrust area of **Sanitation, Health and Hygiene Education**, the programme on **Social aspects of sanitation** has been dropped. The scope overlaps with the programme on **Rural sanitation and hygiene education** and the social issues will be addressed in this programme in the future. The programme will now be called **Health and hygiene education.**
- In consolidating the portfolio, a few projects have been re-allocated to their correct programme areas.

BUDGET FOR 2005/06

The approved funding of the research portfolio for 2005/06 leads to a committed funding budget of R27 325 000. The focus of this portfolio will continue along the current trend.

NEEDS ANALYSIS

During 2005/06, the KSA in its endeavour towards identifying research needs, as well as developing and improving research strategies at the thrust level, has continuously engaged at a strategic level both nationally and internationally, to identify any gaps and strengthen the portfolio of priority research topics and areas requiring attention. In this regard, a number of small consultancies were awarded and the outcomes will provide the following:

- The state of stormwater management in South Africa
- The state of sewerage in South Africa
- The state of ponding and small systems in South Africa

Added to the above the following strategies were developed during the year that assisted to shape the KSA portfolio:

- Towards a research strategy and agenda to support sanitation delivery South Africa
- Strategy of the health domain will influence activities in the programmes related to drinking water quality and supply
- A research strategy on algal toxins that will cut through the four KSAs to address needs in collaboration with international initiatives.

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

- The EDC research programme, also crosscutting, has been revised and updated to ensure that all relevant issues are addressed.

In reviewing the wealth of information generated through the various processes and some of the incidents such as the typhoid outbreak in Delmas (failure of many municipalities in providing basic services), it is clear that the key challenges facing the water sector in South Africa as identified last year remain unchanged and warrant greater emphasis and support. These being:

- 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 African 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 as follows:

- 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 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
- 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 this need to be managed effectively. Lack of attention over the past few years on O&M, together with the lack of training and capacity is beginning to show its weaknesses in the state of our water infrastructure. This valuable investment if not given due attention could prove costly for the country.

OVERVIEW OF TECHNOLOGICAL TRENDS

At an international level there is a continuous move towards new approaches as to the provision of water services and adaptation of new approaches to improved domestic water quality and improve availability of water through alternative advance technologies. An emerging trend in developing countries is to decentralise the management of services to a local level or to a local government level, with the national authorities moving into a stronger regulatory environment. This shift provides a number of challenges of capacity and competency in the delivery of water services, especially in developing countries when there is the need of 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 African 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 less and less chemicals to the treated water product (Improved source quality). 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. 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 faecal-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 the developed world, there is greater attention and focus being put on managing source quality for improved potable water quality, secondly as desalination technologies become cheaper we see more use of these technologies (Singapore/Middle East are examples). This source of water is also being seriously considered by some South African coastal cities. Further with the concerns of the diminishing levels of fossil fuels, water and waste are being looked at amongst the renewable resources for energy creation. Greater attention is also being given to new promising technologies such as nano-technologies, membranes etc. as they may greatly benefit water treatment technology.

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 that 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 yet to embrace 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.

CORE STRATEGY

STRATEGIC CONTEXT

No major changes with regard to water use have emerged over the past few years, except for the 2004 tsunamis that have raised the importance of how to deal with a disaster and its mitigation.

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

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

population, it is the industrial and mining sectors which play a primary role in the development of the South African economy and hence in development of the country in terms of wealth creation, employment creation and export earnings. Sanitation and wastewater treatment are essential elements of maintaining a healthy environment for our population. Environmentally, the mining and industrial sectors have common features such as an intensive demand on material and energy resources, a major impact on the landscape, a relatively small demand on the national water use and a proportionately much higher pollutant profile. This includes effluents of high concentration, contaminants that are difficult or expensive to remove, and with the potential to degrade large volumes of water, thereby rendering them less fit for other beneficial uses. Effluents from all of these sources arise either as point sources (e.g. piped effluents from factories or sewers) or as non-point sources (e.g. runoff from un-serviced 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 that has resulted in at least half the population of South Africa not having access to safe and reliable water services. The Government has made this the focus of attention since 1994 and great strides have been made in improving this situation. The radical policies and strategies that have been introduced to accelerate and achieve the goal of complete coverage, has in itself generated and posed a number of new challenges on the issue of sustainability of water services.

The costs of providing clean water and sanitation to a fast-expanding and growing economy will continue to escalate. In an environment of increasing resource and financial constraints, coupled with the vision of some for all and the need to redress past imbalances, efficient use of water for domestic, industrial and mining purposes, as well as improved sanitation, would be critical for improving public health, eradicating poverty and contributing to global competitiveness.

To achieve the above more innovative policies and improved implementation, strategies for water use and waste management will be required, supported by a good basis for appropriate technologies, changes in infrastructure approaches and broader water management policies. It is inherent that institutional processes and capacity be in place, supported by sound technologies and methodologies.

Over the past 30 years, the science of water supply and collecting, treating and beneficially using wastewater and stormwater has grown significantly. As a nation we have gone from rudimentary treatment to complex systems involving multiple phases and types of treatment. We have also expanded considerably the infrastructure of collection systems feeding increasingly sophisticated treatment plants. But much still needs to be done. As water and wastewater flows continue to increase, supply and treatment systems must be optimised for better management and efficiencies. This can be achieved not only by increasing infrastructure but by finding new and innovative technologies and processes that will enhance the performance of systems. An example is treatment processes that can target development of new media and increasing treatment flow through. New innovative and appropriate 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 worthy to note that the importance of research and development has also been strongly emphasized. Any major emerging changes are incorporated and absorbed into the current context.

STRATEGIC INITIATIVES UNDERTAKEN DURING 2005/06

NATIONAL INITIATIVES

Ongoing initiatives were undertaken within the thrust areas as a process to update and to identify research needs and strengthen the portfolio of strategic research needs to be addressed over the short to medium term (2 to 5 years). During the year the following research strategies have been developed:

- Research strategy to support the acceleration of basic sanitation provision in South Africa
- Research strategy of the health domain, which has a significant influence on the KSA areas related to water quality, hygiene education, HIV and diseases
- Research strategy to address toxic algal research needs and international collaboration
- Revision, update and expansion of EDC research strategy to areas not yet investigated
- Studies were 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.
- KSA members continue to occupy key positions on a variety of strategic bodies and forums. Examples of these are the, Steering Committee - Waste Minimisation, Water Sector Leadership Group, Water information Network, JASWIC, WISA.
- KSA member appointments include the Chair of the Ministers Water Advisory Committee and the National Benchmarking Initiative
- KSA member volunteered and was part of the South African Tsunami Response team, which was deployed to the Maldives to assist with water supply and sanitation restoration
- KSA developed and presented the concepts of Working for Sanitation, proposal submitted to Minister and DWAF. This input has contributed to the launch of the national sanitation job creation project
- KSA is a key partner and driver of the national component of the Global Review of Private and Public Sector Participation, which will be formally launched in 2006 as funds have been secured
- The KSA facilitated the establishment of the National Water Services Benchmarking Initiative. An MoU signed between DWAF/WRC and SALGA saw the launch and the first conference being held during the year.
- The KSA has successfully secured funding and hosted four courses on Sanitation Planning and Management at different centres in the country. This course received overwhelming response and requests for a repeat have been received.
- The KSA featured on two occasions on SABC-TV: feature on BioSURE and AMD
- KSA members have made a number of presentations on live radio on subjects of priority. Research findings on stormwater/sewerage, attracted about 8 radio interviews and 7 published articles. Another area which enjoyed media attention during the year was that of Acid mine drainage and that of solar distillation, where an international article in Arabic was written on the project.
- The KSA hosted 13 workshops, and partnered 5 national workshops; these form the basis for stakeholder consultation and national initiatives. Note must be taken of three key national workshops, i.e. developing action plans for setting up water quality laboratories; people affected with HIV/AIDS; and determination of research needs to address the national nitrate-in-water problems.

The element of customer/ stakeholder relationship is further enhanced by WRC and its staff representations on a number of important bodies and forums. The WRC and the KSA are represented on the following forums:

- DWAF's Policy Group and Project Steering Committee for the implementation of the Waste Discharge Charge System
- DWAF's Project Steering Committee concerning the development of Best Practice Guidelines for the Mining Industry
- Work Team of DWAF's Project Steering Committee for the implementation of the Waste Discharge Charge System to define approaches to deal with non-point source pollution
- DWAF's Project Steering Committee concerning the development of a Comprehensive Framework for Integrated Water Resource Management in the Mining Industry
- Chamber of Mine's Steering Committee to develop Guidelines for

the Vegetation of Residue Deposits against Water and Wind Erosion
- Coaltech 2020's Surface Environment Committee
- DEAT's Steering Committee to Develop a National Strategy On Cleaner Production and Sustainable Consumption
- Management Committee of WISA's Mine Water Technical Committee
- Management Committee of WISAs Health Related Issues Technical Committee
- Organising Committee of IWA-WISA Diffuse Pollution Specialist Conference
- Organising Committee of IWA-WISA Management of Residues Emanating from Water and Wastewater Treatment
- Organising Committee of the International Ecosan Conference, May 2005, Durban
- Member of the task team to arrange the Gauteng Water Summit held on 13 & 14 October 2005
- Board of WISA
- NTMP and NMMP programmes steering committee
- Management and Steering Committee of the National Benchmarking Initiative
- DWAF Water Services Regulations Steering Committee
- DWAF Water Services Asset Management Steering Committee
- DEAT National Strategy for Sustainable Development.

INTERNATIONAL INITIATIVES

- Ten South African presentations on new emerging and innovative developments addressing drinking water are being prepared for the biennial *Emerging Technologies Forum* held in Switzerland in April 2006. South Africa is one of the leading countries regarding new technologies. All 10 innovations are wholly or partly funded under KSA 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. A report emanating from this exercise was presented during the year.
- The KSA contributed towards 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 accrued to the WRC when a workshop was 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 Dr Gerhard Offringa. Further GWRC initiatives include cooperation in a membrane bioreactor research strategy plan and in a water reuse project. The KSA also participated in the development of the GWRC International Research Strategy to Support Asset Management in the Water Services Sector. The KSA research programme will contribute and provide inputs into the GWRC projects.
- The KSA is participating in an EU - FP6 bid on a sanitation project led by the IRC and form part of the African partner contingent. Progress on this bid is quite promising and the bid has passed the first round qualification.
- The KSA signed an MoU with WEDC, UK, together with a host of African and Asian partners, and as lead agents prepared and submitted a proposal to support and manage DFID's research activities in the area of sanitation. Unfortunately the bid was not successful.
- KSA is the coordinator for the South African contributions to a new European Union project - TECHHNEAU (technology enabled universal access to safe water) EU project to start in 2006. The project aims at rethinking current water supply options.
- KSA was invited on a WHO task team to set up an international collaborative network for small community water management; this was established and the WRC is now a member of the WHO International Group for Small Community Water Supply Management.

AFRICAN LEADERSHIP

- KSA organised and participated in a workshop on future research cooperation between the WRC and the City of Windhoek, Namibian Dept. of Water Affairs, NAMWATER, WINGOC and the University of Namibia. This has resulted in the signing of an MoU for collaboration in research.
- As highlighted the KSA played a role in the organising of two international conferences:
  - WISA-IWA 2005
  - International Ecosan Conference – Durban 2005
- The KSA visited a number of institutions in Mozambique, with the aim of forging partnerships and research collaboration. First discussions with the Mozambican Dept. of Rural Water and the University Eduardo Mondlane in Maputo.

Although great progress was achieved, the KSA has not adequately performed in terms of strengthening its leadership in Africa. We have not managed to secure a joint research project with African counterparts. Experience tells us that this is a slow process and needs persistence.

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

GROWING THE KNOWLEDGE BASE

CAPACITY-BUILDING INITIATIVES

At the end of the year 2005/06, 42 projects were finalised resulting in 38 Masters degrees and 12 Ph.D.s obtained through these projects. A further estimate of 50 undergraduate activities contributed to these projects. In terms of demographics 45 Black males, 31 Black females, 14 White males and 10 White females were involved.

Progress to date on ongoing projects indicates that the number of students undergoing post-graduate training at tertiary institutions under WRC-funded projects in this KSA was estimated as 241 in total. Of the 241 students, 194 students (about 80%) are from previously disadvantaged groupings.

Of the 35 projects finalised to date, has resulted in 35 research reports being published, 17 popular articles, 60 presentations and 19 workshops. On the academic level 7 doctorates, 28 masters and 13 Honours have been achieved and 139 students have been involved of which 76 were reported from the previously disadvantaged background.

The following table illustrates the number of post-graduate students who benefited from WRC-funded research in this KSA and highlights the institutions which are actively involved in capacity building:

Organisation	Total previously disadvantaged students	Total no of students
Arcus Gibb	2	2
African Water Institute (AWI)	1	1
BKS	1	1
Cape Peninsula University of Technology	4	4
C Swartz	10	10
Coaltech 2002	0	0
Council for Geoscience	2	3
CSIR	12	12
Digby Wells and Associates	2	4
Durban Institute of Technology	2	2
Emanti Management (Pty) Ltd	2	3
ERWAT	3	3
Golder Associates Africa (Pty) Ltd	4	6
Human Sciences Research Council	1	1
Independent Economic Researchers	0	0
Institute of Natural Resources	0	0
Mvula Trust	2	2
Nelson Mandela Metropolitan University	0	0
Nemai Consulting	3	3
Partners in Development	2	2
PD Naidoo & Associates	0	0
Proxa	1	2
Pulles, Howard & de Lange	6	6
Rand Water	12	19
Rhodes University	21	24
Sustainable Environmental Technologies	1	1
TBR Project	1	1
Tshwane University of Technology/ Technikon Pretoria	0	0
Umgeni Water	12	14
University of Cape Town	7	14
University of Fort Hare	11	11
University of Johannesburg	5	5
University of KwaZulu-Natal	14	17
University of the North	0	0
University of the North West	3	3
University of Pretoria	5	9
University of Stellenbosch	17	24
University of the Western Cape	13	19
University of the Witwatersrand	0	0
University of Venda	9	10
University of Zululand	0	0
Waterscience cc	0	0
WRP Consulting Engineers	2	2
Zakhe Training College	0	0
Zitholele Consulting (Pty) Ltd	1	1
Total	**194**	**241**

KNOWLEDGE SHARING AND LEADERSHIP

Internal learning, innovation and dissemination are paramount to the WRC meeting its goals. The following are some of the achievements of KSA 3 to date:

- The majority of research results are published in the form of manuals with computer models, guidelines or standard reports. These are disseminated as widely as possible. The number of final reports published at the end of 2005/06 amounted to 38, out of 42 research contracts finalized; 35 projects were finalised as of January 2006. This is supported by 17 popular articles and 60 scientific papers (including conference papers). Progress made during 2004/5 on completed projects realised 38 published research reports and associated with these projects 6 popular articles, 67 scientific papers, publications and conference presentations were made.
- KSA-related adverts were placed in the *IMESA* journal, Commonwealth Local Government Federation yearly publication highlighting the WRC and its contribution to the local government sector.
- KSA-specific exhibitions included :
  - WISA – IWA – Johannesburg
  - International Ecosan Conference - Durban
  - *IMESA* – Mossel Bay
- The KSA hosted the following workshops
  - Two national workshops on the development of sanitation research strategy
  - Five national workshops to determine needs in the stormwater and sewerage subject areas
  - National workshop to develop ToRs for waste as a resource – using drainage water for irrigation
  - National workshop on inventory of water use in industry, mining and energy sectors
  - ToRs for innovative approaches to brine handling
  - Determination of research needs to address the national nitrate-in-water problems
  - EDC strategic planning workshop
  - Workshop on future research cooperation between WRC and the City of Windhoek, Namibian Dept. of Water Affairs, NAMWATER, WINGOC and the University of Namibia
  - National benchmarking workshop
  - A new framework for human health related research
- In addition many research projects are increasingly building technology transfer activities as a key objective in their research methodology. These take the form of popular articles, specialist workshops and web-related promotion activities.
- The following technology transfer actions were undertaken:
  - Interview with *Radio Pretoria* on acid mine drainage
  - Interview for Programme on Acid Mine Drainage for the *SABC 2 Programme 50:50* on 21 June 2005
  - Interview with E*ngineering News* (30 June) on WRC involvement with brine disposal
  - Presentation to Tshwane Municipality on concepts and piloting of shallow sewers
  - *SABC Morning Live* Biosure shoot at ERWAT. Clip aired on 12 September 2005
- The following papers have been presented by WRC staff at international and local conferences:
  - Presented the 'South African and Namibian Situation Report on Water Reuse Research in Southern Africa' at a GWRC workshop in Utrecht, the Netherlands
  - 'Research on the Development of Regional Mine Closure Strategies for Gold Mines'. Presented at the WISA Conference
  - 'Developments in mine water research, presented at the Mine Water Division Conference on Mine Closure'. Randfontein Estates Gold Mine on 6 - 7 April 2005
  - 'Benchmarking, Lessons and Experiences from the WRC Study'. National Benchmarking Workshop, Durban 7 June 2005
  - DEAT-workshop WRC EDC Research Coordination and Experiences
  - 'Quality of Water Resources - Issues and Trends'. Presentation to post-graduate students in Environmental Water Management. University of Pretoria. 12 July 2004.
  - 'Small Community Water Supply in South Africa'. Presented at the WHO Workshop on Small Community Water Management. Alice Springs, 19-22 July.
  - WRC activities on multiple use - IWMI Workshop
  - 'Water Challenges'. Paper presented at the WITS Water Colloquium - 26 Aug
  - 22 Aug - SALGA Benchmarking Workshop, presented paper on WRC guidelines and software to support BM
- The WRC pilot initiative on Benchmarking of Water Services, has during the year received greater priority from the sector. Together with DWAF, SALGA the national initiative was formally launched by the Minister
- Presentations were made to the Parliamentary Portfolio Committee on two occasions
- Eight popular articles have been published on KSA research outputs related to membranes, water losses, wastewater treatment, shallow sewers, stormwater, sewerage and sludge guidelines
- The KSA contributed to WRC Open

Day sessions in Ethekweni and Pretoria
- At an international level, the WRC article headlined: 'Small is Beautiful - and it Works!' appeared in the *Arab News*, Saudi Arabia's largest selling English newspaper on 12 November 2005

KEY STAKEHOLDERS

The following stakeholders continue to be of key importance 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.

IMPLEMENTATION PLAN

RESEARCH PORTFOLIO FOR 2005/06

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 objectives of the KSA remain the same.

The following structural changes, as highlighted earlier have been made within the thrusts, as follows:

- In the thrust area of **Water Services and Institutional Management Issues**, one new programme as planned is being introduced. This emanates as a direct result of the Water Service Research Strategy which identified the following area as priority:
  - Water services regulation.
- In the thrust area of **Sanitation, Health and Hygiene Education**, the programme on **Social aspects of sanitation** has been dropped. The scope overlaps with the programme on **Rural sanitation and hygiene education** and the social issues will be addressed in this programme in the future. The programme will now be called **Health and hygiene education**.

Forty two (42) new projects have been approved for funding, made up of 29 non-solicited and 13 solicited projects. The scope and expected outcomes of the thrusts and programmes are provided in Table 1. Table 2 lists the current research portfolio (ongoing and new projects) for this KSA for 2005/06. Project titles and budgets are grouped under the five thrusts and respective programmes that constitute the project portfolio in the thrusts. Table 3 provides information on the scope and relevance of all solicited and non-solicited projects and programmes selected for funding starting in 2005/06.

The approved funding of the research portfolio for 2005/06 provides the basis for the funding of new projects for 2006/07. In 2005/06 we have continued to put greater emphasis on aspects related to **Water Supply and Treatment and Sanitation, Health and Hygiene Education**. The portfolio has evolved to include a large number of solicited projects across the thrusts. As per last year's processes, we have continued to direct investment to the new emphasis areas, such as sanitation, health aspects, operational issues, stormwater and sewerage research, and have achieved this by reducing investments in traditionally strong areas.

The research portfolio for 2005/06 is presented in **Table 1** which provides an overview and description of research thrusts and programmes.

TABLE 1

Overview and description of thrusts and programmes

THRUST 1: WATER SERVICES - INSTITUTIONAL AND MANAGEMENT ISSUES	
Scope: The efficient functioning of water service institutions and their viability is key to sustaining water services in rural and urban areas. The focus of this thrust is to address strategic research aspects related to policy issues, institutional reform, regulation, infrastructure management,, water-related competencies and capacity required to the strengthening of water institutions (water services providers, water services authorities, water boards, national departments) in providing sustainable water services.	
Programme 1: Cost-recovery in water services	**Scope:** The issue of cost-recovery has been identified as a critical aspect affecting sustainable services. In an environment where genuine poverty affects cost-recovery, this program intends to develop innovative strategies and processes to tackle the problem. The focus will be on generating in-depth knowledge of the problem and testing of new approaches.
Programme 2: Institutional and management issues - Water services	**Scope:** Relationships and partnerships between service providers, both external and internal, are a key to sustainable water service delivery. This program's objective is to generate knowledge and processes that would support this new form of service delivery. Innovative management techniques are a necessity for viable and sustainable water service provision. This programme intends to find innovative solutions to critical problems with the financing and management of essential services such as water supply and sanitation.
Programme 3: Innovative management arrangements - Rural water supply	**Scope:** The focus of research within this programme is to provide support to water service institutions with special reference to sustainable cost-recovery and implementation of the free basic water policy; key performance indicators for monitoring and evaluation of service delivery; guidelines for sound management of water service institutions and development of effective strategies for promoting an integrated approach to rural development.
Programme 4 (New): Regulation of water services	**Scope:** Regulation of water services is important for the sector to achieve improved functioning and performance of the delivery of water and sanitation services, to the benefit of the population. Further, it ensures greater efficiency and improved management of the infrastructure and customers. This programme will support through knowledge creation the development of an effective water regulatory environment.
Programme 5 (New): Impact of Water and Sanitation interventions	**Scope:** The programme will address aspects related to determining and quantify the sociological, economic, technical, health etc. impacts and benefits of 10 years of water supply and sanitation interventions in South Africa. Over the years the government has spent billions of rand to meet the backlogs and substantial progress has been made. However, very little work has been undertaken to quantify the benefits which improved water and sanitation has brought to the communities and the countries. Thus the time is most appropriate to undertake a study of this nature.

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

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 both urban and rural 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 operation and maintenance, affordability and willingness to pay for water services.
Programme 3: Drinking water quality	**Scope:** The programme aims to protect human health by ensuring that water supplies are of acceptable quality and standards. Outcomes include improved analytical methodologies, treatment technologies and hygiene practices.
Programme 4: Water distribution and distribution systems	**Scope:** The programme aims to optimise the quality, quantity and reliability of the distribution and supply of treated, potable water to the end-users thereof. The programme has the following expected outcomes: To develop reliable processes in the predicting and improving the operational efficiencies in distribution systems, with the purpose of reducing both capital and operational costs. To ensure that the quality and quantity of water is maintained in the distribution system - from the water treatment plant to the furthest end user. To develop innovative methods, tools and processes that will improve system integrity and reliability.

THRUST 3: WASTEWATER AND EFFLUENT TREATMENT AND REUSE TECHNOLOGY

Scope: 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 security, affordability and application.
Programme2: Sludge characterisation, treatment, utilisation and disposal	**Scope:** This programme deals with the systematic characterisation, quantification and categorisation of sludge 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:** The programme 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.
Programme 6: Biotechnological co-treatment of industrial / 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: 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: 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.

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

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.
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.
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 operation and maintenance costs for the different sanitation technology choices.

COMPLETED

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

For a long time it has been believed that the solution to the management problem is training, and as a result very substantial sums of money have been spent by DWAF on training community committees to manage their schemes effectively. As projects have moved into the operational phase, it has been realised that training in itself does not ensure that projects will be properly managed. For example, at Nhlungwane, which is one of the better run community water projects in South Africa, the Mvula Trust found on one return visit that the book-keeper had stopped keeping books because the committee never looked at them. The people who make up rural committees are like any other people anywhere – *regardless of how well they know what they should do, they do what you inspect, not what you expect*. The problem is that newly emergent local authorities (the responsible inspectors) still have very little idea of what questions to ask when visiting projects, nor how to ask them - i.e. the inspection needed to stimulate good management is not taking place on any effective level.

There are scores of different key performance indicators (KPIs) that are encountered in government reporting systems. The problem is that these are typically too numerous and varied to help the harried council official who needs to know the answers to simple but critical. The challenge is therefore to develop simple and effective reporting systems, easily understood by rural water committees, which they can be expected to use to report to their own communities, as well as to the relevant authorities. The set of KPIs must pictorially depict trends (good or bad) in strategic areas such as service performance, financial health and accountability. With such a system in place, monthly visits from municipal officials can become more effective occasions for communication, problem identification and problem solving.

In the course of this study a number of monitoring initiatives taking place around South Africa have been reviewed. Some are very ambitious, and some are quite basic. At community level, systems of KPI recording are needed which are simple, practical and effective. In the course of this research a method of KPI recording at community level using standard data sheets and standard charts was tested. These sheets and charts are filled in by hand, which means that it is not essential to have computer facilities to do basic management. It was found that community level administrators could understand and work with this system, although only the simpler KPIs were tried out. With a longer term management commitment, there is no reason why more complex KPIs could not be tackled.

The KPIs that were successfully tested (income, expenditure, water losses, number of taps, energy bill, etc.) were found to be useful in understanding trends in the water schemes being managed. In order to convey the meaning of KPIs, they should be displayed graphically over time. By so doing, trends can be observed, and it can be deduced whether the scheme being observed is stable, getting worse or getting better. Even at the community level administrators should be taught how to record and plot simple but vital KPIs.

Cost: R271 000
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

The aim of the research project was to carry out a review of different approaches (with emphasis on technological interventions) which have the potential to render sustainable water supply schemes, to carry out project-specific technical and economic analysis on identified projects representing an individual approach in order to gauge sustainability and utilisation. And to develop, validate and disseminate the demand-led planning tool that promotes and supports a technically viable approach integrating rural water supply to community activities.

Whilst three approaches were identified, i.e. the on-site generation of chlorine, micro-hydro technology as

well as food gardens, the majority of the work focused on the former two. On-site chlorine generators based on the chlor-alkali process utilises common salt, electricity and water as the only raw materials. Products of the chlor-alkali process are gaseous chlorine, caustic soda and/or hypochlorite. All the by-products from the chlor-alkali process can be sold to generate income for the rural communities.

Some existing schemes with the above themes were either visited, researched, and analysed to determine how they could be made to improve in the objective of ensuring schemes' sustainability.

Cost: R496 100
Term: 2001 - 2003

Programme 3: Drinking water quality

Protocol for surveillance and prospective epidemiological studies of gastro-intestinal health effects due to consumption of drinking water
Published as one of the volumes in the series: *Management of Water-related Microbial Disease* –
Volume 2: *What Causes the Problem?* – What to Do For Water Suppliers *Following* Diarrhoea Incidents
Scientific Services, Rand Water
No 1028

Internationally there is growing concern about the general failure of authorities to understand the public health impact of waterborne and related infectious diseases. The water supplier is responsible for protecting the health of the public by providing water that is considered to be safe. When cases of diarrhoea occur in the community, the public is also very quick to blame the water. Confidence in the quality of the water can then only be restored if the allegation has been investigated to the satisfaction of the public.

This handbook provides practical guidelines on how to conduct such an investigation. The methods and materials are not original, and can be found in many books and publications that abound in the fields of water management and epidemiology. No attempt is made in this handbook to discuss all the issues surrounding the recommended procedures - the relevant literature will provide far greater insight. What sets this book apart is the fact that it pulls together the relevant methodology from traditionally remote disciplines, the methodology that is required to find out whether cases of diarrhoea could be due to water consumption.

The water quality and water treatment data routinely collected by the water supplier form an important starting point in finding out whether the water could be responsible for cases of diarrhoea. This handbook shows how to record and interpreted such routine data appropriately so that they facilitate the investigation.

The target audience for this handbook includes both the water supplier and the district health services, for example the water quality officer and the environmental health practitioner. The successful implementation of the recommended procedures depends on the involvement of both sectors. All water suppliers, however large or small, should take note of the guidelines provided in this handbook.

Cost: R225 000
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

Pressure is on water distributors to supply water that is of the highest quality, free from disease-causing agents at the point of delivery. This task is made increasingly difficult by large and distribution systems where bacteria grow at the pipe and reservoir surfaces, forming biofilms and thereby acting as a zone of re-growth and possible contamination post-treatment. Treatment deficiencies may allow the passage of unharmed or sub-lethally damages organisms. Bacteria in biofilms are orders of magnitude more resistant to a wide range of antibacterial agents, including oxidizing agents such as chlorine. Because biofilms are dynamic, parts are released sporadically. This would pose a possible gastrointestinal threat where the water is consumed and a respiratory threat where aerosols are inhaled, eg. in showers and recreational facilities.

The aim of this project was to gather data on the occurrence and distribution of biofilms of drinking water distribution systems. The prevalence of pathogenic bacteria in biofilms of drinking water distribution systems and containers used for distribution and storage was studied in various locations by two research teams. Biofilms were sampled within pipes in residential buildings, as well as in buckets used for storage in homes. Biofilms were disturbed and a range of pathogenic bacteria quantified using selective enrichment and isolation procedures by

the MPN approach. A selection of presumptive pathogens was subjected to identification by phylogenetic (16SrDNA) analysis. The associated water samples were also analyzed for aerobic heterotrophic count and faecal coliforms.

The survival of water quality indicator bacteria and of certain bacterial pathogens in biofilms in drinking water distribution systems was studied using on-line systems over a period of 18 months. The fate, survival, growth and release of *Salmonella* in biofilms in drinking water distribution systems were studied under simulated laboratory conditions. The colonization and subsequent growth of the *Salmonella* was studied by fluorescence microscopy, and the numbers in the biofilms as well as those released were determined by selective MPN.

Biofilms developed on the surfaces in the three online systems. The results of all three units showed a variable degree of biofilm development based on the heterotrophic bacterial density. Although the water supplied to the residential building was within the target residual chlorine level of the local municipal authority, pathogens were still found on a number of occasions. However, a higher incidence of pathogens identified was in the biofilms at the office building than at the residential building.

Salmonella colonized established multi-species drinking water biofilms within 24h, growing to form micro-colonies within the biofilm. The *Salmonella* was also released from drinking water associated-biofilm into the flow, and was seen to re-colonize elsewhere. Biofilms are a real threat to water quality and can grow even in well-maintained distribution systems. To prevent or minimize biofilm development residual chlorine levels should be high enough to ensure that water is sufficiently disinfected from the start to the finish of the distribution line. Water stored in tanks before distribution should be monitored regularly and tanks cleaned and disinfected regularly to prevent the development of a biofilm on the tank walls.

Cost: R721 800
Term: 2001 - 2003

Programme 4: Water distribution and distribution systems

The optimisation of water and wastewater treatment and supply systems using advanced process control techniques
Pollution Research Group, University of KwaZulu-Natal
No 1387

In order to take proper advantage of the various strategic tools that have been developed to assist in managing resources so that they are consumed with the maximum benefit and minimum environmental degradation, effective control of water and wastewater systems should be exercised. As technological and management systems have become more complex, process control technology has continued to develop rapidly to provide the required capabilities. This project aimed to build capacity within the South African water industry by demonstrating, applying and further developing advanced control techniques for water treatment processes to achieve more integrated management of water and wastewater systems in the industry and to reveal what opportunities exist for enhanced management and operation. In particular, attention was given to the ability of new-generation digital (compared to analogue) systems to take many input variables into account, manipulate many outputs simultaneously, and to do far more complex calculations in the control algorithm itself. The target market ranges through senior management (appreciation of strategic potential), middle management (project identification and management) and engineers (implementers). The project was based on two case studies of advanced control in the water industry, namely control of the chlorine concentration at the exit of Durban's Umgeni-Wiggins waterworks and optimal distribution of water downstream of the waterworks in the municipal reservoir network of Durban.

The study constituted a number of distinct phases, namely computational fluid dynamics (CFD) modelling, compartment modelling, identification, predictive control and real-time programming. These were successfully integrated to produce an adaptive predictive controller which gained acceptance by the operating staff. It was considered that the performance could be further improved by extending the predictive horizon from two to four hours and by increasing the move suppression.

This on-line implementation of advanced control in a water treatment process showed also the potential for further development in this area, especially in cases such as this where long time constants, temporal changes

in behaviour, and a multivariate dependency, make intuitive operator interventions less effective.

In conclusion, the chlorination control study led to a successful application of the technique and the pumping control study demonstrated that real and significant power cost savings could be achieved. The water industry has lagged in taking advantage of such advanced control techniques which are becoming common in the chemical processing industry. Use of these methods shows definite potential for economic and safety benefits, as demonstrated in more accurate/appropriate chlorine dosing (minimising excesses), minimisation of the use of high-tariff electricity, or merely complying with the minimum and maximum emergency levels required in reservoirs.

Cost: R300 000
Term: 2002 - 2004

THRUST 3: WASTEWATER AND EFFLUENT TREATMENT AND REUSE TECHNOLOGY

Programme 1: Biological sewage treatment processes

Evaluation of the anaerobic baffled reactor for sanitation in dense peri-urban settlements
Pollution Research Group, University of KwaZulu-Natal
No 1248

The provision of water and sanitation services to previously unserved communities is a South African development priority. No single technological solution is universally applicable to solve this backlog and a solution for a particular community requires that a range of technologies to be available for consideration. One option or type is the anaerobic baffled reactor (ABR) as a possible technology for the treatment of water-borne sewage. This system was originally developed for high-strength organic loads as found, for example, in agro-industrial effluent. The ABR's particular attributes are that it provides for efficient COD removal, does not require external power and has been shown to be resilient to shock loads (hydraulic and organic loading). The motivation for this project was that, in Durban, it could take approximately 20 years for water-borne sewage to be provided to some of the dense peri-urban communities of the Metro. Because of the lack of availability of water, both for consumption and household use, the wastewater produced from these areas is concentrated. Moreover, the ambient temperatures in KwaZulu-Natal are relatively high. In this context, it was hypothesised that the application of the ABR could provide an immediate solution to the sanitation problem in dense peri-urban areas, where it could be used to treat the domestic wastewater of a small community. The density of dwelling and the topography of these settlements negate the possibility of implementing treatment options such as anaerobic ponds or wetlands.

The ABR is similar in design and application to the up-flow anaerobic sludge blanket (UASB) but requires no special granule formation for its operation. The ABR has alternately hanging and standing baffles, which divide it into compartments. The liquid flow is alternately upward and downward between the partitions. A sludge blanket accumulates by settling in the bottom of each compartment, and the liquid flow is forced through this blanket as it passes under each hanging baffle. Good contact between wastewater flow and active biomass is ensured by this design. In principle, all phases of the anaerobic degradation process can proceed simultaneously in each compartment. However, the sludge in each compartment will differ depending on the specific environmental conditions prevailing and the compounds or intermediates to be degraded.

This project was undertaken to determine the appropriateness of an anaerobic baffled reactor in treatment of domestic wastewater in low-income communities. A pilot ABR was built and operated at two municipal WWTPs and operation in terms of chemical and microbial performance was characterised under a number of different operating conditions. A study was performed in which water use patterns and wastewater characteristics in a low-income community were measured. These data were incorporated in a model to predict the performance of the ABR would perform in a low-income community. Based on experiences with pilot ABR, a series of design, operating and maintenance guidelines were developed for future installations.

The pilot ABR operated fairly smoothly, showing good biological activity in all of the operating periods. Almost all the problems associated with operation of the system were related to the feeding system and peripheral equipment required to sample wastewater from a much larger flow. These included pump blockages, wear and tear on the compressor and pneumatic valve, limitations of the

programmable logic controller (PLC) algorithm and blockages of the effluent pipe at the magnetic flow meter. In a community installation, none of these problems will occur since the ABR unit would be gravity fed, and would treat the entire wastewater flow generated.

The ABR was found to be a robust treatment system, with biological and hydraulic advantages over septic tank systems, and with considerably reduced installation, operation and maintenance costs compared to aerobic or centralised systems. It also provides an option for communities with dry sanitation that aspire to waterborne sanitation.

However, the ABR was not able to treat wastewater to an acceptable chemical and microbiological standard alone. There must be some post-treatment step and appropriate reuse or discharge method implemented with the ABR as an integrated sanitation system, since unpolished ABR effluent is not fit for discharge to surface or groundwater or for direct use in agriculture. As with septic tank systems, the ABR has no intrinsic mechanism for managing build-up of inert solids. Therefore an installation treating domestic wastewater must include a screening and grit removal pre-treatment step, or a maintenance plan for regular degritting of the first compartment should be in place. A key factor in the management of inert solids in the ABR is to educate system users to avoid disposing of unsuitable substances into the wastewater treatment system.

The ABR meets several critical requirements, namely, it does not require energy for operation; requires low maintenance; is compact and could be mass-produced. Several ABRs could service small sub-groups within an area and eventually connect to a sewer system for further treatment at a WWTP. Some limitations of the ABR are: no nutrient removal; and insufficient pathogen removal.

Cost: R1 500 000
Term: 2001 - 2003

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

A wastewater treatment works (WWTP) comprises a sequence of individual unit operations (e.g. primary settling, activated sludge, anaerobic digestion, etc.) which are interconnected, i.e. outputs or recycle flows from one unit operation become inputs (upstream and/or downstream), to another. Due to this interconnection of individual unit operations, design and operation optimisation of any one unit operation must take into account any impacts on other upstream and downstream unit operations, and hence on the WWTP performance as a whole. In order to assess and quantify the interdependencies of the various unit operations making up a biological nutrient removal (BNR) WWTP, and thereby to aid optimisation of overall WWTP design and performance, mass balance models are required to track the materials of importance such as chemical oxygen demand (COD – electrons), carbon (C), nitrogen (N), phosphorus (P), alkalinity (protons), calcium (Ca) and magnesium (Mg). The overall objective of this project was thus to develop, for the entire WWTP, a steady state and dynamic materials mass balance model and computer program for all the materials of importance. Specific aims were to develop an integrated kinetic process model (i.e. a mixed weak acid/base chemical, physical and biological process model in three phases - liquid, gas and solid) for the anaerobic digestion of sewage sludge (as for established activated sludge models), to characterise primary and secondary sewage sludge as an input into this process, to develop a biological treatment simulation model for the intermittently aerated and decanted activated sludge system (common elsewhere for WWTP up to 20 Mℓ/d) for BNR, and to use the model to compare nutrient (N and P) removal performance between continuous and intermittent BNR systems. To provide the input information for these models, experimental work was carried out on the characterization of raw sewage, the treatment of sewage, and the treatment of primary and secondary sludge. In the course of the project two further aims were identified, namely to extend the activated sludge simulation models to incorporate pH as a predictive parameter and to develop predictive steady state and dynamic simulation models for the path of inorganic components (suspended, soluble and gaseous) through a WWTP.

Overall, the project achieved its (extended) aims, with significant contributions to wastewater treatment science and implementation in each of the aspects indicated briefly above.

Cost: R429 000
Term: 2002 - 2005

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

Inadequate sanitation is a leading cause of water pollution and consequently illness in many underdeveloped countries, including South Africa, for example the Eastern Cape Province, where cholera has reportedly become endemic. As modern wastewater treatment processes are often energy-intensive and expensive, they are not suitable for use in these areas. There is thus a need to develop more sustainable wastewater treatment technologies for application in smaller communities. The integrated algal ponding system (IAPS) was identified as a possible solution to this wastewater management problem and was investigated for adaptation to local conditions at the Rhodes University Environmental Experimental Field Station in Grahamstown.

The system was monitored over a period of nine years, with various configuration adjustments of the high rate algal pond (HRAP) unit operation investigated. Under standard operating conditions, the system was able to achieve levels of nutrient and organic removal comparable with conventional wastewater treatment works.

The mean nitrate level achieved in the effluent was below the 15mg/ℓ South African discharge standard, but nitrate removal in the IAPS was found to be inconsistent. Although the system was unable to sustain COD removal to below the 75mg/ℓ South African discharge standard, an average COD removal rate of 87% was recorded, with the residual COD remaining largely in the form of suspended algal biomass.

Previous studies in the Eastern Cape Province have shown that few small wastewater treatment works produce effluent that meets the microbial count specification. Therefore, in addition to the collation of IAPS data from the entire nine year monitoring period, this study also investigated the use of the HRAP as an independent unit operation for disinfection of effluent from small sewage plants. It was demonstrated that the independent high rate algal pond (IHRAP) as a free standing unit operation could consistently produce water with *Escherichia coli* counts of 0cfu.100/mℓ. The observed effect was related to a number of possible conditions prevailing in the system, including elevated pH, sunlight and dissolved oxygen.

It was also found that the IHRAP greatly enhanced the nutrient removal capabilities of the conventional IAPS, making it possible to reliably and consistently maintain phosphate and ammonium levels in the final effluent to below 5mg/ℓ and 2mg/ℓ respectively (corresponding South African discharge standards are respectively 10mg/ℓ and 3 mg/ℓ).

The quality of the final effluent produced by the optimisation of the IAPS would allow it to be used for irrigation, thereby providing an alternative water source in water-stressed areas. The system also proved to be exceptionally robust and data collected during periods of both high- and low-intensity management regimes were broadly comparable.

In summary, the results of the nine-year study have demonstrated reliable performance of the IAPS and its use as an appropriate, sustainable wastewater treatment option for small communities. For producing a treated water suitable for irrigation, some significant IAPS strengths compared to other wastewater treatment technologies are the relatively low capital and operating costs (e.g. energy), stable performance and low management demands. The system should find ready application in the RSA.

Cost: R630 300
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. Since this process is very slow, organic waste tends to accumulate, thereby posing health and environmental risks and leading to odour production. Microbially-derived products for the treatment of organic waste in pit latrines are claimed to control odour and reduce the bulk of the organic material. Although there are several of these products on the market, there was no, or very little, reliable information available on their efficacy. This project therefore aimed to compare the efficacy of these products by conducting laboratory scale analyses and on-site trials.

Information on the available products was obtained from municipalities, enzyme companies and private traders by conducting telephonic conversations, correspondence by e-mail and internet searches. The products were surveyed on the basis of their claimed mode of action and dosage specifications, as well as price. A total of 16 products were obtained. No information on current or past usage could be obtained from government departments or municipalities. Distributors supply to traders and do not maintain records of actual usage. Most of the products are multi-purpose, and only a small percentage is used to treat pit latrines. Due to the variation in pit latrine size (from 400-2 000 ℓ) and uncertainty about the number of people using a pit latrine, it was difficult to make specific dosage recommendations. It was also not possible to determine usage or cost per capita. Suppliers seem to rely on prescribed dosages for septic tanks, and to adapt these dosages for use in pit latrines. Based on dosages prescribed by distributors, the annual costs of products varied from R13.86 up to R3 180 per pit latrine.

Twelve products were tested in small-scale laboratory trials for their efficacy in digesting faeces, in order to identify the 'top performing' products for evaluation in field trials. The effect of the biological products on the biodegradation of faeces was determined.

Cost: R250 000
Term: 2002 - 2003

Programme 2: Sludge characterisation, treatment, utilisation and disposal

Intermediate scale-up evaluation of the Rhodes BioSURE(tm)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

WRC-funded research into the use of complex organics (such as sewage sludge) to support the biological reduction of sulphate in high-volume sources (such as acid mine drainage) has resulted in the development of process innovations and knowledge in such systems. A spin-off of this research by Rhodes University (EBRU) has been an observed difference in the hydrolysis of complex carbon sources (e.g. sewage sludge), which is of potentially major interest to sewage treatment plant operators.

This project undertook a pilot-scale evaluation of the process for hydrolysis (solubilisation) of primary sewage solids and their subsequent treatment in conventional aerobic treatment processes, to quantify (mass balance) the role of sulphur compounds as inventory reagents in the process, to derive design criteria for the process, and to evaluate application opportunities.

Cost: R700 000
Term: 2000 - 2001

Permissible Utilisation and Disposal of Sewage Sludge (edn.2)
ERWAT
No 1453

The first edition of the Guideline on the *Permissible Utilisation and Disposal of Sewage Sludge* was published in 1997. It soon became clear that the objectives with this document had not been achieved and that further clarification and elaboration were required. The WRC appointed consultants to compile an *Addendum* to the Guidelines for this purpose. This culminated in the publication in 2001 of an *Addendum* to the 1997 Guideline document.

In parallel to the development of the *Addendum*, the WRC initiated a research programme to characterise South African wastewater sludge and to better understand sludge disposal practices. The intention with the research initiative was to develop a local knowledge base and a better appreciation of the issues that could form the basis for a comprehensive revision of the 1997 Guidelines.

