

South African research in the hydrological sciences: 1999–2002

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The principal activities of South African researchers in hydrology and water resources during the reporting period have been concerned with ground- and surface-water interactions, rainfall-runoff modelling, the establishment of improved regional water resource databases, the management of transboundary water resource systems, the ecological reserve, and quantifying the impacts of streamflow reduction activities. Most of these studies have focused on supporting the radically new provisions of the National Water Act of 1998.

Research contributions

Since 1998, a great deal of the research in hydrology and water resources in South Africa has focused on supporting the National Water Act of 1998 (NWA, 1998), which involves a totally revised approach to water resource management within the country and places the emphasis on equity of water distribution, as well as environmental sustainability. This change in emphasis is reflected in the topics funded by the Water Research Commission (WRC) between 1981 and 2000 (Fig. 1). New areas of funding in 2000 include integrated water resource management, water policy and water services, while conservation of water ecosystems also enjoyed a high priority. The WRC has recently restructured its support programme and funding now operates under

five key strategic areas: Water Resource Management, Water-linked Ecosystems, Water Use and Waste Management, Water Utilization in Agriculture, and Water Centred Knowledge (knowledge dissemination and information systems). In addition, four cross-cutting domains (Water and Society, Water and the Economy, Water and the Environment, and Water and Health) have been established to draw together projects and programmes that are under way within each strategic area.

Hughes (2002) reviewed some of the contemporary issues in hydrology and pointed out that a high proportion of hydrological research programmes in South Africa over the last few decades have been orientated towards the solution of practical water resource problems. While this may be seen as a criticism of the development of hydrology as a science, where the supply side has dominated at the expense of the demand side, it was almost inevitable in a country with pressing water-supply problems. One measure of the success of such programmes could be the extent to which they have prepared the country to respond to new challenges. The speed with which the hydrological community (in cooperation with other disciplines) has responded to the challenges of the new Water Act suggests that these programmes have been successful.

As models and other hydrological tools become ever more sophisticated, it is increasingly important for them to be sustained by training and technical support programmes. This is especially true in a country such as South Africa, that has a limited number of individuals or organizations undertaking development work, but a much larger group that needs to apply the methods. As South Africa moves toward a regionalized system of water resource management (through the establishment of catchment management agencies), the training requirements in the application of hydrological estimation methods will

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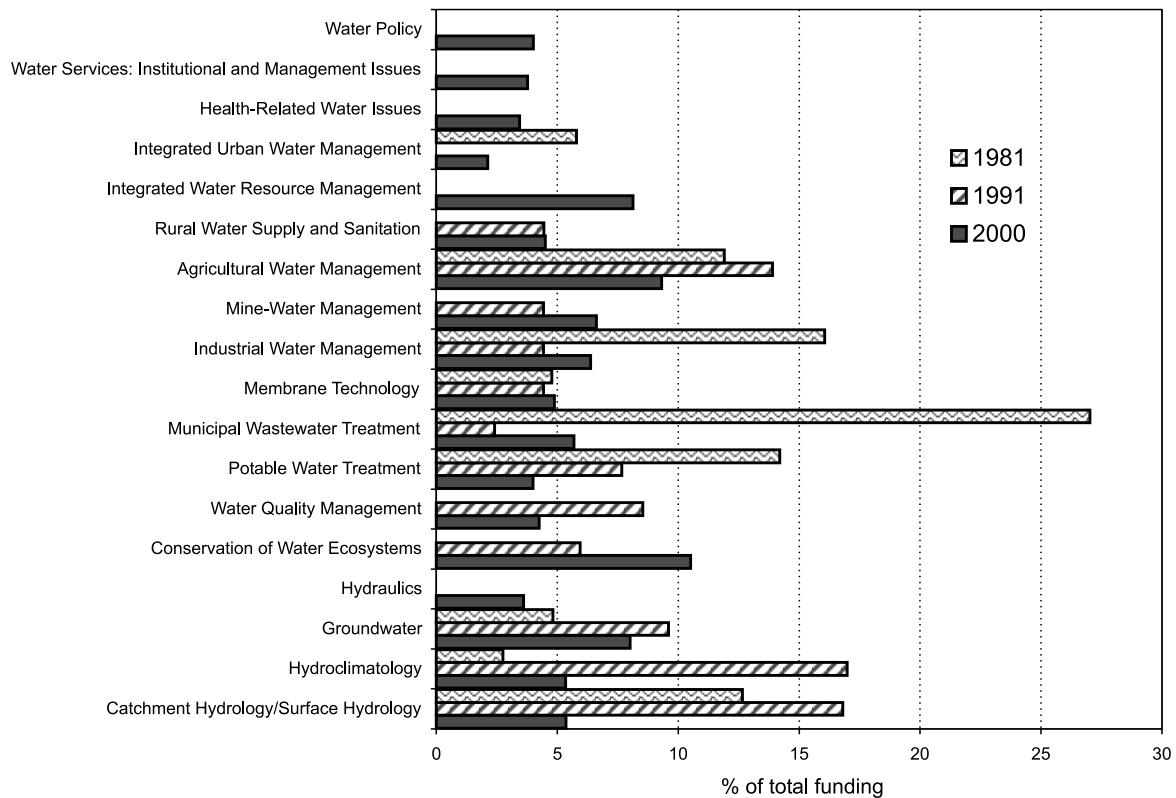