During 2003 the WRC awarded this project to ERWAT with the aim to develop the 2nd edn. of the *South African Sludge Guidelines*. These guidelines were intended to deal with all wastewater sludge management practices, but with a specific focus on utilisation through application to agricultural land. It soon became apparent that it would not be possible to develop a single set of guidelines that would adequately protect all receptors without unduly stringent requirements. The following series of guideline documents were developed:

- A general overview document that provides general guidance about the management options that are available for the use or disposal of wastewater sludge and help a user to decide on the appropriate option for a given situation
- Guidelines on the legal, technical and management requirements for beneficial agricultural use of wastewater sludge, covering issues such as sludge quality, load, soil and crop requirements

The development of the guidelines consisted in the first place of an assessment and review of the current legislation and international and local literature, which culminated in a technical background document that records the rationale and limits put forward in the guidelines. This was followed by consultation with the regulating authorities and key stakeholders about the acceptability of the proposed rationale and the limitations proposed for the guideline and the drafting of a user friendly Guideline document. It is anticipated that these Guidelines will usher in a new era of cooperation between Government and sludge producers to dispose of sludge in an environmentally acceptable and sustainable manner.

Cost: R 326 400
Term: 2003 - 2005

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

Effluent harvesting and detection of steroidogenic agents by affinity separation
Institute for Polymer Science, University of Stellenbosch
No 1165

The presence of biologically active organic species in water is of international concern. A group of these chemicals is known as endocrine disruptive chemicals (EDCs) as they interfere with the endocrine systems of living species that control a large number of physiological processes. EDCs act as pseudo hormones, oestrogen-mimicking agents, and have been held responsible for the global reduction in male fertility, for example. Their concentration levels in water are extremely low, which makes their detection, isolation and characterisation a very difficult and costly exercise. This project aimed to develop a technique by which biologically active species could be separated from water by way of a recognition system, which is very specific for the species targeted, for example EDCs that mimic oestrogen, a female hormone. Affinity separation, the technology referred to here, is commonly practised in many biochemistry laboratories, but the technique had to be adapted to function on membrane surfaces and with the correct functional affinity groups for selective 'catching' of unwanted components in effluents, such as proteins, metals or the oestrogen and oestrogen-mimicking substances.

In this study the foundation was laid for the non-covalent immobilization of different ligand binding moieties on hydrophobic synthetic membranes. An enzyme (horseradish peroxidase) was successfully immobilized using Pluronic-biotin-avidin ligand binding technology and it was shown that a metal-binding Pluronic derivative could be used to bind Ni as well as histidine-tagged proteins. The last objective, the separation of oestrogen-mimicking agents (endocrine disruptive chemicals) from water was not demonstrated at the time this report was documented. The main stumbling block concerned the expression of the ligand-binding domain of the human receptor for oestrogen, which proved not to be a trivial task. However the soundness of the approach to affinity separation investigated was demonstrated in a number of ways. The progress to date has presented one with tested avenues by which to immobilise the ligand-binding domain of the human oestrogen receptor, which lies at the heart of the EDC detection system envisaged. A good understanding of the affinity separation technology originally envisaged was generated. All the biochemical problems associated with the expression of the oestrogen receptor-binding domain have largely been overcome. This will help to expedite the development of an endocrine disruptive chemical (EDC) recognition tool, once the ligand-binding domain of the oestrogen receptor has been expressed in large quantities by fermentation.

Cost: R1 560 000
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

Aqueous waste streams containing toxic organic compounds are of special interest, since conventional treatment methods such as biological waste treatment can not always be used. Other popular treatment methods are often ineffective. The catalytic oxidation of water containing organic waste has been investigated since the 1960s with varying degrees of success. A major problem associated with this method is the high temperatures and pressures required to improve the activation energies involved. Electrochemical oxidation has become a popular method for treating these wastes, since the applied voltage determines the activation energy and, therefore, the process can often be performed under ambient conditions.

This led to the investigation of a unique reactor system for the treatment of such wastes. The reactor utilises proton-

exchange membrane technology to eliminate the requirement of conductivity in wastewater streams to be treated; thus the membrane serves as a solid electrolyte. Experimental data were obtained by operating the reactor in two different modes of operation. Phenol was selected as model contaminant due to its resistance to oxidation. Typical indicator organisms (*Enterococcus faecallis, Escherishia coli* and *Salmonella*) were used to determine the reactor's disinfection capability. An analysis was further performed to determine the actual physical requirements of a system to make it competitive with existing water treatment technologies.

The results showed that the phenol could be oxidised fairly effectively and that oxidation reaction rate depended on both the flow rate and the current density. It was found that, after four hours of electrolysis, complete destruction of all micro-organisms could be achieved. This was verified by allowing a 24-hour period after each experiment, in which no re-growth was observed. However, from the analysis to apply the technology for a water treatment system, it was concluded that the system developed to date was not economical compared to other water treatment technologies.

Cost: R455 000
Term: 2001 - 2002

On-line removal of organic foulants from membranes by use of ultrasonication
Department of Chemical Engineering, University of Stellenbosch
No 1229

Membrane fouling is one of the main problems encountered in membrane process design and operation. This requires periodic cleaning of membranes, which can add considerably to the overall cost of plant operation, as well as reduced lifetime of the membranes. Ultrasound has been identified as a promising approach to combating fouling in membranes. In principle it can be used on-line and may even eliminate the use of chemical cleaning or alternative measures completely. However, these conclusions have been based on small-scale laboratory studies, which have not taken the economic feasibility of the approach into account. The objective of this investigation was therefore to assess the techno-economic feasibility of using ultrasound on a large-scale to alleviate fouling in membrane filtration plants.

Three ultrasonication systems were used in various configurations with small membrane cells of three different sizes. In the first cell designed to contain flat sheet membranes, experiments were done on flat sheet polyamide reverse osmosis membranes in the ultrasonic bath, where effluent containing $CaSO_4$, $FeCl_3$ and CMC were filtrated. In addition, experiments were done on flat sheet (poly-ether sulphone) ultrafiltration membranes, used to filter lignocellulose decomposition leachate, where sonication was done with both the ultrasonic probe and bath.

It was found that foulants can be removed by ultrasound over a wide range of process conditions, frequencies (from 20 to 100 kHz) and specific power inputs (nominally ranging from 0.5-83 W/cm^2). There are some indications from limited work that relatively low frequencies (20 to 28 kHz) provide the best results. No membrane damage could be observed as a result of ultrasonication. Moreover, it was found that similar results to continuous operation could be obtained by means of intermittent sonication. Experiments have further shown that even better results can be obtained by using ultrasound in conjunction with chemical cleaning of the membranes. Ball park estimates suggest that the costs of sonication are still high and the feasibility of using ultrasound on a large-scale to reduce fouling of membranes depends on the capital cost of the ultrasonic equipment, rather than on its operating cost.

Cost: R286 500
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

In up-flow anaerobic sludge blanket (UASB) reactors, sludge production is dramatically lower than in other digestion processes. The microbiological process consists of a stepwise decomposition of complex carbohydrates and proteins via a consortium of micro-organisms living symbiotically in a sludge 'granule'. Typically, UASB reactors have organic removal rates of over 90% of COD and operate optimally at loadings around 10 kg COD/m^3 reactor volume/day. Unfortunately, one major problem severely limits the efficiency and hence economic viability of this reactor: if the reactor is inoculated with un-granulated anaerobic sludge, start-up times of up to 12 months can be expected. The lengthy start-up times motivated that research be undertaken for an artificial way to cultivate UASB granules and stimulate granule

formation. In a previous WRC-funded project (**Report No 667/1/99** 'Enhanced Granulation in UASB Digesters by Process Induction and Microbial Stimulation') by the same principal researcher, early research using laboratory-scale (400mℓ) vessels proved that, under a specified set of environmental conditions, granule growth can occur in an artificial environment. In the current project, the aims are to design, commission, and optimise bench-scale bioreactors that will generate granulated anaerobic sludge in an incubation period of 20 days, and to indicate and begin determining parameters for the scale-up design of a UASB granule-producing reactor of economically viable size.

This study showed that granules of usable size can be cultivated on a larger scale in 20 days. Methods were developed, and information was gathered on various aspects of the process, from selecting a suitable starting material, to operating principles and lessons learned for accelerated granulation, to guidelines for reactor design and operation and for more accurate quantification of results. The next stage envisaged is scaling up to pilot-plant reactors 10x larger than the bench-scale units developed as part of this study, to provide more confidence in the process before attempting to scale up to a commercial size reactor.

Cost: R235 000
Term: 2001 - 2002

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

In the agricultural industry, the processing of food materials often results in problematic organically-polluted wastewaters. As a prime example, the process of table olive production results in a complex, darkly coloured effluent containing high concentrations of phenolic compounds. The phenolics exhibit antimicrobial and phytotoxic properties, and this, together with a high COD of up to 200g/ℓ, makes the process wastewaters resistant to biodegradation. Current practice of using preliminary anaerobic fermentation followed by ponding has not solved the environmental problem, largely because of the presence of the phenolic components. The main aim of the project was to design, construct and demonstrate a biocatalytic bioreactor for the bioremediation of organic-containing wastewaters, such as olive wastewater, with concomitant recovery of high-value products. Using laboratory- and bench-scale studies, a reactor was developed and studies performed on bench-scale reactors.

In order to obtain the high value ($1000/g) product, hydroxytyrosol, from local olive production brines, a novel supported-solvent membrane extractor was developed. Membrane-supported solvent extraction was successfully demonstrated at laboratory scale and was found to be effective for the extraction of hydroxytyrosol from olive wastewaters. This process was then followed by wastewater remediation in a draught-tube reactor. It was found that, in total, more than twice the extent of wastewater biodegradation could be achieved than was possible in normal stirred flasks. The project team has therefore succeeded in developing a technology to facilitate the extraction of hydroxytyrosol from table olive wastewaters, and then to bio-remediate the residual extracted wastewater. Economic spin-off when bio-remediating the effluent can be enormous. Approximately 1 g of hydroxytyrosol could be obtained per litre of olive brine, leading to very high potential income values for the olive-processing plants. This will stimulate the treatment of this difficult type of effluent and ensure that much lower pollution loads enter the environment.

Cost: R594 000
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

Wastewaters from agro-processing, such as wineries and apple juice processing carry large pollution loads. Anaerobic digestion of agro-processing wastewaters has been successfully employed in the past and has several advantages over conventional disposal methods. Anaerobic digestion is, however, a slow process and not very efficient. The efficiency of anaerobic digestion can often be improved by including a pre- or post-treatment step, and advanced oxidation technologies such as ozonation have been shown to be effective and could offer potential as a combination treatment. The need, however, exists to specifically tailor these technologies for smaller agro-processors and also to the variety of unique and specific food and beverage processing wastewaters. The main aim of this research programme was to investigate the efficiency of utilising combinations of ozone and up-flow, anaerobic sludge blanket (UASB) reactor technologies to treat winery and apple juice processing wastewaters.

This was done on both laboratory and pilot scale equipment.
The use of pre- and post-ozonation steps together with anaerobic digestion, in the form of a UASB reactor, is a technically feasible option to treat fruit juice processing and winery wastewaters. For the winery wastewaters, ozone as a pre- and post-treatment to UASB, using an ozone dose of *circa* 350 mg O_3/ℓ, reduced the COD by 91% while also removing some colour, vs. a COD removal of only 65% using UASB alone. Even better results were achieved by pre- and post-UASB ozonation of apple wastewaters, where 97% COD reduction was achieved. On-site wastewater treatment could produce effluents much lower in COD, possibly below the legal limit of 75 mg/ℓ, and therefore reduce the cost of fines payable to municipal wastewater treatment plants. Capital costs and running costs will vary according to the volumes of wastewaters produced, organic load of the wastewaters and specific composition of the organic load. In general, capital costs would amount to ca. R1.00/m^3 for 10 years, where-after the cost would revert to a running cost of only R0.21/m^3.

This study has provided the fruit-juice processing and winery industries with proof that anaerobic digestion and ozonation can be combined into effective and feasible wastewater treatment processes. When the new, low-cost, local ozonators are employed in conjunction with UASB, this combined process could soon be an economically viable alternative for the treatment of these and similar, problematic organic wastewater types.

Cost: R353 000
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

Oily wastewaters constitute a major environmental problem in many industries. Various systems may be utilized for the separation of oils from wastewater, including coagulation and dissolved air flotation, centrifuges and, now also membranes. In the recent past membranes have been gaining significant popularity due to their high separation effectiveness compared to the other processes. The limits however are the costing and technical challenges (such as fouling) associated with the operations of a membrane system. The aim of this project was to determine the potential application of a locally developed membrane for the separation of oil from industrial wastewater. The second key aim was developing expertise in the operations and management of a membrane system for oil/water separation.

The project was initiated by conducting test cell investigations on various oil/water effluents. Based on these initial investigations three companies were selected for pilot scale trials. A single module capillary ultra-filtration membrane pilot plant was designed and commissioned. The trials were conducted in various operating modes including continuous, with/without back flushing and in-batch concentration mode. The separation effectiveness was determined by using chemical oxygen demand analyses. Initially fouling of the membrane occurred due to larger particles present in the oil. Introducing an online strainer solved this problem.

It was found that the membrane was effective in oil-water separation. During short-term tests, fouling was found to be quite low and not to be a big problem. However, the project team was unable to conduct extended trials to determine long-term membrane life, due to various constraints experienced during the project execution (such as the company where the experiments were run, closing its operations). This project will have a positive future impact on oil removal from water, since much higher efficiencies of oil removal were achieved than currently used processes, but at a reasonable, and controllable, fouling rate.

Cost: R200 000
Term: 2002 - 2004

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 reclamation processes, but organics have become more persistent, and difficult to remove. Examples of organic contaminants found in water supplies include halogenated hydrocarbons such as trihaloethylene, tetraethylene and trihalomethanes, aromatic compounds (e.g. benzene, toluene and phenolic compounds), pesticides, hormones, plasticizers, medications and many others. Conventional water purification technologies such as activated carbon, reverse osmosis, zeolites, and molecular sieves have failed to remove organics to desired levels. Recently, new, nanotechnology based, nanoporous cyclodextrin polymers, have come to the fore to compete with activated carbon in

performance, cost and availability. The aim of the project was, therefore, to synthesize a number of nanoporous cyclodextrin (CD) polymers and test their ability to absorb high priority organic pollutants from water at µg/ℓ levels.

CD polymers were successfully prepared in the laboratory giving a 100% yield of the product. When water samples containing a high concentration of organic pollutant (concentrations of 10 mg/ℓ) were treated, the polymers were not as effective at removing organic contaminants as granular activated carbon. The polymers were, however, extremely effective when lower concentrations (10 ng/ℓ) of water samples spiked with known organic contaminants, including 2MIB and geosmin, were treated. In contrast, the organic pollutants could still be detected after treating the same samples with GAC. The CD polymers can be easily regenerated to original adsorptive capacity and do not saturate quickly. The preparation of the polymers is inexpensive and simple, although still more expensive than activated carbon. It is foreseen that a large potential exists for the use of these polymers in certain niche applications, such as the final polishing of water to high-purity levels for the more demanding uses.

Cost: R450 000
Term: 2002 - 2005

Programme 4: Treatment and recovery of inorganics (including sulphate, 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

A particular area of concern is the release of heavy metals by the industrial sector into sewage streams and natural waters. Owing to the financial value of some heavy metals it is also important to recover these metals from wastewater. Current removal and recovery methods rely on precipitation – which generates a lot of unwanted sludge and makes recovery of pure metals difficult and expensive. In this study, the removal and recovery of heavy metals using the biosorbent chitosan (made from the chitin shells of shellfish) to circumvent these problems is investigated on bench scale. As part of the project, a membrane was also manufactured from the biosorbent and its efficacy evaluated.

It was found that, when using 3mm chitosan beads, a high adsorption capacity of 160 mg/g for copper was obtained, higher than reported values for activated carbon and measured values for ion exchange resins. During adsorption column experiments using a 10 ppm copper solution, at least 550 bed-volumes were processed to a < 1 ppm (WHO limit) effluent solution, in three cycles of adsorption and desorption. The copper could be recovered using an acid of pH = 1, obtaining a copper solution of 1 200 ppm, which could be processed further to recover the metal in its pure form. However, the beads were stable to only 5 cycles, using the high acid concentration. A novel adsorption model has been developed, from which it could be concluded that the chitosan has the largest affinity to copper, followed by lead, nickel, zinc and cadmium. Chitosan formed into membranes or immobilised onto an alumina base proved not to be as successful as the beads. A preliminary cost estimate showed that this technology could be competitive with activated carbon, provided that the beads could be made to tolerate more regeneration cycles than what is the case currently.

Cost: R894 000
Term: 1999 - 2002

Simultaneous water recovery and utilisation of two harmful effluents, fly-ash leachate and acid mine drainage, for production of high-capacity inorganic ion-exchange material useful for water beneficiation
Department of Chemistry, University of the Western Cape
No 1242

The huge quantities of fly-ash (FA) that are produced when low-grade coal is burned in coal-powered utilities, presents a serious disposal problem because the FA itself contains high levels 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 FA leachate simultaneously neutralized these two highly corrosive waste streams. The resultant effluent was approximately neutral and could be further treated by ion exchange and electrodialysis reversal. This project further investigated these reactions with the aim to utilise two harmful effluents

to yield useable water while at the same time producing high capacity inorganic ion exchange adsorbate materials.

Utilization of FA as ameliorant for the neutralization of AMD proved to be feasible. The free alkalinity imparted by CaO and other ash components and the fact that FA has a very high surface area and small particle size made FA a good neutralization agent and AMD ameliorant. Bench scale investigations have shown that the co-disposal process is able to simultaneously neutralize the high acidity and remove a high percentage of sulphates and heavy metals from AMD, in one step. Dissolved solids that are precipitated and removed by this process consist of sesqui-oxides, such as poorly crystalline highly Al-substituted goethite and ferrihydrite with large amounts of SO_4 included in the structure. High surface charges and the potential for high surface areas indicate that these precipitates that are deposited upon ash particles have the potential to act as low-grade environmental adsorbents. The procedure worked best for treating high TDS AMD. Sulphate removal rates achieved were above 90%. Fe, Al and heavy metal removal were often dependent on the final pH, and EC was seen to drop to a minimum at pH ~10. Post process waters were significantly purified, with only relatively low concentrations of some species of toxic elements remaining in solution (e.g. As, B, W and Mo). Moreover, the insoluble, pH neutral, bulk solid residues derived from the co-disposal process may be suitable as neutral and stable fill material.

By further processing, solid residues derived from co-disposed fly ash were successfully used to prepare high-capacity adsorbents such as zeolites via a high-temperature thermal fusion step (zeolites have widespread potential application as adsorbents in water treatment or as catalysts). It has also been demonstrated that it is possible to prepare zeolites under milder conditions with hydrothermal temperatures lower than 100°C and requiring no additional fusion steps. Evaluation of several different and milder process parameters was performed for co-disposed residues for preparation of bulk zeolite adsorbents. Zeolite P was successfully prepared at a synthesis temperature of 85°C over 4 days without a high temperature thermal fusion step. Preliminary tests indicate that these zeolites have a significant capacity for the removal of toxic ions. Hg, Se, B, As, Fe, Mn, Ni were removed to a very significant degree.

This study has thus provided proof of concept that co-disposal of coal-mine derived AMD and FA is a suitable method for the low-cost treatment of AMD, and allows recovery of water as well as the preparation of high-quality zeolite adsorbents by post-process synthesis of solid waste residues.

Cost: R580 000
Term: 2001 - 2003

An investigation of the mechanism and kinetics of bacterial sulphate reduction
Department of Chemical Engineering,
University of Cape Town
No 1251

Acid mine drainage (AMD) from both operational and closed mines constitutes one of the major environmental problems in the RSA and elsewhere in the world, and has been the subject of a significant body of research funded by the WRC over a 15-year period to quantify the existing and potential environmental impacts and to develop appropriate remediation and preventative methods. In a previous project (**Report No. 1080/1/04**), a preliminary investigation was carried out into the mechanisms and kinetics of biological sulphate reduction and metal precipitation in AMD waters, using both experimental work and simulation studies, and with particular reference to but not limited to the WRC-patented BioSURE® process. The work carried out was extended in this project (**Report No. 1251/1/05**), with the broad aims of firstly extending the simple systems considered previously for both metal precipitation and biological sulphate reduction to a more complex operating environment (including mixed metal precipitation, product inhibition and mixed microbial cultures), secondly improving the current simulation model for biological sulphate reduction (by replacing the literature-based kinetics with experimentally-determined parameter values), and thirdly developing an overall model of the treatment process (in which sulphide formed from biological sulphate reduction is recycled upstream to a precipitation reactor to precipitate metals from AMD as metal sulphides).

From the metal precipitation and speciation modelling studies carried out, a general conclusion is that the thermodynamically-based, commercial software packages used to predict metal speciation in aqueous solutions are not suitable for predictive modelling of metal precipitation from a complex stream under conditions where the system will not reach

thermodynamic equilibrium. The experimental studies considered the precipitation of metals (iron, copper and zinc in synthetic mixtures, with each metal at representative AMD concentrations) against sulphide / bicarbonate solutions as well as anaerobic digester overflow from a sulphate-reducing reactor. Efficient iron removal (>98%) was achieved in the synthetic system under a narrow range of conditions, but while the use of digester overflow broadened the iron precipitation range the efficiency of iron precipitation did not exceed 75% even under the most favourable conditions. This may be compared with the one-step ambient temperature ferrite process developed by Morgan et al. (WRC **Report Nos. 1244/1/04 and 1454/1/05**) for ferrous and non-ferrous metal removal from AMD waters, in which very low outlet concentrations of iron, zinc, cobalt, nickel and manganese are achieved in the treated effluent.

In the biological sulphate-reduction aspects of the study, a number of significant conclusions were reached. For sulphate reduction at high sulphate concentrations and with the carbon source in excess, the measured kinetic parameters were shown to give better steady state and dynamic simulations than existing literature data. Over the pH range 6 to 7.5 the major sulphide species inhibitory to the sulphate-reducing bacteria was found to be undissociated hydrogen sulphide (H_2S): an H_2S concentration of 230 mg/ℓ was shown to be inhibitory while an aqueous sulphide (HS^-) concentration of 730 mg/ℓ was not inhibitory in the absence of H_2S. Using molecular probes, the sulphate-reducing bacteria Desulfonema, *Desulfobacteriaceae* and *Desulfobulbus* were found to be dominant in the continuous reactors. Three carbon sources of increasing complexity, viz. ethanol, molasses and primary sewage sludge (PSS), were compared in a feasibility study to assess the effects on the outputs and costs of the AMD treatment process. When savings resulting from reduced disposal requirements of PSS from wastewater treatment were included, the complex particulate PSS was the most economically viable carbon source owing to the large burden reduction at the wastewater treatment works.

The results of this study contribute to the development and further understanding of AMD treatment processes and are expected to be taken up by researchers involved in this area and designers and operators of such treatment plants, with anticipated implementation benefits including process optimization, better design and improved process security.

Cost: R1 146 000
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

In 1996 PHD designed and constructed a pilot plant consisting of a number of experimental reactors for the passive treatment of AMD at Vryheid Coronation Colliery (VCC). These reactors have been in operation since then and have been monitored on a daily basis. By now they are the longest running and most closely monitored passive treatment plants in the world. These reactors followed typical trends with regards to sulphate reduction, where initial sulphate reduction rates are high, coinciding with the availability of readily degradable carbon, and thereafter declining as only the more recalcitrant carbon is left. A technological breakthrough to achieve a consistent high rate over the long term was made when PHD developed the degrading packed bed reactor (DPBR) as part of an Innovation Fund project. The secret of the DBPR is to supply readily available carbon (molasses) to the influent of the sulphate-reducing unit on a regular basis. Through a chain of reactions and by creating the right chemical conditions, the addition of molasses cause the degradation of lignocellulose to become a readily available carbon source. This project aimed to continue to monitor, evaluate and verify the long-term performance of the VCC Pilot Plant, implement enhancement strategies to improve its long-term performance, to develop operational and maintenance guidelines for passive treatment plants and to develop design parameters.

The intensive monitoring of the VCC Pilot Plant improved the understanding of its long-term performance. The performance of the pilot plant was measured against a target sulphate removal rate of 60 g sulphate/ m^3 C· day, that is required to render the passive treatment process economically viable. A preliminary maintenance guideline has been implemented and evaluated. It was found that maintenance could be performed fortnightly and should include the replenishment of the readily available carbon, setting of flow rates of splitter boxes, sampling of the passive treatment plant, checking for blocked pipes and general maintenance.

Preliminary design criteria for the construction of full-scale passive treatment plants have been developed. Kinetic column studies form the basis of developing the design criteria. Optimal operating conditions for sulphate reduction is determined using site-specific carbon sources and the actual mine water. Various other design criteria need to be taken into consideration including hydraulics, topographical gradient, etc.

When comparing the older VCC sulphate reduction units with the DPBR results, it is clear that the new DPBR technology has moved the efficiency of the sulphate reduction process to a higher level. The use of the rapid breakdown kick-start carbon source (molasses) has also indicated that it is effective in increasing sulphate reduction for the older sulphate reduction units that were no longer achieving the required performance.

Cost: R600 000
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

Groundwater, particularly from South Africa's gold mining operations, has a high calcium sulphate scaling potential. The Slurry Precipitation and Recycle Reverse Osmosis (SPARRO) process was developed in the early 1980s with the primary objective of desalinating water with a high calcium sulphate concentration. The process uses tubular cellulose acetate membranes in a seeded slurry system and showed early promise in solving the difficult membrane scaling phenomenon. However, problems with fouling, corrosion and membrane damage were experienced and many questions remained unanswered – leading to the requirement for this project. The aims, therefore, were to expand the fundamental understanding of the operation of the SPARRO system; to develop specifications to control the crystallisation on the membrane; to develop design specifications for membrane selection and to define the critical operating parameters for the SPARRO system, in order to render the system a viable treatment option for this type of water. Laboratory studies were executed to modify crystal structure and longer term runs on a membrane system were done to confirm laboratory studies and establish membrane fouling and damage under different crystallisation conditions.

An extensive understanding of the crystallisation aspects of the process and gypsum crystal behaviour has been developed. Design specifications relating to the crystallisation parameters of the system have been determined, based on the critical operating parameters for the SPARRO system. The Project Team has succeeded in establishing and modifying the conditions required to produce optimum crystallisation and platelet crystal forms (in stead of needle-like shaped) in order to minimise both fouling and membrane damage. Models that relate seed volume and super-saturation or sulphate: calcium ratio to gypsum morphology in pure solutions, have been developed and preliminary relationships also established for some real mine waters. These results present a quantum improvement in the knowledge required to operate membrane treatment successfully on scaling mine waters and the technology developed will play a significant role in the early use of membranes in the treatment of this, very problematic, effluent type.

Cost: R822 000
Term: 2002 - 2005

Modelling of metal ion removal from AMD
Dept of Civil Engineering, University of Cape Town
No 1454

Acid mine drainage (AMD) impacts negatively on freshwater resources in the mining areas of South Africa and many other parts of the world. AMD waters are characterised by low pH, high iron concentrations, significantly high concentrations of non-ferrous (mainly heavy) metals, and very high salinity, principally in the form of sulphate. The common approach to the removal of dissolved metals from AMD is to oxidise the ferrous iron to ferric oxide-hydroxide end-products, which then precipitate and settle. A novel one-step Ambient Temperature Ferrite (ATF) process for the removal of metals from acid mine drainage was previously developed and patented (WRC **Report No. 1244/1/03**). In this follow-on project, the same group of researchers undertook further research to better characterize and quantify aspects of the process and to) test the capacity of the process for removing non-ferrous metals from AMD waters.

In the one-step ATF process, lime is used to raise the pH to 10.5 so that ferrous (Fe^{2+}) ion present in AMD precipitates as a 'ferrous intermediate'

(FI) which is then oxidized to magnetite (Fe_3O_4). For this reaction to occur, magnetite seed and a threshold FI concentration are required. Magnetite contains Fe in both divalent and trivalent forms, and magnetite formation therefore requires that the oxidation rate of ferrous to ferric does not exceed the rate of incorporation of the ferrous iron into the crystal structure. If the oxidation rate is too high, ferric-only oxides are formed, an effect exacerbated by the presence of calcium. It was found that magnetite formation in the presence of calcium requires a high magnetite seed concentration (~20 g/ℓ), a threshold FI concentration (~1 700 mg/ℓ,) an oxidation rate (8.5 mg/ℓ min) and an ageing period (3 hours). High FI concentrations are easily maintained by a contact stabilization reactor - settler sequence whose further advantage is the early separation of the metals-containing AMD stream from the bulk AMD volume, resulting in significantly smaller infrastructure needs.

Magnetite is known to accept non-ferrous metal ions into its crystal lattice during its formation, and can thereby remove both ferrous and non-ferrous metals from AMD. The ATF process was successfully tested in this regard, in the presence of calcium, for Co, Ni, Zn and Mn, with an ageing period of 24 hours, and 100% removal of Co and Zn was observed. Ni and Mn removal steadily increased as the process moved towards steady-state with respect to these metals.

The ATF process developed during the course of this research has several advantages over the currently deployed High Density Sludge (HDS) process. Some of the major advantages of the ATF process are:

- In the ATF process, the volume of AMD requiring treatment is immediately reduced by 60 to 70% in the contact stabilisation reactor - settler sequence significantly reducing infrastructure and energy costs. In the HDS process, the entire AMD volume must pass through the entire reactor sequence and precipitated solids (generally > 80% water) are recycled from 10 to 30 times.
- No polymer flocculating agents are required, unlike in the HDS process
- The ATF process requires only air for oxidation, unlike the HDS process where pure oxygen is sometimes required to ensure an adequate oxidation rate
- The final ferrite sludge consists mainly of high-quality magnetite, a valuable product worth more than US$110/t. Magnetite is used in coal preparation plants for the washing of coal and in steel mills as a feed substance.
- If desired the process can be modified such that following the contact stabilisation reactor – settler sequence, the concentrated adsorbed solid metal intermediates can be re-dissolved and the metals recovered separately by other means.
- Operation of the ambient temperature ferrite process is technologically simple, with only a minimum of process control requirements (pH and aeration rate).

The one-step ambient temperature ferrite (ATF) process can operate on any scale, e.g. for treating large AMD flows or smaller industrial waste streams containing dissolved metals (even if iron is absent). In view of its potential for improving water quality in appropriate applications, in South Africa and abroad, the ATF process has been patented jointly by WRC and UCT, and is licensed to a South African consultant for marketing internationally (contact WRC for details).

Cost: R360 000
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

Several industrial processes generate waste materials containing manganese in some form. Manganese is considered a hazardous material, with a hazard rating of 2 according to the minimum requirements of DWAF. The waste hazard rating is assessed with the TCLP and acid rain tests. Experimental work on 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. There is thus a risk that some wastes may have higher classifications than is required

for the protection of the water resource. This project aimed to establish 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. Pyrometallurgically generated wastes were used to develop a generic approach to the management of inorganic manganese-containing wastes.

A comprehensive literature search was undertaken to provide the theoretical background on manganese chemistry, its behaviour in the environment, its toxicity and to investigate alternative hazard assessment methods. A number of pilot trails were conducted and samples collected of the off-gas dust under a variety of process conditions. Other industrial examples of this dust were also obtained. Together with the use of inorganic manganese standards in various solid forms, these samples were then characterised and compared. Each was subjected to a variety of leaching procedures (batch and column) and solutions to investigate the impacts on manganese mobility and what controls it. The effects were quantified and modelled.

Based on these results the authors proposed a revised classification methodology to assess the hazard rating or risk posed by manganese containing wastes. With this system, waste with an unacceptable risk at the lowest level of assessment, is subjected to a more advanced assessment by using tools and procedures that progressively increase in their level of effort and sophistication, until a level is reached where it is clear that the waste either has an acceptable hazard rating (disposed to general landfill) or not (disposed of to a hazardous landfill site).

It was found that a number of process conditions in the smelter process influence the solubility and the form of manganese found in the scrubber dust. This ultimately affects its bio-availability and potential hazard to the environment. Process conditions can thus be manipulated to obtain a desired result. It was found best to store manganese-bearing wastes under oxidising conditions that result in formation of stable manganese-bearing minerals. The levels of manganese leaching from wet reduced scrubber dust samples are reduced when treated with lime or calcite (best).

It is thus concluded that inorganic manganese-containing wastes cannot all be classified into one category. The predominant form of manganese found in the waste plays a significant part in assessing its risk potential. The impact of other trace metals and the chemistry over the long term also need to be considered and this is not always accurately reflected in existing classification methods. This project concluded that the current methodology applied to the classification of manganese containing wastes is inappropriate as it does not consider the mineralogy and kinetic aspects of the waste in question. It is therefore recommended that the existing methodology be revised and that the technical process described and presented in this report be implemented.

Cost: R297 100
Term: 2002 - 2003

Programme 3: Minimising 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

The co-disposal of hazardous wastes with general wastes in sanitary landfills has been practised in many overseas countries, especially in drier areas which have a perennial water deficit. In South Africa this has not been widely implemented, due to various reasons. A research project was negotiated between the Cape Metropolitan Council and the WRC with the objective of developing practical operational criteria for the landfill co-disposal of selected hazardous wastes with general wastes. This could assist smaller landfill operators where only general waste landfills occur and where small volumes of special wastes must be disposed of.

The Coastal Park landfill, constructed in 1985 without a containment liner, situated on the False Bay coastline above the Cape Flats aquifer, with an average separation of 2 m between the base of the waste pile and the water table, forming a 'buffer' zone was selected for the study. It was envisaged that the calcareous sand in this buffer zone and encroaching sea water would attenuate leachate discharged from the site.

Five experimental cells were constructed in which hazardous wastes could be co-disposed and from which leachate could be collected for monitoring. Cell 1 was constructed during March 1986 (control). Cells 2, 3, 4 and 5 were constructed in a line during August 1987, each with a 14 x

14 m HDPE sheet at the base draining via a pipe to a collection sump. The sheets were overlain with 2 m of sand and 2 x 2.5 m layers of refuse were placed above the sand. The final surface was covered with a 500 mm layer of sand. Every effort was made to simulate the usual sanitary landfill procedures when placing the refuse.

The most striking finding of these studies was the small amount of leachate that found its way to the base of the cells, on average 2.5% of the annual rainfall. It would appear that rain water was absorbed and mostly held by the landfilled-general wastes, subsequently being drawn back to surface by capillary action, where it evaporated during the course of each year.

Seasonal variations in leachate flow rate were evident to varying degrees in all cells and an average lag of two months between early winter rainfall peaks and leachate peaks, but late in the rainy season the response to rainfall was more immediate. There was no evidence of breakthrough of any of the applied hazardous waste chemicals or soluble tracer salts over a period of 7 years. The total masses of chemicals found in the leachates were a very small percentage of the applied amounts and sampling of the wastes underlying the cells showed that most of the co-disposed substances had remained within the waste.

To more fully utilize the experimental cells, a proposal was submitted by the Cape Metropolitan Council for an extension of the project at the Coastal Park landfill to research the effects of increasing the moisture absorption capacity of the waste body by increasing its height and the contract term of the project (1998 to 1999) was initially extended by 2 years. When it became apparent that the processes being studied were of a rather long-term nature, the contract period was extended again and eventually ended in March 2004. This allowed a full five-year period of study and observation.

It was found that the leachate flow from the experimental section of landfill was down to 21 mm/yr at the end of the experiment. This is not only within the maximum leakage rate through a liner, permitted for municipal solid waste landfills by the South African Minimum Requirements (1994) of 30 mm/yr, but is of a similar order to measured leakage rates reported for geo-membrane linings, of up to 16 mm/yr. The results also illustrate that apart from a small portion of the infiltration that appears to transit and exit the waste by flow through macro- pores and channels, most of the infiltration is stored in micro-pores and then re-evaporated. The water balance studies clearly indicated, both from the water balance study and the leachate quality study that the landfill is slowly drying out, and this may eventually stop the leachate flow.

Cost: R544 000
Term: 1994 - 2001

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

The concept of a PRB is relatively simple. Reactive material is placed in a subsurface structure to intercept a plume of contaminated groundwater which flows through the barrier under its natural gradient, thereby creating a type of passive treatment system. As the contaminant moves through the reactive material, reactions occur that transform it to less harmful or immobile species. International research has shown this technology to be a cost effective alternative to more traditional treatment methods. In view of the fact that groundwater in South Africa, contrary to the case for most of the international experience, occur relatively deep and in secondary rather than primary aquifers, this project was undertaken as a proof of concept study to assess the application potential of PRBs under local conditions, to determine at a laboratory scale, the efficacy and efficiency of PRBs in the removal of inorganic and organic contaminants, to identify those local conditions to which this technology is most applicable, and to identify further research and development needs.

From the lessons learned in other countries in terms of the design, installation, monitoring and efficacy of PRBs, the study concluded that South African conditions provide unique, although not insurmountable, challenges to the use of PRB technology. The laboratory component of this study focused on the potential to use PRBs to treat an inorganic radionuclide and biodegradable organic contaminants in water.

The inorganic component of the research included a small but comprehensive modelling component. From the close fit between modelled and experimental results it was

concluded that the chemical processes in the column are well understood. A pH of around 8 was found to be the optimum for operating a zero-valent-iron PRB that would simultaneously ensure a high rate of ferrous (dissolved) iron removal and reduce clogging of the PRB by gelatinous ferric precipitates. In practice these conditions are found in a dolomitic system, where bicarbonate acts as a natural pH buffering agent. Pore structure and dynamics play an important role with respect to treatment efficiencies.

The organic research component indicated that although the generally colder, *in situ* temperatures of groundwater environments, will tend to lower the microbial activity rates, many types of organic contaminants, including petroleum-based contaminants, can be successfully reduced (degraded) by micro-organisms (at rates of 90% plus) in what could be called permeable bio-reactive barriers. None of the tested compounds were recalcitrant and accumulating.

This study did not reach an unreserved endorsement and recommendation regarding the potential use of PRBs in the South African environment. Instead, the report provides a thorough and comprehensive review of tools developed internationally that can potentially be used to deal with the unique challenges to implementing the technology under South African conditions, such as dealing with deep groundwater environments. This provides a solid platform for the potential future research projects that were identified.

Cost: R1 900 000
Term: 2003 - 2004

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

Good water management is a critical issue in the water-scarce South African industrial context. Industrial processes often require water with a range of qualities, and produce various effluents also ranging in quality, which allow the possibility of a hierarchical use of water. **Process integration** is a holistic approach to process design, retrofitting and operation which seeks overall eco-efficiency in a multi-process system. **Water pinch analysis** is a process integration tool, adapted from pinch analysis techniques originally developed for optimal design of heat recovery systems and subsequently applied to water-using systems. The methodology involves a set of systematic, formal, mathematical techniques to handle the complex problem of hierarchical water allocation to a multi-process system involving multiple contaminants, and identifying the desired (e.g. most water-efficient or most cost-effective) strategy involving wastewater recycling and reuse (with or without intermediate treatment). The theory is still developing, and practical applications are not that well established, particularly not in a South African context.

This report follows on and complements WRC **Report No. 851/1/03** entitled *The Application of Pinch Analysis for the Rational Management of Water and Effluent in an Industrial Complex*. The earlier report set out the literature, general theoretical background and methodology, together with some practical guidelines, for applying water pinch analysis to an industrial system, and presented some case studies as practical examples. The present project report presents additional case studies, with some further theoretical developments. Broad conclusions drawn about water pinch analysis as a technique included:

- To tackle the full optimisation of all aspects of a process it is usually desirable to break up the problem into more manageable sub-problems in which, for example, pinch analysis can be used to optimise the thermal and/or water utility systems in the process.
- The case studies repeatedly showed that the historical pressure to conserve water in South Africa means that water-saving measures have already been introduced in many industries, i.e. that 'easy' savings reported in the literature are often not available under local conditions.
- Some theoretical difficulties in adapting pinch analysis from energy to water were encountered. These revolved around the quality of water being a more complex concept than the quality of energy (uniquely represented by temperature), the consequent complexity of defining appropriate boundary conditions for water pinch analysis, and the difficulty in separating physical and economic effects in water pinch analysis (unless quality regeneration is excluded as an option). Significant progress was made during the study towards resolving or at least understanding these

difficulties, including possible re-definition of the pinch concept as being the set of all constraints which are active at the optimum.
- The case studies ranged in complexity from single-contaminant to multi-contaminant analyses, with the latter in fact verging on full process optimisation. A generally logical approach concluded was to commence with the simplest scenario and to proceed to more complex and time-consuming levels only if justified by the simpler-level results.
- All the case studies resulted in a number of possible strategies being identified for improved industrial water management, on a case-specific basis

Cost: R1 603 000
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

Previous WRC **Project No. 973** carried out by the UND-PRG was very successful in establishing the feasibility of waste minimisation (WasteMin) clubs as a model for achieving significant improvements in environmental performance by local industry. In this multi-stakeholder approach, the (sometimes contradictory) interests of industry, regulatory authorities and affected communities are constructively combined. Two pilot WasteMin clubs established in the Durban metropolitan region (one in the metal-finishing sector and one cross-sectoral in a major industrial area) has to date led to the establishment of a third metal-finishing WasteMin club in the Cape Town metropolitan area (by others), more than 30 other WasteMin clubs nationally (also by others), and the adoption of the WasteMin Club concept *inter alia* into the DWAF/DEAT National Waste Management Strategy, a current Cleaner Production Initiative by the Western Cape DEAT, and the practices of the National Cleaner Production Centre (Pretoria).

The main aim of this follow-on **Project No. 1171** was to develop a methodology for promoting, managing and sustaining waste minimisation clubs, by producing *inter alia* guides for effectively establishing and managing WasteMin clubs, specific sectoral self-assessment guides, and training material for WasteMin consultants in a franchised operation. The main conclusions reached were:
- That the success to date of WasteMin clubs formed by WRC and others showed the value of the concept
- Stronger governmental support was required for further growth, to roll out the support already given to the concept in National policy
- That this project had developed and outlined a strategy for achieving this

The main technology transfer products produced from the project were a *Facilitator's Manual* and a *Training Manual*. The Facilitator's Manual is aimed at a person or organisation that wishes to initiate a waste minimisation club and requires guidelines for undertaking such a project. It addresses aspects such as how to form a club, call meetings, determine the level of contributions from companies, identify some of the problems that can occur, and explains the various roles of the people involved. It also provides sample letters and presentations, and provides sources of information. The *Facilitator's Manual* draws on the experiences gained in the previous WRC **Project No. 973** and also that gained from facilitators of other waste minimisation clubs in South Africa, facilitated by various organisations such as consultants, university researchers and, in at least one case, by the company itself as an in-house club. In summary, the research products from this project provide a practical and comprehensive guide for establishing, managing and sustaining WasteMin clubs in the RSA, along with detailed information and material for facilitating and training practitioners in such clubs.

Cost: R882 000
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

Good water management is a critical issue in the water-scarce South African context. Different water users, e.g. industrial processes, often require water with a range of qualities, and produce effluents also ranging in quality. This allows the possibility of a hierarchical use of water, with the overall goal of reducing the amounts of water used and wastewater generated, without detrimentally affecting the processes concerned. Options are the direct reuse of water from one operation in a different operation, with or without intermediate treatment (regeneration), or regeneration and recycling back to the same operation. Water pinch

technology, adapted from pinch analysis techniques originally developed for optimal design of heat recovery systems and subsequently applied to water-using systems, is a methodology for optimising the ways in which utilities (e.g. energy or water) are used for a variety of purposes. An inventory is made of all producers (sources) and consumers (sinks) of the utilities and then an optimal scheme of utility exchange between these sources and sinks is systematically designed. The pinch approach sets water-use targets and also recommends network design changes which maximize the reuse of water or energy. The theory is still developing, and practical applications are not that well established, particularly not in the RSA.

In this project, the pinch analysis approach was used to assess the water-saving opportunities in a water-stressed catchment. The application of pinch technology to a multi-sectoral and multi-user application over a large-ish area is relatively novel. The case study selected was the Grootdraai catchment, which DWAF has indicated will soon experience severe water shortages as domestic, industrial and agricultural water use increases. The specific objectives were to develop an inventory of water users and wastewater generators in this catchment and to develop and apply a water pinch technology model that optimises the water use and wastewater re-use in the area. The major users in the catchment draw their water from the Grootdraai Dam (capacity 364 x 10^6 m^3 and include water for irrigation, two power stations, two municipalities, the Sasol industrial complex and an informal township (total annual demand 203x10^6 m^3).

Application of the pinch model developed showed that in principle all the wastewater of the different users could be reused, thereby reducing the demand on the dam. The inflow to the dam would also be reduced, as part of the wastewater is currently released above the dam. A spread-sheet calculation showed that the wastewater can be allocated to the different users without infringing on their quality requirements in terms of maximum inlet total dissolved solids (TDS). All individual users could take a part or all of the total wastewater but without defining further constraints in the model, e.g. the cost to transport the wastewater or additional costs for treatment by the user, there was no preference to allocate the wastewater to a specific user. It was noted that the study catchment may not be representative for other catchments; only a small percentage of the inlet water is released as wastewater, due to the presence of industries that evaporate most water as part of their processes, and that high-TDS water is not returned to the surface water of the catchment, but becomes part of ash disposal sites.

The major overall conclusion reached was that the differences between a catchment and a process plant situation (for which pinch analysis was designed) are significant, and that considerable changes would likely be required in order to use a water pinch model for catchment modelling. Some factors are the variable and numerous sources in a catchment, the effects of groundwater and its movement and the effects of evaporation and transpiration. Other limitations noted were that pinch analysis does not allow for the differences in distance and altitude between 'processes' and that the optimised network solution is thus idealised and not necessarily practicable or cost-effective. Further development of pinch analysis for catchment applications would need to take account of such factors, an aspect which the researchers have noted.

Cost: R281 800
Term: 2001 - 2002

A life-cycle assessment of a secondary water supply
Department of Chemical Engineering, University of KwaZulu-Natal
No 1252

The overall objective of this study was to determine the environmental burdens in an urban context, as measured by an environmental life cycle assessment (LCA), for a terrestrial pathway of the water cycle, i.e. from the abstraction of water from rivers, through treatment, distribution, collection (after use), treatment, recycling and disposal, all of which are aspects of the human-modified water pathway which do not occur in the natural water pathway. A simplified LCA (considering only global warming) showed that most environmental impacts from the construction and operation of the dam are from the operation stage rather than the construction stage; most of the social impacts (negative and positive), however, traced back to the construction stage.

The LCA results were applied to a number of different scenarios as test cases. Two scenarios were the provision of potable water to 200 000 new customers in an urban environment with water-borne sewage and in a peri-urban environment with on-site sanitation. The options analysed were

maximising use of existing assets, recycling water and building new infrastructure. A further option analysed was to provide bottled water for drinking. The LC impact scores calculated for both the urban and peri-urban scenarios showed that the most environmentally friendly option was water recycling, then maximising the use of existing assets, then constructing new infrastructure. The use of bottled water for drinking carried the highest environmental burden. Overall, the use of LCA as a tool for defining environmental impacts and developing appropriate solutions has been demonstrated. The results of this study can be used to evaluate any South African water and sanitation systems that are based on similar processes to those investigated.

Cost: R1 239 000
Term: 2001 - 2003

Programme 5: Improved ability to predict and quantify effects

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 coal-field in Mpumalanga is the most important coal-mining area in South Africa. Large open-cast and underground mines have been developed over an area of approximately 40 000 km^2. This coal-field is 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 which will alleviate the situation. This project aimed to extract available and relevant information from all previous investigations, generate new information, and consolidate this into a report that could assist mining companies, individuals and government departments to improve their understanding of processes and consequences relating to groundwater management in collieries.

The approach followed for this investigation was to select six case-study mines in the process of decanting, or where decanting was imminent, for detailed study. They cover the range of conditions encountered so that other mines should find some similarity to their own current situation(s). Management options for water in the coal-mining industry usually revolve around the execution of a series of well-planned mining strategies; the end result of which is supposed to lead to minimisation of water volumes and salinities. Such strategies should be implemented during and after mining. In the case of this investigation, only the 'after mining phase' could be addressed because the mines have already ceased operations.

Mining methods and mining geometry were found to play a decisive role in the amount of water to be managed during and after mining. While only 1% of rainfall flowed into deep underground board-and-pillar mines with no subsidence, ingress increased to 6 to 15% of rainfall for long-wall mining and 14 to 20% for open-cast. Mine scheduling is one of the most important water management tools to be considered from the outset of mining and throughout the life of a mine. New mines or new development in a mine should be planned so that natural compartments are created in which excess water can be stored while mining continues in other areas. The filling up of mines with water is inevitable after closure and a large proportion of the collieries will eventually decant water onto the surface. Plans to manage the decant must be in place. Many of the larger collieries extend over several catchments. Through proper planning, catchments could be selected into which water can be allowed to decant. The interconnection of collieries may be considered to channel mine water to specific points for treatment or utilisation, rather than having numerous small uncontrolled decants into streams. No significant variation exits in the geology, mineralogy and geohydrology of the area. Mine-water chemistry was found to be controlled by mining methods, and an increase in the base potential of the groundwater to the south. This explains the acid character of the mine water in the north and the alkaline nature of the water in the south. The daily rate of sulphate generation in open-cast mining is 5 to 10 kg/ha· d, compared to 0.4 to 2.7 kg/ha· d for underground mines. The lower rates in underground mines are mainly due to less available reactive surfaces. Flooding of collieries as soon as possible after mining is one of the best management tools. This activates the base potential of the remaining coal and excludes oxygen from the coal seam horizon. Flushing of mines once they are flooded is inevitable. While this could improve the water quality in the mine, it reduces the available base potential of the mine as a whole.

Management options for dealing with mine water at each of six collieries have thus been identified and evaluated. From this, sufficient conclusions could be drawn to ensure that mistakes are not repeated. These results should serve as a guide to develop strategies and procedures with typical projected results for mine water management in the Mpumalanga coal-field.

Cost: R843 000
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

Mineralogy plays a controlling role in the formation of AMD. Mineralogy describes, *inter alia*, whether and in which quantities the acid producing sulphide and acid neutralising minerals are present, how reactive they are, their spatial distribution and ease of weathering. The underlying hypothesis of this project was that this kind of knowledge would enable improved predictions of the occurrence, seriousness and long-term occurrence of AMD. The objective of this investigation was to gain a qualitative understanding of the mineralogy of the coal measures occurring in the Highveld and Witbank coal-fields. The project focused on the identification of minerals occurring in coal, the understanding of the distribution of these minerals among the various coal seams and the lateral distribution patterns of minerals within coal seams. They also tried to establish the relationship between the mineralogy of the coal and the associated water quality.

Samples were collected from the Nos. 1, 2, 4 and 5 coal seams, as well as their roof and floor lithologies in both the Witbank and Highveld coal-fields. Because of the complex nature of coal, specialised analytical techniques and interpretation had to be used for the mineralogical determination (e.g. XRD on low-temperature ashed coal proved to be more accurate in identifying minerals that occur as rare constituents, i.e. < 5 modal per cent).

The mineral components in coal were expressed as a percentage of the inorganic constituents. Minerals detected in the XRD patterns were semi-quantitatively evaluated in terms of dominant (>40% of the mineral fraction), major (10-40%), minor (2-10%), accessory (1-2%) and rare (<1%) constituents. The inorganic fraction consisted primarily of dominant quartz and kaolinite, and sometimes even dominant pyrite, calcite and dolomite. The latter three were almost ubiquitous in the coal. The Ca-phosphate mineral, crandallite was detected in the western region of the Witbank and Highveld coal-fields. Although only present in low concentrations, fluorapatite was detected throughout in the Witbank coal except in the extreme north-eastern region, but not from the Highveld coal.

Chemical analyses confirmed the mineralogical interpretations. Inorganic components make up approximately 8 to 35 wt% of a coal sample. SiO_2 concentrations varied between 0 and 35 wt% of a sample, Al_2O_3 between 0.5 and 16 wt%, Fe_2O_3 between 0.03 and 10 wt%, and S between 0.15 and 8 wt%. Minor concentrations of CaO (0 to 8 wt%) and MgO (0 to 1 wt%) were present. P_2O_5 occurred in concentrations of 0 to 3.5 wt% and K_2O was in the order of 0 to 1.3 wt%. Na_2O values were the lowest varying between 0 and 0.45 wt%. The only difference in chemistry between Witbank and Highveld coal was a slight increase in Na_2O (0 to 0.51 wt%) in the Highveld coal.

Two types of screening criteria were used to determine whether acid or alkaline conditions would prevail once all acid- consuming and acid-producing minerals had been oxidized. From the NNP (net neutralizing potential) it can be predicted that the No. 5 and 4 coal seams and the unit between No. 2 and No. 4 coal seams will be predominantly acidic. The NNP of the other units was so small that they could go either way. The unit between the No. 1 and No. 2 coal seams is the only unit with a positive NNP. However, its magnitude is so small that it could still become acid. The ratio between neutralising and acid-producing potentials (NP and AP) is less than 1:1 for all stratigraphic units (except between No. 1 and No. 2 coal seams) suggesting that acid conditions will dominate. The ratio between No. 1 and No. 2 coal seams is at least 3:1 implying that enough buffering capacity is available to counteract the AP. AP and NP are largely dependent on the presence of pyrite and calcite, respectively. Good correlations were obtained between NP and CaO% and AP and S%. It is thus possible to use mineralogy to predict these factors. It should also be remembered that since these predictions do not take time and weathering rates into account, the predictions hold only for ideal situations.

A significant amount of useful mineralogical information has been compiled during the course of this study. However, the interpretation of the available data has not yet been optimized.

Cost: R580 000
Term: 2001 - 2003

THRUST 5: SANITATION, HEALTH AND HYGIENE EDUCATION

Programme 1: Health and hygiene education

Strategies to ensure sustainable effective disinfection in small municipal water distribution systems
Department of Biochemistry and Microbiology, University of Fort Hare
No 1391

This study evaluated a combined-monochloramine disinfection process for the inhibition of bacterial and biofilm re-growth in a laboratory-scale system. The emphasis was based on the maintenance of an effective residual disinfectant throughout the water system. The bactericidal effectiveness of the process relied on coliforms, heterotrophic plate count and total bacteria. The study aimed at ensuring sustainable effective disinfection in a small rural water supply of Alice in order to improve the quality of potable water in the rural community and to make significant progress toward compliance with bacteriological quality standards at the point of consumption.

The results of the study revealed that a combined chlorine-monochloramine process resulted in a longer residual monochloramine that could be detected up to 7 and 28 d in groundwater and surface water respectively after using initial free chlorine of 2.5mg/ℓ followed by 1.5 mg/ℓ initial monochloramine. While coliforms persisted up to 3 and 28 d in chlorinated surface water and groundwater respectively, complete elimination of coliforms occurred within 1 d in the combined chlorine-monochloramine water system. A combination of chlorine and monochloramine was found to provide an effective treatment for the inhibition of bacterial growth and biofilm formation in the laboratory-scale-unit as long as monochloramine concentrations persist to *ca* 0.2 and 0.35 mg/ℓ in groundwater and surface water systems respectively. Less than 1 bacterial count (viable or total cells) was detected in combined water systems and on the surfaces of piping materials (cement-based materials and plastic-based materials) exposed to the combined chlorine-monochloramine water systems. Chloramination as a second disinfection process for inhibiting bacterial growth in drinking water system was statistically proven to be the safest water purification process.

Cost: R355 000
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

Sub-project: No 1400 A: The development of *Risk Communication Guidelines*
Environmentek, CSIR

Water-related microbial diseases such as cholera and diarrhoea cause untold misery in communities across South Africa every year. As part of the effort to promote awareness and understanding of the conditions promoting infectious disease transmission, water service providers are increasingly required to have a risk communication programme in place.

This guideline document presents the 4th in the five- volume series aimed at addressing the question of how best South Africans can protect themselves against water-related microbial diseases. It provides a framework of principles and guidelines for the communication of health risks, specifically for water service
providers.

Communicating with the pubic is an essential element of health risk communication. Ineffective communication often results in conflict, which in turn leads to the erosion of public confidence, and inefficient use of water service providers' resources. The recognition that people are entitled to make decisions about issues that affect their lives can assist water service providers in forming a better understanding of, and formulating more appropriate reactions, to a particular risk. Appropriate risk communication not only promotes consistency and transparency in arriving at and implementing risk management decisions, it also fosters public trust and confidence in the safety of the water supply.

The report is published under the series: *Management of Microbial Water-related Diseases: Volume 4: How dangerous is the problem? Communicating the Risk.*This document will assist water service providers, government departments, water boards, municipalities and catchment management agencies in communicating with the public when a water quality issue arises that could have a potential impact on health. In this way, the guide will hopefully make a significant contribution protecting the most vulnerable communities against water-related microbial disease.

Cost: R184 000
Term: 2002-2005

Sub-project No 1400C: Development of a child- centred course for teachers to promote basic health and hygiene in rural communities.
Lenehan Consulting

Children have the capacity to actively promote health and hygiene campaigns within their communities. In most countries, the education system is the broadest channel for health education. With this in view, it would seem that any programmes which target children as change agents in rural communities must involve schools and the community at large. This research project aimed to facilitate the development and implementation of health and hygiene programmes on a local level in rural communities and included the development of child-centred course materials that can be reused by educators and adapted for other rural schools.

A literature review of international and local initiatives and case studies relative to child-centred health and hygiene awareness promotion was done and lessons learnt from previous studies were incorporated into the development of the materials including the need for an integrated approach. It was recognised that input from educators in rural schools was imperative and a Preliminary Baseline Survey was developed. A draft health and hygiene awareness programme was developed. Initial piloting of this draft programme was undertaken at the three schools. A questionnaire was included with the draft programme to encourage comments from educators on the draft programme and the piloting process.

The Health and Hygiene Awareness Programme developed in this research project is based on the lesson plan format and is ready for use for by rural school educators. It consists of 10 lesson plans and is designed for learners aged from 6 to 8 years. The aims of these lesson plans are to provide an appropriate format for successful health and hygiene programme for lower primary school learners. Resources to support the lessons were chosen that are typically available in rural schools or relatively easy to substitute, acquire or replicate (e.g. paper, pencils, crayons, plastic bottles). The resource sheet 'Germs' was designed to be easily photocopied and intentionally included images acquired in the internet public domain to avoid copyright infringement.

This research project has reaffirmed that the demand for health and hygiene awareness material in rural primary schools is very high. It is recommended that strong emphasis is put on developing relevant programmes.

Cost: R167 000
Term: 2002-2003

The effectiveness of water and sanitation awareness programmes in informal areas
Nemai Consulting
No 1523

The overall goal of providing sanitation services is to promote health and the quality of life for all, with an emphasis on the need for sanitation projects to include health and hygiene education because improved facilities without an effective health and hygiene education and awareness programme have no impact on the improvement of health. The most significant impact on the prevalence of disease stems from behavioural changes resulting in improved hygiene. Without behaviour change, only improved water quality and quantity will reduce the prevalence of disease. The objective of this study was therefore to investigate the effectiveness of sanitation awareness and education programmes (SEAPs) in informal settlements in reducing the incidence of disease.

The project focused on a range of awareness creation and education techniques that may be utilized in SEAPs, and the effectiveness of these techniques. Seven SEAPs across South Africa were reviewed as case studies and included in the study. From previous research it is apparent that community involvement and the PHAST approach are essential for a successful and sustainable SEAP. However, although most SEAPs use PHAST tools, the concept of PHAST where a community is responsible for identifying their health and sanitation problems and implementing their own solutions is not usually fully realised. Often PHAST tools are simply used as effective education tools, while a pre-designed solution is implemented.

The study found that:

- Sustainability is a major problem. Most SEAPs are run as part of a larger sanitation service provision project and when the construction of toilets is complete the SEAP ends too. People from the area where the project was implemented and who have been trained and employed as Health Promoters are no longer active as educators after the implementing agent has left. Their skills and knowledge may not remain in the community in informal settlements as the turnover of residents is high.
- Officially the responsibility for health and hygiene education passes

over to the Department of Health, but most often the DoH fieldworkers have not been intimately involved in the SEAP and will simply continue to do the same work that they always were doing in that area, with no specific focus on the issues that the SEAP was concerned with. In the same way, any person who has been reached by the SEAP may move to a different area at any time, and be replaced by someone who has not been educated on the use and maintenance of the sanitation service in the area. This applies in some degree to any residential or township area, but is aggravated in informal settlements, which are often only a short-term home for residents. Thus the temporary nature of informal settlements is hindering the sustainability of SEAPs.

- There is a perception that there is an unwillingness to pay for services in informal settlements. This is not necessarily true, and a contribution from each household towards improved sanitation facilities is an important part of creating a sense of ownership towards the facilities.
- Given information and imbued with knowledge, the people in informal settlements have the capacity to organise themselves to change their own situations. A high level of commitment and initiative is shown in areas where people have been empowered with knowledge about hygiene and sanitation issues. This is in line with the PHAST methodology and means that the success of an SEAP is not dependent upon the continued presence of the implementing agent. A project where the SEAP is run by the community itself is infinitely more sustainable than one where the impetus for educational activities is temporary and controlled by the implementing agent.

Cost: R200 000
Term: 2004 - 2006

Programme 2: Peri-urban sanitation research

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

The Strategic Framework for Water Services (2003) directs that water and sanitation programmes should be designed to support sustainable livelihoods and local economic development. The directive is framed by the following statement: 'The provision of water supply and sanitation services has significant potential to alleviate poverty through the creation of jobs, use of local resources, improvement of nutrition and health, development of skills, and provision of a long-term livelihood for many households'.

If basic sanitation services are central to development in poor communities in informal settlements then current approaches focused on infrastructure delivery will not meet the challenges of the growing sanitation crisis in burgeoning informal settlements. Most of the current infrastructure delivery approaches are not able to integrate the components of health, infrastructure delivery and effective pro-poor community partnerships in any meaningful way. Moreover, capacity in support organizations is often lacking.

Based on the investigation of sector approaches, development sector lessons and the development and a capacity review of the cases studies, the following principles were developed as fundamental to integrated programme design and capacity for the provision of sanitation services and developing a process to improve service delivery. The study covered the following aspects:

- Assessing capacity for Integrated programme delivery
- Improving capacity for integrated service delivery

In response, two tools were developed. A review table incorporating the integration and capacity principles was developed as a rapid capacity assessment tool. Subsequently a detailed programme assessment tool based on the review table was developed to specify the knowledge requirements, to record the organizational information especially the tacit knowledge and therefore provide structure for the planning of improvements.

Based on the application of the review table and the assessment tool the following process is proposed for planning improvements. Guidelines drawing on the experience in the development and application of the review table and the programme assessment tool, the steps and outputs outlined were used as the framework for the development of the guideline for the application of the project findings.

Cost: R550 000
Term: 2003 - 2005

CURRENT

THRUST 1: WATER SERVICES – INSTITUTIONAL AND MANAGEMENT ISSUES

Programme 2: Institutional and management issues - Water services

Sustainable development indicators for urban water systems: Case study 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

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: R1 500 000
Expected term: 2003 - 2006

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 head- loss, 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 and 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

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

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

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

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 through examining: i) the knowledge of consumers regarding purified water and the purification system, and ii) their attitudes towards purified water and a purification system will further be determined. 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

Inflammatory potential measurement as a supplement to health-related microbial water quality assessment
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: R500 000
Expected term: 2003 - 2006

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
Expected term: 2004 - 2006

Methods manual for monitoring phytoplankton and cyanobacteria
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

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

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

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 project 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 to relate this to erf size, number 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 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

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

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

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: R500 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

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 project 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 characterisation, treatment, utilisation and disposal

Scale-up development of the Rhodes BioSURE™ process for sewage sludge solubilisation and disposal
Department of Biochemistry, Microbiology and Biotechnology, Rhodes University
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 LC50 calculations and not on experimental values. This project will determine and quantify the composition of organic pollutants in sewage sludges. The investigation will also test and suggest the best method(s) of handling and determining these pollutants, so that uniformity can be introduced among the various producers and government laboratories. It is intended to use the same sludge samples that are being used in WRC **Project No 1283** so as to reduce cost.

Estimated cost: R580 000
Expected term: 2002 - 2005

An investigation into the pyrolysis of sewage sludge
Department of Chemical Engineering, Technikon SA
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

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

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

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

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

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

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 project 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 project 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 and mining effluents

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 metalliferous 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

Investigation and development of the biotechnology of sulphur biofilms in the beneficiation and treatment of wastewaters
University 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 TDS be finally removed from the treated stream, but effective sulphur removal remains a technological bottleneck in these processes. This project 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 project 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 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

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

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: R3 000 000
Expected term: 2003 - 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

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 project 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

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

Improving the performance of covers for the rehabilitation of coal-mine residues
Golder Associates Africa (Pty) Ltd
No 1350

A joint WRC-Coaltech 2002 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 on 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

Stability and neutralisation capacity of potential mine backfill material formed by co-disposal of fly ash and acid mine drainage
Coaltech 2020
No 1458

The disposal of both fly-ash and acid mine drainage (AMD) presents 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: R420 000
Expected term: 2003 - 2005

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 mining 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 physico-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-dependent 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 metalliferous 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

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: R686 050
Expected term: 2003 - 2006

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

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 coal-field in Mpumalanga is the most important coal-mining area in South Africa. While this coal-field makes a significant contribution to the economic development of the country it is also the source of potentially the most serious water quality problem facing the region over the longer term. There is thus an urgent need to develop and test tools with which to predict the progression of acid mine drainage (AMD) over time, and to develop, test and apply management options that will alleviate the situation. This project, together with **Project Nos 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

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

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: R913 500
Expected term: 2003 - 2006

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

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

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: R300 000
Expected term: 2003 - 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 project 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
Human Sciences Research Council
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

Programme 2: Peri-urban sanitation research

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 un-researched 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: R820 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: R520 000
Expected term: 2003 - 2005

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

NEW

THRUST 1: WATER SERVICES – INSTITUTIONAL AND MANAGEMENT ISSUES

Programme 1: Cost-recovery in water services

A study of the sustainability of current WSA financial arrangements, including an analysis of how the equitable share is being applied to water services, and the impact of the transfer of water schemes on the viability of Water Service Authorities
Palmer Dev Group/Cape Town Office
No 1609

The project aims to highlight possible problems in current water subsidy arrangements (WSAs) and understand the impact of the transfer of water schemes on the viability of WSAs, and thus developing a model to assist WSAs in determining their viability. The study will utilise a very practical and applied methodology to understand the problem area of subsidy use by local authorities. At present there are no guidelines and support to assist LMs on subsidy use and *ad hoc* decisions are being taken which could lead to long- and short-term problems. The use of the equitable share and the adequacy is a determining factor for the sustainability of the water sector and meeting of targets.

Estimated cost: R207 040
Expected term: 2005 - 2006

The development of models to facilitate financial sustainability of water services provision by Water Services Authorities in rural areas, based on an investigation of full costs and income
Mvula Trust
No 1614

This project aims to establish the real costs and income for providing water services in rural areas, using learning and applied research methodology of engaging and mentoring five WSAs. The identification of the costs and the model will further assist with good budgeting from all tiers in government and will contribute to some standardization.

Estimated cost: R370 000
Expected term: 2005 - 2007

Programme 2: Institutional and management issues - Water services

Water services franchising: An innovative approach to water services delivery in rural and peri-urban areas
Umgeni Water
No 1610

The project aims to assess water franchising for delivery of services in peri-urban and rural areas. The concept proposed is a very new and innovative subject area. The study builds on outputs from a completed scoping exercise, which recommended that the principles and concepts be further established and proven, which would then allow piloting and implementation much more attractive. The concepts will contribute to wider participation of small scale entrepreneurs in the management of water services.

Estimated cost: R600 000
Expected term: 2005 - 2007

Interactive mechanisms for WRC research to support municipal water services knowledge management
Sigodi Marah Martin
No 1611

The project aims to assess the extent to which WSAs access, integrate and apply knowledge to determine the current capacity of WSAs to access, integrate and apply information. The aim is to establish a roadmap for customer driven dimension to knowledge transfer and management at WSA level. This project is fresh and innovative, and tackles the subject of what is the uptake and level of transfer of knowledge at LG level.

Estimated cost: R622 000
Expected term: 2005 - 2007

Programme 3: Innovative management arrangements - Rural water supply

Best practice institutional and project guidelines based on national and international experience to manage the impact of gender in the South African rural water sector
Council for Geoscience
No 1612

Over the past 10 years a lot of emphasis has been afforded to the aspect of gender in the provision of water and sanitation services both at a local level and international level. In fact, it has become a requirement in many initiatives and has become part of policy and legislation. Yet, with all these requirements is progress being made. This project aims to understand the impact of gender on the management of rural water supply and the effects of decentralization of services. Are these new arrangements supporting gender mainstreaming? This is what the study will be highlighting.

Estimated cost: R600 000
Expected term: 2005 - 2007

The state of community consultation in the provision of water services
Sigodi Marah Martin
No 1616

It is imperative that in a changing institutional environment the concepts of community involvement are not lost. As water services authorities take the helm of service delivery, it needs to be ensured that the community aspects are not lost. This study will look at the level and status of community consultation on a range of water services issues. It will aim to identify typical problems areas and successes and come up with recommendation for improving community participation in the sector. This will be of importance to the sustainability of projects, but also to the regulation of water services. This study will undertake a qualitative and quantitative survey to determine the level or status of community consultation.

Estimated cost: R700 000
Expected term: 2005 - 2007

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Programme 1: Drinking water treatment technology

The defouling of membranes by moving magnetic dipole polymer beads, containing nano magnetic particles, in a scouring motion across the membrane using external magnetic fields
University of Stellenbosch
No 1592

Fouling of membranes remains the main problem preventing the large-scale and economic use of membranes in more applications internationally. Various chemical, hydraulic and ultrasonic membrane-defouling methods have been investigated, with varying success. This project aims to investigate nano-technology for the *in situ* defouling of membranes. Nano-magnets will be incorporated into small polymer beads and the magnetic fields in all of the nano-magnets inside the beads will be aligned. Movement of the polymer beads on the surface of the membrane will then be induced in order to scour the surface, which will hopefully clean and prevent

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

fouling on the membrane surface. The resulting system will be evaluated on a typical coloured surface water purification application.

Estimated cost: R794 000
Expected term: 2005 - 2008

Development of improved local anti-fouling spiral wrap membranes
University of Stellenbosch
No 1593

This work will build onto the ongoing research in innovative defouling methods investigated at the Institute for Polymer Research at the University of Stellenbosch. These local innovations, as well as appropriate international developments, will be incorporated into a locally manufactured spiral wrap membrane. A number of trial membranes will be produced and bench-marked against existing membranes. Guidelines for the manufacture of these improved spiral membranes will be provided to the South African membrane industry.

Estimated cost: R720 000
Expected term: 2005 - 2008

The generation of design parameters for the use of the limestone teeter bed reactor for potable water stabilisation and the treatment of Cape coloured waters
RG Batson
No 1594

The project entails the further development and assessment of an improved limestone reactor for the treatment and stabilisation of coloured surface water. A fluidised bed reactor is required when using limestone, since colour and metals in surface water tend to coat the surface of limestone particles, rendering the reactor inefficient after a relatively short operating time. This patented system aims to overcome the disadvantage of fluidised bed reactors in terms of unacceptably high energy consumption, while still ensuring the required scouring action of the limestone particles in order to keep them from becoming coated. The technology will be evaluated and demonstrated on a typical soft, corrosive, Cape Province coloured water.

Estimated cost: R390 000
Expected term: 2005 - 2007

The physical and chemical effects of waters with varying calcium carbonate precipitation potentials (CCPP) and guidelines for the use of CCPP in drinking water stabilization
Rand Water
No 1595

This project aims to improve the accuracy and application possibilities of the water stabilisation methodology as used in the current *Stasoft IV* software. Field data on actual water distribution systems will be collected to determine the current status of calcium carbonate precipitation potential as related to corrosion and aggression potential. The physical effects of waters with varying calcium carbonate precipitation potential will also be determined. Results from this project will be used to upgrade the current *Stasoft Program.*

Estimated cost: R285 000
Expected term: 2005 - 2006

Operational strategies for the cost-effective use of ozone in water treatment
Umgeni Water
No 1596

The aim of this project is to study the factors that affect ozone demand with a view to optimise ozone dose and determine the impact of ozone on downstream processes and downstream water quality. Suitable determinants will be used to optimise ozone dose on three chosen full-scale plants currently using ozone treatment. An analytical test kit for optimizing ozone dose will then be tested in each of the three plants with a view of adapting the procedure for each of the three situations. Control strategies for ozone dose optimization for changing raw water qualities including flows and other operational issues will be developed so that it can be integrated into the general waterworks control system.

Estimated cost: R651 500
Expected term: 2005 - 2007

Programme 2: Water treatment for rural communities

Assessment of the occurrence and key causes of drinking-water quality failures within non-metropolitan distribution networks in South Africa, and guidelines for the practical management thereof
Emanti Management
No 1597

Small water service providers are having problems in proactively managing drinking water quality within their distribution networks. This project aims to analyse the relatively high percentage of water quality failure in two provinces of South Africa and in particular contrast the water quality at the water treatment plant with that at point of use. Guidelines will then be developed for the management of drinking-water quality in non-metropolitan distribution systems. The guidelines will include legislative compliance requirements, technical inputs (e.g. optimum free chlorine residual levels), best practices (e.g. pro-active maintenance requirements), monitoring and management protocols and reporting protocols to consumers, provincial and national government. These guidelines will then be used in a 'road show' to make the appropriate officials aware of

the need for effective monitoring and management.
Estimated cost: R452 300
Expected term: 2005 - 2007

The development of immersed membrane microfiltration systems for the treatment of rural waters and industrial waters
Durban Institute of Technology
No 1598

This proposed project will focus on developing the local woven fibre immersed membrane micro-filter into systems for the pretreatment of high turbidity surface waters as well as the gravity-fed treatment of water in remote regions. The project will complement and enhance the applicability of other local technological developments in rural water treatment, e.g. the locally developed capillary ultrafiltration system. The project will develop a standard membrane pack for immersed microfiltration membrane applications. Different configurations and operating protocols will be evaluated so as to minimize fouling and maximize ease of cleaning. A simple, gravity fed water treatment system for water provision in remote areas will be demonstrated.

Estimated cost: R765 000
Expected term: 2005 - 2008

A manual and training aids for operation and maintenance on small water treatment plants
CD Swartz
No 1599

In a study of 20 small water treatment plants (WRC **Report No. 738/1/00** *Guidelines for the Upgrading of Small Water Treatment Plants*) it was found that most local small water treatment plants experience problems in operating on a sustainable basis. This was due to a number of both technical and human factors. However, due to the wide and encompassing nature of this investigation, it was not possible to identify and characterise the operation and maintenance-related problems fully. This project, therefore, aims to survey current management practices, determine optimal small plant operation and management methodologies for South Africa and compile a user friendly operation and maintenance manual. Based on the manual, training aids will be developed and this knowledge will be disseminated by means of a 'road show', demonstrating the training aids.

Estimated cost: R1 500 000
Expected term: 2005 - 2008

Programme 3: Drinking water quality

National standards for water and wastewater treatment chemicals
Umgeni Water
No 1600

The national standards for many water treatment chemicals in everyday use are out-dated and describe analytical procedures which are in some cases obsolete and very time consuming. In addition to this, there are many water treatment chemicals for which no national standards exist, in spite of the fact that some of these are used extensively in the water and wastewater treatment industry. Therefore, this project aims to evaluate current South African standards and international standards for water and wastewater treatment chemicals; assess the needs of the industry in terms of national standards for water and wastewater treatment chemicals; and produce a report containing recommendations which will serve as the basis for the up-dating and re-issuing of current standards and for the creation of new standards where these do not currently

Estimated cost: R241 800
Expected term: 2005 - 2007

Determination of the specific origin of contaminating bacteria in drinking water of rural households by elucidating the contamination pathway using amplified fragment length polymorphism (AFLP)
CSIR
No 1602

Method development at the DNA level has made the identification of the exact origin of specific contaminating and other organisms possible. This ability may have a profound impact on our understanding of exactly where contaminating organisms originate from and where in the contamination pathway introduction of these organisms into drinking water supplies takes place. Understanding the latter will in turn allow identification of the specific human behaviours and practices that contribute to contamination of drinking water. The information will enable the design of preventative measures aimed at the very core of the problem and in doing so minimize health impacts and direct resources optimally. Using the amplified fragment length polymorphism (AFLP) methodology, the project therefore aims to identify those human behavioural factors and practices that are directly associated with the identified contamination pathway and identify the exact point where bacterial contamination of drinking water takes place in rural households without access to in-house piped water. Recommendations will be made that would address those behaviours or practices associated with the identified pathway so that contamination can be prevented or minimized in future

Estimated cost: R371 320
Expected term: 2005 - 2007

KSA 3 WATER USE AND WASTE MANAGEMENT (CONTINUED)

On-line real-time enzymatic biosensor system for the rapid detection of faecal contamination of water intended for drinking purposes
Rhodes University
No 1603

The unique enzymatic profiles present in primary sewage sludge during were investigated in 2000/03, one of the first studies of its kind in the world and results from this study have already been presented and accepted in internationally peer-reviewed journals. Subsequently, another two-year project was funded for the establishment of a suitable bio-probe and biosensor system for the rapid enzymatic detection and enumeration of indicators of faecal contamination in water. This project is a follow-up and the key outputs of the current study will be the design of a suitable bio-probe strip for the rapid detection of faecal contamination. A provisional patent is currently being secured to protect this innovation. Results from the current study have shown proof of concept, paving the way for the finalisation of the improved development and construction of a novel enzyme based biosensor for the rapid detection of faecal contamination via the presence of indicator micro-organisms and their metabolic enzymes.

Estimated cost: R700 000
Expected term: 2005-2007

Programme 4: Water distribution and distribution systems

Development of a national water consumption archive
Rand Afrikaans University
No 1605

Domestic water consumption is a function of various factors, including stand size, income, household size, climate, pressure and water price. However, the overriding problem with studying water consumption is that quality data are difficult to get hold of. In recent years, a unique software product called *SWIFT (Sewer and Water Interface from Treasury)* was developed, allowing access to municipal treasury databases to obtain demographic and water consumption information of large numbers of users. This is a very valuable source of information on the topic of water consumption both now and in the future. This project aims to ensure that this valuable source of information is not lost. A procedure will be developed to collect existing and future water demand data from the different municipalities in South Africa and installing the data in an archive that will be accessible to researchers and other interested parties in South Africa.

Estimated cost: R150 000
Expected term: 2005 - 2006

The status and use of drinking water conservation and savings devices in the domestic and commercial environments in South Africa
Partners in Development
No 1606

South African water legislation supports and recommends the use of water conservation and savings devices, towards meeting future goals of water assurance. Yet, in the seven years of existence of the new Act and despite the development of water conservation strategies, very little progress has been made in term of a water responsibility ethic amongst water users and providers. There are number of areas that may inhibit the promotion of water conservation ethics. These include lack of implementation of policy, lack of commitment by service providers and the lack of use and availability of affordable technologies. The study intends to investigate the status quo on the use of efficient devices in the domestic and commercial (schools, churches, sports fields, garages, hotels, restaurants, terminuses, etc.) environments through auditing exercises. Recommendations and strategies to enhance the use of water-efficient devices at domestic and commercial level will be developed and a financial cost assigned to introducing water savings and the concomitant benefits.

Estimated cost: R700 000
Expected term: 2005 - 2007

THRUST 3: WASTEWATER AND EFFLUENT TREATMENT REUSE TECHNOLOGY

Programme 1: Biological sewage treatment processes

IAPS algal biomass and treated effluent utilisation as a key strategy in sustainable and low-cost sanitation
Rhodes University (Centre for Entrepreneurship in collaboration with Sustainable Environmental Technologies)
No 1619

Historically, the focus in sewage treatment in the RSA (in line with much of the 'developed' world) has been to seek 'efficient' end-of-pipe processes for converting the organic and inorganic residuals of human diets to end-products that are (superficially) more environmentally neutral - carbon to CO_2/CH_4, nutrients (e.g. N & P) to non-eutrophying compounds, etc.). Simultaneously, as global food demands increase, these same compounds constitute valuable agricultural resources. This project targets this strategic niche, by firstly capturing sewage nutrient-values in algal form and then applying the product as a fertilizer for food production. This approach creates a barrier between sewage treatment and crop production to control the potential health risk (the major problem with direct reuse of sewage

wastewaters), but without seeking to 'destroy' the nutrient) values in the wastewater stream. The specific aims of the project are to investigate uses of algal biomass from integrated algal ponding systems (IAPS) in value-chain crop production and horticultural applications, to determine the role and mechanisms of IAPS algae in plant growth stimulation, to evaluate different methods for efficient harvesting and recovery of algal biomass from IAPS, and to carry out a preliminary economic feasibility study and business plan development for implementation of such schemes at IAPS treatment works. The project thus also has strong elements of interventions for effective and practical poverty alleviation.

Estimated cost: R395 200
Expected term: 2005 - 2007

Materials mass balances modelling of wastewater treatment systems
University of Cape Town (Department of Civil Engineering)
No 1620

This project follows on WRC **Project No. K5/1338** in which the novel and far-reaching integrated chemical / physical / biological process modelling approach for biological waste treatment processes was developed and confirmed. In the new project, the overall aims are:

- To develop a mass-balance-based steady state model for wastewater treatment plants (WWTP) for preliminary design and operations overview
- To develop a kinetic simulation model that integrates the mixed weak-acid/base chemical, physical and biological processes for detailed design, dynamic simulation, process operation and optimization.

These two aims represent high-end long-term objectives that require closing of several important knowledge gaps with experimental research at laboratory and full-scale supported by theoretical modelling. The project has far-reaching implications with significant spin-off benefits for other WRC research projects, as already demonstrated in the previous **Project No. 1338** which is delivering knowledge of high scientific and practical value – the basic model structures developed have been used as a platform for preliminary modelling of activated sludge, algal ponding, and methanogenic and sulphidogenic anaerobic digestion processes

Estimated cost: R720 000
Expected term: 2005 - 2007

Programme 2: Sludge characterisation, treatment, utilisation and disposal

Development of the South African wastewater sludge disposal guidelines dealing with land and ocean disposal, beneficial use, use in commercial products and thermal treatment
Zitholele Consulting (Pty) Ltd
No 1622

Soon after the publication of the 1st edition of the guidelines on the *Permissible Utilisation and Disposal of Sewage Sludge* in 1997, the WRC embarked on a process to revise these guidelines. A research programme was initiated to characterise South African wastewater sludge and better understand sludge disposal practices in order to develop a local knowledge base and a better appreciation of the issues that should form the basis for a comprehensive revision of the 1997 Guidelines. An Addendum to the 1997 Guidelines was published in 2001 to clarify and elaborate on certain issues where this was required. A start with the development of the 2nd edition of the *South African Sludge Guidelines* was made in 2003. This initiative saw the publication of the first two volumes (a general overview document and guidelines for beneficial agricultural use) of the new guidelines in 2006. The current project, which is being co-funded by DWAF, will complete the process and produce a further three documents, which will give guidance for:

- The non-beneficial disposal of wastewater sludge by employing options such as dedicated land disposal, landfills, lagoons and ocean discharge
- The beneficial use of wastewater sludge at high loading rates in agriculturally related practices, such as mine tailing rehabilitation, nursery growth material and landfill capping
- The production of commercial products such as bricks, cement and fertilisers as well as thermal treatment of wastewater sludge

Estimated cost: R1 428 800
Expected term: 2005 - 2008

Scoping assessment for land disposal of sludges from potable water treatment
University of KwaZulu-Natal/Pietermaritzburg
No 1601

In the production of potable water from primary sources, chemicals (e.g. aluminium sulphate, ferric salts, lime, polyelectrolytes, etc.) are generally used to promote flocculation and settling. After dewatering to around 30% solids, the flocculated material termed 'water treatment sludge' (WTS) requires disposal. Traditionally, WTS disposal has been to landfill but an option gaining acceptance internationally is application of WTS directly to land, termed land disposal or land treatment, wherein the physical, chemical and biological properties of the soil are used to digest the applied waste without creating negative effects on soil quality, groundwater or plant growth. This project

is a scoping study to definitively assess the potential of this land disposal/treatment option for WTS in the RSA, including an assessment of the pro's and con's in terms of potential movement of key inorganic and organic substances through soil and water (aquifers) after land disposal of WTS, the associated economics and health factors, etc. The specific objective is to produce a technical support document with a view towards developing appropriate guidelines for land disposal/treatment of WTS.

Estimated cost: R250 000
Expected term: 2005 - 2006

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

Development of sustainable low-cost management for saline sewage and saline mine drainage wastewaters using integrated algal ponding systems
Rhodes University (Environmental Biotechnology Research Unit)
No 1621

The WRC has invested substantially in the development of sustainable management technologies for saline wastewaters from a range of sources including industry and mining. One specific innovation involves the use of ponding systems for the treatment of mine drainage wastewaters in the *Algal Sulphate Reducing Ponding Process for Acidic Metal Wastewater Treatment (ASPAM®)* which was preliminarily investigated at bench-scale and reported on (**Report No. TT 192/02**). The mining industry has identified the importance of the general approach and has requested evaluation of the process at pilot-scale with a view towards full-scale implementation. The aims of this project are accordingly to undertake pilot-scale process development of the WRC-patented ASPAM® system using algal ponding for low-cost sustainable treatment of metal-contaminated acidic sulphate-saline wastewaters, including investigating factors relating to the linkage and integration of the various unit operations of the process, determining kinetic values and design parameters required for full-scale implementation, undertaking a fundamental investigation of the algal proton-absorption capacity of the ASPAM® system underpinning the metal precipitation and neutralisation unit, characterising fundamentally the sulphur biofilm formation operation, and developing a descriptive model for the system.

Estimated cost: R1 139 700
Expected term: 2005 - 2007

Continued evaluation of the integrated managed passive water treatment system (IMPI), long-term monitoring of VCC passive treatment plant and three-dimensional characterisation of decommissioned sulphate reducing units
Pulles, Howard and de Lange Inc.
No 1623

In the RSA a sustained 9-year research programme with a 2004 value of around R21m. (from various funding sources) has aimed at developing passive water treatment technology that can reliably remove sulphates, acidity and metals from AMD waters. This research effort has resulted in the development of a **degrading packed bed reactor** that is a world leader in volumetric sulphate removal rates from mine-waters, by almost an order of magnitude compared to other international technologies. A key feature of the technology is that it will generally be required to operate for a number of years, typically decades, and continue to perform in accordance with its specified duty. A strategic concern of the mining industry and the regulatory authorities relates to the confidence that can be placed in the long-term performance of such units and their eventual fate. As a logical final stage in developing and evaluating passive treatment processes, this project will extend and intensify the monitoring of existing passive AMD treatment plants while at the same time de-commissioning and autopsying other similar long-running units.

Estimated cost: R400 000
Expected term: 2005 - 2006

Programme 6: Biotechnological co-treatment of saline and sewage wastewaters

Exploitation and further development of beneficial applications of biotechnological processes for co-treating saline and sewage wastewaters
Rhodes University (Environmental Biotechnology Research Unit)
No 1637

Treatment of AMD wastewaters remains a high national priority in the RSA, affecting both the aquatic environment and the available water resource. This solicited project follows on a 2-year programme commissioned in 2004 by WRC, in which the overall aim is to exploit and further develop beneficial applications of biotechnological processes for co-treating saline (AMD and other) wastewaters and sewage in the sustainable and integrated management of various water-related community, industrial, agricultural and environmental needs. Specific objectives of the new project are to:

- Establish and model cost-effective and efficient pre- and - post-treatment processes for metal removal from acid mine drainage (AMD) wastewaters in AMD treatment trains

- Further develop, verify and model processes for polishing treated wastewaters from AMD bio-desalination processes to standards suitable for discharge and/or selective reuse
- Model and integrate process development of AMD treatment trains encompassing metal precipitation / removal, neutralization, biological sulphate reduction using complex organics as the carbon source, potential on-site carbon source generation (e.g. via biomass production), solid-liquid separation, effluent polishing, etc., all to appropriate organic, inorganic and microbiological treated.

Estimated cost: R1 000 000
Expected term: 2005 - 2007

THRUST 4: INDUSTRIAL AND MINE-WATER MANAGEMENT

Programme 1: Quantification of water use and waste production

A first order assessment of the quantity and quality of non-point sources of pollution associated with the industrial, mining and power generation sectors
Pulles, Howard and de Lange
No 1627

It is increasingly recognised that non-point source (NPS) 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 not feasible 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. This project will determine at a scoping level, the quantity and quality of NPS pollution that originate from the mining, industrial and power generation sectors. This information will *inter alia* be used at a strategic level, to determine whether the present investment in research in this KSA and more specifically the thrust on industrial and mine-water management, reflect the need in this regard.