Fig. 1. Water Research Commission funding: proportion of total funding divided amongst the sectors identified in the Annual Report for 2000.

significantly increase. Unfortunately, the country appears to be experiencing declining technical capacity and the average age of practising hydrologists is increasing, a situation that needs to be reversed as soon as possible.

The following sections highlight some of the research directions that have been dominant in the hydrological sciences within South Africa during the reporting period. Some recent contributions to international journals and other sources complete the review. Much of the research undertaken in the hydrological sciences in South Africa is documented in WRC reports. Further information about past, current and future research programmes supported by the WRC can be found at their web site, which also includes lists of publications (see <http://www.wrc.org.za>).

Hydrology and the ecological reserve

The ecological reserve is the quantity and quality of the flow regime of a river (or estuary, ground water or wetland) that is 'reserved' under the NWA for the purposes of sustaining the environment in a predetermined condition. The determination of the reserve has become a relatively complex multi-disciplinary process that also involves the stakeholders living near the resource. From a hydrological point of view, the introduction of the reserve concept into South African water resource management provided a number of research challenges. It was soon discovered that the hydrological analysis tools to support the reserve determination process were not available and had to be developed for practical application as a matter of some urgency. This problem has now largely been addressed and there are several well-developed model packages available to assist ecologists in the process (Hughes, 2001; Hughes and Hannart, 2002). There remain several challenges related to the implementation of the reserve by regional water management authorities. Some of the problems are of a technical nature and relate to the real-time determination of reservoir releases or abstraction

curtailment, while others are of an institutional nature. Many of these are currently being investigated by various groups in cooperation with the Department of Water Affairs and Forestry.

Ground- and surface-water interactions

Traditionally, within South Africa there has been a quite substantial divide between the two disciplines of ground- and surface-water hydrology. While this has been recognized as a not very satisfactory situation, it has proved difficult to resolve. The NWA calls for an integrated approach to water resource development and this has generated renewed interest in resolving issues related to surface-ground water interactions. One of the research programmes supported by the WRC over the last few years has been an investigation of the contribution that groundwater discharge makes to low flows in rivers. One of the main purposes of this research is to determine the level of development of groundwater resources that can be permitted without adversely affecting surface water resources. This has always been difficult to quantify in South Africa, where the majority of the ground water is stored in fractured rock aquifers. Some progress is being made through an improvement in the understanding of the associated hydrological processes by scientists from both disciplines.