Estimated cost: R1 000 000
Expected term: 2005 - 2007

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

Geochemical sampling and analyses for environmental risk assessments using the Wits Basin as a case study
Pulles, Howard and de Lange Inc
No 1624

Each environmental risk assessment (ERA) study is faced with questions regarding the location, number, size and type of samples that need to be collected for a proper assessment. Answers of these questions are partially dependent on the predictions that need to be made, the available material and costs. This project will establish a methodology to guide users of an ERA process to quantify the uncertainty associated with predicted mine drainage quality as a function of sample representivity. Existing mineralogical and geochemical data for the Wits Basin, that are available from previous studies, will be used to demonstrate the application of the methodology that will be developed.

Estimated cost: R 562 000
Expected term: 2005 – 2008

Programme 4: Minimising waste production

Development of a complete process integration framework for wastewater minimisation in multipurpose batch plants
University of Pretoria
No 1625

This project aims to minimize the wastewater production and pollution emanating from batch processes where equipment is shared in the production of high value / low volume specialty chemicals. For this purpose a mathematical optimization model that operates on a continuous timing interval, will be developed and tested by using the General Algebraic Modelling System (GAMS) software. The model will be designed to optimize for both maximum profits and minimum effluent. The development of this product is important because of the extremely high toxicity of effluents produced by these processes and the ever tightening environmental requirements.

Estimated cost: R198 000
Expected term: 2005 – 2006

Cleaner production evaluation system and optimization for metal finishing
Durban Institute of Technology
No 1626

The metal finishing industry is notorious for its polluting activities. Cleaner production audits to benchmark a company's operations and identify room for improvement, require a level of detailed information that is normally not recorded by smaller companies. This project aims to develop a tool that can be used to readily conduct a systematic environmental evaluation of

electroplating plants and which will provide a comprehensive audit, with limited data, in a consistent way

Estimated cost: R492 000
Expected term: 2005 – 2007

Programme 5: Improved ability to predict and quantify effects

Prediction of how different management options will affect drainage water quality and quantity in the Mpumalanga coal mines up to 2040
Golder Associates Africa (Pty) Ltd
No 1628

Coal-mining in the Mpumalanga coal-field is a mature activity. Many mines have already closed and several more are heading for closure during the next 20 years. The acid mine drainage (AMD) that emanates from closed and operating mines have a huge impact on the water quality of the area. Because of the lag effect, it is likely that this impact will increase in future. Several investigations over the last decade were aimed at obtaining an improved understanding of how different management options would affect the quantity and quality of AMD emanating from mines. This project will build on mainly available information to predict how the quantity and quality of acid mine drainage emanating from coal mines in the Mpumalanga Highveld will change over the next 40 years for a range of different management scenarios.

Estimated cost: R1 500 000
Expected term: 2005 – 2007

THRUST 5: SANITATION AND HYGIENE EDUCATION

Programme 1: Rural sanitation and hygiene education

Molecular relatedness of enteric pathogens isolated from water sources and HIV/AIDS patients with diarrhoea in rural communities in the Limpopo and Eastern Cape Provinces
Reserved
No 1633

The project aims to establish any epidemiological linkage between entero-pathogens from water sources and those in infected patients. To isolate and characterise bacterial and protozoan entero-pathogens and determine their antimicrobial susceptibility, the study addresses the issues of scientific and technical links to other aspects such as hygiene practices, water quality and type of service rendered, all aspects of storage in containers, identifying water-borne opportunistic bacteria specifically of concern to the HIV compromised and the rate of infection.

Estimated cost: R900 000
Expected term: 2005 -2008

Health and hygiene education
Mvula Trust
No 1634

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.
The following research topics will be addressed under this programme:

- Investigation of the linkage between poor sanitation and HIV/AIDS and also possible linkage between the high incidence of cholera outbreaks and prevalence of HIV/AIDS infection
- Investigate modes for the spread of cholera in South Africa and recurrence of cholera outbreaks
- Development of indicators for measuring health improvement and assessing the use of proxy indicators; this should include evaluation of the impact of health and hygiene in the creation of a demand for sanitation

Guideline: *Education and Awareness Building on the Detrimental Effects of Pollution*

Estimated cost: R 800 000
Expected term: 2005 -2007

Programme 3: Knowledge/information management and advocacy

Knowledge/information management and advocacy
Hlathi Development cc.
No 1635

The overall aim of 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 study will investigate:

- Development of a sanitation knowledge/ information dissemination strategy including appropriate distribution channels, for example, the concept of sanitation resource centres
- Preparation of sanitation best practice guidelines

Development of a strategy for promoting application of research, this research should address the whole process from research topic identification to dissemination, advocacy, and the integration of new knowledge into human resource development initiatives within the sanitation sector.

Estimated cost: R300 000
Expected term: 2005 -2006

Programme 5: Technical sustainability of sanitation services

Research into urine diversion toilets in eThekwini
University of KwaZulu-Natal
No 1629

The study aims to provide a scientific basis for the design and operation of urine diversion (UD) toilets, evaluate their effectiveness and determine the fate of Ascaris eggs in the toilets. The study puts forward a problem that is emerging around service delivery issues related to the use of urine diversion toilets. Ethekweni has taken on the championing of the technology and has modified its design. Success of Etheweni's initiative will be of relevance to the rest of the country in the use of the technology. This research is a direct outcome of a strategy workshop hosted by Ethekweni and WRC. The fate of pathogens in UD toilets is not clear, that is what happens to pathogens in a dehydration process that is the basis of the operation of UD systems. This lack of understanding is an inhibitory factor in the use of pit contents, as well safe handling of faecal sludge. Thus, the management and operation of the UD provide greater challenges than just the sanitation convenience. The study intends to find answers to these challenges which would make the option of UD more acceptable and improve the management aspects.

Estimated cost: R600 000
Expected term: 2005 -2007

Scientific support for the design and operation of ventilated improved pit-latrines (VIPs)
University of KwaZulu-Natal
No 1630

The project aims to investigate and determine the fate of different pit-latrine additives and their performance, using newly developed testing procedures in wastewater treatment. The project is very important in light of previous attempts by the WRC to evaluate pit additives that did not live up to promise. The sector is continuously in demand for this information.

Estimated cost: R600 000
Expected term: 2005 -2007

Enhancement and acceleration of dehydration processes in urine-diversion (UD) ecological sanitation systems
CSIR
No 1631

The overall aim of the study is to develop and test suitable dehydration accelerators, which can completely sanitise faeces in UD toilets, taking into account that the challenge that exists in understanding and influencing the process of dehydration will have definite benefits for UD toilets. The concepts proposed by the research are very new and not developed or tested.

Estimated cost: R337 500
Expected term: 2005 -2006

Programme 6: Financial sustainability of sanitation services

Financial sustainability of sanitation services
Partners in Development
No 1632

This programme addresses capital investments in infrastructure for households without access to basic sanitation services and financial requirements for ongoing operation and maintenance including future infrastructure replacement costs. 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 operation and maintenance costs for the different sanitation technology choices:

- Financial models for free basic sanitation service provision and operation and maintenance costs of on-site sanitation services focusing on technology choice, funding arrangements, institutional requirements and household contribution
- Development of an overall cost strategy for meeting the 2010 target of eradication of the sanitation backlog
- Analysis of financial resources of municipalities and their ability to comply with the legislative requirements
- Assessment of the real costs of sanitation subsidy
- Investigation of different models for subsidy allocation and best-practice case studies
- Exploration of credit finance options for household sanitation improvement programmes

Estimated cost: R600 000
Expected term: 2005 -2007

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KSA 4

WATER UTILISATION IN AGRICULTURE

Dr Gerhard Backeberg
Director

SCOPE

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

- Irrigated agriculture
- Dry-land agriculture
- Woodlands and forestry
- Grasslands and livestock watering
- Aquaculture

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

OBJECTIVES

The **primary objective** is to increase household 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 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.

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 natural processes and people-induced impacts of resource use.

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

KSA 4 WATER UTILISATION IN AGRICULTURE (CONTINUED)

RESEARCH PORTFOLIO FOR 2005/06

In this KSA a holistic approach is followed for knowledge creation and dissemination to enable people to utilise water in a sustainable way for food production and improved livelihoods. Key issues being addressed are the productivity of water use for crops and livestock, poverty eradication in rural areas and prevention of resource degradation. These efforts are aligned to the agricultural sector plan in South Africa and to the comprehensive Africa agricultural development programme of NEPAD. Work will continue to fill knowledge gaps that exist in the utilisation of water in agriculture, under the following themes of the research portfolio:

- Irrigation and water use efficiency
- Fitness for use of 'grey water' in peri-urban agriculture
- Water use efficiency in agro-forestry
- Aquaculture in rural livelihoods
- Rainwater harvesting and conservation
- Adaptive research of technologies in rain-fed and irrigated agriculture
- Technology transfer of water management models
- Impact of land use management on point and diffuse pollution in agriculture

During the past three years a strategic shift has been made to achieve a balance between research projects in irrigated and rain-fed agriculture, agro-forestry and aquaculture; to promote farmer involvement in poor rural communities through participatory action research; and to take research projects further to practical application of results with technology transfer projects. In future research, emphasis will be placed on water use of indigenous crops; social and economic acceptability of water harvesting; training and extension guidelines for water management by subsistence and emergent farmers; utilising wastewater as a resource; and the impact of climate change on land use.

BUDGET FOR RESEARCH PORTFOLIO IN 2005/06

The approved funding of the research portfolio of current projects and projects commencing in 2005/06 leads to committed funding of R13 837 808. The focus of this portfolio will continue along current trends.

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.

Overview of technological trends related to needs

Assessment of technological needs indicated that no major changes in the trends described previously have occurred.

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.

CORE STRATEGY

STRATEGIC CONTEXT

The water resource base is of key importance in agriculture. Together with other renewable and interdependent natural resources, it forms the ultimate support of the productive economic activity of people.

Water utilisation can best be quantified as rainfall-dependent, surface water- and groundwater-dependent use. Approximately 12% and 62% of rainwater in South Africa is used annually for respectively dry-land cropping and by natural grasslands, woodlands and forests. Rainwater runoff and deep percolation become available as surface- and groundwater of which approximately 62% is used for irrigation. It is therefore clear that the biggest share of water is used for both extensive and intensive production in agriculture.

In South Africa, at least 35% of the economically active population are directly or indirectly dependent on agriculture. This consists primarily of small-, medium- and large-scale enterprises, which provide employment opportunities for formal and casual labour. Furthermore, 42.7% of the population are rural survivalists with traditional agrarian lifestyles. Recent estimates also show that 48.5% of the population is living below the poverty line.

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). The forward linkages to processing industries and backward linkages to input suppliers in agriculture are, however, of considerable importance for economic activity in urban and rural areas, increasing the contribution to 20 to 30% of GDP. Agriculture is also a net exporter of food, contributing 10% of total exports of which 50% are processed products.

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.

Against this background the strategic focus of water research in this KSA will continue to be 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)

STRATEGIC INITIATIVES UNDERTAKEN DURING 2005/06

The KSA was involved in a number of key national, Africa- focused and international initiatives

NATIONAL INITIATIVES

- The WRC continued to play a leading role in the activities of the South African National Committee on Irrigation and Drainage (SANCID), of which the WRC is a founding member. KSA staff were respectively re-elected as Chairman and newly elected as Treasurer for a term of 3 years up to September 2008. During 2005/06 one annual general meeting and two ordinary meetings of SANCID members were organised and chaired, as required by the constitution.
- Similarly, the Network on Irrigation Research and Extension for Small-scale Agriculture (NIRESA) held its annual national workshop at the Nkomazi Irrigation Scheme in Mpumalanga on 23 February 2006. The workshop was organised and chaired by the WRC and involved 25 participants from the national and provincial departments of agriculture, science councils, universities and private companies. The 2006 workshop focused on 'Training, capacity development and empowerment of previously disadvantaged smallholder producers - encouraging the adoption of appropriate technological innovations'.
- Following discussions during a meeting of the SA-IWMI Consultative Committee on 10 October 2005, a new initiative was taken to develop a database for water-related research projects for agriculture in South Africa. Covering letters and a questionnaires requesting data on project title, project leader, total project budget, percentage funding contributions and project duration were sent to 46 representatives of research organisations, with 31 March 2006 as return date.
- A project-specific survey was done amongst service providers to evaluate the performance of reference group meetings. Although only 29 out of 172 respondents completed the assessment, the rating is between 4 and 5 (good to excellent) for 14 performance criteria.
- During two nationally televised news items, the WRC was cited as supporting research on water harvesting and conservation to promote food security in rural villages of Thabanchu in the Free State Province and agroforestry to stabilise fodder flow in the Upper Thukela catchment of KwaZulu-Natal Province.
- In the 1st edition of the National Agricultural Directory, reference is made to the leadership for research and development provided by the WRC, as well as publications available from the WRC, under the headings **Water Management and Irrigation** respectively.

AFRICAN INITIATIVES

- The Southern African Regional Irrigation Association (SARIA) arranged a workshop and steering committee meeting at the Roodevallei Country Lodge in Pretoria between 30 January and 1 February 2006. The association is comprised of representatives from 10 SADC countries and additional members from Kenya and Tanzania. The three-day event consisted of a technical tour to the Hartbeespoort Irrigation Scheme in the North-West Province, a one-day workshop and a steering committee meeting. The WRC chaired the meeting and co-hosted and co-organised the entire event together with the national Department of Agriculture (DoA) and the Agricultural Research Council (ARC). The 12 participating African countries adopted a memorandum of understanding (MoU) to guide future cooperation.
- During 2005 discussions were held with Prof N Hatibu and Prof B Mati of the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and the

Soil and Water Management Research Network (SWMNET) on establishing collaborative links on various projects. Initial discussions focused on the commencement of joint projects in agroforestry and rainwater harvesting. Further negotiations were held during the SARIA event, on commencing cooperative projects in Kenya, Tanzania and South Africa on rainwater harvesting.

- As one of only a few active members, South Africa was represented by the DoA and WRC on the Africa Regional Working Group of the International Commission on Irrigation and Drainage (ICID) held on 11 September 2005 in Beijing, China. Different options are under consideration to encourage participation by African countries on issues of irrigation, drainage and flood control. In this regard a start has been made by activating SARIA members, under leadership of the WRC.

INTERNATIONAL ACTIVITIES

- On 19 May 2005 a paper was presented on 'Reform of user charges, market pricing and management of water: problem or opportunity for irrigated agriculture' during the ICID 21st European Regional Conference on 'Integrated Land and Water Resources Management: Towards Sustainable Rural Development', which was held in Frankfurt (Oder), Germany.
- During a Special Session on 'Driving Research for Change in Irrigation and Drainage Practices' held on 12 September 2005 during the 19th ICID Congress in Beijing, China a paper was presented on 'The research and development strategy for water utilisation in agriculture - responding to diverse needs of farmers in South Africa'. At the same congress a submission was made on behalf of South Africa on 'Policy guidelines for the evaluation of social, economic and political impacts of drought and aridity', as part of the activities of the ICID Working Group on Irrigated Agriculture under Drought and Water Scarcity, where the WRC participates as Vice-Chairman.
- In addition the WRC participated as a local partner in a session on 'Capacity Development Strategies and Social Learning among Stakeholders for a Sustainable Irrigation and Drainage Sector', organised during the 4th World Water Forums on 20 March 2006 by UNESCO-IHE, IPTRID and ICID. A presentation was made on 'Revitalisation of smallholder rain-fed and irrigated agriculture in South Africa', which is based on the WRC research report (**No 1357/1/05**) on guidelines for farmer trainers and facilitators.

GROWING THE KNOWLEDGE BASE

CAPACITY-BUILDING INITIATIVES

Capacity building and competence development occur at the individual, organisational and community level:
Individual capacity development: Currently 105 students are receiving training as part of KSA 4 projects, of which 84 (80%) are from previously disadvantaged (PD) backgrounds. The total number of students has therefore increased by 27 from 78. The number of previously disadvantaged students participating in these research projects has increased by 35 from 49. Thirty female students (24 Black and 6 White) or 29% of the total number are receiving project-related training.

The following table illustrates the number of post-graduate students who benefited from WRC-funded research in this KSA and highlights the institutions which are actively involved in capacity building:

Contractor	Students from previously disadvantaged backgrounds	Total no students
ARC	3	6
ARCUS Gibb	2	2
Coaltech	4	5
CPH Water	0	2
CSIR	8	9
Fort Hare	6	6
Free State	2	6
KwaZulu-Natal	1	2
Sigma Beta	1	4
PICWAT	2	2
Pretoria	25	29
Rhodes	1	1
Rural Integrated Eng	10	10
SASRI	2	2
Stellenbosch	1	3
Tshwane Univ of Technology	13	13
Zakhe Training College	3	3
TOTAL	**84**	**105**

Organisational capacity development: Eight current projects are being undertaken by private consultants. Three of these are emerging consultancy groups which have received research funding for the first time.

Community capacity development: Ongoing efforts are being made to undertake participatory action research projects where farmers benefit directly while the research is being done. At least 40% of the current and new projects involve some form of on-farm research in previously disadvantaged communities which enables project-related education and training of farmers. More concerted focus on this type of research is envisaged for new projects in 2006/07 and thereafter.

KNOWLEDGE SHARING AND LEADERSHIP

Leadership in water-centred knowledge consisted of chairing national meetings of SANCID, NIRESA and SARIA; participating in international conferences and ICID workshops; and presenting two papers which will be published in the international journal Irrigation and Drainage (**Volume 55**, 2006).

Effective knowledge sharing was achieved by organising five workshops of KSA research initiatives:

- Workshops to develop the terms of reference (ToR):
  - Utilising Waste as a Resource – The Use of Drainage and Other Poor Quality Waters for Irrigation
  - Development of Training Material for Extension in Integrated Water Management
  - Assessment of the Social and Economic Acceptability and Institutional Arrangements for Rainwater Harvesting and Conservation in Rural Communities
  - Water Use of Pastures
  - Rainfall Projections for Land Use Planning
- A presentation was made on 'Supporting people-centred development through research on water utilisation in agriculture' during a workshop on 'Perspectives and Future Directions in Community Based Natural Resource Management or People-Centred Policy, Practice and Research', organised by the University of the Western Cape together with the University of Zimbabwe from 27-28 February 2006 in Johannesburg.

An information meeting was organised with DWAF officials on 29 November 2005 on 'Integrated Implementation of Models for Improved Water Management in Irrigated Agriculture'. KSA 4 participated in two WRC Open Days by showcasing relevant projects, and presentations were made by WRC-sponsored researchers on the social and economic acceptability of water harvesting and conservation.

Renewed efforts were made to improve the public understanding of water-related issues by means of popular articles 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.

KEY STAKEHOLDERS

Firstly, key stakeholders in this KSA remain as previously described. These 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 (DoA) 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 is an initiative by DoA to give policy direction to development through integrated water management for agricultural use and DWAF has completed five pilot projects to

implement the water conservation and demand management strategy in agriculture. An Interdepartmental Co-ordinating Committee on support for small-scale irrigation has also been formed, and as part of this action a task team is revising guidelines for project evaluation.
Locally the Human Sciences Research Council (HSRC) has reorganised its research activities and regrouped its projects into interdisciplinary new priority areas (NPAs). The NPA of Integrated Development is to undertake research which is designed to promote sustainable development in rural and urban areas. In addition various Institutes of the Agricultural Research Council (ARC) obtain funding and undertake research on water-related subjects. Of particular relevance is water research in relation to soils and climate, engineering, field, horticultural and forage crops. At eight Universities across South Africa there are Faculties or Departments of Agriculture, many of whom have in the past mainly relied on WRC funding to undertake water research (see also Section 1.1.5 below).

Globally the International Water Management Institute (IWMI), as 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 done under four revised themes:

- Understanding basin-scale water productivity
- Increasing water productivity for sustainable livelihoods
- Low quality water, livelihoods, health and nutrition
- Water, sustainable agriculture and ecosystems

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, KwaZulu-Natal, Free State, Stellenbosch, Fort Hare and Tshwane University of Technology); science councils (various Institutes of the Agricultural Research Council (ARC) and Environmentek of the CSIR); as well as established and emerging private consulting groups.

IMPLEMENTATION PLAN

RESEARCH PORTFOLIO FOR 2005/06

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.

The research portfolio for 2005/06 is presented in **Table 1** which provides an overview and description of research thrusts and programmes.

KSA 4 WATER UTILISATION IN AGRICULTURE (CONTINUED)

TABLE 1

Overview and description of thrusts and programmes for 2005/06

THRUST 1: WATER UTILISATION FOR FOOD AND FIBRE PRODUCTION	
Scope: The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the processes of production of field, horticultural and industrial crops.	
Programme 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture	**Scope:** Water productivity can be increased by producing more with the same use of water or by producing the same with less use of water. This requires understanding of water dynamics in the soil-water-plant-atmosphere continuum, the equipment which is used and the method of production which is followed. Research on all these aspects can contribute to higher water use efficiency in agriculture.
Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture	**Scope:** Various processes and factors, which are site-specific, have an influence on the quality of water for crop, livestock and fish production. Significant shortcomings exist in assessment of the fitness-for-use of water sources and identifying water-related production problems. The emphasis in this programme is on the efficient use of water and management of water quality for irrigation of crops, livestock watering and aquaculture in rivers, ponds and dams.
THRUST 2: WATER UTILISATION FOR FUELWOOD AND TIMBER PRODUCTION	
Scope: The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the processes of production of trees in woodlands, plantation forestry and trees planted in combination with food and forage crops.	
Programme 1: Water-efficient production methods and systems in agro-forestry, woodlands and forestry plantations	**Scope:** In catchment areas where trees are a prominent feature of land use, runoff and deep percolation of water can be reduced. Management of these so-called streamflow reduction activities necessitates an understanding of the water use by trees and the competitive or complementary relationship of water use by trees and water use by staple food and forage crops. Due to research specialisation, separate attention is given in this programme to increase the efficiency of water use by trees in woodlands and plantations for fuelwood and timber production.

THRUST 3: WATER UTILISATION FOR POVERTY REDUCTION AND WEALTH CREATION IN AGRICULTURE	
Scope: The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the management processes undertaken by people who are using water.	
Programme 1: Sustainable water-based agricultural activities in rural communities	**Scope:** Poverty, hunger and malnutrition amongst rural people are widely recognised as major problems. These members of rural communities, consisting mainly of women, children and the elderly, are also disadvantaged or marginalised for various social, economic and political reasons. A wide-ranging programme is required to support the sustainable development of rangeland livestock, rain-fed and irrigated crop production. Efficient use of water through a combination of agricultural activities can contribute to improving living conditions. Empowerment of rural people can further be promoted through participatory action research which improves knowledge, farming skills and leadership capabilities.
Programme 2: Integrated water management for profitable farming systems	**Scope:** Commercial farming is a major user of water resources and faces a particular challenge to ensure that this share of water is used effectively and efficiently. There is invariably a close link between efficient use and allocation of water and whole-farming profitability. Water management on farms is also time-dependent and based on incomplete knowledge of changes in the weather, prices and technology. Under these circumstances modelling is a powerful tool to provide decision-support and management advice. The focus in this programme is therefore on developing procedures, methods and models to provide advice to farmers on best management practices and the optimal combination of crop and livestock enterprises within the constraints of water, land and capital resources.
THRUST 4: WATER RESOURCE PROTECTION AND RECLAMATION IN AGRICULTURE	
Scope: The direction and driving force for research activities and outputs are determined by the strategic focus to improve the knowledge of the processes of production of field, horticultural and industrial crops.	
Programme 1: Sustainable water 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.

EXPECTED OUTCOMES

In KSA 4 a holistic approach is followed to enable people to utilise water in a sustainable way for food production. This contributes towards improved living conditions, maintenance of the productive capacity of water resources and availability of food and fibre products from rain-fed and irrigated cultivation. The participation of end-users in research projects and the application of knowledge generated through research are considered to be key success factors. This approach has been accepted by stakeholders but more time is required to demonstrate impact and therefore no change is considered at this stage.

RESEARCH PROJECTS FOR 2005/06

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 2005 and 31 March 2006.

COMPLETED

THRUST 1: WATER UTILISATION FOR FOOD AND FIBRE PRODUCTION

Programme 1: Water-efficient production methods in relation to soils, crops and technology in rain-fed and irrigated agriculture

Evaluation of the filtering and back-flushing efficiency of different irrigation filters
IAE, ARC
No 1356

Filtration systems are regarded as the heart of a successful operating micro-irrigation system, because an effective filtration system will assist in preventing micro-irrigation systems from clogging. When clogging occurs in micro-irrigation systems, it results in ineffective usage of water and the loss of optimum yields. Sufficient maintenance schedules of irrigation systems and the correct choice and management of the filtration system is therefore of utmost importance to ensure optimum performance. However, current design norms and standards for filtration systems are very outdated and not scientifically founded.

Laboratory and field tests, to determine the filtration and backwashing efficiency were therefore conducted in order to assist designers and producers in the appropriate selection of filtration systems. Appropriate information (accurate data), will enable a user to make an informed decision regarding the optimum economic choice of a filter, as well as the type of filter that is best suited in areas of stressed water resources with different water qualities. In this project, several irrigation filters were evaluated to determine their filtration efficiencies and backwash management efficiencies.

The results of the field evaluations and the laboratory tests provided a greater understanding of the performance of filters and the requisite management principles for the different type of filters under various water quality situations. Field evaluations were carried out in four seasons over two years, on six filter models, on 29 farms in five regions around the country. The dirtiness index (DI) of the water sources in the five regions ranged from clean (DI < 1%) to very dirty (DI = 43%) and the filters managed to clean the water to a DI level of between 0.15% and 10.0%. The filtration efficiency of the filters varied between 31.0% and 96.6% and on average, the filtration efficiencies of the different filters were: sand filters 89%, automatic screen filters 20% and disc filters 52%. All the measured operating pressures of the filters were within the recommendations of the manufacturers. In backwash management testing, the sand filters used an average of 1.63 m^3, the disc filters 0.37 m^3 and the screen filters 0.15 m^3 of water per backwash. However, the screen and disc filters backwash more regularly than the sand filters (to filter 1 000 m^3 of water with a DI of 10%, both the screen and sand filter used 28 m^3 of backwash water and the disc filters only 4.4 m^3).

In laboratory tests, three disc filters, two sand filters and three automatic filters were intensively tested over a period of one and a half years. Friction loss, filtration capacity and performance (filtration and backwash efficiency, variability efficiency between filters and impact of different cleaning operations efficiencies) were tested. The filtration efficiency of the sand filters were 98.5%, the disc filters 50.5% and the automatic screen filters 55.4%. Results confirmed that a flow-rate of at least 60 $(m^3/h)/m^2$ should be used to obtain a 90 to 100% backwash efficiency with sand filters. The backwash efficiency of the disc filters was a low 33.1% and with the automatic screen filters, a backwash water percentage was determined and only 3.5% of the filtered water was used to clean the filters.

The research resulted in guidelines for the selection and use of filters. The guidelines provide specific information regarding: the choice of filter in relation to water quality and the irrigation system; the choice of equipment; design principles; and the commissioning of filters; operation of filters; and maintenance of filters.

Cost: R760 000
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

Previous water quality guideline research, conducted since 1990 for the WRC and DWAF had focused on establishing scientifically based guidelines for livestock watering relevant in South Africa. During the course of the research it was observed that in rural communal livestock production systems, communities were exposed to hazardous concentrations of elements, such as bromide, selenium, lead, cadmium, strontium, fluoride, nitrate and iodine. This study was, therefore, formulated to identify and propose management options for key water quality hazards in rural communities.

The initial objective of the study was to utilize the software tool *CIRRA (Constituent Ingestion Rate Risk Assessment)* **Version 2.03** to develop formal procedures for addressing water quality related hazards and risks for humans and livestock in rural communities within rural communal production systems. Targets were set to investigate the possible benefits of applying a generic level assessment followed by site-specific sampling in order to achieve this. These targets were:

1. To quantify and substantiate the risk posed to animals in selected communities due to the presence of potentially hazardous concentrations of identified water quality constituents within the production environment
2. To quantify the risk posed to humans in selected communities due to the ingestion of water, food, milk, meat, organs and other livestock products
3. To substantiate the risk posed to humans based on the results from targets (1) and (2) above by the use of community health procedures
4. To formalize procedures involving the use of animal tissues and histopathological data for identifying potential risk for humans associated with hazardous water quality constituents
5. To develop another version of the software program CIRRA to cater specifically for risk assessment procedure and solution driven management options viable for both humans and livestock in the communal livestock production system context
6. To update version of CIRRA, and substantiate case study evidence of applications

The methodology for the study included sampling to perform biological experiments, investigating the extent of the hazards in groundwater in other communities in South Africa, and developing and proposing a system for managing naturally occurring water- related hazards in rural communities. The research observed the occurrence of geochemical anomalies, assessed as potentially hazardous chemical constituents (PHCC), in predominantly groundwater used for agricultural and domestic uses.

The study found PHCCs in point of use samples in rural communities at concentrations that exceed the local and international guideline limits by several orders of magnitude. These pose significant hazards to the recognized norms for water use for both domestic and animal uses. This extends to multiple user categories within user types, for example, drinking, food preparation and bathing for domestic use, and use for household layers, broilers and crops.

The vast majority of household and village drinking water was classified as completely unfit for domestic purposes. The potentially fatal consequences of the excessive nitrate values warrant intervention, and a report detailing the hazards was submitted to the Limpopo Provincial authorities at Polokwane. Significant differences between villages were noted for elements reflected in different tissue types that accorded with the water chemistry observed. Differences in the presence of sensitive user groups (pregnant women, breastfeeding mothers, infants) and varying routes of exposure and dosages necessitate that the detection of PHCCs be used as an action level on which site-specific investigations commence. It was found that liver samples predicted the variability between elements the best. Environmental samples did not describe element variance significantly and the collection of poultry specimens, either household or project sourced, appears to be the most reliable biological indicator.

The formulation of risk management strategies requires appropriate management that can reduce the risk to allow production and safe groundwater use to continue. However, failure to measure and monitor water quality prevents any successful management programme from being implemented. Failure to adequately describe water chemistry consequently reflects in uncertainty regarding adequate description of baseline conditions, a necessary step in fundamental epidemiological studies.

A generic level water quality risk assessment is recommended as the first step in determining baseline exposures required for the identification of constituents in the geochemical environment that may contribute to adverse effects on health, productivity, and product quality in animal users, and for health-related norms for domestic users.

Any potential hazards identified then require further investigation regarding the water, user, environment and nutrition in order to ascertain the hazard posed by the presence of toxic constituents at concentrations that exceed the various forms of recommended guidelines, and in so-doing acquire relevant site-specific risk factor information required for risk management strategies to be formulated.

This approach is addressed in detail by a proposed model that is a tool for Hazard Management for Rural Water Sources, referred to as HMRWS, and functions as a multidisciplinary effort between groups with specializations and commonalities, within a discreet functioning units that may be linked for various reasons (geographical and technical) referred to as a HUB.

The main components of the HMRWS are:

- A series of parent-child software programs
- A Central Administrator that receives, processes and directs information between five Specialist Groups:
  - Analytical Group
  - Animal Health Group
  - Geochemistry Group
  - Community Health Group
  - Rural Groundwater Implementation and Monitoring Group

The main processes within the HMRWS occur as four phases:

- Hazard Identification Phase (HIP)
- Exposure Assessment Phase (EAP)
- Toxicity and Risk Assessment Phase (TA & RA)
- Risk Management Strategy Phase (RMSP)

The HMRWS objectives are:

- Generic objectives: For sustained water resource management issues in rural communal agricultural systems
- Specific objectives: For community-dependent risk factors that may range from agricultural productivity to safe household food preparation of high-risk agricultural products

It is suggested that the HMRWS should be implemented on a national scale, but initially commence as a single unit (HUB) that could serve to assess the most appropriate means for future expansion, and may consist of various stakeholders identified on a regional or provincial level. Primary stakeholders are specialist groups, whilst recipients of group outputs vary according to need, and level of application (local or provincial). The stakeholders presented in this chapter should not be seen as prescriptive, but rather as an example of viable working groups. The allocation of various stakeholders to groups is based on the facilitation of processes in the different phases, with flexible involvement in multiple phases suggested. Several protocols specific Research Partnerships may be incorporated where appropriate.

Cost: R1 600 000
Term: 2000 - 2005

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.

Cost: R490 000
Term: 2004 - 2005

THRUST 3: WATER UTILISATION FOR POVERTY REDUCTION AND WEALTH CREATION IN AGRICULTURE

Programme 1: Sustainable water-based agricultural activities in rural communities

Implementing and testing the WRC guidelines on developing sustainable small-scale farmer irrigation in poor rural communities
IWMI, ARC
No 1357

The WRC guidelines *Developing Sustainable Small-Scale Farmer Irrigation in Poor Rural Communities: Guidelines and Checklists for Trainers and Development Facilitators* (WRC **Report No. 774/1/00**) are directly relevant to the implementation of two government programmes. The guidelines are applicable to the presidential programme, Integrated Sustainable Rural Development (ISRD), and the Revitalisation of Smallholder Irrigation Schemes (RESIS) Programme in Limpopo Province and form the basis of this research project.

In this study, these WRC guidelines were tested and expanded as a means of increasing meaningful training and capacity building in the small-scale irrigation sector. Smallholder farmers currently have limited access to training. Furthermore, formally available training is focused almost exclusively on scaled-down versions of high-cost, high-risk commercial production practices, which are especially inappropriate for resource-poor households. Much of the current training also requires trainees to be away from their homes for periods ranging from three weeks to several months. This is impossible for many, especially so for the women responsible for food-insecure households. Most of the farmer training in the Limpopo RESIS Programme is offered on-farm

The approach of 'development through needs-based training', as developed by Johann Adendorff, was first applied successfully in the training of approximately 7 000 poverty-stricken dry land maize farmers in Phokoane in the Nebo district of the Limpopo Province over a period of five 5 years. Through appropriate training, organisation and

improved self-confidence, farmers considerably improved their yields from an average of 3.5 bags per typical 1.2ha holding, to a new average of 40 bags. The 'development through needs-based training' approach has since been used in several dry dry-land areas in South Africa and is currently being used in poor rural communities with access to irrigation schemes. In particular, the Limpopo RESIS Programme provided a valuable opportunity to implement and test Adendorff's training and the WRC guidelines.

The project included the development of training material and the training of farmer trainers. It also assessed how training can be provided through the Agricultural Colleges in Limpopo Province. This process was viewed as a pilot exercise for national expansion and aligned to the development of the National Strategy for Education and Training for Agriculture and Rural Development. The information and data gathered in this project on the various training methods used in the RESIS Programme were used to develop further training courses and training modules. These curricula are now being institutionalised at the two agricultural colleges in the Limpopo Province, Tompi Seleka (Marble Hall) and Madzivhandila (Thohoyandou). The training material has been registered with the Primary and Secondary Agriculture Sector Education and Training Authority (AGRIseta). AGRIseta supplied the project team with copies of all the existing registered unit standards within the AGRIseta. From this information, gaps could be identified of unit standards that were needed but not yet developed.

Attention was given to the development of a training package that can be given to prospective trainers or facilitators to use in the field when presenting training to farmers. The package includes information such as the expected outcomes and training content material, as well as notes to trainers regarding important issues to consider throughout the training.

Appropriate procedures for introductions were also considered. The package includes information on equipment requirements, such as flip charts, paper, pens or other visual aids that may be necessary for presentation of specific training modules, as well as the actual technical training content. The training package consists of four parts, namely: A facilitator's guide on farmer training; training tools – a coded set of transparencies and other aids to be used during training sessions; assessment tools – used for the assessment of training / learners' progress and; audio-visual reference material - training in the field captured on video for reference purposes. Current training material includes modules on maize production, cotton production, basic scheme management and water management. Further outcomes based training modules being developed will over time also be incorporated into the facilitator's guide.

Cost: R860 000
Term: 2002 - 2005

Programme 2: Integrated water management for profitable farming systems

Generalised whole-farm stochastic dynamic programming model to optimise agricultural water use
Department of Agricultural Economics, University of the Free State
No 1266

The National Water Resources Strategy (NWRS) of 2004 describes how water in South Africa will be protected, used, developed, conserved and managed. The National Water Conservation and Demand Management Strategy forms an integral part of the NWRS. The agricultural sectoral strategy was recently finalised and endeavours to provide a supportive and enabling framework to improve irrigation efficiency. Thus, there is a clear need to optimise water use in the agricultural sector.

The main objective of this research was to develop a generalised whole farm stochastic dynamic linear programming model to assist farmers and water user associations (WUA) with optimal water use within the framework of integrated catchment management.

The research was done on the Vaalharts Irrigation Scheme, the largest irrigation scheme in South Africa which comprises a total of 37 000ha of irrigation plots of some 680 land owners. Canals supply the water to the irrigation plots. Flood irrigation is the dominant irrigation type followed by pivot irrigation. The most important cash crops in the area are maize, groundnuts, wheat,

lucerne and cotton and the most important long-term crop is pecan nuts.

GAMS (General Algebraic Modelling System) was chosen as the preferred modelling environment to develop the generalised stochastic dynamic optimising model since it allows for the construction of the programming matrix through the use of generalised mathematical equations. Furthermore it is the standard optimisation software used by agricultural economists locally and internationally.

The dynamic optimisation model is theoretically sound and is based on standard capital budgeting procedures. All the necessary cash inflows and outflows are dynamically accounted for and the model is therefore able to model cash-flows better when compared to any of the existing models. Thus, the model is able to evaluate the cash flow implications of alternative investments decision more accurately thereby enhancing the quality of advice that farmers can get.

Although risk plays an important role in the optimal development path of the farm the timing of water shortages did not impact severely on the risk return tradeoffs. However, the time value of money plays an important role in the calculation of forgone income due to water shortages.

Procedures were developed in this project to separate data manipulation and calculation of input parameters from the matrix generating equations used to construct the model. Through the adoption of such a procedure, the accounting equations that determine the underlying structure of the programming matrix are more transparent. Thus, it will be easy in further research to understand the underlying structure of dynamic-stochastic model and to modify the equations for specialised applications.

Cost: R880 000
Term: 2002 - 2005

Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers
Tlou Water Management
No 1353

The last decade has witnessed significant land and water reforms in South Africa including land tenure and local governance on water to ensure sustainable development and management of the resources. This is fundamental to creating an enabling environment for rural communities to lift themselves out of poverty. However, the growing recognition of the importance of land tenure to sustainable development has not been supported by an investigation into how it influences smallholder irrigation in improved food production efficiency. This study was commissioned by the WRC to review the land tenure systems and support structures in South Africa, to identify constraints and opportunities relating to land tenure and support structures, with a view to developing a framework for sustainable settlement on small-scale irrigation schemes.

The study method included the collection and analysis of existing international and local literature on land tenure, security of tenure and support systems. This was supported by case studies of existing small-scale irrigation schemes with specific focus on the Eastern Cape Province. Two schemes were selected for detailed study and interviews were conducted with selected key informants and farmers including relevant government departments in the province, and civil society groups.

A review of the land tenure system in the case studies revealed that communally-held land was problematic as far as small-scale irrigation schemes with low production levels were concerned. Tenure security is a major issue affecting settlement on smallholder irrigation schemes (SIS) in long term viable conditions. The state controls large parts of the land. Through the Communal Land Rights Act, the South African government is seeking to clarify land rights by transferring title from the state to local communities. Furthermore, the intention is to establish administration structures to govern the process of issuing and registering land tenure rights to individuals in communal areas. This will improve access to financing because the land can be held as collateral.

The other issues researched were the financing, marketing and management support systems for SIS in order to ensure they become sustainable and the farmers themselves take ownership of these schemes. In terms of production it was clear that small-scale irrigation farmers need access to markets where they can sell sufficient quantities of produce at prices that will enable them to make a worthwhile return on their investments and farming efforts. Without this, there is in effect no

incentive for them to go beyond farming purely as a means of supplementing their daily food requirements. In terms of the long-term viability of the schemes researched, attention needs to be paid both to farmers' ability to access credit and their ability to service credit once obtained, and it must be ensured that adequate training is available.

An analytical framework was developed to provide a basis for understanding the dynamics of the development of SISs. It was demonstrated that this framework provided insight into the interaction of various elements such as intensification/extensification and increased productivity/increased land size. Each step in this development path was carefully considered, the impacts on land tenure systems as well as all other support systems (production, marketing, irrigation, financing, institutional and social) were evaluated and appropriate recommendations were made on this basis.

Cost: R795 200
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 10 years, three WRC-funded research projects were undertaken to develop user-friendly models to provide decision-support for farmers. The aims of this technology transfer project were firstly, to train agribusinesses, bureau services and advisors in the main irrigation areas of South Africa to implement the RiskMan (Risk Management), IrriCost (Irrigation Cost Estimator) and FARMS (Firm Level Agricultural Management Simulator) computer software for decision-taking support in the field of risk management, irrigation cost estimation and whole farm planning respectively; and secondly, to give these organisations and individuals the necessary support in order for them to apply the abovementioned computer software on a continuous basis.

New technology must pass through several stages before it is accepted. The five stages of adoption are awareness, interest, evaluation, trial and adoption. The implementation strategy with this technology transfer project consisted of a combination of methods, messages and approaches followed by the research team. The first step was to identify target groups to whom the three programs were demonstrated. The demonstrations were attended by the contact person of that area together with potential adopters of the technology. These demonstrations were used to create awareness and interest in the use of the models. The next step was to arrange workshops for interested persons for specific models to make further progress with the technology adoption process. The website was used to provide additional information about forthcoming courses and continuous support on larger scale adoption and application.

The third step was to present the courses on IrriCost, FARMS and RiskMan as one-day workshops. Altogether 23 courses were presented to 311 trainees. The trainer was a project researcher who has been fully involved in the development of all three models since 1998. The course evaluation responses of the trainees were in general positive. The vast majority of the respondents were of the opinion that the course contents of all three programs are good.

It can be concluded that the first project objective was achieved through workshops and training courses in at least six provinces for each of the three models. With regard to the second objective it cannot be claimed that all 311 trainees will be able to use these models on a continuous basis. With hindsight better results could have been attained, if the train-the-trainer model had been applied from the beginning of the project. Technology is one the greatest drivers for progress in agriculture. However, new technology is only a tool. Therefore, the most important aspect is how the technology is used. The role of the trainers should be to demonstrate how the use of the new technology could make a difference in the lives of communities.

Cost: R800 000
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

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

The Orange River Replanning Study, indicated potential for water quality related problems in the Lower Orange WMA, particularly in the river reach between Boegoeberg and Onseepkans, where 35 000ha of land are irrigated, grapes (60%) and cotton (20%) constitute the main crops. Although the irrigation water quality is still of acceptable quality, research in the Breede River Valley indicated that grapevines are more sensitive to salinity than suggested by international guidelines. DWAF furthermore predicts a 25% increase in salinity by 2030, while anecdotal evidence points to the irrigation of higher lying foothill soils as salinity sources. Grape producers, furthermore, expressed concern about salinity issues. This study analysed the existing information and utilised satellite imagery and field surveys in selected areas, with an aim to evaluate the present situation and to identify likely future trends regarding water quality and soil salinity management in the area, and to identify the need for policy development and research, in order to protect soil and water resources.

An investigation of DWAF's water quality data base indicated the water to be of good quality for irrigation and not likely to pose any serious problems regarding salinity, sodicity or ion specific toxicity. However, if current trends were to continue, quality would over the next 40 years deteriorate to levels worse than the best irrigation water class. Concerns about salt retention in the river reach between Boegoeberg to Onseepkans, appear to be valid, but should be viewed in context. It appears that salt is retained within this reach during periods of relatively high river flow and released during low flow. The phenomenon may be explained by the development of waterlogged conditions in low lying soils, during high flow conditions. Drainage water originating from over-irrigation of foothill soils may aggravate the situation. Laboratory investigations on salt leaching potential of shallow saprolitic soils, deep Kalahari sands and calcareous terrace soils from the foothills indicated that (with some exceptions) these soils are not particularly saline in their virgin state. When irrigated they release both soluble salts as well as salts produced by accelerated weathering of primary minerals. It is estimated that during the earlier stages of vineyard development, these soils can release several times more salt than that applied through irrigation water alone. The procedure used to assess the area of saline soils indicated that a mere 1.7% of the area was too saline for grapevine production. The low percentage of saline soils may be partially explained by the fact that sampling occurred during a period of lower river flow, which is characterised by desalinisation. This survey also indicated that only 14% of the poor growth can be attributed to soil salinity. The balance was induced by other causes such as water deficits and localised water-logging. Technology transfer regarding irrigation scheduling and water table management at farm level thus appears to be essential.

Specific management actions are recommended to limit water quality deterioration and soil salinisation. Different actions are proposed for national government, local authorities, local extension services and farmers. The proposed management actions focus on reducing unnecessary leaching and improving drainage management. These recommendations provide valuable guidance to the Northern Cape Department of Agriculture concerning the technology transfer and other actions they need to initiate to manage the situation.

Cost: R388 000
Term: 2002 - 2005

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 - 2006

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 number 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

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 R1 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 - 2006

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: R2 249 616
Estimated term: 2003 - 2008

KSA 4 WATER UTILISATION IN AGRICULTURE (CONTINUED)

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

Integrating flood-plain agriculture into a diverse rural economy by enhancing cooperative 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 cooperative 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 cooperative 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 - 2006

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 - 2006

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: R1 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: R1 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: R3 000 000
Expected term: 2003 - 2008

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

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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

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 - 2006

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 - 2006

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 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 - 2006

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 000ha 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

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

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

Adapting the Wetting Front Detector to the needs of small-scale furrow irrigators and providing a basis for the interpretation of salt and nutrient measurements from the water sample
University Pretoria/Plant Production and Soil Science
No 1574

The Wetting Front Detector was developed by Australian scientist Richard Stirzaker following a number of years work at the Tompi Seleka College of Agriculture in the Limpopo Province. The WRC funded a project (WRC **Report No TT 230/04** Building *Capacity in Irrigation Management with Wetting Front Detectors)* between June 2000 and December 2003 to continue the development of the Detector and introduce the technology to irrigation farmers in South Africa. Early results from field trials and feedback from farmers were sufficient to convince an irrigation agronomist from a South African Irrigation Manufacturer, Agriplas Pty Ltd, to consider developing the detector into a commercial product. The project was nominated by SANCID as contender for the WATSAVE award and won the international prize for 'Outstanding Contribution to Water Saving and Water Conservation in Agriculture' presented by the International Commission of Irrigation and Drainage in France in 2003. However, the Detector, which strives to make more efficient irrigation accessible to the majority of farmers, is in its infancy. In particular, there is a lack of understanding of how to deploy the device for furrow irrigation and how to interpret the salt and nutrient concentrations measured from solution captured by the detector. Most of the current requests for information and support arise from these applications; furrow irrigation and solution sampling. Ninety five percent of the research work on the Detector has been carried out on drip, micro-jet, and sprinkler systems. Most of the small-scale farmers, a key target audience, use furrow irrigation. The WRC **Report No TT 230/04** provides conflicting evidence on the usefulness of detectors for furrow irrigation. Pilot studies carried out in Australia have demonstrated that monitoring of salt and nitrate can provide very useful information to farmers. In South Africa, 54 people using Detectors were asked in a survey why they were interested in the technology and 20% replied that their interest lay in monitoring electrical conductivity and nutrients in the soil water sample collected by the Detector. Numerous enquiries about which solutes to monitor, what techniques to use and how to interpret the result as soon as the Detector becomes widely available are anticipated. Therefore, there is an urgent need to do the underpinning science in order to provide reliable information.

Estimated cost: R1 202 000
Expected term: 2005 - 2008

Real-time irrigation advice for small-scale sugar-cane production using a crop model, weather data and cellular communication
SASRI
No 1576

Water use efficiency in irrigated sugar-cane agriculture is notoriously low and could be increased dramatically if farmers applied established scheduling methods. A recent survey showed that 70% of sugar-cane farmers use dragline irrigation and that 50% of these use fixed irrigation schedules. This leads to severe over-irrigation in times of low water demand and impacts negatively on the profitability of irrigated sugar-cane production and on the environment. Pressure is also building for water users to demonstrate efficient use of the scarce and sought-after resource. The main reasons for non-adoption of scheduling technology as determined from a survey that was conducted were:

- The complexity of technology in relation to practical constraints on the farm
- An under-estimation of the benefits of accurate scheduling. This applies especially to small-scale growers who do not have access to computers, the Internet or expensive equipment.

The challenge therefore is to provide simple, practical and useful advice to farmers using state of the art technology such as crop models and weather stations, and to convince farmers of the benefits of irrigation scheduling through on-farm demonstration. The Agronomy Department at SASRI has developed a prototype of a system (called *My Canesim*) consisting of the following: Weather data recorded by automatic weather stations and remotely downloaded daily through the cellular network; A web-based simulation model that suggests irrigation actions; An Internet-based user interface for advisors and extension staff to enter field, crop and irrigation system data and to view simulation results; The automatic distribution of irrigation

on/off advice in isiZulu through SMS technology to farmers' cellular phones. In a pilot case study, the system was implemented in 2004 on a limited scale in Pongola. Irrigation advice is provided to six small-scale growers and its impact monitored. Initial results are very promising and indications are that water savings of 30% and cost reduction of R1 400/ha could be achieved for small-scale growers. There is enough evidence to push for wider implementation of this service. These direct benefits are possible on 8 000ha to more than 1 500 small-scale farmers in Pongola, the Makatini flats, and the Komati area. The technology could also be used by commercial growers on 56 000ha. Indirect environmental benefits are reduced water extraction from river systems, and reduced runoff, deep drainage and water pollution.

Estimated cost: R350 000
Expected term: 2005 - 2008

Increasing water use efficiency of irrigated sugar-cane production by means of good agronomic practices
SASRI
No 1577

Low irrigation water use efficiency (IWUE) has been identified as a major problem in irrigated areas and this is even more important when the source of water is limited. Results reported by Olivier and Singels (2003) indicate that IWUEs of between 12 to 18t cane/100mm irrigation are possible as compared to 6t cane/100 mm averaged in the Onderberg at present. Agronomic practices such as the use of a trash (plant residues) blanket, growing suitable varieties, reduced row spacing and appropriate irrigation scheduling could increase the IWUE by saving water and/or increasing yield. Thorburn *et al.* (1999) have indicated that a trash blanket can reduce soil evaporation by an amount equal to 16% of annual rainfall. However, a trash blanket could also have a negative effect on the crop by slowing down initial growth, tillering and radiation interception and creating problems with trash worm and *Eldana*. Recent plant crop results by Olivier and Singels (2003) have shown that yields of a drip-irrigated plant crop can be increased by 10% and IWUE by 6% when changing row spacing from the standard single row spaced at 1.5 m to dual rows spaced at 1.8m. The response to trash blanketing and high density planting depends on variety. According to Singels and Smit (2003) the very large yield responses to row spacing (53% per 1m reduction) reported in Australia are the result of certain varieties having a low tiller production potential in the plant crop and therefore performing poorly in wide rows. It is believed that IWUE could be increased considerably by providing farmers with custom-made irrigation scheduling strategies for specific trash blanket, variety and row spacing combinations. Simple and easy-to-use irrigation calendars (with appropriate cycle and stand times) will be generated for areas with overhead irrigation by applying an accurate crop model to historic climate data. The outcomes of this research will include recommendations on best management practices (BMP, combinations of trash blanket, variety, row spacing, and irrigation scheduling strategy) for efficient and profitable use of irrigation water. Information will be available for the development of a trash blanket algorithm for the *Canesim* simulation model.

Estimated cost: R234 500
Expected term: 2005 to 2008

Integrating and upgrading of SAPWAT and PLANWAT to create a powerful and user-friendly irrigation planning tool
PICWAT
No 1578

SAPWAT is an easy to understand, user-friendly program that is currently used by more than 200 users as an aid to the planning of irrigation requirements of crops and for training of farmers and students in both the commercial and the beginner-farmer category. Although it is a good educational aid for the understanding of crop irrigation requirements, it has some shortcomings, two of these being the inability to store the results of calculations and the inability to import weather station data for the expansion and updating of its existing weather station data. PLANWAT, the development of which was paid for by the International Water Management Institute, was initiated, amongst others, to overcome one of the above problems, namely the inability to store calculated data. SAPWAT is run out of PLANWAT and the resultant crop irrigation requirements are stored in a data file to enable the user to build an expected water requirement picture for backyard and community gardens, fields, farms, water users associations and for drainage regions. PLANWAT has a water harvest module where the output of SAPWAT is used to calculate required water harvest areas and required storage capacities for run-on situations of water harvesting, mainly for Third World situations. Its one drawback is that it does not provide for in-field water harvesting situations. In addition, as a planning tool the present combination of the two programs does not provide for interactively determining the best potential scenarios of irrigation water use

coupled to gross crop margin to enable farmers to select the best option for their circumstances. A need has been expressed that the capabilities of SAPWAT be expanded to also provide for automated or semi-automated calculations of irrigation water requirements for cases where mass calculations have to be done for river systems. The project will aim to integrate these programs into a sensible unit and upgrade them to fulfil a more complete role as a planning aid for irrigation requirements of crops and the related economic scenarios.

Estimated cost: R537 500
Expected term: 2005 - 2007

Programme 2: Fitness-for-use of water for crop production, livestock watering and aquaculture

Guidelines for sustainable use of grey-water in small-scale agriculture and gardens in South Africa
University of KwaZulu-Natal/School of Biological and Conservation Sciences
No 1639

The White Paper on Agriculture emphasises food security. Since household and urban food gardens form part of the spectrum of production systems and processes that can contribute to food security, they are supported by government. However, a shortage of water to supplement rainfall often limits the application potential of these systems. The use of grey-water may overcome this limitation by providing a dependable water source 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. Initial indications from a scoping study to evaluate the fitness-for-use of grey-water in urban and peri-urban agriculture are that there is considerable potential to use this largely untapped source to augment household food security. However, there are also risks involved with the practice that need to be better assessed and quantified under controlled conditions. These risks are largely associated with factors that affect the sustained productivity of the irrigated soil and health considerations. A workshop is planned to prioritise these risks and finalise the appropriate experimental approach to address them before finalising the terms of reference and soliciting project proposals

Expected cost: R1 670 000
Estimated term: 2005-2008

THRUST 3: WATER UTILISATION FOR POVERTY REDUCTION AND WEALTH CREATION IN AGRICULTURE

Programme 1: Sustainable water-based agricultural activities in rural communities

Participatory development of training material for agricultural water use in homestead farming systems for improved livelihoods
Rural Integrated Engineering (Pty) Ltd
No 1575

The rural landscape of South Africa is characterized by high levels of poverty with approximately 70% of the country's poor residing in these areas. Most of the rural poor are vulnerable to malnutrition and the incidence of diseases such as HIV/AIDS. While research in smallholder farming has increased substantially in the last decade, much of the information generated has not been packaged for resource-poor farmers. Most of these farmers are illiterate but experienced in farming. Therefore, initiatives geared towards improving productivity of smallholder farmers need to acknowledge indigenous knowledge to ensure that the intervention is sustainable. Several categories of smallholder farmers can be broadly identified according to the smallholder's progress on a path of development from food-insecure household, to subsistence and emerging farmer to profitable commercial small-scale farmer. These farmers can further be differentiated according to the type of production location ranging from homestead yards, dry-land fields to irrigated fields. One of the overarching principles of the Government's integrated food security strategy is that the food-insecure should be made agents of their own development. However, smallholder farmers currently have limited access to any training, and formal training is focused mostly on available courses of commercial production practices, which are especially inappropriate to food-insecure households. The project intends to develop training guidelines for food-insecure households. The fulfilling of this desperate need has to be done in collaboration with experienced development facilitators and agricultural colleges who are mandated specifically to train farmers in different regions of South Africa.

Expected cost: R2 750 000
Estimated term: 2005-2009

Nutritional value and water use of indigenous crops for improved rural livelihoods
University of Pretoria/Centre for Nutrition
No 1579

KSA 4 WATER UTILISATION IN AGRICULTURE (CONTINUED)

Under-nourishment is a major problem in many rural and peri-urban communities, particularly amongst children. A variety of indigenous crops can meet the taste and dietary requirements of household members. Completed research by the ARC has tested the drought tolerance of crops such as cowpea, bambara groundnut and marog (WRC **Report No 944/1/04**). It is also important to determine the nutritional value and water requirements of these crops. The best combination between indigenous crops and a range of home-grown vegetables, and other foodstuffs to achieve a balanced diet, has to be evaluated. In a study by the University of the Free State on the socio-economic acceptability of in-field rainwater harvesting and conservation for homestead food production, the minimum area necessary to meet the caloric requirements of a household was calculated (WRC **Report No 1267/1/04**). Given the seasonal variability of rainfall, appropriate technology similar to that tested by the Tshwane University of Technology (Khosa, 2003) has to be evaluated to supplement water supply and stabilise food production in homestead gardens. The purpose of this project is to investigate the linkages between dietary requirements, nutritional value, water requirements and technology for production of a combination of food crops. Laboratory, on-station and participative action research will be undertaken to develop best practices in order to improve food security and well-being of households. Further consultation with stakeholders has to take place to develop the specific objectives and deliverables of this project.

Expected cost: R2 250 000
Estimated term: 2005 - 2009

Programme 2: Integrated water management for profitable farming systems

Revitalisation of provincial fish hatcheries and training facilities to promote profitable aquaculture
Rhodes University/ Dept Ichthyology and Fisheries Science
No 1580

A baseline study on the **Contribution of Aquaculture to Rural Livelihoods** in South Africa has been done by Rhodes University (WRC **Report No TT235/04**). This study showed that the present factors constraining aquaculture in rural areas were mainly a consequence of a lack of policy and institutional capacity and that the development of rural aquaculture will depend principally on a public sector led intervention, inclusive of technical support and fingerling supply. The study revealed that there are many state-owned hatcheries and training facilities falling under various Government Departments that are unproductive, privatised, or defunct. Though not assessed these assets are worth millions of Rand. Based on the survey results it was further agreed that the involvement of the private sector in rural aquaculture would be essential for sustainable growth. As policy issues were being addressed by the National Department of Agriculture, it was suggested that the WRC should support the undertaking of workshops in preparation for participatory action research (PAR) with the various public and private sector stakeholders to appraise the potential role of these hatcheries in the light of emerging policy, and where applicable to develop a framework for a community private public partnership (CPPP) to revitalise government hatcheries that are currently under-utilised. The workshops have been completed and the PAR can now proceed. The PAR is a process which includes research and implementing goals and objectives. Stakeholders in the Limpopo, Mpumalanga and Eastern Cape Provinces will be engaged and an end-point will be identified (for example, through CPPP revitalising a specific government hatchery). Once the end-point has been identified, the role of the PAR implementers would be to actively facilitate and record the process, so that it is successful and repeatable elsewhere.

Expected cost: R2 250 000
Estimated term: 2005 - 2008

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KSA 5

WATER-CENTRED KNOWLEDGE

Dr Innocent Msibi
Director

SCOPE

During 2005/06 additional emphasis will continue to be put 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 and even further a field in Africa and the developing world. 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 continued 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, with special emphasis given during 2005/06 on the finalisation and implementation of a fund management system.

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's plan was reviewed and activities will now be grouped into the following key areas:

KNOWLEDGE MANAGEMENT [FOCUS: 70% EXTERNAL; 30% INTERNAL]

The focus of this thrust is knowledge-sharing and knowledge dissemination to meet the objectives of the WRC (of being a knowledge hub) in its knowledge creation and learning activities and the core process of knowledge generation. It will develop a culture based on the understanding that 'knowledge resides in the user and not in the collection of information '... it is the reaction of the user to a collection of information that matters'. Thus there needs to be a clear link between the KSA and the other water KSA's, 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.

INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) [FOCUS: 50% EXTERNAL; 50% INTERNAL]

This area aims to meet the information and communication needs of the WRC's stakeholders and also the internal needs of the WRC regarding information 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 completed in the coming period. Key focus will be on designing tools for driving water-centred knowledge dissemination; developing internal 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.

PUBLICATIONS AND DOCUMENT MANAGEMENT (PDM) [FOCUS: 80% EXTERNAL; 20% INTERNAL]

Key focus for the next financial year will be on driving the handling and digital storage of documents, archiving, and maintaining library and information services. Key focus is on dissemination of knowledge created via the support of the WRC as well as other sources (originating from the national and international arena) through publication of an internationally rated journal and the ongoing publication of research reports and technology transfer (TT) documents. Working with Thrust 1 (see above), there will an effort to support the proper repackaging for better sharing of knowledge.

INTELLECTUAL PROPERTY RIGHTS AND COMMERCIALISATION (IPC) [FOCUS: 50% EXTERNAL AND 50% INTERNAL]

This thrust will focus on the effective management of all the WRC's patent portfolios, all issues relating to intellectual property rights and their protection. It will also support innovation and commercialisation of research and research products, while also supporting the WRC in the management of its contracts with researchers and suppliers.

BUDGET FOR 2005/06

The approved funding of fixed costs, running costs, printing and publishing costs and human resource costs leads to committed funding of R6 974 002.

CORE STRATEGY

STRATEGIC CONTEXT

The strategic context as presented in the previous year's plan 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

KSA 5 WATER-CENTRED KNOWLEDGE (CONTINUED)

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.

Following progress already achieved during the past financial year, this KSA continues to 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 diagram below illustrates the KSA's conceptualisation of knowledge management:

The business objectives of the WRC are externally focused and are based on investing in water research and development and developing competence and skills while making optimal use of the latest global information/knowledge and other available technologies. While the four water-centred KSAs are focused on investment in the creation of new knowledge and capacity-building, using the latest technologies and tools, the products thereof are linked and enhanced through other externally available information to prepare it for dissemination, transfer or 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. The way we approach this has not changed.

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.

We shall continue in the belief that the overarching need is to develop one seamless system for employees to navigate, even though the information may ultimately be pulled from several different systems 'behind the scenes'. From the user's point of view it is a system that is always ready to supply the content that is needed, may it be performance data, budget, policies, professional contacts, experts and specialists, current research data, etc.

External customers

The level of knowledge of water-centred knowledge management in the communities in general is limited and that position has not changed much. The following issues are still considered high priority even in 2005/06:

- 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.

So are the main external customers:

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.

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 system development needs are 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. Whilst this was identified much earlier as a priority development, it had to wait for the completion of the Fund Management System. In 2005/06 it will be implemented.

KEY STAKEHOLDERS

Creation, transfer and dissemination of knowledge require an appropriate knowledge base, that is water-related experts, practitioners, academics, science councils, the government (at all levels) and other research organisations. The WRC has to be able to effectively translate needs into research ideas and further transfer research results and new technologies to end-users or end-user representatives and communities.

Other key stakeholders include the water sector, service providers, user communities and the general public.

OTHER PLAYERS

A number of national and international organisations work in collaboration with the WRC and in some cases formal agreements exist. These include the following as examples:

- American Water Works Association Research Foundation (AWWARF)
- International Water Association (IWA)
- Water Research Foundation (WRF)
- nternational Water Management Institute (IWMI)
- Water and Sanitation Collaborative Council (WSSCC), etc.

Scope
In the year 2004/05, even though the key areas and the issues within the key areas were prioritized, still a lot of groundwork (to lay a proper foundation) had to be done. Practically it was only in 2005/06, that we were better positioned to fully execute the identified priority activities. While the scope may appear to have changed conservatively, the level at which these are going to be carried out is different. At the same time we need to acknowledge that most of these are about the way we do business and hence can be defined under continuous improvement.

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 revenue. 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.

Information and communication technology
We will continue with 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

KSA 5 WATER-CENTRED KNOWLEDGE (CONTINUED)

as a human community capable of providing diverse meanings to information output generated by such activities as research and development. The challenge is to make the organisational information base accessible to external organisations and individuals. This is important, given the increasingly fast-paced and dynamic business environment that creates disconnections between the process of decision-making at the top and implementation of such decisions at the grassroots. This is even truer in the water sector.

The preferred approach to information processing should be tested in the near future. Two approaches (water metaphors) should be considered:

- It is important to find useful knowledge, bottle it, and pass it around
- There is a great big river of data out there. Rather than building dams to try and bottle it all up into discrete little entities, we just give people canoes and compasses.

LINKS TO WRC MISSION AND VISION

From the vision and mission of the WRC, to be a globally recognised leader in providing innovative solutions for sustainable water management to meet the changing needs of society and of the environment' and to be 'a dynamic hub for water-centred knowledge, innovation and intellectual capital', the above statements have been crystallised into a number of strategic imperatives (which are also linked to the organisation's objectives), from which the response of the knowledge-centred KSA has been crafted. These have not changed from 2004/05.

PROGRESS AGAINST SET KPAs FOR 2005/06

The following examples are used to present the progress to date:

- The fund management system (FMS) will be ready for commissioning at the end of February 2006, and thereafter it will be in full use
- The Intranet is fully operational and used by staff
- The target for responding to the queries of the electronic Communications Security (Pty) Ltd. Act, with the deadline of May 2005, has been met
- The KSA has built strong links with the Department of Science and Technology. A WRC programme of research capacity-building will be funded by the DST, in cooperation with the French.
- Currently more than 70% of all patents have been licensed out, and possibly more than 80% would have been licensed out by end of March 2006; an income of R200 000.00 has been received to date
- Completion of the WASH document presented in Stockholm in August during Water Week (English/ French Version). The WRC logo is visible
- WIN-SA undertook more than three workshops. Two initiated by WRC/WIN-SA and in more than two, WRC/WIN-SA participated.
- The electronic publication of Water SA, and the digitisation of reports older than 1999 are two other key achievements
- A survey addressing the KSA's activities with special reference to knowledge dissemination resulted in very positive feedback and on average the rating for all issues was about 80%, i.e. a rate of 4 out of 5.
- Organising SA-France Water Workshop
- It is envisaged that sales of special reports and other related materials will exceed R200 000 (as at end of March 2006)
- More that 65% of all IT-related audit queries have been addressed. The main one related to the Disaster Recovery Plan, which has been completed.
- At the time of drafting this business plan, the KSA was on track to achieve less than 20% deviation between budgetary target and actual expenditure.
- External funding examples:
  - WIN-SA funding, exceeding R5m. and has completed more than 4 projects and more than 4 are ongoing
  - Leverage from DST to the amount of R2.4m. for the SA/France initiative
  - EU project funds for the African Water Programme to the amount of R0.2m.

SCOPE

Even though some of the key areas and the issues within the key areas have been prioritised during 2005/06, still a lot of work has to be done during the 2006/07 financial year to continuously improve the benefits of knowledge management. Practically, it is only in 2007/08 that we are better positioned to fully execute the identified priority activities. While the scope may appear to have changed conservatively, the level at which these are going to be carried out is different. At the same time, we need to acknowledge that most of these are about the way we do business and hence can be defined under continuous improvement.

Intellectual property

In order to encourage successful invention and subsequent solid patents, the WRC will continue to address the creative needs of the researchers and foster an inventive environment within the research area and engage with the researchers at all levels. By supporting the creation and protecting technological developments the WRC strives to further improve knowledge transfer (utilisation and commercialisation) of its research results (in collaboration with its research providers and the water sector at large) where and when applicable.

Publications and public understanding of science
There will be some special publications and initiatives design to capture public interest in Water and Water-related issues. The continuous improvement of ***The Water Wheel*** as a public understanding of science tool will continue to capture the younger members of our society.

Information and communication technology
During the 2006/07 financial year, there will be more emphasis on the implementation of the newly developed Fund Management System, improvement of information safety, adoption and compliance with an identified (single) recognised information safety standard (most likely SABS 17799). Further, the KSA will make great strides in dealing with the regulatory framework and resolve conclusively most of the outstanding audit issues.

Ongoing initiatives in the adoption and use of relevant communication technology will see full implementation during this financial year. These will include the cell phone-based communication systems, video calls, and digital fax systems.

KNOWLEDGE MANAGEMENT AND WATER INFORMATION NETWORK (WIN-SA)

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) are utilised, through WIN-SA as follows:

- It is important to find useful knowledge, bottle it, and pass it around
- There is a great big river of data out there. Rather than building dams to try and bottle it all up into discrete little entities, we just give people canoes and compasses.

HIGHLIGHTS FOR THE 2005/06 FINANCIAL YEAR IN TERMS OF THRUSTS

THRUST 1: KNOWLEDGE MANAGEMENT

Water Information Network (WIN-SA)
The WRC is leading the Water Information Network (WIN-SA) on behalf of the water sector. WIN-SA is a partnership initiative between all bodies concerned with capacity building for local government and information required for instituting water services. WIN-SA is a knowledge dissemination and capacity- building initiative. During the current financial year, WIN-SA has secured funding of approximately R2.6m. The funds will be utilised to support the water sector in terms of lesson learning, reviewing current collaboration within the sector, and strengthening partnerships. WIN-SA also launched its web-portal at the end of July. In addition, six more programmes are planned for the near future, based on funding from Switzerland. The role of WIN-SA in cultivating a knowledge management culture within the water sector continues to be highly influential.

One of the important areas requiring the building of competence is that of the provision of sanitation services. The WRC (WIN-SA initiative) has successfully developed and led a special course on Sanitation Planning and Management (in partnership with DWAF and the Water Sector Leadership Group). The course, which featured Prof Duncan Mara (Leeds University), an international expert on the subject, took place during January - February 2006 in four different locations in the country. To date, the course received overwhelming response (350 registered) and all courses in all locations were fully booked and there have been many requests for a repeat course.

The WRC led and organised a capacity-building initiative on planning and management of sanitation. The WRC presented courses on sanitation planning and management.

THRUST 3: PUBLICATIONS AND DOCUMENT MANAGEMENT

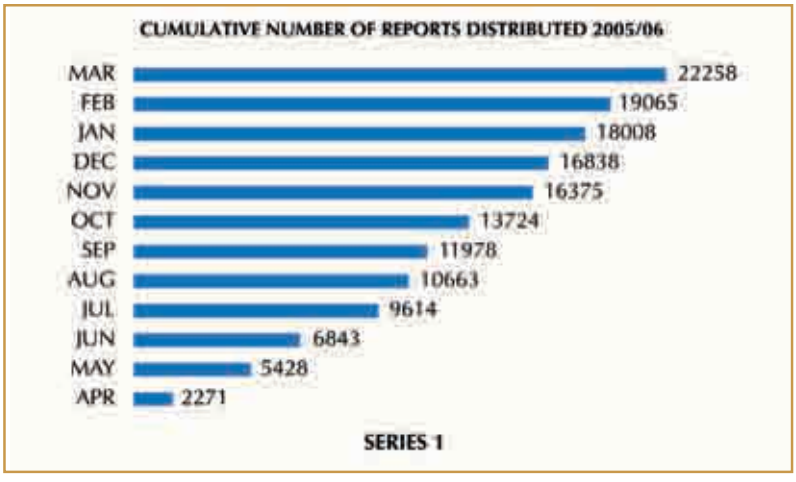
At the conclusion of a project and also while research is still under way, results are evaluated in respect of possible use and application and depending on the nature of the results a decision is taken on publication, dissemination and application thereof.

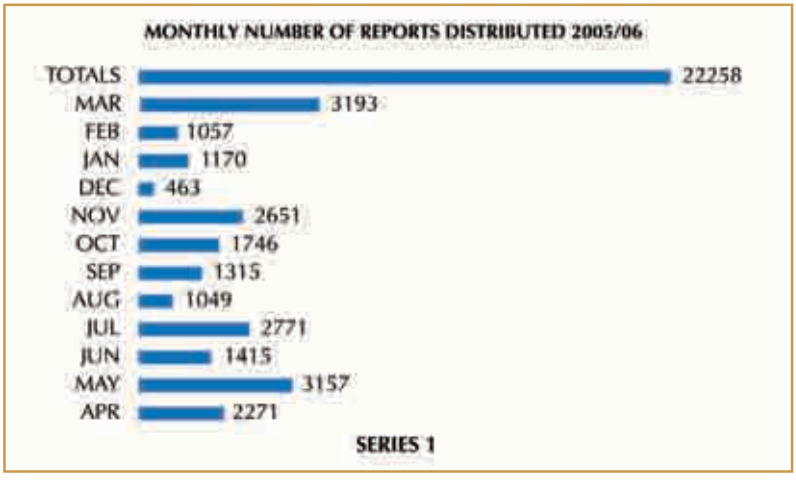
An effective marketing strategy for the knowledge assets was developed. A report catalogue of selected TT reports has been compiled and is being widely distributed. During the year under review 88 new reports were published (30 000 copies printed) and approximately 22 258 reports were dispatched upon request from stakeholders; some of these were sold and the income generated in this way came to R78 978.

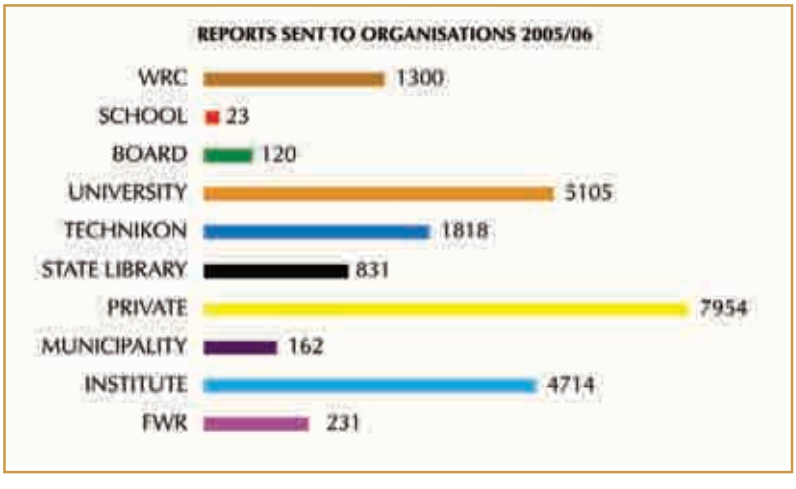
An efficient printing strategy based on print-on-demand was implemented and has considerably reduced the overall costs for knowledge dissemination, e.g. storage and postage.

The following graphs illustrate the cumulative figures for the number of reports distributed during the year under review:

KSA 5 WATER-CENTRED KNOWLEDGE (CONTINUED)







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*, has grown in reach and popularity since it made its debut in December 2002. 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.

During the year under review, a number of topics were covered, including the reuse of greywater, water treatment chemicals, catchment management issues, aquaculture and groundwater management. The magazine now has more than 8 000 subscribers from all sectors of South Africa, including engineers, teachers, farmers and officials from all levels of government, and it remains a popular addition to exhibitions and conferences.

The Water Wheel remains free of charge; however, advertising space is sold in the publication to defray the continuously escalating production costs and postage. Advertising rates are available from the editor (laniv@wrc.org.za) at the WRC. During 2005, the magazine was a finalist in the Best External Magazine category in the SA Publication Forum's Corporate Publication Competition.

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 2005/06 *Water SA* published 75 articles written by 225 authors and reviewed by 188 international and Southern African reviewers. *Water SA* has an extensive local as well as overseas readership. From April 2005 these subscribers have received their copies electronically free of charge. Currently we have 1 213 subscribers on our e-mail alert list in order to notify readers that the next edition is available on the WRC Website (www.wrc.org.za). *Water SA* 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

The WRC has a widely accepted Intellectual Property (IP) Policy and a Benefit-Sharing Policy. These policies clarify its contractual requirements for future research projects and improve the level of understanding/knowledge regarding the protection of IP within the water research community. The WRC continues to play an active part in the activities of the South African Research and Innovation Association (SARIMA), and engages with other institutions, such as the Innovation Fund and the Department of Science and Technology on the developments in the IP rights arena.

About 88% of the WRC's patent portfolio is licensed out. A number of licensing agreements have been reviewed and some are being re-negotiated with new contracts. In addition, new patents have been through the process of being registered. The licensed WRC patent portfolio includes the Secondary Metabolites, a cluster of 13 patents, currently licensed to Synexa and the product is already being marketed, with the first payment of royalties due shortly. The overall patent portfolio includes the Petro® Process which was licensed to Presario, but since the licence has expired, the WRC has been exploring alternative commercialisation strategies and partners. The Petro® Process is a cluster of 8 patents. Capillary Ultra Filtration (CUF) Technology comprises a cluster of 5 patents and products which are still at various development and piloting stages. This cluster of patents is licensed to FiltRSA and an extension of the licence agreement is currently under negotiation. BioSURE® is a cluster of 36 patents. The products arising from this cluster are under final development and piloting and 27 of the patents are licensed to ERWAT. Possible involvement of the Innovation Fund/IDC in funding commercialisation is being investigated. Acid Mine Drainage (ferrite process) is currently licensed to the Environmental Technologies Agency and the product is still under development. Detection of Fouling of Membranes is a patent registered only in South Africa and the product is still under development. It is licensed to IFU, a German company.

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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 cooperative 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

As described in the previous year's business plan, 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 R11.2m. for 2005/06 (R1.6m. more than in 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 2005 and 31 March 2006.

COMPLETED

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, University of KwaZulu-Natal, Pietermaritzburg
No 1195

The National Water Act defines rivers as a resource that must be sustained in order to safeguard the supply of goods and services to society. To achieve this objective the Act makes provision for reserving a quantity of water of appropriate quality to meet the basic needs people have for water and to sustain aquatic ecosystem functioning. This is known as the Reserve. Implied in the reservation of water to sustain river systems is the assumption that by doing so, rivers will continue to provide for the needs of society. It is well known that rural people rely on the goods and services of rivers to sustain life. This encourages us to perceive the needs rural people have of rivers systems to be defined in material terms such as water, fish and construction materials and we commonly fails to take account of spiritual needs.

As the intention of the environmental component of the Reserve is to sustain ecological processes in rivers, it is established largely through ecological determinations. Consequently, it may be that human dependencies are not adequately taken into account and the patterns of flow defined in the determinations of the Reserve may not meet the requirement of rural people. If they do not, the intentions of promoting collaboration in the management of river systems may be jeopardised.

The premise of this project is that if the needs of rural people are not adequately taken into account in the determination and implementation of the Reserve, the pressures rural people feel in meeting these needs will confound attempts to sustain the resource as defined in the Act.

The project sought to improve our understanding of the nature of the

relationships between the needs of rural households, the rivers system and sustainable use. Since much is already known about material needs, the research was directed at two issues namely, improving our understanding of the role of non-material needs, particularly traditional and contemporary belief systems and values, and how use of river system goods and services is regulated. Since belief systems and values define the norms that in turn direct behaviour, they are strongly connected to regulatory systems.

In order to gain insight into how belief and regulatory systems are changing and how these changes might be harnessed in co-management, the research focused on a community that was in transition from rural to urban.

Notwithstanding their peri-urban situation, the people of Salem make extensive use of the Mlazi River for a variety of uses such as washing, bathing, and watering livestock, but they also use the river frequently for rituals and ceremonies. Some of these relate to traditional beliefs and values whilst others are founded in contemporary Christian religions. The traditional belief systems and values persist, but are weakening whereas the belief systems and values associated with the Zionist Christian Church may be strengthening. Both the traditional and contemporary belief systems show strong connections with the river and therefore offer opportunity for promoting co-management, particularly as respondents indicated concern for river condition.

Respondents in the survey observed that there was not control over access to and use of river resources. The Traditional Authority whilst having a stronger presence in the area than elected councillors has lost much of its influence. It is suggested that there should still be a role for the Traditional Authorities in co-management. It is also suggested that constituencies such as the Zionist Christian Church that have spiritual connections with river systems should be encouraged to participate in co-management. All parties would however need to be empowered to do so. This requires that there are opportunities to participate. At present a structure and processes for co-management do not exist in the area and people have no opportunity to participate. It is also clear that they have neither the self-confidence nor the competencies for effective participation. Suggestions are made for a structure, the characteristics of constituencies that might participate and for agreements that would define roles and accountability of participants in co-management.

Cost: R315 000 (KSA 1)
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 on habitat requirements
University of Venda, Department of Zoology
No 1197

In recognition of the close dependence of the rural poor on a wide range of ecosystem services, this project determined the influence of anthropogenic factors on the biodiversity which underlies the provision of these services which people obtain from rivers and wetlands and provides indicators on how to assess the state of the resource. It also builds towards decision-making capacity towards the management of the resource.

The approach adopted was to compare two geomorphologically similar sites, one situated below a village on the Luvhuvhu River where there was a lot of activity and the other from the smaller, more remote Mutale River.

The recovery of the river from the 2000 floods could be seen in the changes in the macro-invertebrate fauna in both rivers. At both sites the feeding guild of collectors was dominant, predators and scrapers occurred in smaller quantities and shredders were absent. *Leptophlebeid* mayflies were the dominant group of macroinvertebrates. The fish fauna (numbers and diversity) also changed steadily throughout the period of fieldwork and this was attributed to the recovery of the rivers after the flood. The change was less marked in the Mutale River than it was in the Luvhuvhu River, possibly because the flood disturbance was cushioned by Lake Fundudzi just upstream of the sampling site. While the fish assemblages as a whole showed a greater overall response to water quality, the *Leptophlebeid* mayflies were the single most responsive group to water quality.

Preliminary results indicate that a neural network approach could be used to predict the influence of human disturbance on biodiversity in ecosystems, although this needs further development.

Cost: R95 975.08 (KSA 2)
Term: 2000 - 2005

Developing and trialling guidelines for participatory water resource management at catchment and water management area scales
Geography Department, Rhodes University
No 1233

South Africa's National Water Act of 1998 makes the management of any water resource a partnership between local water users, regional catchment managers, and DWAF. The Act encourages communities to become actively involved in developing and managing their water resources.

The three sets of guidelines - *Participatory Guidelines, Environmental Guidelines, Planning and Economic Guidelines* – are aimed at IWRM practitioners who work with stakeholder communities. The guidelines help practitioners make participatory water resource management a reality. They introduce the necessary social tools and scientific knowledge to enable communities to participate as envisioned by the legislative framework.

The *Participatory Guidelines* are concerned with good Integrated Water Resource Management (IWRM) practice, applying the philosophy of participatory IWRM and describing methodologies and case studies for community participation. Good IWRM entails capacity building, networking and conflict resolution, all of which require consistent work over time. The practitioner's responsibility is to help participating stakeholders to become knowledgeable about catchment issues and to build well-organised groups who can sustain the IWRM work when the project comes to an end.

The *Environmental Guidelines* describe the legislative and ecological context within which integrated water resource management practice takes place. They give the reader/ practitioner guidance in three ways - they outline national policy for water resource protection, they describe the environmental principles that inform good catchment management and IWRM, and they list some of the IWRM procedures and partnerships currently in operation.

The *Planning and Economic Guidelines* present tools and conceptual models for participatory financial planning and decision-making, and outline the economics of IWRM. The tools allow project priorities to be quantified and rationally assessed. This is the first time that many of these tools have been introduced in South Africa, but they have been tried and tested elsewhere in the world and constitute international best practice.

Cost: R1 000 000(KSA1)
Term: 2001 - 2003

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 report presents the findings of an action research project aimed at developing understanding related to the governance of shared, scarce natural resources. Worldwide there is increasing pressure on society to achieve equitable, efficient and sustainable use of ecosystem goods and services. The challenge we face is to reconcile the distribution of costs and benefits for society as a whole. The process that should underpin this reconciliation must be founded on trade-offs that have continually to be achieved through democratic processes. Only if these trade-offs are made democratically can we hope for the popular support that leads to compliance. In this way, attainment of equitable, efficient and sustainable use of ecosystem goods and services will reflect the extent to which democracy is institutionalised in society and the agencies that act on its behalf.

South Africa provides compelling opportunities to improve understanding of the complex nature of democracy in the context of decision-making around trade-offs in the use of the goods and services derived from ecosystems. Prominent amongst these opportunities are the trade-offs that determine the allocation of rights to use river system goods and services and the distribution of costs and benefits resulting from their use. This provides motivation to research the institutionalisation of democracy in water resources management.

The research was conducted in the Sabie-Sand catchment in Mpumalanga Province, South Africa. The project was divided into three phases. The objective of Phase I was to develop familiarity with relevant underlying theories and to describe the social-ecological system in the Sabie-Sand catchment with respect to decision-making structures, processes and behaviours. From this, issues were selected to focus the action research phase of the project (Phase II). The objective of Phase III was to draw lessons from the research experience and to highlight the implications for the development of appropriate relationships and cultures for sharing a common property resource.

CROSSCUTTING DOMAINS (CONTINUED)

Phase I identified three models, or frameworks, that would be particularly useful in guiding the research. These were Senge's process for profound change, a form of action research known as appreciative enquiry, and Cook's model for understanding empowerment.

Senge's process for profound change provided a process-oriented framework of the components of change and the reality of delays inherent in the change process. One of the striking aspects of Senge's process is the focus on the need to build social capital (aspects such as confidence and trust) long before tangible results are realized.

Appreciative inquiry is based on the principles of empathy and respect. It encourages groups to expand their collective vision by amplifying the strengths of a group; an appreciative and inquiring attitude promotes the co-evolution of values as opposed to a rights- and conflict-based approach to resource-sharing. Appreciative inquiry concepts are based on the organisational sciences, which confirm that future-building is a more appropriate approach to problem-solving than focusing on current problems.

Cook's empowerment model recognises the need for capacity enhancement in three distinct areas: Subjective empowerment (relating to confidence); Objective empowerment (relating to responsibility and opportunity); and competence (relating to skills, knowledge and attitudes). People tend to often focus on skills development in empowerment efforts, and tend to be unaware that building confidence and an ability to see and use opportunities also form an important part of the overall empowerment process.

Phase I also identified a number of issues around river resource governance in the Sabie-Sand catchment. These were:

- Large discrepancies between organizations and individuals
- Very little co-ordinated decision-making between organisations, which tend to engage government to resolve resource issues, rather than each other:
- A lack of formal representation of the interests of many resource users
- A predominance of decision-making structures that were not necessarily geared to address their constituency's resource-related issues

Apart from the issues identified, a number of opportunities were also identified:

- The Sabie River Irrigation Board had a vision (and matching enthusiasm) to expand its scope to include a number of downstream users. In this way, the board would enhance its representation and empower others. This offered a significant opportunity to the research project.
- The private forestry sector (Global Forest Products) and the Kruger National Park stood out as organisations that are outward-looking, well-resourced and able to seek, engage and drive cooperative processes. They are at opposite ends of the catchment, again providing an opportunity for focus and for integrating upstream/downstream concerns.

At the end of project Phase I, differentials in levels and types of empowerment emerged as a major obstacle to stakeholders' collective capability to develop shared understanding and make wise trade-offs. Learning about what constitutes empowerment and cooperative empowerment therefore became a focus area for Phase II of the project. The Cook Model of empowerment was used to guide the research team and resource stakeholders.

Phase II focused on action research. It applied strategic adaptive management (SAM) concepts in its approach. SAM is based on the acceptance of the uncertainty and variability inherent in social-ecological systems and the need to proceed with incomplete information. Thus, management should be experimental, adaptive and learning-oriented, so that learning from each round of implementation informs the next. This approach moves away from the balance of nature theory to a concept of nature as a system of hierarchical patches that are changing and diverse over space and time. SAM introduced an emphasis on being strategic, or future-focused. The future orientation of SAM was extremely important to the project discussed here. Phase II had the following aims:

- To determine the potential of well-resourced interest groups to own and drive a cooperative empowerment process for the collective benefit of a broader group with shared interests in the same resource
- To apply the strategic adaptive management and future-building processes as a vehicle for

cooperative empowerment
- To draw lessons from the action research experience relevant to catchment stakeholders and water policy implementers

Phase II of the research project proceeded, in the first place, as a series of individual consultations with the 'well resourced' stakeholders. Once their agreement to participate further in the process was obtained, a joint workshop between the stakeholders, the research team, and DWAF was held. This was followed by a further by a further meeting.

There were a number of outcomes arising from the above process. Well-resourced stakeholders were willing to engage and invest in local-level informal processes, but they felt that they would benefit greatly from explicit acknowledgment and endorsement of their endeavours by DWAF. Related this, there is a question about where the responsibility of an informal process ends, and where that of more statutory processes begin. There was also a perceived need for adequate and appropriate representation when people strive to make decisions together. There is a tension between being representative (i.e. having all groups present, but perhaps not participating equally) and building relationships, perhaps more slowly but more thoroughly and meaningfully, to achieve full representation.

The research conducted during this project has allowed the team to identify a number of important lessons regarding cooperative resource governance. These include the following:
- Relationship-building cannot be rushed (as predicted by Senge's Model)
- Repeated reinforcement is important for sustaining relationships
- Stakeholders can learn to value relationships as much as the decisions they support
- Informal resource governance processes require support from formal processes, and there is a risk of failure if they are not supported
- There is a need to balance the requirements for empowerment (which takes time), and representation (which can be achieved relatively rapidly, but does not necessarily lead to voluntary compliance and truly empowered resource sharing)
- Individual champions, or catalysts, play a critical role in sustaining and fostering relationships in informal resource sharing processes.

This report provides a broad overview of the outcomes of the research. However, the main products of this research are in the form of papers that have been submitted for publication in the open literature. These papers are contained in the appendices to this report.