Rainfall-runoff modelling

South Africa has a long history of developing and, more specifically, the practical application of rainfall-runoff models for estimating water resources. Recent initiatives in this field have involved the use of such models for the assessment of water use by managed forest plantations, the role that commercialization can play in sustaining the development and support of models and associated software, and the selection of the most appropriate models for use by the catchment management agencies of the future. The WRC is currently reviewing the existing approaches with the intention of developing a strategy for

future funding support. Once again the emphasis is on the practical use of scientific research in the field of water resource planning and management. During the 1990s, the well-known Pitman monthly model was used to generate natural time series for 1946 so-called quaternary catchments covering the whole of South Africa, Lesotho and Swaziland. While not without problems, these data have provided the baseline information for a wide range of water resource assessments. Terms of reference are currently being developed to update this information and to extend the simulations to incorporate interactions between ground and surface water to enhance the countries' ability to undertake integrated water resource planning. A similar project has been envisaged for the whole of southern Africa and terms of reference for such a study have already been accepted by the Southern African Development Community (SADC), Water Sector Coordination Unit (SADC, 2001). Financial support for this large and ambitious project is still being sought. From a research perspective, both the South African update and the SADC-wide projects have the potential to promote improvements in a model that has been available and widely used for about 30 years. Such improvements are likely to include the incorporation of a better understanding of natural processes, as well as artificial influences, and how to incorporate these into practical water resource management tools. The projects also offer an opportunity for improving the format of the model software and the way in which it links to existing databases.

Models (notably the ACRU model) have also been used to investigate issues such as the impact of land-use changes on water resource availability (see below), as well as the possible effects of climate change.

Management of transboundary (shared) water resource systems

The last few years has seen a dramatic increase in the interest and concern expressed with regard to the importance of effective management of shared aquatic systems (both surface waters and groundwater aquifers) throughout the world. These concerns are most acute in the more arid regions of the globe. Shared or transboundary aquatic systems in southern African have also attracted their share of attention and there is growing awareness amongst water resource managers in SADC countries of the need to collaborate with their neighbours to ensure that shared water resources are used in an equitable and sustainable way. In southern Africa, most attention has been focused on key river systems that span the territories of several countries that currently experience water stress or water shortages. Particular attention has been focused on the Cunene, Incomati, Limpopo, Okavango, Orange and Zambezi systems. There is considerable international interest in the Okavango system, driven by a variety of local, national and international agendas. Specific concerns have been voiced around perceptions that basin states might undertake unilateral and/or 'unfair' abstraction of water from the system with the possibility that this may give rise to disputes between basin states. As a result, considerable attention is being focused on the development of a management plan for the entire Okavango basin. A selection of recent publications dealing with the management of transboundary river systems in southern Africa and options that can be considered to prevent conflict over access to water are listed at the end of this report.

Research related to streamflow reduction activities in South Africa

Land-uses that cause significant diffuse reductions in streamflows are currently controllable under the NWA (1998).

While the only streamflow reduction (SFR) activity so far declared under the act is commercial afforestation, other impacts such as sugar-cane cultivation and widespread catchment invasions by alien plants are also being investigated for this purpose. These have been important, yet not well-quantified, issues in South African water resource management for many years. The country is spending a great deal of time and money on the clearance of invasive alien plants which are known to use more water than indigenous species, but the effects of clearing have yet to be adequately quantified.

Recent published South African research in this field focused on three themes:

- Improved field-scale and catchment-scale experiments and high-tech monitoring of actual consumptive use of the relevant plants or plant categories, or of the downstream changes in streamflow or groundwater availability.
- Improvements to catchment or profile models to represent the impacts of the SFR activities at various spatial and temporal scales
- Evaluation of the relative magnitudes of SFRs in terms of utilizable yields from dams and complex river systems.

The ACRU model has played a major role in some of the studies related to streamflow reduction and has been enhanced through the development of new algorithms to estimate the effects of tillage practices and afforestation, for example.

A number of publications on this topic were generated during the reporting period. Some of these are listed below, while other reports are available from the Water Research Commission.