Cost: R1 416 000(KSA1)
Term: 2002-2005

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

The North-West Dolomitic aquifer (also known as the North-West Dolomitic Water Area (NWDA)) is shared between three water management areas (WMAs). These are Crocodile West-Marico, Middle Vaal and Lower Vaal WMAs. This presents a number of institutional challenges to manage the NWDA as a common resource.

A study was conducted to identify and analyze resource management issues through a situational assessment. The situational assessment involved a description of the ecological as well as the social and institutional contexts. The ecological context primarily includes a geohydrological assessment. The social and institutional context includes a water demand/use assessment, institutional assessment and legal review.

Geohydrological assessment
The geohydrological assessment, which was a continuation from Phase 1 (WRC Report KV 140/02), concluded with a conceptual model. This forms a sound basis for a hydrodynamic (numeric) model as well as an educational tool to hone a wide range of stakeholders' knowledge of the NWDWA. Information on the resource was adapted for a handbook to be circulated to local water managers and users.

Water demand assessment
A water demand assessment was done structured according to main water uses, namely agriculture (irrigation and stock), industrial, domestic, and environment. Good results were generated for the domestic demand but there were concerns about the quality of data for the remainder of the uses. Of greatest concern was the data for irrigation as this use consumes three-quarters of the resource. The problem of quantifying and projecting irrigation demand requires high-level attention and co-ordination.

Institutional assessment
An array of organizations influences the use and management of groundwater. This assessment concentrated on the local and regional players and found that overall there was extremely limited capacity for sustained and intensive contributions in the process of groundwater management. This would be less of a problem if the designated organizations, namely CMAs and water user associations (WUAs) were in place. But since they are not and there are problems with legal compliance, the study concluded that the regional offices should be better resourced, there should be stronger lines of communication between all the main role-players and that a campaign is required that will stimulate the formation of WUAs.

As a result, of the above management alternatives were recognized which was developed through a process of scenario building. Four scenarios were developed, and from these a range of coping measures was identified. These coping measures allow for both interim and long-term options. An interim option, while intense institution building is underway, is to appoint an NWDWA coordinator who can act in the interests of the aquifer, ensuring that it is represented in the plethora of organizations that exist and affect the management of and demand for this resource. In the long term, the institutional arrangements that govern the resource may be a dolomitic water management committee, which will pull the different role-players together into one committee and serve to centralize decision-making around the aquifer. However, for this approach to be effective, the participating organizations need to be strong and their strength will depend largely on how they are set up and to what extent stakeholders are capacitated to play a meaningful role in water management.

Cost: R762 906(KSA1)
Term: 2002-2004

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

The South African government system is fragmented vertically between three spheres of government, viz. National, Provincial and Local Government as well as horizontally between government departments with different but inter-related mandates. Based on this inter-related nature of South Africa's government system; the constitution, although not prescriptive, provides a chapter that gives a broad framework on how to manage interrelated mandates. Chapter 3 (three) of the constitution provides for Cooperative Government as well as the principles that should guide cooperative government. Section 41(2) provides that through an act of parliament that government must establish institutions or provide:

- Structures and institutions to promote and facilitate cooperative governance
- Mechanisms and procedures to promote and facilitate intergovernmental relations

The implications of this section of the Constitution are the following:

- A need to develop strong appropriate policy, legislation and strategies as the foundation for cooperation
- A need to create a balance between the technical requirements for interaction between the tiers of governance and political relations
- The ability to accommodate the interests of the various tiers of governance while managing the areas of disputes that may arise.

The Constitution therefore becomes the main driver of cooperative governance between institutions of government. The constitution describes the spheres of government as distinctive, independent and interrelated in nature. The distinctive nature of the spheres of government refers to the legislative and executive autonomy that they have while interdependent nature relates to the degree in which each sphere of government depends on another for fulfilment of its constitutional mandates. The inter-related nature relates to the manner in which spheres of government fosters relations between themselves based on mutual trust and good faith for the greater good of the country as whole. The implications are that although the spheres of government are distinct and independent, they cannot function without cooperating with one another as their activities impact on one another. In terms of Section 41(1), cooperation between the spheres of government should be guided by three principles, namely unity, decentralisation and cooperation. These are underlined by:

- Fostering friendly relations between all levels of government
- Assisting and supporting one another

- Informing one another of, and consulting one another on, matters of common interest
- Coordinating their actions and legislation with one another
- Adhering to agreed procedures
- Avoiding legal proceedings against one another

In trying to achieve cooperative governance the South African Government have in the past years developed a number of mechanisms and strategies, which have been faced by a number of challenges. These mechanisms have been developed both at political level as well as at executive / administrative levels. At political level structures such as the MINMEC which is a committee between the minister of a specific department and the MEC for the relevant department, the Intergovernmental Forums, which comprised political office bearers from the three spheres of government and the Presidential Coordinating Council aimed at bringing together all Premiers, the state President and DPLG to address issues of common interests were all developed to promote cooperation.

Cooperative governance at planning level is governed by the same principles used at political level; however these are further put into perspective by the policies and strategies that govern planning within the different institutions. Within these policies and strategies cooperative governance is realised through integrated development planning. Policies and strategies such as the Integrated Development Plans and the Municipal Systems Act, NEMA, the National Water Act and the National Water Resource Strategy, etc promotes cooperative governance. Cooperative committees such as the IDP Committees, National Environmental Advisory Forum and Committee for Environmental Coordination, etc. also promote cooperation.

The National Water Act (Act 36 of 1998) enables the establishment of catchment management agencies (CMAs) in the 19 water management areas (WMAs) established in South Africa. These CMAs will ultimately take responsibility for all activities required to enable and support water resources regulation, including authorising the use of water and ensuring that water related activities are performed in accordance with the Catchment Management Strategy (CMS) that is developed in the relevant WMA.

The Local Government 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. In particular, local government has key responsibilities related to water resource management (WRM) including ensuring provision of municipal services, rural development strategies, municipal spatial development and infrastructure planning, environmental management, including pollution control and waste management.

The first paragraphs of the summary referred to the requirements by the Constitution, which states that all organs of state and spheres of government should observe and adhere to the principles and conduct their activities within the parameters of cooperative governance. Although there is general acceptance and support for this requirement, the water sector has not been particularly effective at pragmatically implementing these sentiments nor making them operational. As CMAs are established and local government continues to take on its Constitutional mandates, the need for cooperation between these two institutions will be critical to the effective, efficient and sustainable implementation of WRM.

CMAs are in the process of being established and therefore there is a significant opportunity to ensure that they foster cooperative governance, particularly with local government as a key partner each with their respective mandates in each WMA. This should be the case based on a number of reasons when taking into account the expected functions that local government should perform. As an example the Municipal Systems Act (Act 32 of 2000) gives reference to the role of local government planning in cooperative governance. Section 24(1) stipulates that *'any planning must be aligned with, and complement development plans and strategies of other affected municipalities and other organs of state so as to promote cooperative government contained in section 41 of the Constitution'.* Based on this and the functions that they perform, local government has planning strategies that impact on water resource; these include spatial planning, water services planning (WSDPs) and environmental management planning.

On the other hand the National Water Act requires that CMAs when developing the catchment management strategy take into account the planning by other institutions including local government water services development plans. In relation to water-related activities, local government impact on water resource management is through water use, which permits the institution to abstract or discharge wastewater based on licence granted by DWAF/CMA.

Besides water-related activities and planning imperatives, cooperation between the two institutions is triggered by other roles, which include the role of local government as a stakeholder representing activities at a less binding level, e.g. non-consumptive use of water for recreational purposes as part of tourism initiatives. The second and critical factor is around conservation of water as a scarce resource. Local government as a major water user may need to monitor the efficiency of water use by its clients so as to conserve water. The CMA may provide the techniques for water conservation.

The areas of cooperation between the two institutions are indicated, based on relevant legislation and policy mandates. Overload of tasks and capacity limitations remains the factor for full local government participation on IWRM. The implications are that the CMAs should take the responsibility for promoting and enabling cooperative governance around WRM between these institutions. The CMAs are therefore faced with a task of developing and driving mechanisms for cooperation with local government.

Certain local government institutions have capacity to simultaneously engage with the CMAs on these processes, it is therefore imperative that they become partners in these processes. CMAs and local government should consider the following mechanisms in their engagements.

Governance, accountability and representation

The CMA Governing Board (GB) must have local government representation, although the nature of this representation is not clear. It is clear that the diverse interests of typically 10 to 20 municipalities within a WMA must be represented by a limited number of GB members (probably less than 3). Furthermore, the GB is legally accountable to the Minister of Water Affairs and Forestry and National Parliament (through SCOPA) and has a fiduciary duty to the CMA rather than their individual constituencies. DWAF will oversee the activities of the CMA and the functioning of the GB.

However, the local government representative/s on the GB can promote the interests of local government in policy and strategy decisions that the GB is responsible for. It is therefore in the interests of municipalities to ensure that these members are aware of the WRM issues facing local government and can represent the diversity of municipalities in that particular WMA. *Municipalities should take the CMA GB Advisory Committee process and subsequent nominations seriously.* It may even be appropriate for municipalities to develop a caucus / forum to promote their interests through the GB member, but it is more appropriate that this be under the auspices of a formal committee established by the CMA. These committees are discussed in chapter 9 of the document.

Legislative and policy alignment

Local Government may establish bylaws around a range of activities that affect WRM. The CMA has an interest in ensuring that these are aligned with (or at least are not inconsistent with) WRM legislation and approaches. The development of model bylaws may contribute to this, but the ***CMA may take a proactive role in evaluating municipal bylaws in the WMA and advocating changes where these may be inappropriate from a WRM perspective.***

Similarly, it is in the CMA interest that WRM legislation and policy is aligned with the environment in which Local Government operates. Although CMAs do not establish regulations they can advocate that DWAF ensures this alignment, taking account of the specific challenges that that particular CMA faces with the municipalities within the WMA. This may also involve promoting dialogue and alignment with Provincial legislation.

Coordinated strategy development

The NWA requires the catchment management strategy (CMS) to be aligned with other development plans. For local government, this requires alignment with the range of plans developed by local government under the integrated development planning. Although the principle is clear, operationalising this alignment requires an agreed approach between the CMA and municipality. It may

include

- **Participation** / involvement by relevant staff from municipalities in CMS development processes and CMA staff in IDP development process, through the relevant forums
- **Informal meetings** between the CMA and municipal planning sections to identify and resolve areas of inconsistency
- **Formal review** and commenting on draft CMS or IDPs
- Active process of **joint strategy** *development,* from initiation to development of relevant parts of the CMS or IDP

Participation in strategy / plan development processes is the minimum level of engagement acceptable, possibly supported by informal meetings or formal review (where problems are identified). Even this requires capacity from both institutions that is often likely to be missing. From the perspective of WRM, **the CMA must engage with the IDP process. Furthermore, the CMA should make every effort to engage the municipalities in the CMS process,** possibly through dedicated bi-lateral or multi-lateral local government forums, particularly where the municipality has limited capacity. It should be acknowledged that although ultimately desirable, the likelihood of joint strategy development is limited in the short to medium term, except where there is a real driver for this alignment, possibly related to severe water shortages or water quality problems.

Based on the findings it can be concluded that CMAs and Local Government Institutions do have areas of cooperation, which are critical for realisation of integrated water resources management. While work overload and capacity are recognised limitations of local government and are also anticipated with the CMAs; it is critical that both institutions recognise the importance of cooperative governance therefore playing a proactive role in engaging and driving cooperative processes. CMAs as managers of water resources which other institutions and individuals depend upon should be in the forefront of these cooperative processes.

The manner and level at which local government is involved within the CMA processes and activities should reflect the various roles of local government as an institution, i.e. from integrated planning, water services and being democratically elected institutions representing the interests of all stakeholders within an area of jurisdiction. The implications are that CMAs need to recognise the importance of local government as the driver of local social and economic development, therefore the need to create closer ties for integrated planning and development.

The current approach to CMA establishment processes on local government engagement largely lies at higher political level, therefore excluding certain levels of administration. It is critical that this process engage officials at administrative level particularly for planning alignment purposes.

Cost: R290 000 (KSA 1)
Term: 2003 - 2004

International freshwater agreements
CSIR

No 1515

South Africa shares four rivers with its six neighbours - the Incomati, Orange, Limpopo and Maputo. The water in these rivers is increasingly under pressure due to increased water demands in South Africa as well as in the neighbouring states. South Africa has ratified the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (United Nations, 1997), which calls for the exchange of data and information, the protection and preservation of shared water bodies, the creation of joint management mechanisms, and the early settlement of disputes (UNEP, 2002).

Essential tools for achieving the objectives of the UN Convention are the various treaties, protocols, memoranda and agreements entered into between basin states (collectively referred to as agreements). South Africa is party to a range of bilateral, multilateral and regional agreements on 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 to with neighbouring states.

The overall goal of this research project was to contribute to the good governance of South Africa's shared watercourses, by making available copies of the agreements the country is party to and analysing selected treaties. To achieve this, the project had four objectives:

- Compile a list of all freshwater agreements to which South Africa is

a signatory
- Update the Transboundary Freshwater Dispute Database (TFDD)
- Store the agreements in a database, and make it available in CD-Rom format
- Using the Legal Assessment Model (LAM) of the International Water Law Research Institute (IWLRI) to determine how effective current agreements are

The initial challenge for the project team was to develop a methodology for the inclusion of agreements in the final list and the database. After consultation with the project steering committee and the Department of Foreign Affairs (DFA), it was decided to include all agreements that the Government of South Africa had entered into with another **sovereign state** since 1910 with a direct impact on the management of freshwater resources.

These agreements cover a variety of issues and were sourced principally from DWAF and DFA archives. The final list of agreements contains 59 entries that were included in the database entitled **International Freshwater Agreements Database.tba** and distributed with this report. The database is fully searchable using a variety of fields. The hard copy agreements were then scanned and saved as PDF files, viewable from the database. The final list of agreements was used to update the TFDD, housed on an Oregon State University website, once permission was granted by the WRC. This is important as the TFDD is used extensively as an authoritative source of data and information on global freshwater agreements.

The database analysis showed that the rate at which South Africa enters into agreements with other countries is increasing. This is linked partly to the normalisation of South Africa's relationship with the international community and partly to the global trend of concluding more multilateral treaties on water resources and management. There are indications that this will continue, making it important to keep the database up to date.

The original project proposal would have used the Legal Assessment Model (LAM) to analyse a selection of agreements. However, once the LAM became available, it became clear that it is more useful for determining if a proposed water use is permissible, rather than as an overall analytical tool. International agreements tend to have an evolutionary aspect, increasing their range, scope and complexity over time. In order to draft agreements that will work effectively in practice, and to support that evolutionary process by bringing in scientific processes to support future negotiating teams, it is necessary to understand which components to include in such agreements, and which matters should be regulated by such agreements.

The project analysed two key agreements of regional importance to which South Africa is a party: the 'Tripartite Interim Agreement Between the Republic of Mozambique and the Republic Of South Africa and the Kingdom Of Swaziland for Co-operation on the Protection and Sustainable Utilisation of the Water Resources of the Incomati and Maputo Watercourses', signed on 29 August 2002 (hereafter called the Incomaputo Agreement), and the 'Treaty on the Lesotho Highlands Water Project between the Government of the Republic of South Africa and the Government of the Kingdom of Lesotho', signed on 24 October 1986 (hereafter called the LHWP-Treaty).

The analysis showed that these two agreements meet the requirements for effective operation. While the LHWP-Treaty contains important elements of 'modern' international water law, the Incomaputo Agreement reflects the developments of international water law to a higher degree. With its comprehensive basin-wide management regime, the Incomaputo Agreement is well suited to function as a model agreement for other, future basin-wide water agreements that may be considered in the SADC region. Importantly, the analysis has shown that certain improvements to the Incomaputo Agreement are desirable and indeed possible.

This study revealed the intricacy of international agreements – both in terms of the domestic ratification process that must be followed, and on an international level with other states. Importantly, older agreements that were entered into while South Africa was still a British colony or with other colonial powers prior to those territories gaining independence, are still valid, and their provisions – both rights and responsibilities – are still in place, unless they had been specifically revoked by the country concerned after independence.

The degree of legal predictability that agreements provide contributes to a spirit of cooperation and collaboration over shared water resources. However, the long-term effectiveness of these agreements depends on their regular upkeep; in this case ensuring that they

are readily accessible to present day decision-makers, planners and managers.

Two key recommendations are made. The first is to distribute the database widely to a broad range of stakeholders, and ensure that it is maintained regularly to include the latest agreements. The second recommendation is that a similar project should be conducted for the entire SADC region – to provide a centralised register of all the international freshwater agreements to which SADC states are party.

Costs: R270 000 (KSA 1)
Term: 2004 - 2005

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

For a long time it has been believed that the solution to the management problem is training, and as a result very substantial sums of money have been spent by DWAF on training community committees to manage their schemes effectively. As projects have moved into the operational phase, it has been realised that training in itself does not ensure that projects will be properly managed. For example, at Nhlungwane, which is one of the better run community water projects in South Africa, the Mvula Trust found on one return visit that the book-keeper had stopped keeping books because the committee never looked at them. The people who make up rural committees are like any other people anywhere – *regardless of how well they know what they should do, they do what you inspect,* not what you expect. The problem is that newly emergent local authorities (the responsible inspectors) still have very little idea of what questions to ask when visiting projects, nor how to ask them - i.e. the inspection needed to stimulate good management is not taking place on any effective level.

There are scores of different key performance indicators (KPIs) that are encountered in government reporting systems. The problem is that these are typically too numerous and varied to help the harried council official who needs to know the answers to simple but critical. The challenge is therefore to develop simple and effective reporting systems, easily understood by rural water committees, which they can be expected to use to report to their own communities, as well as to the relevant authorities. The set of KPIs must pictorially depict trends (good or bad) in strategic areas such as service performance, financial health and accountability. With such a system in place, monthly visits from municipal officials can become more effective occasions for communication, problem identification and problem solving.

In the course of this study a number of monitoring initiatives taking place around South Africa have been reviewed. Some are very ambitious, and some are quite basic. At community level, systems of KPI recording are needed which are simple, practical and effective. In the course of this research a method of KPI recording at community level using standard data sheets and standard charts was tested. These sheets and charts are filled in by hand, which means that it is not essential to have computer facilities to do basic management. It was found that community level administrators could understand and work with this system, although only the simpler KPIs were tried out. With a longer term management commitment, there is no reason why more complex KPIs could not be tackled.

The KPIs that were successfully tested (income, expenditure, water losses, number of taps, energy bill, etc.) were found to be useful in understanding trends in the water schemes being managed. In order to convey the meaning of KPIs, they should be displayed graphically over time. By so doing, trends can be observed, and it can be deduced whether the scheme being observed is stable, getting worse or getting better. Even at the community level administrators should be taught how to record and plot simple but vital KPIs.

Cost: R271 000 (KSA 3)
Term: 2001 - 2002

Alternative approaches for sustainable water supply schemes
Options to Solutions
No 1223

The aim of the research project was to carry out a review of different approaches (with emphasis on technological interventions) which have the potential to render sustainable water supply schemes, to carry out project project-specific technical and

economic analysis on identified projects representing an individual approach in order to gauge sustainability and utilisation. And to develop, validate and disseminate the demand-led planning tool that promotes and supports a technically viable approach integrating rural water supply to community activities.

Whilst three approaches were identified, i.e. the on-site generation of chlorine, micro-hydro technology as well as food gardens, the majority of the work focused on the former two. On-site chlorine generators based on the chlor-alkali process utilises common salt, electricity and water as the only raw materials. Products of the chlor-alkali process are gaseous chlorine, caustic soda and/or hypochlorite. All the by-products from the chlor-alkali process can be sold to generate income for the rural communities.

Some existing schemes with the above themes were either were visited, researched, and analysed to determine how they could be made to improve in the objective of ensuring schemes' sustainability.

Cost: R496 100 (KSA 3)
Term: 2001 - 2003

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

The Strategic Framework for Water Services (2003) directs that water and sanitation programmes should be designed to support sustainable livelihoods and local economic development. The directive is framed by the following statement: 'The provision of water supply and sanitation services has significant potential to alleviate poverty through the creation of jobs, use of local resources, improvement of nutrition and health, development of skills, and provision of a long-term livelihood for many households.'

If basic sanitation services are central to development in poor communities in informal settlements then current approaches focused on infrastructure delivery will not meet the challenges of the growing sanitation crisis in burgeoning informal settlements. Most of the current infrastructure delivery approaches are not able to integrate the components of health, infrastructure delivery and effective pro-poor community partnerships in any meaningful way. Moreover, capacity in support organizations is often lacking.

Based on the investigation of sector approaches, development sector lessons and the development and a capacity review of the cases studies, the following principles were developed as fundamental to integrated programme design and capacity for the provision of sanitation services and developing a process to improve service delivery. The study covered the following aspects:

- Assessing capacity for Integrated programme delivery
- Improving capacity for integrated service delivery

In response, two tools were developed. A review table incorporating the integration and capacity principles was developed as a rapid capacity assessment tool. Subsequently a detailed programme assessment tool based on the review table was developed to specify the knowledge requirements, to record the organizational information especially the tacit knowledge and therefore provide structure for the planning of improvements.

Based on the application of the review table and the assessment tool the following process is proposed for planning improvements. Guidelines drawing on the experience in the development and application of the review table and the programme assessment tool, the steps and outputs outlined were used as the framework for the development of the guideline for the application of the project findings.

Cost: R550 000 (KSA 3)
Term: 2003 - 2005

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

Modelling scenarios indicate that climate change impacts are expected to alter the present hydrological resources in South Africa. Despite uncertainties, the majority of the models suggest a decline in rainfall over the western parts of South Africa in the coming decades. Based on these projections, the most severe impacts are likely to occur in this region, where small towns and subsistence farmers are most vulnerable. The available literature suggests that it would be prudent to account for climate change in water resource planning to meet the development objectives of South Africa. With this in mind, this study investigates the adaptive capacity of small towns and communities in the Northern Cape Province to climate variability, specifically drought. By testing these strategies against sustainable

development criteria, planning policies for national and water resource planning and management are recommended to ensure water security against the impacts of climate change. A simple multi criteria decision analysis methodology was used to test the long term suitability of the strategies developed was done in consultation with representatives of the various Local Municipalities in the Northern Cape Province and members of the Provincial Drought Task Team.

Based on this study and the responses obtained from the stakeholder group, the following portfolio of strategies should be further investigated when developing a water resource management strategy that takes future climate change impacts into account:

Supply side management:

- Reduction of leaks programmes
- Regional water resource planning
- Local water resource management and monitoring
- Conjunctive use of surface and groundwater
- Rainwater harvesting

Demand side management:

- Dry sanitation systems
- Education programmes
- Tariff structures
- Water restrictions

Emphasis should be placed on demand side management given the finite amount of water. This is reinforced by the fact that the top three strategies rated by the stakeholders were all on the demand side. However, that is not to reduce the responsibility for better management by the water service providers to reduce wastage and losses in the delivery systems.

Groundwater is likely to be most severely affected, with the groundwater table dropping due to reduced recharge. Strict groundwater management systems should be put in place with early warning mechanisms to report depleted groundwater reserves. Continual monitoring of the aquifer against climate conditions will provide some knowledge of the future potential under projected climate conditions.

Cost: R261 260 (KSA 1)
Term: 2004 - 2005

The effectiveness of water and sanitation awareness programmes in informal areas
Nemai Consulting
No 1523

The overall goal of providing sanitation services is to promote health and the quality of life for all, with an emphasis on the need for sanitation projects to include health and hygiene education because improved facilities without an effective health and hygiene education and awareness programme have no impact on the improvement of health. The most significant impact on the prevalence of disease stems from behavioural changes resulting in improved hygiene. Without behaviour change, only improved water quality and quantity will reduce the prevalence of disease. The objective of this study was therefore to investigate the effectiveness of sanitation awareness and education programmes (SEAPs) in informal settlements in reducing the incidence of disease.

The project focused on a range of awareness creation and education techniques that may be utilized in SEAPs, and the effectiveness of these techniques. Seven SEAPs across South Africa were reviewed as case studies and included in the study. From previous research it is apparent that community involvement and the PHAST approach are essential for a successful and sustainable SEAP. However, although most SEAPs use PHAST tools, the concept of PHAST where a community is responsible for identifying their health and sanitation problems and implementing their own solutions is not usually fully realised. Often PHAST tools are simply used as effective education tools, while a pre-designed solution is implemented.

The study found that:

- Sustainability is a major problem. Most SEAPs are run as part of a larger sanitation service provision project and when the construction of toilets is complete the SEAP ends too. People from the area where the project was implemented and who have been trained and employed as Health Promoters are no longer active as educators after the Implementing Agent has left. Their skills and knowledge may not remain in the community in informal settlements as the turnover of residents is high.
- Officially the responsibility for health and hygiene education passes over to the Department of Health, but most often the DoH fieldworkers have not been intimately involved in the SEAP and will simply continue to do the same work that they always were doing in that area, with no specific focus on the issues that the SEAP was concerned with. In the same way, any person who has been reached by the SEAP may move to a different area at any time, and be replaced by someone who has not been educated on the use and maintenance of the sanitation service in the area. This applies in some degree to any residential or

township area, but is aggravated in informal settlements, which are often only a short-term home for residents. Thus the temporary nature of informal settlements is hindering the sustainability of SEAPs.

- There is a perception that there is an unwillingness to pay for services in informal settlements. This is not necessarily true, and a contribution from each household towards improved sanitation facilities is an important part of creating a sense of ownership towards the facilities.
- Given information and imbued with knowledge, the people in informal settlements have the capacity to organise themselves to change their own situations. A high level of commitment and initiative is shown in areas where people have been empowered with knowledge about hygiene and sanitation issues. This is in line with the PHAST methodology and means that the success of an SEAP is not dependent upon the continued presence of the implementing agent. A project where the SEAP is run by the community itself is infinitely more sustainable than one where the impetus for educational activities is temporary and controlled by the implementing agent.

Cost: R200 000 (KSA 3)
Term: 2004 - 2006

THRUST 4: POVERTY ALLEVIATION

Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers
Tlou Water Management
No 1353
The last decade has witnessed significant land and water reforms in South Africa including land tenure and local governance on water to ensure sustainable development and management of the resources. This is fundamental to creating an enabling environment for rural communities to lift themselves out of poverty. However, the growing recognition of the importance of land tenure to sustainable development has not been supported by an investigation into how it influences smallholder irrigation in improved food production efficiency. This study was commissioned by the WRC Water Research Commission (WRC) to review the land tenure systems and support structures in South Africa, to identify constraints and opportunities relating to land tenure and support structures, with a view to developing a framework for sustainable settlement on small-scale irrigation schemes.

The study method included the collection and analysis of existing international and local literature on land tenure, security of tenure and support systems. This was supported by case studies of existing small-scale irrigation schemes with specific focus on the Eastern Cape Province. Two schemes were selected for detailed study and interviews were conducted with selected key informants and farmers including relevant government departments in the province, and civil society groups.

A review of the land tenure system in the case studies revealed that communally communally-held land was problematic as far as small-scale irrigation schemes with low production levels were concerned. Tenure security is a major issue affecting settlement on smallholder irrigation schemes (SIS) in long term viable conditions. The state controls large parts of the land. Through the Communal Land Rights Act, the South African government is seeking to clarify land rights by transferring title from the state to local communities. Furthermore, the intention is to establish administration structures to govern the process of issuing and registering land tenure rights to individuals in communal areas. This will improve access to financing because the land can be held as collateral.

The other issues researched were the financing, marketing and management support systems for SIS in order to ensure they become sustainable and the farmers themselves take ownership of these schemes. In terms of production it was clear that small-scale irrigation farmers need access to markets where they can sell sufficient quantities of produce at prices that will enable them to make a worthwhile return on their investments and farming efforts. Without this, there is in effect no incentive for them to go beyond farming purely as a means of supplementing their daily food requirements. In terms of the long-term viability of the schemes researched, attention needs to be paid both to farmers' ability to access credit and their ability to service credit once obtained, and it must be ensured that adequate training is available.

An analytical framework was developed to provide a basis for understanding the dynamics of the development of SISs. It was demonstrated that this framework provided insight into the interaction of various elements such as intensification/extensification and increased productivity/increased land size. Each step in this development path was carefully considered, the impacts on land tenure systems as well as all other support systems (production,

marketing, irrigation, financing, institutional and social) were evaluated and appropriate recommendations were made on this basis.

Cost R795 200 (KSA 4)
Term: 2002 - 2005

Implementing and testing the WRC guidelines on developing sustainable small-scale farmer irrigation in poor rural communities
IWMI, ARC
No 1357

The WRC guidelines *Developing Sustainable Small-Scale Farmer Irrigation in Poor Rural Communities: Guidelines and Checklists for Trainers and Development Facilitators* (WRC **Report No. 774/1/00)** are directly relevant to the implementation of two government programmes. The guidelines are applicable to the presidential programme, Integrated Sustainable Rural Development (ISRD), and the Revitalisation of Smallholder Irrigation Schemes (RESIS) Programme in Limpopo Province and form the basis of this research project.

In this study, these WRC guidelines were tested and expanded as a means of increasing meaningful training and capacity building in the small-scale irrigation sector. Smallholder farmers currently have limited access to training. Furthermore, formally available training is focused almost exclusively on scaled-down versions of high-cost, high-risk commercial production practices, which are especially inappropriate for resource-poor households. Much of the current training also requires trainees to be away from their homes for periods ranging from three weeks to several months. This is impossible for many, especially so for the women responsible for food-insecure households. Most of the farmer training in the Limpopo RESIS Programme is offered on-farm.

The approach of 'development through needs-based training', as developed by Johann Adendorff, was first applied successfully in the training of approximately 7 000 poverty-stricken dry land maize farmers in Phokoane in the Nebo district of the Limpopo Province over a period of five 5 years. Through appropriate training, organisation and improved self-confidence, farmers considerably improved their yields from an average of 3.5 bags per typical 1.2ha holding, to a new average of 40 bags. The 'development through needs-based training' approach has since been used in several dry dry-land areas in South Africa and is currently being used in poor rural communities with access to irrigation schemes. In particular, the Limpopo RESIS Programme provided a valuable opportunity to implement and test Adendorff's training and the WRC guidelines.

The project included the development of training material and the training of farmer trainers. It also assessed how training can be provided through the Agricultural Colleges in Limpopo Province. This process was viewed as a pilot exercise for national expansion and aligned to the development of the National Strategy for Education and Training for Agriculture and Rural Development. The information and data gathered in this project on the various training methods used in the RESIS Programme were used to develop further training courses and training modules. These curricula are now being institutionalised at the two agricultural colleges in the Limpopo Province, Tompi Seleka (Marble Hall) and Madzivhandila (Thohoyandou). The training material has been registered with the Primary and Secondary Agriculture Sector Education and Training Authority (AGRIseta). AGRIseta supplied the project team with copies of all the existing registered unit standards within the AGRIseta. From this information, gaps could be identified of unit standards that were needed but not yet developed.

Attention was given to the development of a training package that can be given to prospective trainers or facilitators to use in the field when presenting training to farmers. The package includes information such as the expected outcomes and training content material, as well as notes to trainers regarding important issues to consider throughout the training. Appropriate procedures for introductions were also considered. The package includes information on equipment requirements, such as flip charts, paper, pens or other visual aids that may be necessary for presentation of specific training modules, as well as the actual technical training content. The training package consists of four parts, namely: A facilitator's guide on farmer training; training tools - a coded set of transparencies and other aids to be used during training sessions; assessment tools - used for the assessment of training / learners' progress and; audio-visual reference material - training in the field captured on video for reference purposes. Current training material includes modules on maize production, cotton production, basic scheme management and water management. Further outcomes based training modules being developed will over time also be incorporated into the facilitator's guide.

Cost: R860 000 (KSA 4)
Term: 2002 - 2005

CURRENT

THRUST 1: WATER AS A SHARED RESOURCE

Integrating flood-plain agriculture into a diverse rural economy by enhancing cooperative 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 Jozini Dam. This project will promote effective cooperative 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 (KSA 4)
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 (KSA 1)
Expected term: 2002 - 2006

Integrated development planning for estuaries
Institute for Natural Resources
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 (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). It, therefore, offers the opportunity on a pilot scale to develop and apply methods of establishing a cooperative 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 (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 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 cooperative 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 (KSA 1)
Expected term: 2004 - 2006

THRUST 2: SOCIAL NEEDS FOR WATER SERVICES

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

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: R300 000 (KSA 3)
Expected term: 2003 - 2005

CROSSCUTTING DOMAINS (CONTINUED)

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 - 2008

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 · day) before water can be allocated for use by the various sectors. The notion of the BHNR essentially elevates the status of water for basic human needs to that of a human right. Although an orientation that accepts access to water as a human right is enshrined in South African law, it represents a very new concept in water management in South Africa (and the world). One of the major obstacles hampering implementation is a lack of familiarity and understanding of the notion of the BHNR by the very people tasked with the responsibility for ensuring that it is honoured, i.e. local government. An informal, preliminary survey conducted by AWARD indicates that most members of local government have not heard about the BHNR.

The objectives are:
- An exploration of the concept of 'water as a human right' within the context of the South African legal framework
- Enhanced understanding, capacity and competence within Local Government to implement the National Water Act and allocate water resources with consideration for the concept of 'The Reserve'
- To produce and test learning support materials regarding the concept of the Reserve
- To research, understand and document the way that access to water resources as a human right can be implemented in South Africa

To share findings generated by a research orientation with other catchments and local governments in South Africa.

Estimated cost: R173 100 (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 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 (KSA 3)
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 (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 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 project offers a fresh approach at using local resources and systems to promote good sanitation and hygiene.

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 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 (KSA 3)
Expected term: 2004 - 2006

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, and 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 151 000 (KSA 4)
Expected term: 1999 - 2006

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 (KSA 4)
Expected term: 2002 - 2006

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

CROSSCUTTING DOMAINS (CONTINUED)

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 (KSA 4)
Expected term: 2002 - 2006

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 (KSA 4)
Expected term: 2002 - 2004

Principles, approaches and guidelines for participatory revitalization of smallholder irrigation schemes
ARCUSS Gibb Consortium
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: R1 195 000 (KSA 4)
Expected 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 (KSA 4)
Expected 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: R3 000 000 (KSA 4)
Expected term: 2003 - 2008

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 (KSA 4)
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.

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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

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 (KSA 4)
Expected term: 2004 - 2009

NEW

THRUST 2: SOCIAL NEEDS FOR WATER SERVICES

Water services franchising: An innovative approach to water services delivery in rural and peri-urban areas
Umgeni Water
No 1610

The project aims to assess water franchising for delivery of services in peri-urban and rural areas. The concept proposed is a very new and innovative subject area. The study builds on outputs from a completed scoping exercise, which recommended that the principles and concepts be further established and proven, which would then allow piloting and implementation much more attractive. The concepts will contribute to wider participation of small scale entrepreneurs in the management of water services

Estimated cost: R600 000 (KSA 3)
Expected term: 2005 - 2007

The state of community consultation in the provision of water services
Sigodi Marah Martin
No 1616

It is imperative that in a changing institutional environment the concepts of community involvement are not lost. As Water Services Authorities take the helm of service delivery, it needs to be ensured that the community aspects are not lost. This study will look at the level and status of community consultation on a range of water services issues. It will aim to identify typical problems areas and successes and come up with recommendation for improving community participation in the sector. This will be of importance to the sustainability of projects, and also to the regulation of water services. This study will undertake a qualitative and quantitative survey to determine the level or status of community consultation.

Estimated cost: R700 000 (KSA 3)
Expected term: 2005-2007

THRUST 3: GENDER AND OTHER LIMITATIONS REGARDING ACCESS TO WATER

Best practice institutional and project guidelines based on national and international experience to manage the impact of gender in the South African rural water sector
Council for Geoscience
No 1612

Over the past 10 years a lot of emphasis has been afforded to the aspect of gender in the provision of water and sanitation services both at a local level and international level. In fact, it has become a requirement in many initiatives and has become part of policy and legislation. Yet, with all these requirements is progress being made. This project aims to understand the impact of gender on the management of rural water supply and the effects of decentralization of services. Are these new arrangements supporting gender mainstreaming? This is what the study will be highlighting.

Estimated cost: R600 000 (KSA 3)
Expected term: 2005-2007

THRUST 4: POVERTY ALLEVIATION

Participatory development of training material for agricultural water use in homestead farming systems for improved livelihoods
Rural Integrated Engineering (Pty) Ltd
No 1575

Most of the rural poor are vulnerable to malnutrition and the incidence of diseases such as HIV/AIDS. While research in smallholder farming has increased substantially in the last decade, much of the information generated has not been packaged for resource-poor farmers. Most of these farmers are illiterate but experienced in farming. One of the overarching principles of the Government's integrated food security strategy is that the food insecure should be made agents of their own development. However, smallholder farmers currently have limited access to any training, and formal training is focused mostly on available courses of commercial production practices, which are especially inappropriate to food-insecure households. The project intends to develop training guidelines for food insecure households. The fulfilling of this desperate need has to be done in collaboration with experienced development facilitators and agricultural colleges who are mandated specifically to train farmers in different regions of South Africa.

Estimated cost: R2 750 000 (KSA 4)
Expected term: 2005-2009

Real-time irrigation advice for small-scale sugarcane production using a crop model, weather data and cellular communication
SASRI
No 1576

Water use efficiency in irrigated sugarcane agriculture is notoriously low and could be increased dramatically if farmers applied established scheduling methods. The challenge for researchers and advisors is to provide simple, practical and useful advice to farmers using state of the art technology such as crop models and weather stations, and to convince farmers of the benefits of irrigation scheduling through on-farm demonstration. The Agronomy Department at SASRI has developed a prototype of a system (called *My Canesim*) consisting of, among others, the following; weather data recorded by automatic weather stations and the automatic distribution of irrigation on/off advice in isiZulu through SMS technology to farmers' cellular phones. In a pilot case study, the system was implemented in 2004 on a limited scale in Pongola. Initial results are very promising and indications are that water savings of 30% and cost reduction of R1 400/ha could be achieved for small-scale growers. There is enough evidence to push for wider implementation of this service.

Estimated cost: R350 000 (KSA 4)
Expected term: 2005-2008

Nutritional value and water use of indigenous crops for improved rural livelihoods
University of Pretoria/Centre for Nutrition
No 1579

Under-nourishment is a major problem in many rural and peri-urban communities, particularly amongst children. A variety of indigenous crops can meet the taste and dietary requirements of household members. The best combination between indigenous crops and a range of home-grown vegetables, and other foodstuffs to achieve a balanced diet, has to be evaluated. In a study by the University of the Free State on the socio-economic acceptability of infield rainwater harvesting and conservation for homestead food production, the minimum area necessary to meet the caloric requirements of a household was calculated (WRC **Report No 1267/1/04**). Given the seasonal variability of rainfall, appropriate technology similar to that tested by the Tshwane University of Technology (Khosa, 2003) has to be evaluated to supplement water supply and stabilise food production in homestead gardens. The purpose of this project is to investigate the linkages between dietary requirements, nutritional value, water requirements and technology for production of a combination of food crops. Both laboratory, on-station and participative action research will be undertaken to develop best practices in order to improve food security and well-being of households.

Estimated cost: R2 250 000 (KSA 4)
Expected term: 2005-2008

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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 recognized 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 recognized 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.

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, while a study to model the cost associated with eutrophication is being started. Further studies need to be undertaken to determine the economic costs associated with other forms of pollution (e.g. 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 have been conducted. The most prominent of these are projects in support of the development of the Waste Discharge Charge System currently being implemented by DWAF.

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 R4.4 million for 2005/06, which represents an increase of 30% from the previous year.

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 2005 and 31 March 2006.

COMPLETED

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

The National Water Resources Strategy (NWRS) of 2004 describes how water in South Africa will be protected, used, developed, conserved and managed. The National Water Conservation and Demand Management Strategy forms an integral part of the NWRS. The agricultural sectoral strategy was recently finalised and endeavours to provide a supportive and enabling framework to improve irrigation efficiency. Thus, there is a clear need to optimise water use in the agricultural sector.

The main objective of this research was to develop a generalised whole farm stochastic dynamic linear programming model to assist farmers and water user associations (WUA) with optimal water use within the framework of integrated catchment management.

The research was done on the Vaalharts Irrigation Scheme, the largest irrigation scheme in South Africa which comprises a total of 37 000ha of irrigation plots of some

680 land owners. Canals supply the water to the irrigation plots. Flood irrigation is the dominant irrigation type followed by pivot irrigation. The most important cash crops in the area are maize, groundnuts, wheat, lucerne and cotton and the most important long-term crop is pecan nuts.

GAMS (General Algebraic Modelling System) was chosen as the preferred modelling environment to develop the generalised stochastic dynamic optimising model since it allows for the construction of the programming matrix through the use of generalised mathematical equations. Furthermore it is the standard optimisation software used by agricultural economists locally and internationally.

The dynamic optimisation model is theoretically sound and is based on standard capital budgeting procedures. All the necessary cash inflows and outflows are dynamically accounted for and the model is therefore able to model cash-flows better when compared to any of the existing models. Thus, the model is able to evaluate the cash flow implications of alternative investments decision more accurately thereby enhancing the quality of advice that farmers can get.

Although risk plays an important role in the optimal development path of the farm the timing of water shortages did not impact severely on the risk return tradeoffs. However, the time value of money plays an important role in the calculation of forgone income due to water shortages.

Procedures were developed in this project to separate data manipulation and calculation of input parameters from the matrix generating equations used to construct the model. Through the adoption of such a procedure, the accounting equations that determine the underlying structure of the programming matrix are more transparent. Thus, it will be easy in further research to understand the underlying structure of dynamic-stochastic model and to modify the equations for specialised applications.

Cost: R880 000
Term: 2002 - 2005

Investigation of different farm ownership models and support structures for establishing small-scale irrigation farmers
Tlou Water Management
No 1353

The last decade has witnessed significant land and water reforms in South Africa including land tenure and local governance on water to ensure sustainable development and management of the resources. This is fundamental to creating an enabling environment for rural communities to lift themselves out of poverty. However, the growing recognition of the importance of land tenure to sustainable development has not been supported by an investigation into how it influences smallholder irrigation in improved food production efficiency. This study was commissioned by the WRC to review the land tenure systems and support structures in South Africa, to identify constraints and opportunities relating to land tenure and support structures, with a view to developing a framework for sustainable settlement on small-scale irrigation schemes.

The study method included the collection and analysis of existing international and local literature on land tenure, security of tenure and support systems. This was supported by case studies of existing small-scale irrigation schemes with specific focus on the Eastern Cape Province. Two schemes were selected for detailed study and interviews were conducted with selected key informants and farmers including relevant government departments in the province, and civil society groups.

A review of the land tenure system in the case studies revealed that communally-held land was problematic as far as small-scale irrigation schemes with low production levels were concerned. Tenure security is a major issue affecting settlement on smallholder irrigation schemes (SIS) in long term viable conditions. The state controls large parts of the land. Through the Communal Land Rights Act, the South African government is seeking to clarify land rights by transferring title from the state to local communities. Furthermore, the intention is to establish administration structures to govern the process of issuing and registering land tenure rights to individuals in communal areas. This will improve access to financing because the land can be held as collateral.

The other issues researched were the financing, marketing and management support systems for SIS in order to ensure they become sustainable and the farmers themselves take ownership of these schemes. In terms of production it was clear that small-scale irrigation farmers need access to markets where they can sell sufficient

quantities of produce at prices that will enable them to make a worthwhile return on their investments and farming efforts. Without this, there is in effect no incentive for them to go beyond farming purely as a means of supplementing their daily food requirements. In terms of the long-term viability of the schemes researched, attention needs to be paid both to farmers' ability to access credit and their ability to service credit once obtained, and it must be ensured that adequate training is available.

An analytical framework was developed to provide a basis for understanding the dynamics of the development of SISs. It was demonstrated that this framework provided insight into the interaction of various elements such as intensification/extensification and increased productivity/increased land size. Each step in this development path was carefully considered, the impacts on land tenure systems as well as all other support systems (production, marketing, irrigation, financing, institutional and social) were evaluated and appropriate recommendations were made on this basis.

Cost: R795 200
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 10 years, three WRC-funded research projects were undertaken to develop user-friendly models to provide decision-support for farmers. The aims of this technology transfer project were firstly, to train agribusinesses, bureau services and advisors in the main irrigation areas of South Africa to implement the RiskMan (Risk Management), IrriCost (Irrigation Cost Estimator) and FARMS (Firm Level Agricultural Management Simulator) computer software for decision-taking support in the field of risk management, irrigation cost estimation and whole farm planning respectively; and secondly, to give these organisations and individuals the necessary support in order for them to apply the abovementioned computer software on a continuous basis.

New technology must pass through several stages before it is accepted. The five stages of adoption are awareness, interest, evaluation, trial and adoption. The implementation strategy with this technology transfer project consisted of a combination of methods, messages and approaches followed by the research team. The first step was to identify target groups to whom the three programs were demonstrated. The demonstrations were attended by the contact person of that area together with potential adopters of the technology. These demonstrations were used to create awareness and interest in the use of the models. The next step was to arrange workshops for interested persons for specific models to make further progress with the technology adoption process. The website was used to provide additional information about forthcoming courses and continuous support on larger scale adoption and application.

The third step was to present the courses on IrriCost, FARMS and RiskMan as one-day workshops. Altogether 23 courses were presented to 311 trainees. The trainer was a project researcher who has been fully involved in the development of all three models since 1998. The course evaluation responses of the trainees were in general positive. The vast majority of the respondents were of the opinion that the course contents of all three programs are good.

It can be concluded that the first project objective was achieved through workshops and training courses in at least six provinces for each of the three models. With regard to the second objective it cannot be claimed that all 311 trainees will be able to use these models on a continuous basis. With hindsight better results could have been attained, if the train-the-trainer model had been applied from the beginning of the project. Technology is one the greatest drivers for progress in agriculture. However, new technology is only a tool. Therefore, the most important aspect is how the technology is used. The role of the trainers should be to demonstrate how the use of the new technology could make a difference in the lives of communities.

Cost: R800 000
Term: 2002 - 2005

CURRENT

THRUST 1: THE VALUE OF WATER TO DIFFERENT SECTORS OF THE ECONOMY

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

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 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 cooperative 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 cooperative 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 cooperative 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: R300 000
Expected term: 2003 - 2005

THRUST 4: THE USE OF ECONOMIC INSTRUMENTS TO PROMOTE EQUITABLE AND EFFICIENT WATER ALLOCATION AND DISTRIBUTION

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

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: R1 195 000
Expected term: 2003-2006

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: R173 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 1535

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: R650 000(KSA 3)
Expected term: 2004-2006

Development of an appropriate tool: Voice, measure and intervention in ensuring the sustainability of municipal water services to the poor
Human Sciences Research Council
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

NEW

THRUST 1: ASSESSING THE VALUE OF WATER FOR THE DIFFERENT SECTORS OF THE ECONOMY

Econometric model to predict the effect that various water resource management scenarios would have on South Africa's economic development
Conningarth Economist
No 1570

With water being a limited resource it is accepted that its availability will constrain the economic development of South Africa. At present it is very difficult to predict which unforeseen negative effects well-intended management decisions may have on development. Australia developed a model of the Australian economy that relates the present and future water demands to potential growth in production in 55 industry groups across 18 regions. This model is used to predict how the Australian economy would be affected under different scenarios of water resource management. The model that will be developed under this project will do the same for the South African situation.

Estimated cost: R2 000 000 (KSA 1)
Expected term: 2005-2008

THRUST 2: THE ECONOMIC ADVANTAGES AND DISADVANTAGES OF WATER RESOURCE DEVELOPMENT

Development of a model to assess the costs associated with eutrophication
Umgeni Water
No 1568

Eutrophication and its accompanying effects is one off the intractable symptoms of water pollution associated with modern society. It diminishes the quality of our water resources for many uses and costly treatment is often required to overcome its negative effects. In the prevention vs. cure debate, it is important to not only know the cost of prevention, but also the cost associated with eutrophication when it occurs at various levels, in order to justify often expensive preventative measures. Knowledge of the cost associated with eutrophication will also help in determining and justifying the introduction of waste discharge charges. Similar to a study that assessed the cost to users that can be associated to water salinity, a multidisciplinary team will conduct this project to determine the cost associated to eutrophication that are experienced by different water users, such as those associated with water purification, recreation, irrigation and the aquatic environment.

Estimated cost: R2 000 000 (KSA 1)
Expected term: 2005-2008

Free basic water (FBW) services: Are we making a difference?
Reserved
No 1615

This study will review and investigate the progress and impact (social/technical/economic), that the FBW policy is having on the sector and the individual. It will undertake a thorough interrogation of achievements to date and as an output provide improvements which require to be introduced to make FBW more sustainable and effective.

Estimated cost: R600 000 (KSA 3)
Expected term: 2005-2007

THRUST 4: THE USE OF ECONOMIC INSTRUMENTS TO PROMOTE EQUITABLE AND EFFICIENT WATER UTILISATION

Towards the establishment of water market institutions for effective and efficient water allocation
CPH Water
No 1569

The National Water Act provides for the transfer of water use licences through a water market. A recent WRC review of the value of water to different sectors of the economy has revealed that the market mechanism has proved to be an efficient tool to effect the transfer of water to more efficient users and improve water use efficiency under South African conditions. However, due to high transaction cost, this mechanism is under-utilised. In order to utilise the efficiency of market mechanisms, it would thus be necessary to develop institutions that facilitate transfer and reduce transaction costs. On the other hand, safeguards also need to be instituted to prevent potential negative externalities associated with transfers. This project will focus on three case studies to determine which steps and institutions are required to balance these requirements.

Estimated cost: R1 500 000 (KSA 1)
Expected term: 2005-2007

Financial sustainability of sanitation services
Partners in Development
No 1632

This programme addresses capital investments in infrastructure for households without access to basic sanitation services and financial requirements for ongoing operation and

maintenance including future infrastructure replacement costs. 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 operation and maintenance costs for the different sanitation technology choices.

- Financial models for free basic sanitation service provision and operation and maintenance costs of on-site sanitation services focusing on technology choice, funding arrangements, institutional requirements and household contribution
- Development of an overall costing strategy for meeting the 2010 target of eradication of the sanitation backlog
- Analysis of financial resources of municipalities and their ability to comply with the legislative requirements
- Assessment of the real costs of sanitation subsidy
- Investigation of different models for subsidy allocation and best practice case studies
- Exploration of credit finance options for household sanitation improvement programmes

Estimated cost: R600 000 (KSA 3)
Expected term: 2005-2007

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WATER AND THE ENVIRONMENT

Dr Renias Dube
Head

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
- 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

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 supported by the various KSAs and focusing on this domain, is estimated at about R9.1m. for 2005/06.

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 2005 and 31 March 2006.

COMPLETED

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 core strategy of the Water Research Commission calls for specific mechanisms to address key strategic issues of national importance; these are dealt with in crosscutting domains that have been established specifically for this purpose. These research domains form integrating frameworks that cut across the key strategic areas (KSAs) and draw together ongoing programmes and projects within the portfolios of each of the KSAs, and address issues relevant to the domains. This document provides the strategic context for the Water and Environment Domain and describes the proposed investment framework for this domain. The report also provides detailed insights into how the cross cutting domain, Water and the Environment functions within the Water Research Commission.

Cost: R200 000
Term: 2005

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: R999 900
Expected term: 2003 - 2006

CROSSCUTTING DOMAINS (CONTINUED)

Facilitating the free passage of migratory aquatic biota in South African rivers
Consortium; University of Stellenbosch (lead agent)
No 1409

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

Estimated cost: R2 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: R1 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: R200 000
Expected term: 2003 - 2004

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 can not 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

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 (KSA1)
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: R300 000(KSA2)
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(KSA2)
Expected term: 2003 - 2004

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

NEW

THRUST 1: ENVIRONMENTAL FUNCTIONING WITHIN THE HYDROLOGICAL CYCLE

Framework development for the sampling, classification and geographical occurrences of stygobiont amphipods in South Africa
Univ of Johannesburg (RAU)
No 1586

97% of the world's freshwater is subterranean, and there is an increasing demand for the development of this resource to meet the increasing needs of the population. Little is known about the stygobiont fauna or the interaction between underground and surface water. During this project the following aims will be addressed:

- Formulate a framework to characterize the geological occurrences and geographical distribution of the subterranean amphipods using GIS techniques
- Discussion on the applicability of the sampling protocol
- Identifying microbial composition in association with stygobiont amphipods
- Trace of inorganic macro-elements for water quality
- A primary framework development for the characterization of groundwater systems

Estimated cost: R1 350 000 (KSA 2)
Expected term: 2005 - 2008

Environmental water requirements in non-perennial systems
University of the Free State
No 1587

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: R3 000 000 (KSA 2)
Expected term: 2005 - 2007

The freshwater requirements of temporarily open/closed estuaries on the South Eastern and South Western Cape coasts
SAIAB
No 1581

This project is the result of recommendations of a CERM strategic planning meeting held in March 2004 and is a multifaceted project in order to answer the generic questions routinely posed during DWAF RDM workshops.

Estimated cost: R1 753 000 (KSA 2)
Expected term: 2005 - 2008

Development, testing and installation of a real-time ecological Reserve implementation method for the Thukela River
Rhodes University (IWR)
No 1582

Previous work on implementing the Reserve has identified the need for suitable hydrological triggers to be used to specify the Reserve flows required in real time. It has also identified some of the limitations of the Regional Offices of DWAF to deal with, and make use of, the reserve information supplied by the DWAF RDM Office. During the recent reserve determination on the Thukela River some concepts were developed on how this could be done.

During the project the researchers will develop and test a real time Reserve implementation method, and install the system in the KZN DWAF Regional Office, for application to the Thukela River A manual for the method and training of KZN DWAF Regional Office staff will also be developed. The model will be based on a standard model for which initial calibrations are available for all the quaternary catchments country-wide, so the model will be widely applicable.

The development and application of a real-time reserve implementation method will assist in the implementation of the NWA on the ground. The outcome of this research will deepen knowledge on the functioning of temporarily open and closed estuaries. The results will be worked into estuary management as the work progresses as the team are involved with DWAF and MCM initiatives in estuary management, including the determination of the reserve.

Estimated cost: R690 800 (KSA1)
Expected term: 2005-2007

Development of a diatom protocol for river health assessment
DH Environmental Consulting
No 1588

Increasingly, diatoms are finding their place in the suite of water quality assessment tools available elsewhere in the world. The collection on which this project will be based spans a half-century, and the information that may be gleaned is potentially very valuable. A diatom assessment protocol (DAP) for river health assessment will be developed during this project, and this process will happen in three distinct phases.

In phase 1 a South African diatom taxonomic identification key will be developed, and diatom images will be transferred from the SA Diatom Collection onto electronic format. In Phase II the DAP protocol will be comprehensively tested to compare it with SASS indices within the River Health Programme, and there will be user training. It will also be linked to a central reporting database by means of a software resource centre before being calibrated, refined and released for wider use. Phase III will involve the continuing extraction of historical water quality and information on ecosystem condition from the SA Diatom Collection.

Estimated cost: R292 000(KSA1)
Expected term: 2005-2006

Secondary and tertiary impacts on water resources due to primary changes in temperature and precipitation
University of Cape Town
No 1562

The WRC is currently funding a project to investigate the potential impact of global and regional changes in climate and climate variability on water resources, but this focuses only on hydrology at present. There are likely to be secondary effects on water resources arising through changes in flow regimes and ambient temperature – these include changes in nutrient cycling, changes in processes affecting sequestration of toxic substances such as metals, changes in chemical and biochemical oxidation and reduction processes, and changes in background concentrations of dissolved salts. The complex changes in water quality, water quality and temperature due to climate change will in turn have effects on aquatic ecosystem structure and function, with further implications for the quantity, quality, reliability and availability of water resources. This project will build on recent and current research within the WRC and other organisations, to generate potential scenarios for the secondary and tertiary impacts of climate change on

water resources, with the aim of supporting the development of policy responses and coping mechanisms.

Estimated cost: R2 500 000(KSA1)
Expected term: 2005-2008

Persistent organic pollutants (POPS) in the water environment
University of the North West
No 1561

South Africa is a signatory to the recent Stockholm Convention, which is intended to minimise and prevent the release of harmful persistent toxic substances in the environment. Although the WRC has recently funded work on persistent organic pollutants (POPs) in the water environment, this research now needs to be taken further in order to:

- Better identify and quantify the fate and effect of selected POPs in the hydrological cycle
- Assess with higher confidence the scale and significance of the occurrence of POPs in the environment in South Africa, and the potential short-term and long-term impacts on water resources and water-linked ecosystems
- Support the development of appropriate policy and regulatory measures to ensure implementation of the requirements of the Stockholm Convention

Estimated cost: R1 500 000(KSA1)
Expected term: 2005-2008

Flow conceptualisation, recharge and storativity determination in Karoo aquifers (with special emphasis on the Eastern Cape (Mzimvubu to Keiskamma Water Management Area)
SRK
No 1565

The Karoo rocks outcrop over almost three quarters of South Africa and act as a host for an important groundwater resources. Hundreds of villages in the rural areas of the Eastern Cape and KwaZulu-Natal provinces obtain their water supplies from boreholes adjacent to or within the area of influence of dolerite dykes and sills, which have intruded the Karoo sediments. These conditions produce s unique and complex hydrogeological system, which complicates the study and the development of groundwater. This project aims to:

- Conceptualise flow dynamics and groundwater flow paths
- Determine recharge-discharge and storativity and generate target maps for groundwater exploitation

Estimated cost: R3 400 000(KSA1)
Expected term: 2005-2009

Refining tools for evaporation monitoring in support of water resource management
CSIR
No 1567

Evaporation, after precipitation, is the largest component of the hydrological cycle at the land surface. It includes evaporation from open water surfaces, moist soil and wet foliage, as well as the transpiration of plants. There are many compelling water-resource related reasons (among them demands created by recent water legislation) for being able to measure/estimate and monitor evaporation with sufficient accuracy and precision. While many potentially suitable techniques and methods exist, there is a lack of knowledge regarding their appropriate use and capacity in applying them. Consequently, this project will aim to:

- Classify and characterise land uses/units and water-resource management applications for which evaporation measurements/estimates are needed
- Assess accuracy and precision requirements relating to evaporation measurement/estimation for various water resources

Estimated cost: R1 600 000(KSA1)
Expected term: 2005-2008

THRUST 2: ENVIRONMENTAL GOVERNANCE SYSTEMS

Econometric model to predict the effect that various water resource management scenarios would have on South Africa's economic development
Conningarth Economists
No 1570

With water being a limited resource it is accepted that its availability will constrain the economic development of South Africa. At present it is very difficult to predict which unforeseen negative effects well- intended management decisions may have on development. Australia developed a model of the Australian economy that relates the present and future water demands to potential growth in production in 55 industry groups across 18 regions. This model is used to predict how the Australian economy would be affected under different scenarios of water resource management. The model that will be developed under this project will do the same for the South African situation.

Estimated cost: R2 000 000 (KSA1)
Expected term: 2005-2008

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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 have been kept the same as presented in the previous year's ***Knowledge Review***, pending a strategic planning exercise launched to re-evaluate the domain and its thrusts.

THRUST 1: MICROBIAL WATER QUALITY AND ASSOCIATED HEALTH IMPACT

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 IMPACT ON HEALTH

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. This information is used to guide the development and implementation of cost-effective control and treatment strategies. Special emphasis is given to studies on endocrine disrupting contaminants (EDCs), algal toxins associated with eutrophication of water resources, and general toxicants, such as nitrates. Emphasis is further on the development of simple, rapid, cost-effective detection techniques, as well as treatment technologies for the removal of these unwanted chemicals.

THRUST 3: SAFEGUARDING PUBLIC HEALTH

This thrust focuses 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 household and personal 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 at R7.2m. for 2005/06. The total investment in health-related research appears to have declined somewhat, from R8.6m. in 2004/05. This may be regarded as normal variation when viewed in the light of occasional large projects referred to below.

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 2005 and 31 March 2006.

COMPLETED

THRUST 1: MICROBIAL WATER QUALITY AND ASSOCIATED HEALTH IMPACT

Programme 2: Known and emerging water-borne, water vector and water related pathogens causing diseases

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

Pressure is on water distributors to supply water that is of the highest quality, free from disease-causing agents at the point of delivery. This task is made increasingly difficult by large and distribution systems where bacteria grow at the pipe and reservoir surfaces, forming biofilms and thereby acting as a zone of re-growth and possible contamination post-treatment. Treatment deficiencies may allow the passage of unharmed or sub-lethally damages organisms. Bacteria in biofilms are orders of magnitude more resistant to a wide range of antibacterial agents, including oxidizing agents such as chlorine. Because biofilms are dynamic, parts are released sporadically. This would pose a possible gastrointestinal threat where the water is consumed and a respiratory threat where aerosols are inhaled, eg. in showers and recreational facilities.

The aim of this project was to gather data on the occurrence and distribution of biofilms of drinking water distribution systems. The prevalence of pathogenic bacteria in biofilms of drinking water distribution systems and containers used for distribution and storage was studied in various locations by two research teams. Biofilms were sampled within pipes in residential buildings, as well as in buckets used for storage in homes. Biofilms were disturbed and a range of pathogenic bacteria quantified using selective enrichment and isolation procedures by the MPN approach. A selection of presumptive pathogens was subjected to identification by phylogenetic (16SrDNA) analysis. The associated water samples were also analyzed for aerobic heterotrophic count and faecal coliforms.

The survival of water quality indicator bacteria and of certain bacterial pathogens in biofilms in drinking water distribution systems was studied using on-line systems over a period of 18 months. The fate, survival, growth and release of *Salmonella* in biofilms in drinking water distribution systems were studied under simulated laboratory conditions. The colonization and subsequent growth of the *Salmonella* was studied by fluorescence microscopy, and the numbers in the biofilms as well as those released were determined by selective MPN.

Biofilms developed on the surfaces in the three online systems. The results of all three units showed a variable degree of biofilm development based on the heterotrophic bacterial density. Although the water supplied to the residential building was within the target residual chlorine level of the local municipal authority, pathogens were still found on a number of occasions. However, a higher incidence of pathogens identified was in the biofilms at the office building than at the residential building.

Salmonella colonized established multi-species drinking water biofilms within 24h, growing to form microcolonies within the biofilm. The *Salmonella* was also released from drinking water associated-biofilm into the flow, and was seen to re-colonize elsewhere.

Biofilms are a real threat to water quality and can grow even in well-maintained distribution systems. To prevent or minimize biofilm development residual chlorine levels should be high enough to ensure that water is sufficiently disinfected from the start to the finish of the distribution line. Water stored in tanks before distribution should be monitored regularly and tanks cleaned and disinfected regularly to prevent the development of a biofilm on the tank walls.

Cost: R721 800
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 most common source of contamination of surface waters is still human and animal wastes and introduction of water-borne pathogens by these sources is of particular concern. High levels of microbial pollution in source water can lead to breakthrough in the treatment process. The Water Act in 1998, and the publication of the World Health Organization's *Drinking-Water Quality Guidelines* in 2004, has placed emphasis on the protection and management of water quality within catchments. A catchment management approach towards microbial pollution will only be successful if it is based on a clear understanding of the origin, fate, survival and transport of pathogens that have been introduced into the water body.

The scope of this project was to investigate the possible sources, survival and clinical relevance of selected water-borne pathogens in a rural and peri-urban area, and to investigate the environmental factors and social determinants that contribute to the transmission of such diseases. The information provided by this study could form the basis for the development of appropriate catchment management and intervention strategies to reduce the health risk to various water users. The project aimed to create a better understanding of the fate and / or clinical relevance of selected parasites (*Cryptosporidium*) and bacteria (*Salmonella* and *Vibrio cholerae*) in fresh water environments.

Based on the study it seems unlikely that cryptosporidiosis is commonly transferred from animals to humans in the South African context. The high percentage of the human genotype (80%) observed in the cases investigated suggests the importance of person-to-person contact and human sewage contamination of drinking water, recreational water and food sources, as a means of spreading the parasite. This finding was supported by the prevalence data for *Cryptosporidium* oocysts in calves. The

prevalence was found to be lower than what have been reported for other countries. *Cryptosporidium* infection is most prevalent amongst young calves between 1-2 weeks of age. Good management and hygiene practices are however, still required to prevent the spread of *Cryptosporidium* to other animals and the aquatic environment.

The results of the present study have revealed that *Salmonella* was prevalent in environmental and clinical samples examined. *Salmonella* isolates were also isolated from raw vegetables (cabbages, tomatoes and onions) obtained from local rural gardens, which used river water for irrigation. Strains isolated from human stools, water, sediments and food were phenotypically and genetically correlated which provide evidence for the epidemiological link between environmental reservoirs and human infection in an endemic area. This confirms that water and food could be important sources of human salmonellosis in rural areas. *Salmonella typhimurium* is the most commonly isolated serotype from clinical cases in the Venda area and a GFP labelled strain was therefore used to investigate the survival and behaviour of *Salmonella* in freshwater sediments. The study indicated that *Salmonella* survived for extended periods of more than 6 months in sediments at temperatures typically associated with fresh water streams and rivers in South Africa. This is of concern as they could easily be released from the sediment into the water phase at high concentrations during rain events or other disturbances of the sediment.

The *ompW* based PCR identification was found to be ideal for surveillance work and was more reliable than the biochemical identification approach. The identity of Vibrio cholerae stains isolated from the Vaal Barrage catchment area were confirmed with this PCR technique and thereafter a selection of these strains were typed with AFLP. With the AFLP typing a high level of genetic diversity was seen. It is therefore believed that the *Vibrio cholerae* population in the Vaal Barrage system is not a product of one or two strains that have adapted to local conditions, nor that it consist of diverse clones that only occupy specific niches in the aquatic system. The population in the Vaal Barrage is rather made up of highly diverse clones that constantly compete, resulting in genetic shifts only perceivable within short time frames and localized regions. Using environmental *Vibrio cholerae* as a model, it is suggested that enterotoxigenic strains may exhibit the same degree of persistence and survival in inland aquatic systems, being able to survive for extended periods and posing as potential future health risk.

For the KwaZulu-Natal outbreak, no statistical correlations could be established between the %CIR and the climatic variables of rainfall, temperatures (minimum, maximum and average) and humidity. There may have been correlations within specific months when cholera was at peak but not when the entire dataset was statistically considered. A number of socio-economic factors could be correlated with high CIR percentages in the DCs. They included traditional households, no sanitation or the use of bucket system, the use of river water for household purposes and the lack of refuse removal. This again stresses how the lack of basic services exposes communities to the risk of infectious disease and increases their overall vulnerability.

Cost: R635 000
Term: 2002 -2005

THRUST 2: CHEMICAL QUALITY OF WATER AND ASSOCIATED IMPACT ON HEALTH

Programme 1: Detection, prevention and management of EDCs in water sources

The development and validation of bioassays to detect oestrogenic and anti-androgenic activity using selected wildlife species
University of Stellenbosch, Department of Zoology
No 926 and 1253

This report incorporates the results of following WRC projects:

No 926: An assessment of the extent of oestrogenic activity in Western Cape water resources

Cost: R463 000
Term: 1998 - 2000

and

No 1253: Endocrine disrupting contaminants (EDCs) in South African water resources: Development and validation of *in vitro* and *in vivo* bioassays to detect endocrine interaction and characterize physiological disruption in non-mammalian animals

Cost: R400 0000
Term: 2001 - 2002

During the nineties, after several keystone papers had been published on the potentially adverse effects on human and wildlife health by various environmental contaminants, the endocrine disruption hypotheses soon emerged, stating that: 'Synthetic, and some naturally occurring, chemical substances in the environment are disrupting the normal functions of the endocrine system and its hormones in humans and wildlife' The first WRC funded project, mainly a literature review, regarding oestrogen and oestrogen mimicking substances in the water environment was published in 2000 and recommended that screening and testing methodology being developed or optimized, *in vitro* and *in vivo* bioassays, as well as analytical methods for the specific detection of suspected EDCs in the aquatic environment and consumer products.

It was against this background that the WRC was approached to fund basic research on biomarker characterization followed by the development of bioassays using the local animal modes, e.g. the African clawed frog, *Xenopus laevis*, as bio-indicators.

The aims of the two projects were to study the normal reproductive cycles of *X. laevis* and the turtle species, *Pelomedusa subrufa* in order to gain baseline information for comparative eco-toxicological studies as well as to identify potential biomarkers for use in bioassays; the vitellogenin response in the frog, *X. laevis* when exposed to natural and selected xenobiotic oestrogens; to investigate the practical implementation of vitellogenin as a biomarker for xenobiotic oestrogens using either fish, amphibian or turtle model systems; and to develop and validate bioassays to eventually be employed in a battery of bioassays for hazard and risk assessment of EDCs in water resources:

The local aquatic amphibian species, the African clawed frog, *X. laevis* and the widespread local aquatic turtle species, *P. subrufa* was used in a seasonal reproductive biology study. This research programme represents a first attempt to utilize local endemic vertebrate species as bio-indicators investigating the potential of specific biomarkers such as the hepatic produced yolk precursor, vitellogenin (Vtg) to determine environmental oestrogenic activity. It successfully highlighted the use of biomarkers related to the male androgenic system as well as the sex determination and differentiation developmental systems. In addition, the potential of using the functional involvement of the thyroid endocrine gland in the early developmental and metamorphosis programme in amphibians as biomarker system for studying the interaction with the thyroid systems proved valuable.

The bioassays developed and validated through these projects using endemic animal species contribute towards the greater objective to eventually establish a batter of EDC screening bioassays.

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 water quality situation in the Umtata River has always been giving cause for concern (DWAF, 1998). The results of a pollution study on Umtata River done between May 1999 and March 2002 (WRC, 2003) indicated high levels of cadmium in the river, which ranged from 0.01 mg/ℓ to 0.08 mg/ℓ for representative data.

The high levels of cadmium in the river have given rise to worries that water supplied from the river will be unfit for domestic use and may also impact on the 'health' of the community that live on the river banks that depend on it primarily for their domestic water supply. Recommendations were then made aimed at preventing or reducing cadmium pollution in the Umtata River one of which was an intervention programme to manage the pollution of the river and a workshop was conducted for all stakeholders in the catchment (DWAF staff, DEAT staff, staff of the local industries in the catchment, municipal staff, councilors and local communities) on actions to take to reduce pollution of the river. The workshop was well attended and the need to implement the recommendations in that report (WRC 2003) was impressed on them.

The major aim of the project was to re-investigate the levels of cadmium in the river catchment. A subsidiary aim of the project was to carry out a risk assessment study of the possible health effect of cadmium in the river on the community who are primary users of water from the river for their domestic supply.

Calibration standards were prepared for cadmium and zinc (zinc has a synergistic interaction with cadmium. The detection limits for cadmium and zinc were determined using the

lowest concentrations of each of the elements that gave the least detectable signal by the flame AAS. Quality assurance studies were performed with distilled water samples fortified at levels of 0.005 mg/ℓ for Cd and 10 mg/ℓ for Zn using comparative open beaker digestion technique and extractive concentration method with amino pyrolidine dithiocarbamate (APDC) as complexing agent and methyl isobutyl ketone (MIBK) as the extracting solvent, respectively. Samples for chemical analyses were collected according to standard procedures described in the sampling guide (DWAF, 1992, 1999) and analysed by the open beaker digestion method (DWAF, 1992) as it gave better recoveries and better repeatability than the extractive concentration method (Van Loon, 1982). Temperature (determined on site) and pH (with un-acidified water samples) were determined using the Merck (Pty Ltd) 330 pH meter. Risk assessment study was done using the standard USEPA (USEPA, 1989) method to access the potential health risks to community making use of the river water as their primary domestic water source.

The mean (SD) values of Cd in the river water samples ranged from 0.002 (0.001) mg/ℓ to 0.007 (0.002) mg/ℓ. The levels of Zn varied between trace and 0.196 (0.10) mg/ℓ. The levels of cadmium detected in the Umtata River in this study were much lower than the levels detected in previous study between May 1999 and April 2000 (WRC, 2003) and the levels generally fell within the SA guideline of 0.005 mg/ℓ (WRC, 1998). The results for Zn levels in the river also fell within the SA guideline for Zn in water for domestic supply, which is 3 mg/ℓ (WRC, 1998).

The hazard quotients calculated from the data presented in this study varied between 0.35 and 1.22 for adult exposure and between 0.2 and 0.8 for child exposure. The hazard quotients using representative data calculated from the previous study (WRC, 2003) ranged from 1.8 to 14.0 for adult exposure and from 1.2 to 9.3 for child exposure (hazard quotients that exceed 1.0 indicate the possibility of non-cancer toxic risks from exposure).

Cadmium concentrations in the Umtata River has substantially reduced compared to the results of the previous study and the levels now fell within the normal safe range expected in river water for domestic uses (WRC, 1998). At these levels of cadmium and zinc in the river the effect of the any synergistic interaction of zinc with cadmium would be negligible.

While for samples taken during May 1999 to March 2000 (WRC, 2003) the risk assessment study showed exceptionally high hazard quotients which indicate that if people were using the water for domestic purposes, adverse health effects would occur, the results of the new study with samples taken between October 2002 and December 2003, indicates that generally the hazard quotients are acceptable. The greater part of the anticipated adverse health effects arise as a result of ingestion of fish or shellfish (approximately 60% of the calculated dose is a result of assuming exposure via ingestion of fish/shell fish). However, if one were to assume that no fish or shellfish were consumed, the anticipated health risks would be significantly reduced. This effect would be most significant for the exposure calculations during the 2nd sampling run between October 2002 and December 2003.

The remedial actions taken following the 1999 to 2000 sampling appear to have been successful in reducing the cadmium levels in the Umtata River water and have therefore resulted in reducing the potential health effects.

Cost: R250 000 (KSA1)
Term: 2002 - 2003

THRUST 3: SAFEGUARDING PUBLIC HEALTH

Programme 2: Public awareness and education material

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
Sub-project: No 1400 A: The development of *Risk Communication Guidelines*
CSIR

Water-related microbial diseases such as cholera and diarrhoea cause untold misery in communities across South Africa every year. As part of the effort to promote awareness and understanding of the conditions promoting infectious disease transmission, water service providers are increasingly required to have a risk communication programme in place.

CROSSCUTTING DOMAINS (CONTINUED)

This guideline document presents the 4th in the five- volume series aimed at addressing the question of how best South Africans can protect themselves against water-related microbial diseases. It provides a framework of principles and guidelines for the communication of health risks, specifically for water service providers.

Communicating with the pubic is an essential element of health risk communication. Ineffective communication often results in conflict, which in turn leads to the erosion of public confidence, and inefficient use of water service providers' resources. The recognition that people are entitled to make decisions about issues that affect their lives can assist water service providers in forming a better understanding of, and formulating more appropriate reactions, to a particular risk. Appropriate risk communication not only promotes consistency and transparency in arriving at and implementing risk management decisions, it also fosters public trust and confidence in the safety of the water supply.

The report is published under the series: ***Management of Microbial Water-related Diseases: Volume 4: How dangerous is the problem? Communicating the Risk*** .This document will assist water service providers, government departments, water boards, municipalities and catchment management agencies in communicating with the public when a water quality issue arises that could have a potential impact on health. In this way, the guide will hopefully make a significant contribution protecting the most vulnerable communities against water-related microbial disease.

Cost: R184 000 (KSA3)
Term: 2002-2005

Sub-project No 1400C: Development of a child- centred course for teachers to promote basic health and hygiene in rural communities.
Lenehan Consulting

Children have the capacity to actively promote health and hygiene campaigns within their communities. In most countries, the education system is the broadest channel for health education. With this in view, it would seem that any programmes which target children as change agents in rural communities must involve schools and the community at large. This research project aimed to facilitate the development and implementation of health and hygiene programmes on a local level in rural communities and included the development of child centred course materials that can be re-used by educators and adapted for other rural schools.

A literature review of international and local initiatives and case studies relative to child-centred health and hygiene awareness promotion was done and lessons learnt from previous studies were incorporated into the development of the materials including the need for an integrated approach. It was recognized that input from educators in rural schools was imperative and a Preliminary Baseline Survey was developed. A draft health and hygiene awareness programme was developed. Initial piloting of this draft programme was undertaken at the three schools. A questionnaire was included with the draft programme to encourage comments from educators on the draft programme and the piloting process

The Health and Hygiene Awareness Programme developed in this research project is based on the lesson plan format and is ready for use for by rural school educators. It consists of 10 lesson plans and is designed for learners aged from 6-8 years. The aims of these lesson plans are to provide an appropriate format for successful health and hygiene programme for lower primary school learners. Resources to support the lessons were chosen that are typically available in rural schools or relatively easy to substitute, acquire or replicate (e.g. paper, pencils, crayons, plastic bottles). The resource sheet 'Germs' was designed to be easily photocopied and intentionally included images acquired in the internet public domain to avoid copyright infringement.

This research project has reaffirmed that demand for health and hygiene awareness material in rural primary schools is very high. It is recommended that strong emphasis is put on developing relevant programmes.

Cost: R167 000 (KSA3)
Term: 2002-2003

CURRENT

THRUST 1: MICROBIAL WATER QUALITY AND ASSOCIATED HEALTH IMPACT

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 2: Known and emerging water-borne, water vector and water related pathogens causing diseases

Develop and apply an innovative assay system to provide direct and reliable assessments of the role of domestic water supply in causing diarrhoea in rural households
Technikon Witwatersrand
No 1444

Diarrhoeal disease accounts for a high proportion of the preventable deaths and illness in South Africa, especially in deep rural areas. The study aims to apply an innovative water quality screening approach to find a link between water quality and diarrhoea since current assays fail to indicate the presence or effects of metabolites of micro-organisms on human health. Current bio-assay methods for testing these inflammatory effects of pathogen metabolites will be adapted for water quality assessment and application to these communities at risk.

Estimated cost: R424 400
Expected term: 2003 - 2004

THRUST 2: CHEMICAL QUALITY OF WATER AND ASSOCIATED IMPACT ON HEALTH

Programme 1: Detection, prevention and management of EDCs in water sources

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

CROSSCUTTING DOMAINS (CONTINUED)

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

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

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

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.

Cost: R500 000
Term: 2003 - 2006

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

Health and hygiene education
Mvula Trust
No 1634

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.
The following research topics will be addressed under this programme:
- Investigation of the linkage between poor sanitation and HIV/AIDS and also possible linkage between the high incidence of cholera outbreaks and prevalence of HIV/AIDS infection
- Investigate modes for the spread of cholera in South Africa and recurrence of cholera outbreaks
- Development of indicators for measuring health improvement and assessing the use of proxy indicators; this should include evaluation of the impact of health and hygiene in the creation of a demand for the sanitation guideline: *Education and Awareness Building on the Detrimental Effects of Pollution.*

Estimated cost: R 800 000
Expected term: 2005 -2007

NEW

THRUST 1: MICROBIAL WATER QUALITY AND ASSOCIATED HEALTH IMPACT

Programme 1: HIV/AIDS water-related linkages and impact on water use and waste

Molecular relatedness of enteric pathogens isolated from water sources and HIV/AIDS patients with diarrhoea in rural communities in the Limpopo and Eastern Cape Provinces
Univ. of Venda
No 1633

The proposal aims to establish any epidemiological linkage between enteropathogens from water sources and those in infected patients, to isolate and characterise bacterial and protozoan enteropathogens and to determine its antimicrobial susceptibility. The study will address the issues of scientific and technical links to other aspects such as hygiene practices, water quality and type of service rendered, all aspects of storage in containers, identification of water-borne opportunistic bacteria specifically of concern to the HIV compromised and the rate of infection.

Estimated cost: R900 000(KSA3)
Expected term: 2005-2008

Programme 2: Known and emerging water-borne, water vector and water-related pathogens causing diseases

Management of environmental flows to keep incidence of aquatic vector diseases to a minimum
Environmental Assessment and Reporting, Institute of Natural Resources
No 1589

This research will concentrate on bilharzia-carrying snails and malaria-carrying mosquitoes. The two main areas to be addressed would be the effect of river flow manipulation on the vectors through the Resource Directed Measures (RDM) process, including incorporating these measures in the RDM procedures. The education of people exposed to the threat - on how to reduce their risk to these vectors - will form an important component of this project.

Estimated cost: R1 200 000(KSA2)
Expected term: 2005-2008

Guidelines for sustainable use of grey-water in small-scale agriculture and gardens in South Africa
University of KwaZulu-Natal/School of Biological and Conservation Sciences
No 1639

The White Paper on Agriculture emphasises food security. Since household and urban food gardens form part of the spectrum of production systems and processes that can contribute to food security, they are supported by government. However, a shortage of water to supplement rainfall often limits the application potential of these systems.

The use of grey-water could overcome this limitation by providing a dependable water source that is under the control of the household gardener. However, there are also risks involved with the practice that need to be better assessed and quantified under controlled conditions.

Estimated cost: R1 670 000(KSA 4)
Expected term: 2005-2008

Determination of the specific origin of contaminating bacteria in drinking water of rural households by elucidating the contamination pathway using amplified fragment length polymorphism (AFLP)
CSIR
No 1602

Method development at the DNA level has made the identification of the exact origin of specific contaminating and other organisms possible. This ability may have a profound impact on our understanding of exactly where contaminating organisms originate from and where in the contamination pathway introduction of these organisms into drinking water supplies takes place. Understanding the latter will in turn allow identification of the specific human behaviours and practices that contribute to contamination of drinking water. The information will enable the design of preventative measures aimed at the very core of the problem and in doing so minimize health impacts and direct resources optimally. Using the amplified fragment length polymorphism (AFLP) methodology, the project therefore aims to identify those human behavioural factors and practices that are directly associated with the identified contamination pathway and identify the exact point where bacterial contamination of drinking water takes place in rural households without access to in-house piped water. Recommendations will be made that would address those behaviours or practices associated with the identified pathway so that contamination can be prevented or minimized in future.

Estimated cost: R371 320
Expected term: 2005 - 2007

THRUST 2: CHEMICAL QUALITY OF WATER AND ASSOCIATED IMPACT ON HEALTH

Programme 2: Detection, prevention and management of toxin pollution in water sources

Persistent organic pollutants (POPs) in the water environment
North West University
No 1561

Although the WRC has recently funded work on persistent organic pollutants (POPs) in the water environment, this research will now be taken further in order to:

- Better identify and quantify the fate and effect of selected POPs in the hydrological cycle
- Assess with higher confidence the scale and significance of the occurrence of POPs in the environment in South Africa, and the potential short-term and long-term impacts on water resources and water-linked ecosystems
- Support the development of appropriate policy and regulatory measures to ensure implementation of the requirements of the Stockholm Convention

Estimated cost: R1 500 000 (KSA1)
Expected term: 2005-2008

CROSSCUTTING DOMAINS (CONTINUED)

Osmoregulation in freshwater invertebrates in response to exposure to salt solution
Rhodes University
No 1585

The project aims to undertake acute and chronic toxicity tests using selected salts and indigenous macro-invertebrates as well as oxygen consumption and osmolarity tests to evaluate the salt boundary values for application in environmental water quality in setting resource quality objectives.

Estimated cost: R209 000 (KSA2)
Expected term: 2005-2007

THRUST 3: SAFEGUARDING PUBLIC HEALTH

Programme 1: Monitoring systems

Compilation of a generic water safety plan for small community water supply
Umgeni Water
K8/649

The guide already developed for Rand Water treatment and supply systems will be adapted and modified to assist and suit the needs of general water treatment plants in South Africa. The methodology taken up in the completed Guide will be explained at training sessions at selected centres in the country.

Estimated cost: R200 000 (KSA3)
Expected term: 2005-2006

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Appendix

2006 CATALOGUE OF AVAILABLE WRC TT REPORTS

2006 CATALOGUE OF AVAILABLE WRC TT REPORTS

KSA 1:

An explanation of a set of national groundwater, plus 2 hydrogeological maps (SA Price: R114.00)

Vegter JR

Advances in hydrogeology over the past years, and the increasing demand on groundwater resources, have given rise to the need to portray hydrogeological information in such a manner that planners and various groundwater users can make decisions by means of a quick and accurate overview of the most up-to-date information. Hydrogeological maps are seen as a powerful tool to meet this objective.

Report No: TT 74/95 ISBN: 1 86845 183 6 Overseas price : $70-00 excl postage

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Explanation of the 1:500 000 hydrogeological map 2326 Pietersburg (SA Price: R50.00)

Water Systems Management & DWAF

This is a high-quality hydrogeological map of the Pietersburg map sheet at a scale of 1:500 000 and a set of explanatory notes which provide guidelines as to the need for detailed groundwater investigations and what hydrogeological conditions are expected to occur.

Report No: TT 75/95 ISBN: 1 86845 188 7 Overseas price : $35-00 excl postage

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Dealing with reservoir sedimentation (SA Price: R171.00)

Basson GR & Rooseboom A

Dam siltation has always been and still is a serious problem in South Africa. This report presents different techniques for controlling and managing dam siltation in South Africa.

Report No: TT 91/97 ISBN: 1 86845 299 9 Overseas price : $70-00 excl postage

• **Sluicing flumes: A new structure for discharge measurement in sediment-laden rivers**

Rossouw J, Loubser C, Rooseboom A & Bester A

This report confirms the flumes' good characteristics with respect to handling heavy sediment loads.

Report No: TT 103/98 ISBN: 1 86845 368 5 Overseas price : $35-00 excl postage

• **Dealing with reservoir sedimentation -Dredging (SA Price R200.00)**

G R Basson A & Rooseboom

In this report the reservoir sedimentation theory and dam dredging techniques from around the world are evaluated. A criteria for selecting dredging techniques which emphasise on cost cutting measures is presented.

Report No: TT 110/99 ISBN: 1 86845 493 2 Overseas price : $60-00 excl postage

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A Global Overview of Inter- Basin Water Transfer Schemes, Socio- Economic and Socio - Political Implications, and Recommendations for their Management

Snaddon CD, Davies BR & Wishart MJ

This report combines two source documents. The first is the report on the research done during the project and the second is a worldwide synthesis of information on inter-basin transfer (IBTs) with contributions from scientists in the USA and Australia.

Report No: TT 120/00 ISBN: 1 8645 583 1 Overseas price : $20-00 excl postage

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• **Groundwater Development in South Africa and an introduction to the Hydrogeology of Groundwater Regions**

Vegter J R

This report presents a historical overview from the introduction of the first drill in 1880 -a manually powered diamond rig - up to the present. The following topics are covered:

- groundwater exploration and exploitation
- investigation and research; and
- the evaluation of groundwater legislation

Report No: TT134/00 ISBN: 1 86845 642 0 Overseas price: $25-00 excl postage

• Hydrogeology of Groundwater: Region 1 - Makoppa Dome

by JR Vegter

Report No: TT135/00 ISBN: 1 86845 643 9 Overseas price:$ 20-00 excl postage

• Hydrogeology of Groundwater: Region 3 – Limpopo Granulite-Gneiss belt

JR Vegter

Report No: TT136/00 ISBN: 1 86845 644 7 Overseas price: $20-00 excl postage

• Hydrological information and techniques to support the determination of the water quality component of the ecological reserve for rivers

Hughes DA; Munster F

Report No: TT137/00 ISBN: 1 86845 646 3 Overseas price: $20-00 excl postage

• Hydrogeology of Groundwater: Region 7 – Polokwane/Pietersburg Plateau

JR Vegter

Report No: TT 209/03 ISBN: 1 86845 027 2 Overseas price: $20-00 excl postage

• Hydrogeology of Groundwater: Region 19 – Lowveld

JR Vegter

Report No: TT 208/03 ISBN: 1 86845 026 4 Overseas price: $20-00 excl postage

Estimation of streamflow reductions resulting from commercial afforestation in South Africa

Gush MB, Scott DF, Jewitt GPW, Schulze RE; Lumsden TG, Hallowes LA & Görgens AHM

The main objective of this report is to present the verification of the ACRU model on available streamflow data from experimental or research afforested catchments and thereafter to apply the model to all regions with economically viable afforestation potential.

Report No: TT 173/02 ISBN: 1 86845 845 8 Overseas price: $30-00 excl postage

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A manual for cost benefit analysis in South Africa with special references to water resource development

Conningarth Economist

This document entails the guidelines in the format of a manual for conducting Cost Benefit Analysis (CBA) in South Africa with specific references to evaluating the development and management of water resources. This evaluation of projects is often a difficult task since costs and benefits do not occur only once but appear over time. This manual is specifically aimed at the decision maker in the public sector, but can be used outside the public sector too.

Report No: TT 177/02 ISBN: 1 86845 851 2 Overseas price: $30-00 exc postage

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Hydrogeology of the main Karoo basin: Current knowledge and future research needs

AC Woodford and L Chevallier

This document is aimed primarily at the *groundwater practitioners* working in Karoo fractured-rock aquifers, especially those involved on rural water supply projects and WRC-funded research projects. The level of information presented is also useful to other professionals with only limited groundwater knowledge

Report No: TT 179/02 ISBN: 1 86845 851 2 Overseas price: $40-00 exc postage

Evaluation of the role of water user associations in water management in South

Guy Pegram; Gugu Mazibuko

The new institutional reforms in water resource management prescribed in the National Water Act of 1998, delegate many water resource management functions (particularly resource protection and allocation) to organisations within Water Management Areas (WMA), namely Catchment Management Agencies (CMAs) and Water User Associations (WUAs). WUAs are statutory bodies intended to operate at a restricted localised level aimed at facilitating 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.