Design rainfall and flood estimation

Engineering project designs rely heavily on estimates of design floods; poor estimates have resulted in substantial losses to the economy, environment and human and animal life. Reliable estimates of floods, their peaks and the frequency of such peak flows and volumes have continued to challenge the hydrological practitioners. A recently completed study linked the techniques developed in previous projects which concerned short and long-duration design rainfall estimates. The techniques from these studies were further developed to give regionalized and actual hydrographs for South Africa and to produce a computer package for design rainfall estimation. The design rainfall estimation techniques were linked to the regionalized index-flood-based design storm estimation method using *L*-moments at selected catchments. A Java-based program developed in this study implements the procedures devised to enable users to estimate design rainfall at any location in South Africa for return periods of 2 to 100 years and for durations of five minutes to seven days.

There has been a long-term research programme (under G. Pegram's leadership at the University of Natal, Durban) to estimate spatial rainfall fields from radar data and combining this with information from ground-based observations (rain gauges) and satellites to generate improved estimates of spatial rainfall variations over the whole country.

Operational hydrology research

As the water requirements in the Orange River catchment continue to grow, the water is becoming ever more valuable. It is therefore increasingly important to optimize the releases from impoundments, in order to meet the downstream demands whilst minimizing any excess releases, so as to conserve the valuable resource. The main difficulty in optimizing reservoir releases is that it can take several weeks for water released from upstream to reach the river mouth where the domestic, indus-

trial and environmental demands must be satisfied. The time taken for the releases to reach the mouth depends on the prevailing conditions in the river in relation to the amount of water released. Releases during low-flow conditions may take up to 6 weeks to reach the mouth. It is evident that there can be no quick relief from any shortages that might be experienced along the lower Orange River through additional releases. Owing to the nature of these demands, any water shortages would have a major impact, both economic and environmental. A project was recently completed that developed a decision support tool to be used by the reservoir operators. The strategy recommended by this study will provide a rational basis for the operators of upstream dams to determine a discharge release pattern to ensure that the various demands downstream are satisfied. As the model is based on sound hydraulic principles rather than simplified routing methods the users can be confident in the simulated results, provided that the real-time data are accurate and available. The use of real-time data further improves the simulation because unmodelled events such as localized inflows can be taken into account.

Issues related to the incorporation of the reserve and an allowance for environmental flow requirements in real-time water resource management also fall within this section. Research on such issues has lagged behind that on methods for determining the requirements from an ecological point of view, but the pressure to implement is such that there is an urgency to solve the problems. Many of the problems are not of a technical nature, but more related to the institutional factors associated with change in the procedures used to manage water resources.

Conferences and symposia

The *Fourth International Conference on FRIEND* (Flow Regimes from International Experimental and Network Data) with the theme 'Bridging the gap between research and practice' was held in Cape Town during March 2002. The conference was financially supported by UNESCO, IAHS, WMO, the UK DFID, the IHP National Committees of Germany, the Netherlands and Japan, the French Ministry of Foreign Affairs and IRD (Institut de Recherche pour le Développement), while the Institute for Water Research was responsible for the local organization.

The *2nd International Symposium on Integrated Water Resources Management* was held in Stellenbosch during January 2003. This conference was well attended with delegates from Europe, the U.S.A. and Australia, apart from many delegates from southern Africa and some from East Africa.

The *10th National Hydrology Symposium* was held at the University of Natal, Pietermaritzburg, during September 2001 and this saw the inauguration of the Des Midgley Memorial Lecture (given by Denis Hughes on practical problems associated with the implementation of the ecological reserve for rivers). The late Professor Des Midgley has been considered as the 'father' of South African engineering hydrology and many of the senior hydrologists in the country today were once his students.

The *11th National Hydrology Symposium* is scheduled to be held

in Port Elizabeth during September 2003 and will involve focused workshops together with more general plenary sessions. Some of the workshop sessions that are planned include discussions of the potential for commercialization of model and software developments, interactions between surface and ground water, and the shrinking technical capacity being experienced by some South African organizations.

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