Report No: TT 204/03 ISBN: 1 8645 982 9 Overseas price : $25-00 excl postage

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Guidelines for integrating the protection, conservation and management of wetlands into catchment management planning.

Dickens C; Kotze D; Mashigo S; MacKay H; Graham M

The South African legal environment provides for the sustainable use of the country's water resources. Yet, all is not well with the wetland resources of this country. Already suffering from years of abuse and over-utilisation, wetlands remain under threat as part of the water resource. These guidelines provide management agencies **with much needed information for the management of wetlands.** The impact of these guidelines is expected to be significant, especially for professional staff and interested members of society working at ground level

Report No: TT 220/03 ISBN: 1 77005 096 5 Overseas price : $30-00 excl postage

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An assessment of the water policy process in South Africa (1994 to 2003):

de Coning C; Sherwill T

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 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.

Report No: TT 232/04 ISBN: 1 77005 180 5 Overseas price : $15-00 excl postage

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- **Sediment control at river abstraction works in South Africa: Vol 1**

Brink CJ; Basson GR; Denys F

This report presents a review of the international and South African state of the technologies available for controlling sediments at river abstraction works. Optimum abstraction locations, flushing channel designs and suitable pumping designs. Guidance for planning and design of river abstraction works is one of the main highlights of this report**.**

Report No: TT 259/06 ISBN: 1 77005 410 3 Overseas price : $85-00 excl postage

- **Considerations for the design of river abstraction works in South Africa: Vol 11**

Basson GR

Report No: TT 260/06 ISBN: 1 77005 411 1 Overseas price : $40-00 excl postage

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- **Guide for local government cooperation with catchment management agencies.**

Mazibuko G; Pegram GC

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 report provides 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. The guide is a user friendly document for all levels of local government.

Report No: TT 270/06 ISBN: 1 77005 460 8 Overseas price : $15-00 excl postage

- **Guide for catchment management agency cooperation with local government**.

This is a working guide for Catchment Management Agencies to cooperate with local governments in their areas of operation to achieve common objectives in the management of water resources and hence the development of their respective areas.

Report No: TT 271/06 ISBN: 1 77005 439 1 Overseas price : $15-00 excl postage

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A synthesis of the hydrogeology of the Table Mountain Group - Formation of a research strategy

Pietersen K; Parsons R

A project was initiated during 2000 to synthesize the current knowledge about the Table Mountain Group (TMG) aquifer systems. This resulted in a document on the "Synthesis of the Hydrogeology of TMG – Formation of a Research Strategy." The document is subdivided into technical papers and appropriate case studies. This exercise resulted in the understanding that to realize the potential, of this groundwater supply, many uncertainties and barriers need to be overcome, including: deficient understanding of the occurrence, attributes and dynamics of TMG aquifer systems; lack of understanding of environmental impacts of exploitation; and uncertainties about how best to manage the resource within a multi-objective environment. Research of a multi-disciplinary nature is thus needed to find appropriate answers to questions concerning the water resource potential and optimal management of TMG aquifers, in the interest of furthering integrated water resource management in the region.

Report No: TT 158/01 ISBN: 1 86845 804 0 Overseas price : $40-00 excl postage

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KSA 2:

Hydrology and water quality of the Mgeni catchment

Kienzle SW; Lorentz SA; Schulze RE

The ACRU hydrological model was configured for the Umgeni catchment upstream of Inanda Dam to simulate daily streamflow for 137 subcatchments for a 34-year period from 1 January 1960 to 31 January 1993. Simulated streamflows were verified against observed

data for a limited number of sub-catchments. All verifications gave a coefficient of determination above 78%. In all cases simulated streamflow was within 6% of the observed values. It was found that the simulated impact of present land uses compared with pristine conditions can be highly significant.

Report No: TT 87/97 ISBN: 1 86845 297 2 Overseas price : $30-00 excl postage

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The biological and chemical database. User manual (SA Price: R28.50)

Dallas H & Janssens P

A Biological/Chemical Database was developed as part of this project, incorporating virtually all the ecological studies done on South African rivers which include both taxonomic and chemical data. Using SASS4 (South African Scoring System, version 4), several of the water-quality variables in the DWAF guidelines for environmental water quality were tested for each of the four regions (mountain, foothills, transitional and low-land rivers).

Report No: TT 100/98 ISBN: 1 86845 421 5 Overseas price: $50-00 excl postage

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Guides to the freshwater Invertebrates of Southern Africa

The principle aim of the series of ten books is to synthesize much of the existing knowledge on the identification of freshwater invertebrates into a standard format that is accessible to users who wish to identify taxa beyond their field of expertise.
This series will include an introductory volume containing general information and a key to the families of invertebrates.

- **Volume 1: In preparation**

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- **Guides to the freshwater Invertebrates of Southern Africa. Crustacea I (SA price: R50.00)**

Day JA, Stewart BA, De Moor IJ & Louw AE

Report No: TT 121/00 ISBN: 1 86845 581 5 Overseas price : $25-00 incl postage

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- **Guides to the freshwater Invertebrates of Southern Africa. Volume 4: Crustacea III**

(SA price: R50-00)

Day JA, Stewart BA, De Moor IJ & Louw AE

Report No: TT 141/01 ISBN: 1 86845 676 5 Overseas price: $25-00 incl postage

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- **Guides to the freshwater Invertebrates of Southern Africa. Volume 3: Crustacea II (SA price: R50-00)**

Day JA, Stewart BA, De Moor IJ & Louw AE

Report No: TT 148/01 ISBN: 1 86845 703 6 Overseas price : $25-00 incl postage

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- **Guides to the freshwater invertebrates of Southern Africa Vol 5: Non-Arthropods (SA Price: R114-00)**

Day JA & IJ deMoor

Report No: TT 167/02 ISBN: 1 86845 827 X Overseas price: $50-00 incl postage

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- **Guides to the freshwater invertebrates of Southern Africa Vol 6: Arachnida & Mollusca: Araneae, Water Mites & Mollusca (SA Price: R50-00)**

Day JA &IJ deMoor

Report No: TT 182/02 ISBN: 1 86845 875 X Overseas price: $50-00 incl postage

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- **Guides to the freshwater invertebrates of Southern Africa Vol 7: Insecta: Ephemeroptera, Odonata & Plecoptera (SA Price: R114-00)**

IJ de Moor, JA Day & FC de Moor

Report No: TT 207/03 ISBN: 1 86845 875 X Overseas price: $50-00 incl postage

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- **Volume 8: Guides to the freshwater invertebrates of Southern Africa: Volume 8 (SA Price: R100-00)**

de Moor IJ; Day JA; de Moor FC

Report No: TT 214/03 ISBN: 1 77005 055 8 Overseas price: $50-00 incl postage

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- **Guides to the freshwater invertebrates of Southern Africa Vol 9: Diptera (SA Price: R100-00)**

JA de Moor, AD Harrison & IJ de Moor

Report No: TT 201/02 ISBN: 1 86845 900 4 Overseas price: $50-00 incl postage

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- **Volme 10: In preparation**

The Kruger National Park rivers research programme

C Breen, M Dent, J Jaganyi, B Madikizela, J Maganbeharie, A Ndlovu, J O'Keeffe, K Rogers, M Uys & F Venter

The Kruger National Rivers research programme is a co-operative undertaking by resource-use managers, funding agencies and researchers. It addresses the water quality and water quantity requirements of the natural environments of rivers, particularly those flowing through the Kruger National Park.

Report No: TT 130/00 ISBN: 1 86845 622 6 Overseas price: $35-00 excl postage

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State of the Rivers Report

DWAF, WRC, CSIR, Mpumalanga Parks Board & Dept of Environmental Affairs

Between 1996 and 1999, the River Health Programme (RHP) conducted surveys on the three major river systems of Mpumalanga, the Crocodile, Sabie-Sand and Olifants Rivers, including some of their tributaries.
The RHP collected and assessed a substantial body of data on the ecological health of these rivers during the surveys.

The following reports are available:

1) State of the Rivers Report: Letaba and Luvuvhu River Systems 2001 (TT 165/01)
2) State of the Rivers Report (TT 147/00)
3) State of the rivers report: Umngeni River and neighbouring rivers and streams. (TT 200 /02)

Report No: TT 147/00 ISBN: 1 86845 689 7 Overseas price : $20-00 excl postage

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Ecological risk assessment guidelines (South African price: R50-00)

Claassen M, Strydom W F, Murray K & Jooste

Ecological risk assessment is a structured approach that describes, explains and organizes scientific facts, laws and relationships and provides a sound basis to determine sufficient protection measures and to develop utilization strategies. The risk assessment process has the potential to improve communication between scientists, managers and the public, thereby promoting mutual understanding and collaboration. Appropriate use of this guideline document will thus promote cooperative governance and sustainable development

Report No: TT 151/01 ISBN: 1 86845 721 4 Overseas price : $25-00 excl postage

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The Botanical importance Rating of the Estuaries in former Ciskei/Transkei

Colloty BM, Adams JB & Bate GC

Botanical importance refers to the contribution of the plants to the conservation status of an estuary. In this study botanical importance is the sum of functional importance, species richness, community richness and community type rarity.

Report No: TT 160/01 ISBN: 1 86845 790 7 Overseas price : $20-00 excl postage

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Guidelines for *Legionella* levels in water: A code of practice

Pauline Coubrough

The guidelines are intended for use in South Africa, taking in account South African environmental conditions. International guideline documentation, results from outbreaks that have occurred throughout the world, and the National *Legionella* Action Group's research findings were used in the formulation of the guidelines.

Report No: TT 174/02 ISBN: 1 86845 846 6 Overseas price : $15-00 excl postage

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Predicting water quality and biotic response in ecological reserve determinations

Malan H; Day JA

The management of water quality in the environmental Reserve is more complex than that of water quantity. The principal aim of this project is to examine the relationship between water quality and water quantity with particular reference to instream flow requirement assessments, and to produce a framework for the assessment of water quality in IFR studies. Secondary aims are to investigate how the Biobase database may be used in the assessment of water quality guidelines.

Report No: TT 202/02 ISBN: 1 86845 923 3 Overseas price : $30-00 excl postage

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Prioritisation of South African estuaries based on their potential importance to estuarine-associated fish species

RC Maree, AK Whitfield and NW Quinn

This report presents a ranking of South African estuarine systems based on their importance to estuarine-associated fish species, and aims to facilitate the identification of South African estuaries with a high conservation priority, by placing all South African systems in a regional and national context.

Report No: TT 203/03 ISBN: 1 86845 979 9 Overseas price: $10-00 excl postage

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- **Freshwater fish and human health: Overview guide**

Heath R; du Preez H; Genthe B; Avenant-Oldewage A

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

Report No: TT 212/04 ISBN: 1 77005 046 9 Overseas price: $20-00 excl postage

- **Freshwater fish and human health: Reference guide.**

Heath R; du Preez H; Genthe B; Avenant-Oldewage A

Report No: TT 213/04 ISBN: 1 77005 047 7 Overseas price: $25-00 excl postage

Environmental water quality in water resources management

Palmer T; Berold R; Muller N

The release of harmful and potentially harmful substances into the environment has caused water quality problems worldwide. Toxicology offers a cost-effective way of measuring the likely impact of an effluent on the environment, in that it will identify whether the effluent is toxic, including any synergistic and antagonistic effects. This will allow for both the determination of the suitability of the effluent for discharge to be determined for licensing purposes, and for specific industries to monitor their compliance with licence conditions.

Most toxicity tests measure acute effects and the chronic values are calculated empirically. The measurement of sub-lethal methods will, thus, provide accurate values on which to base decisions, so enhancing the capacity of managers to protect the water resource.

During this project new methods will be developed for quantifying the chronic effects of toxic effluents at sub-lethal concentrations.

Report No: TT 217/04 ISBN: 1 77005 083 3 Overseas price: $25-00 excl postage

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The effect of water quality variables on aquatic ecosystems review

Dallas HF; Day JA

Water is a scarce resource in South Africa, and increasing population pressure has meant that the resource is heavily exploited and carries an increasing pollution load. Aquatic ecosystems are able to remediate a certain amount of pollution, but once this level has been exceeded then the ecosystem, together with its ability to remediate pollution declines.

Chapters 2 and 3 of the review provide a general introduction to the issue of water quality in relation to aquatic ecosystems. Chapters 4 to 12 synthesyse what is known about the effects on aquatic ecosystems of specific physical attributes and chemical constituents. Specifically, these include temperature, turbidity, pH, total dissolved solids and dissolved oxygen. Organic enrichment, including bacterial contamination, as well as the effects of enrichment by specific nutrients are covered, as are biocides and trace metals. The last eight chapters examine the effect of different types of whole effluents or other specific disruptions resulting from human activities, including agriculture, aquaculture, engineering and construction with specific reference to river regulation, forestry, industrial effluents, mining and urban runoff.

Report No: TT 217/04 ISBN: 1 77005 083 3 Overseas price: $25-00 excl postage

The effect of water quality variables on aquatic ecosystems review

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Water is a scarce resource in South Africa, and increasing population pressure has meant that the resource is heavily exploited and carries an increasing pollution load. Aquatic ecosystems are able to remediate a certain amount of pollution, but once this level has been exceeded then the ecosystem, together with its ability to remediate pollution declines.

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Report No: TT 224/04 ISBN: 1 77005 131 7 Overseas price: $30-00 excl postage

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Towards the conservation and sustainable use of Eastern Cape estuaries.

Breen C; et al

The ACRU hydrological model was configured for the Umgeni catchment upstream of Inanda Dam to simulate daily streamflow for 137 subcatchments for a 34-year period from 1 January 1960 to 31 January 1993. Simulated streamflows were verified against observed data for a limited number of sub-catchments. All verifications gave a coefficient of determination above 78%. In all cases simulated streamflow was within 6% of the observed values. It was found that the simulated impact of present land uses compared with pristine conditions can be highly significant.

Report No: TT 237/04 ISBN: 1 77005 235 6 Overseas price: $20-00 excl postage

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Spatsim, an integrated framework for ecological reserve determination and implementation.

Hughes DA; Palmer CG

Water quality is currently trailing water quantity in the ecological Reserve methodology. Further development of the methods used is necessary to enable the water quality component to be considered adequately. The aims of this project are to develop acceptable time-series data for selected water quality variables, encapsulate the expert water quality knowledge in an organised way and encode these for inclusion into the DSS currently being developed as part of a parallel project, and co-ordinate this with other water quality projects working on the Reserve. This will ensure that decisions taken on water quality in the Reserve determination process are done in a standard way and in parallel with those on water quantity.

Report No: TT 245/04 ISBN: 1 77005 296 8 Overseas price: $25-00 excl postage

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The SA diatom collection: An appraisal and overview of needs and opportunities

Harding WR; Archibald CGM; Taylor JC; Mundree S

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. 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. 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.

Report No: TT 242/04 ISBN: 1 77005 275 5 Overseas price: $25-00 excl postage

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Managing sedimentary processes in SA Estuaries: A guide

Hay D; Huizinga P; Mitchell S

Ingress of marine sediments into estuaries was the single most important issue in estuary management identified in the western part of the Eastern Cape during the early stages of the EC Management Programme. The local authority for the Port Alfred / Boesmans River area has committed funds to develop the predictions of the effect of interventions on the problem. If the predictions indicate that an intervention may be successful, then the EIA around the planned intervention will be undertaken within this project. Thereafter, the implementation of any technology will be for the expense of the local authority.

Report No: TT 241/05 ISBN: 1 77005 272 0 Overseas price: $20-00 excl postage

KSA 3:

Applicability of waste minimisation clubs in South Africa: Results from pilot studies.

Barclay S; Buckley C

Industrial small-, medium- and micro-enterprises (ISMMEs) are a strategic growth sector in the RSA but cumulatively are significant sources of pollutants which detrimentally affect sewage treatment. The overall objective of the project was the development of regional waste minimization clubs, in which cleaner production practices can be cost-effectively established as a contribution to the sustainability in South Africa of ISSMEs that are both competitive and environmentally responsible.

Report No: TT 161/05 ISBN: 1 86845 831 8 Overseas price: $30-00 excl postage

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Guidelines for the utilisation and disposal of wastewater sludge: Volume 1 of 5: Selection of management options.

Snyman HG; Herselman JE; Kasselman G; Steyn CE; Wilken JW

This work implements the major recommendation arising from the comprehensive multi-stakeholder WISA Sludge Management Group in the consultative process coordinated by the WRC to review and update the current published sludge management guidelines.

Report No: TT 261/05 ISBN: 1 77005 422 7 Overseas price: $20-00 excl postage

Guidelines for the utilisation and disposal of wastewater sludge: Volume2 of 5: Requirements for the agricultural use of wastewater sludge

Snyman HG; Herselman JE; Kasselman G; Steyn CE; Wilken JW

Report No: TT 262/05 ISBN: 1 77005 423 5 Overseas price: $20-00 excl postage

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Water purification works design: (SA Price R150-00)

Van Duuren FA

This project was aimed at facilitating the optimal, most economical water purification and treatment works by providing a design guide based on water quality considerations, processes and operations. This guide indicates water quality requirements, control and management of procedures, and water demands in all sectors. It also categorises water purification and treatment processes and operations

Report No: TT 92/97 ISBN: 1 86845 345 6 Overseas price : $50-00 excl postage

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Information transfer extraction management systems (ITEMS)
(SA Price R114-00)

Howard MR; Perkins M

This project developed a computerised Information Transfer, Extraction and Management System (ITEMS) which enables users to gain access to local and international information on mine-water quality, management, treatment and research. The six modules incorporated in ITEMS, viz. literature, water quality guidelines, contaminant properties, research results, an impact assessment manual and a mine-water management manual, and the options available in each of the modules, render ITEMS an extremely versatile information tool. The total computer file size of the databases is 87 Mbytes. ITEMS is available on CD-ROM

Report No: TT 94/98 ISBN: 1 86845 378 2 Overseas price : $70-00 excl postage

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Solids-free sewer systems in South Africa: a community leader's guide

Du Pisani JE

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

Report No: TT 96/98 ISBN: 1 86845 401 0 Overseas price : $20-00 excl postage

Handbook to guide communities in the choice of sanitation systems

Bernhardt Dunstan & Associates

The main aim of this study was to evaluate on-site sanitation systems from a socio-economic perspective with special reference to affordability, appropriateness and social acceptability. The study was undertaken in three case study areas, namely, Soshanguve TT, Ivory Park and Ga-Mmotla. The study concluded that in all three case study areas, communities were dissatisfied with their on-site sanitation systems. Women were unhappy about being excluded from decision-making on the selection of sanitation technologies, because as the main users, they are better qualified to select a sanitation system that could be operated and maintained by the users.

Report No: TT 104/98 ISBN: 1 86845 425 8 Overseas price : $10-00 excl postage

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Guidelines for the design and operation of sewage sludge drying beds

Ceronio AD; Van Vuuren LRJ; Warner APC

Current information and guidelines for the design and operation of sewage sludge drying beds in the RSA are very limited. The design data available are largely empirical and give almost no insight into the effect of climate, sludge concentration, loading rates, sludge volume index, filter media, etc. on the drying bed area required. Based on the research and support of experimental work done, as well as information obtained from literature, the study produced a guideline that is specific for South African conditions called Guidelines for the Design and Operation of Sewage Sludge Drying Beds (WRC Report NoTT 107/99)

Report No: TT 107/99 ISBN: 1 86845 491 6 Overseas price : $25-00 excl postage

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Guidelines for the calibration of measuring flumes in sewers

Rooseboom A; Goodey GM

During 1992 a detailed investigation revealed that the majority of open channel flumes on South African sewer mains and at municipal wastewater treatment plants, do not comply with the generally accepted British Standards 3680. In this project tests were performed on different flumes in order to establish the impact of differences in shape and surface roughness on calibration coefficients. These guidelines are the product of a large number of practical tests, combined with existing standards for the measuring of fluids by flumes. The result is a set of methodologies and worked examples, which clarifies and simplifies

measuring flume design to the point where plant personnel in the smaller plants will also be able to follow and utilise the guidelines to the full.

Report No: TT 111/99 ISBN: 1 86845 501 7 Overseas price: $25-00 exc postage

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Corrosion brochure for local authorities

Ramotlhola JS; Ringas C

The brochure highlights cost-effective ways in which external corrosion can be minimised. The brochure can also be useful to repair teams working in the field. The brochure contains colour photographs showing the different forms of corrosion in order to assist field teams to correctly identify the cause of the failure. Appropriate repairs can then be carried out. The brochure also describes how each local authority can build up its own database, thereby assisting in the long-term strategy of each local authority by ensuring that correct corrosion prevention strategies are used.

Report No: TT 112/99 ISBN: 1 86845 510 6 Overseas price: $15-00 excl postage

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DOMESTIC WATER SUPPLY: GUIDES

The provision of an adequate and safe water supply to all people is one of the goals of the South African Government. To ensure the safety of water supplies, a need for a user-friendly Guide to facilitate evaluation of the health-related quality of water supplies was identified as a priority by both the Departments of Health and Water Affairs and Forestry. This resulted in the production of a series of guides.

This Guide forms part of a series which is intended to provide water supply agencies, water resource managers, workers in health-related fields, as well as communities throughout South Africa, with the information they need to sample, analyse, assess and interpret the quality of domestic water supplies.
The following documents from the series:

Quality of domestic water supplies –
Vol I: Assessment Guide' TT 101/98

Report No: TT 101/98 ISBN: 1 86845 416 9 Overseas price: $25-00 excl postage

Quality of domestic water supplies –
Vol II: Sampling Guide1 TT 117/99

Report No: TT 117/99 ISBN: 1 86845 543 2 Overseas price: $15-00 excl postage

Quality of domestic water supplies –
Vol III: Analysis Guide1 TT 129/00

Report No: TT 129/99 ISBN: 1 86845 620 X Overseas price: $20-00 excl postage

Quality of domestic water supplies-
Vol 4: Treatment guide TT 181/02

Report No: TT 181/99 ISBN: 1 86845 873 3 Overseas price: $30-00 excl postage

Quality of domestic water supplies –
Volume 5: Management Guide TT162/01

Report No: TT 162/99 ISBN: 1 86845 809 1 Overseas price: $30-00 excl postage

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The management of urban impoundments in South Africa volume 2. Guideline manual

Freeman MJ; Howard MR; Wiechers HNS

This Urban Impoundment Management Guideline Manual is the product of a research project carried out for the Water Research Commission to investigate the water- quality problems most commonly experienced in South African urban impoundments, as well as the management techniques which can be used to address them.

The purpose of the Guideline Manual is to assist those responsible for, or with an interest in, the management of the water quality of urban impoundments. It is thus aimed predominantly at those persons in local authorities who must manage the water bodies in their areas.

Report No: TT 119/00 ISBN: 1 86845 553 X Overseas price: $25-00 excl postage

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The economic cost effects of salinity - integrated report

Urban-Econ Development Economists

As the salt content of water increases, the water becomes less suitable for most users, and additional costs are incurred. The study was undertaken because of uncertainties about some of the methodology and assumptions that were used in the desk study and the need for a versatile economic model that can be used to quantify the effect of salinity in monetary terms and to compare the cost-benefit ratios of alternative options. A generic methodology to determine the financial, economic and social impacts associated with an increase in salt concentration was first developed, and then applied by conducting a survey to determine the impacts of increased salt concentrations in the middle Vaal River.

Report No: TT 123/00 ISBN: 1 86845 590 4 Overseas price: $20-00 excl postage

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Defluoridation, denitrification and desalination of water using ion - exchange and reverse osmosis

Schoeman JJ; Steyn A

This project concentrated on demonstrating the feasibility of using advanced adsorption, ion-exchange and membrane technologies to remove fluorides, nitrates and dissolved suspended solids from groundwater in order to produce potable water for rural communities which are remote from first-world infrastructure. Activated alumina, ion-exchange and reverse-osmosis systems were evaluated at a number of rural sites in terms of both technical and social acceptance factors. The results achieved in these demonstration studies show that activated alumina and ion-exchange processes and advanced water treatment processes such as membrane filtration can be employed successfully for the purification of adverse-quality groundwater to potable standards in the rural areas.

Report No: TT 124/00 ISBN: 1 86845 597 1 Overseas price: $20-00 excl postage

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Land -based effluent disposal and use: Development guidelines and expert systems-based decision support

Murphy K O'H

Effluents and soils were identified as factors which help in the process of making decisions on the applicability of a specific effluent on a specific land. The identification of the effluent takes into account health-related aspects, the risk of pollution to the water source and the effects of it on plants. The identification of the soil relates to the ability of soils to attenuate the contaminants in the effluents.

The user guide takes one through the process in order to be able to determine whether the combination is acceptable or not and whether it conforms to health guidelines. If this is

acceptable, it is indicative of restrictions or protective measures. ELADS Effluents to land - application decision-support software is the expert systems-based decision-support software developed. It could be used not only for sewage effluents, but also for organic effluents, to some extent for nitrogenous effluents and effluents containing potentially toxic trace elements. It could be modified to accommodate any site, soil or effluent-related limits specified by new regulations. (WRC Report No TT 125/00).

Report No: TT 125/00 ISBN: 1 86845 551 3 Overseas price: $20-00 excl postage

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The level of communication between communities and engineers in the provision of engineering services

Pybus P; Schoeman G; Hart T

The purpose of this research was to test the hypothesis above and to establish how engineering information, for example, concerning the level of service, can best be given so that the community leaders can make a decision based on sound knowledge of the technicalities of the situation. In an analysis of the major factors that negatively affect communication between consultants (specifically engineering) and communities, it was found that the majority of factors stemmed from a lack of integrated and comprehensive project planning. The findings from this study are supported by an excellent set of guidelines, aimed at improving communication processes between practitioners and communities in water and sanitation development projects

Report No: TT 133/00 ISBN: 1 86845 630 7 Overseas price: $20-00 excl postage

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• Waste minimisation guide for the textile industry: A step towards cleaner production: Vol I

Barclay S; Buckley C

The Waste Minimisation Guide for the Textile Industry has been found to be a useful tool for assisting the RSA textile industry to improve its environmental performance in the following areas of application:

$ The textile industry can use the Guide to self-assess and improve its implementation of waste minimisation practices and, hence, its aquatic environmental performance
$ Similarly, use of the Guide will assist factories in achieving compliance with environmental management standards e.g. 1S0 14000, and, thereby, improving their international competitiveness

$ Local regulatory authorities can use the Guide both as a training tool and as a management tool for monitoring and assessing the performance of textile manufacturers in their area of jurisdiction.

Report No: TT 139/00 ISBN: 1 86845 659 5 Overseas price: $20-00 excl postage

• Waste minimisation guide for the textile industry: A step towards cleaner production. Vol II

Report No: TT 140/00 ISBN: 1 86845 659 5 Overseas price: $20-00 excl postage

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Hygiene awareness workshop

Duncker LC

The study showed that the level of general knowledge regarding hygiene practices was high in all case study areas. However, the practice of appropriate hygienic lifestyle was hampered by poverty and a lack of access to basis water supply and sanitation services. It was found that rural communities lacked a specific knowledge regarding causes, transmission and prevention of water-related and faeces-related diseases. The level of knowledge on the treatment of these diseases was high because of their prevalence in these communities. This research has produced the following manuals:

$ A Manual on Knowledge, Attitude and Practice (KAP) Study for Hygiene Awareness in the Rural Areas of South Africa (K5/819)
$ Hygiene Awareness Programme (TT144/00)

Report No: TT 145/00 ISBN: 1 86845 633 1 Overseas price: $25-00 excl postage

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Human resources planning and management system (HRPMS) user manual

Stewart Scott

The study has developed a management tool to help managers to implement integrated human-resource planning of water service institutions. The report focuses on the human resources that are required in order to support the infrastructure, as well as the organisational structure requirements of various sizes of water service institutions. The computerised human resources planning and management system (HRPMS), which was developed for water service institutions through this study, includes facets of both a management information system (MIS) as well as a decision support system (DSS). The management component of the HRPMS includes portions of the job analysis and employee

profile modules. The reporting facilities provided by the HRPMS facilitate management, planning and decision-making.

Report No: TT 146/01 ISBN: 1 86845 686 2 Overseas price: $15-00 excl postage

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

Lima Rural Development Foundation

The study highlights parameters in which attended coupon operated access point cost recovery system operates efficiently by analyzing seven existing schemes. The research to identified the operational constraints that community water supply schemes are currently facing by conducting sample surveys in the schemes.

Report No: TT 150/01 ISBN:1 86845 716 8 Overseas Price: $15-00 excl postage

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• Development of a simple and pragmatic approach to benchmark real losses in potable water distribution systems in South Africa: BENCHLEAK

Ronnie McKenzie & Allan Lambert

The BENCHLEAK software and this User Manual are part of the ongoing process of refining and improving the methodologies for calculating and presenting performance data associated with management of public water supply systems in South Africa.

Report No: TT 159/01 ISBN: 1 86845 773 7 Overseas Price: $20-00 excl postage

***The BENCHLEAK software is available from the Water Research Commission and further details can be obtained from the web site at*: http://www.wrc.org.za**

• Development of a Windows based package for assessing appropriate levels of active leakage control in potable water distribution systems: ECONOLEAK

Ronnie McKenzie

The ECONOLEAK model is aimed specifically at determining when a water supplier should invest in active leakage control for a specific zone metered area.

Report No: TT 169/02 ISBN: 1 86845 832 6 Overseas Price: $20-00 excl postage

***The ECONOLEAK software is available from the Water Research Commission and further details can be obtained from the web site at*: http://www.wrc.org.za**

Guidelines for the implementation of benchmarking practices in the provision of water services in South Africa

Philip Pybus

The guidelines are intended to encourage the local authorities to benchmark their activities with their peers with a view to delivering water and sanitation services in a more effective and efficient manner.
Benchmarking offers a route to more effective and efficient service delivery.

Report No: TT 168/02 ISBN: 1 86845 842 3 Overseas price: $20-00 excl postage

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Environmentally responsible mining: Water management guidelines for small-scale mining

Clacherty A; Moodie Peter

This report identifies and characterises the critical water-related impacts of small-scale mining and is developing appropriate tools to assist their environmental management. The study focussed primarily on the water-related issues of peat extraction, clay-mining for brick making, alluvial diamond-mining and other small-scale mining activities associated with gravels, alluvial sands and sediments.

Report No: TT 168/02 ISBN: 1 86845 842 3 Overseas price: $20-00 excl postage

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A manual for cost benefit analysis in South Africa with special references to water resource development

Conningarth Economist

This document entails the guidelines in the format of a manual for conducting Cost Benefit Analysis (CBA) in South Africa with specific references to evaluating the development and management of water resources. This evaluation of projects is often a difficult task since costs and benefits do not occur only once but appear over time. This manual is specifically aimed at the decision maker in the public sector, but can be used outside the public sector too.

Report No: TT 170/04 ISBN: 1 86845 833 Overseas price: $20-00 excl postage

Guidelines for the application of natural stone trickling filters with some reference to synthetic media trickling filters

Wates, Meiring & Barnard (Pty) Ltd

Trickling filters are applied in many domestic and industrial wastewater treatment plants in Southern Africa. Trickling filtration technology is still evolving and this document provides current information on the design, operation and maintenance of filters.

Report No: TT 178/02 ISBN: 1 86845 852 0 Overseas price: $15-00 excl postage

Water and wastewater management in the oil refining and re-refining industry: NATSURV 15

CSIR

In this study the water intake, water use and pollutant loads of the crude oil refinery, synthetic fuel refinery and refining sectors of the industry were surveyed and characterised. Crude oil refineries in the RSA were found to have a relatively narrow range of specific water intake (SWI 0.51 to 0.67 m3/t) and re-refining SWIs were found to vary widely (0.06 to 7.2 m3/t), depending on the type of process used. The results obtained present a snapshot of the water and wastewater characteristics of the industry in which crude oil refining (at four refineries) is around 20 million t/a, syn-fuel refining (at two refineries) is around 9 million t/a and oil re-refining is around 120 000 t/a. In addition to the water and effluent survey data, the Guide produced contains a number of specific recommendations for reducing water use and effluent generation in the industry.

Report No: TT 180/05 ISBN: 1 86845 508 4 Overseas Price: $15-00 excl postage

Elementary handbook of water disinfection

FHH Carlsson

The salient features of the handbook covers:
• Description of water disinfection processes, principally chlorination and chloramination but including ozonation, peroxone, chlorine dioxide and ultraviolet treatments

• Written such that it is understandable by non-specialists in water treatment plants and informed lay-persons
• To be used as an aid in effective education and training of plant personnel while avoiding detailed chemistry
• To be used as a ready reference for daily use on water purification plants where disinfection is implemented.

Report No: TT 205/03 ISBN: 1 86845 983 7 Overseas price:$20-00 exl postage

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Watrex expert system for water treatment plant design:
(South African price: R500-00)

FR Sutherland

This is a Windows-based software package that applies expert system technologies to water treatment plant design. The software allows data acquisition, unit process design and modeling, process selection, and dynamically responding plant design, modeling and sensitivity analyses.

Report No: TT 206/03 ISBN: 1 77005 016 7 Overseas price:$200-00 exl postage

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An assessment of the trickle feed system as a tool for implementing the free basic water policy

AM Lenehan; L Abelitis

This study investigated the cost-recovery efficiency of the trickle feed system. In this system a known quantity of water is delivered each day to a storage tank at each customer's house. This allows the implementation of a monthly prepaid cost-recovery system with relatively low administration. There are potential benefits of implementing the trickle feed system in rural areas and it is currently implemented in pilot projects in Northern KwaZulu-Natal.

Report No: TT 210/03 ISBN: 1 77005 031 0 Overseas price:$10-00 exl postage

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The measurement and reduction of urban litter entering stormwater drainage systems

Mark Marais; Neil Armitage

This project addresses the following aims:
• The improvement in the knowledge of the source type and amount of urban litter coming from different types of urban catchments; and
• Provision of scientific data on the efficacy of various management techniques in reducing the amount of urban litter reaching drainage systems. This information, together with the knowledge, would enable the development of Litter Management Plans (LMPs) resulting in reduced litter loadings and realizing considerable cost savings.

Report No: TT 211/03 ISBN: 1 77005 041 8 Overseas price:$30-00 exl postage

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Making Water work for villages

C Moat; C van den Voorden: I Wilson

Evaluation studies of new water projects show that poor operation and maintenance (O&M) of water supply schemes is responsible for the high failure rate of water projects. These studies have also shown that the O&M systems that were implemented were generally unresponsive to user needs. This highlights the importance of basing the development of O&M guidelines on local knowledge. This study captured the different methods that communities have used to manage their water supply schemes prior to the implementation of new water projects. The study has also documented local knowledge and experience that has formed the basis for the development of O&M guidelines.

Report No: TT 216/03 ISBN: 1 77005 073 6 Overseas price:$20-00 exl postage

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A guidebook on household water supply for rural areas with saline groundwater

Goldie I; Sanderson RD

This report captures and presents options of small-scale water purification technologies for potable water supply to farms, schools, clinics and small communities from brackish surface water sources. The report produced in the form of a guide will assist decision makers in the selection of these technologies. Both membrane-and distillation-based technologies have been assessed, mostly in terms of a desk study. Recently developed local innovations are also included into this guide.

Report No: TT 221/04 ISBN: 1 77005 107 4 Overseas price:$30-00 exl postage

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Feasibility of water fluoridation for South Africa

B Genthe; CE Herold;J Haarhoff; Hosking S; G Syke

A team, consisting of five experts in their fields, was requested to perform a desk study to identify both the positive and negative consequences which could be expected to arise following the fluoridation of potable water supplies in South Africa.. Results from the study for the first time summarize and bring together a whole spectrum of aspects to take into consideration when potable water supplies are fluoridated. The results show that further actions, including further research, are required before fluoridation can be effected with full safety and confidence in a developing country such as South Africa.

Report No: TT 222/04 ISBN: 1 177005 108 2 Overseas price:$24-00 exl postage

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A summary of lessons and experiences from the Ethekwini pilot shallow sewer study

Patti Eslick; John Harrison

Sanitation, because of the major impact it has on health and quality of life, is a service with a high priority. Findings from a previous WRC study indicated that shallow sewer systems provide a viable intermediate sanitation alternative, with a total cost between Ventilated Improved Pitlatrines (VIPs) and conventional sewerage. With this as a stimulus, the Durban Metro Water was the first local authority to indicate interest in taking the recommendations further. This study captures the lessons and experiences from the pilot implementation of the shallow sewers.

Report No: TT 225/04 ISBN: 1 77005 135 X Overseas price:$20-00 exl postage

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An introduction to the concepts of customer relations management for water services institutions

Naidoo J; Mosdell T

The fact that the concept of customer service has received little attention in South Africa is perhaps related to the historic situation where water supply and sanitation services were provided on a monopolistic take it or leave it basis, particularly in the case of poorer customers. It is now recognized increasingly that successful water services provision is strongly associated with the application of good business principles. This implies a service orientation, with a primary focus on the customer. This report provides an overview of customer management, principles and methodology.

Report No: TT 227/04 ISBN: 1 77005 147 3 Overseas price:$20-00 exl postage

Community identified performance indicators for measuring water services

Schoeman G; Magongoa

This work implements the major recommendation arising from the comprehensive multi-stakeholder WISA Sludge Management Group in the consultative process coordinated by the WRC to review and update the current published sludge management guidelines.

Report No: TT 228/04 ISBN: 1 77005 158 9 Overseas Price: $15-00 excl postage

Guidelines for economic regulation of water services in South Africa

Palmer Development group

For the regulation of water services to become effective in South Africa, considerable work needs to be undertaken. In particular the methodology to be used in undertaking economic regulation is one of the key components. This report has investigated the subject of economic regulation and its relevance to South Africa and has defined the manner in which water services authorities should regulate water services providers, within the current legislative framework. It highlights the importance of the methodology for economic regulation and in particular regulating tariffs and associated financial parameters. This report is aimed to stimulate discussion on the subject matter, towards effective economic regulation.

Report No: TT 229/04 ISBN: 1 77005 164 3 Overseas price:$20-00 excl postage

Guidelines on reduction of the impact of water infiltration into sewers.

Stephenson D; Barta B

The effects of urban developments on stormwater quality and quantity as well as groundwater infiltration into the sewer facilitites cannot be left anymore to ad hoc solutions and there is an urgency for a strategic approach to these problems. This report based on identifying and quantifying the problem of ingress, provides the necessary strategy and answers to these problems.

Report No: TT 239/05 ISBN: 1 77005 264 X Overseas Price: $20-00 excl postage

Benchmarking of leakage from water reticulation systems in South Africa

McKenzie RS; Seago C

In the 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 bet the most reliable and meaningful indicator.

Report No: TT 244/05 ISBN: 1 77005 282 8 Overseas Price: $25-00 excl postage

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Water and waste-water management in the power generating industry (NATSURV 16)

Van Zyl HD; Premlall K

The power-generating industry in the RSA is a substantial water user and effluent producer and impacts nationally both on water use allocations and the maintenance of resource water quality. The report provides the volumes and breakdown of water taken in and discharged by major and minor power generating plants, to determine pollutant loads and identify suitable wastewater management processes and strategies, and to a guideline document assisting both the industry and regulators in effective water and wastewater management of this sector.

Report No: TT 240/05 ISBN: 1 77005 270 4 Overseas Price: $15-00 excl postage

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Ecological sanitation - Literature review

Austin LM; Duncker LC; Marsebe; Phasha MC; Cloete TE

Urine-diversion sanitation systems 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. This report captures the state of knowledge on urine diversion toilets.

Report No: TT 246/05 ISBN: 1 77005 322 0 Overseas price: $25-00 excl postage

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Guidelines for ensuring sustainable effective disinfection in small water supply systems.

Momba MNB; Brouckaert BM

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 report provides strategies which will ensure sustainable effective disinfection in small municipal water distribution systems.

Report No: TT 249/05 ISBN: 1 77005 321 2 Overseas price: $30-00 excl postage

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Water poverty mapping: Development and introduction using a case study at the local municipal scale for the Eastern Cape.

Cullis J

This report demonstrates the feasibility of using water poverty mapping to define and study the nature of water poverty in South Africa as well as the basis for 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.

Report No: TT 250/05 ISBN: 1 77005 337 9 Overseas price: $20-00 excl postage

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Handbook for Waterworks Operation

Christiaan Frederick Schutte (Editor)

There are a number of different books and instruction guides (mostly sourced from abroad and excessively priced in South African terms) available to assist with training of water treatment works operators, but a survey of these showed that none of the existing books is suitable to be used as a basis book for reference and for training. This report is an excellent reference book for training of water plant operators, as well as for the operation of water treatment works.

Report No: TT 265/06 ISBN: 1 77005 428 6 Overseas price: $25-00 excl postage

The development of a successful unaccounted-for water management programme in the rural water supply context.

Ross-Jordan J

The challenge to develop simple and effective systems that are easily understood by water committees, has resulted in this report which can be used by the community as well as their local authority to manage water lossess in distribution systems.

Report No: TT 256/06 ISBN: 1 77005 392 1 Overseas price: $20-00 excl postage

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The use of key performance indicators in the benchmarking of rural water supply schemes: An aid to development of meaningful local government capacity.

Still D; Balfour F

New local authorities have limited knowledge on the nature of inspection needed to promote good management at community level. Therefore, the challenge was 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 report provides a set of key performance indicators (KPIs) which have been tested on a number of RDP projects that are presently being transferred from Umgeni Water to relevant district councils in KwaZulu-Natal.

Report No: TT 255/06 ISBN: 1 77005 391 3 Overseas price: $25-00 excl postage

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The WRC community based health and hygiene model and implementation kit

Onabolu Bolu; Ndlovu Maliti

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.

Report No: TT 264/06 ISBN: 1 77005 427 8 Overseas price: $20-00 excl postage

A strategic framework for water-related human health research.

Venter SN; Mjoli NP

The report is a compilation of a framework and strategy plan to guide the future funding of priority research on the improvement of water related human health in Southern Africa. The plan had to include health related aspects of all human-water interactions. The plan further identifies research gaps for future, local, research on water related human health and a list of institutions and researchers active in health research, both nationally and internationally.

Report No: TT 257/06 ISBN: 1 77005 404 9 Overseas price: $20-00 excl postage

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KSA 4

Using Sapwat to estimate water requirements of crops in selected irrigation areas managed by the Orange - Vaal and Orange - Riet water users association

Van Heerden PS, Crosby CT & Crosby CP

This report serves as a user manual for the application of SAPWAT. Furthermore, it demonstrates that the estimation of irrigation requirements can be credible and that the requirements that the National Water Act (36 of 1998) sets for future water management can be met.

Report No: TT 163/01 ISBN: 1 86845 812 1 Overseas price $30-00 excl postage

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Micro-irrigation for smallholders - Guidelines for funders, planners, designers and support staff in SA

Du Plessis FJ; Van Averbeke W; Van der Stoep I

The objective of this project was to assess how small-scale farmers experience the concept of micro-irrigation systems and how they cope with problems. The aim was to identify those aspects that eventually determine the success or failure of small-scale crop production, utilising these systems. During the course of the project it became apparent that external factors, generic to any small-scale farming system and seemingly unrelated to micro-irrigation, had a significant influence, and that it would, therefore, be almost impossible to evaluate the former without taking the latter into account. The aim of the guideline report is to help prevent mistakes of the past and, hopefully, it will contribute to

policy-making on a small scale regarding the utilisation of micro-irrigation. Thus, the successful use of the systems is ensured.

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Contribution of aquaculture to rural livelihoods in South Africa: A baseline study

Rouhani QA; Britz PJ

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.

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Guidelines for irrigation water measurement in practice.

Vd Stoep I; Benade N; Smal HS; Reinders FB

Effective management of water resources can be vastly improved if water use is measured accurately. This applies in particular to efforts to influence the quantity of water demanded by levying tariffs on the volume of water actually consumed. However, on most irrigation schemes water flow is not measured and water tariffs are presently still levied on an area and not a volumetric basis. This report is as a result of a comprehensive study of water measurement in irrigation.

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Irrigation scheduling using the Soil Water Balance (SWB) model as a user-friendly irrigation scheduling tool.

John George Annandale; Joachem Marthinus Steyn; Nico Benade; Nebojsa Zarko Jovanovic; Puffy Soundy

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 uses 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 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.

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