Editorial

WRC 40-Year Celebration Conference – syntheses of themed sessions

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Session 1: Water security in a water-scarce country

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The 15 papers comprising Session 1 provided a clear illustration of the necessarily complex, multi-faceted and highly integrated character of water resource management required to achieve the overarching goal of water security in a water-scarce country like South Africa. Collectively, the papers addressed the following broad topics:

- Availability of water, of acceptable quality, in South Africa (water resource assessment)
- Reconciling water availability with future socio-economic and environmental demands for water, water being key to SA's ongoing growth and development
- Appropriate water resource development and augmentation options
- Learning to accommodate climate variability, climate change and extreme climate events in water resource management, given the potential impacts and associated uncertainties
- Overcoming governance constraints to effective integrated water resource management
- Capacity constraints that need to be overcome.

Water resource assessment

Water resource assessment in South Africa has become ever more complex over recent decades, owing to burgeoning growth in land-use intensity and variety, deterioration in water quality, and recognition that surface water - groundwater interactions need to be part of the assessment equation. The exponential growth in computing power and the concomitant development of appropriate computer modelling expertise and tools, however, has enabled these growing complexities to be accommodated, as evidenced by the proven utility of major assessments, the two most recent of which are the well-known WR90 and WR2005 assessments. The ongoing development of new observational tools augurs well for enhancing understanding and quantitative representation of the hydrological cycle at various spatial scales. Satellite remote sensing of spatially-distributed evaporation from land surfaces, especially, is being refined continuously and is helping to address, arguably, the weakest link in current hydrological models being used for water resources assessment.

Nevertheless, the serious decline in surface hydrological and hydro-climatological networks is compromising the water sector's ability to build on datasets that will, especially in years to come, be crucial for ground-truthing, model validation and climate-change detection purposes within the water-resource assessment context. How best to address and overcome this limitation needs to be investigated as a matter of urgency.

Balancing (reconciliation of) water availability and water requirements

Complexity evident in water resource assessment extends to, and is further compounded in, water resource management. Eight large system reconciliation studies and a large number of single-town studies by the Department of Water Affairs (DWA) have yielded strategies for meeting growing water demand with the water resources available. Broadly speaking, strategies reflect acknowledgement that opportunities for accessing additional freshwater resources are very limited and other options for augmenting supplies need to be exploited. Prominent among these are water conservation and demand management practices. Further measures, such as moving some water from irrigation to other uses without compromising food security and, within the irrigation sector, the moving of irrigation water from lower value to higher value uses, need to be considered. One approach to avoiding unwanted food-security impacts would be to seriously investigate regional (trans-boundary) opportunities for supplementing food production.

Environmental flow requirements for providing the resource with the necessary level of protection to ensure sustainability constitute a crucial component of the country's water balance. The WRC was an early supporter (from the mid-1980s) of research, across disciplinary boundaries, which gave rise to the development of innovative methods for environmental flow assessments (EFAs) in South African rivers. The development of EFA methods had an important impact on the drafting of the National Water Act (NWA). Internationally, South African EFA development has been used as the basis for training and capacity building in environmental flows in more than 15 developing countries in Africa, Asia, South America and Eastern Europe.

Despite advances, it is contended that research has not yet succeeded in enabling a balanced assessment to be made of all feasible options for reconciling water supply and demand. The failure to estimate the full costs and benefits associated with the various options contributes to the risk of poor decision-making regarding water security. To rectify this, gaps in past and current research programmes, especially those reliant on resource economics, need to be identified and systematically addressed.

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Water resource augmentation options

Reconciliation studies referred to above reveal that groundwater, currently undervalued and under-utilised, has an important role to play in meeting future demand. There is also huge potential for water recycling and reuse. Whilst desalination is already used on a limited scale, large-scale desalination of mine-water and seawater is very much part of South Africa's water future. Various planning analyses have indicated that the conservation and rehabilitation practices – notably with regard to the control of invasive alien plants, but also in terms of catchment conservation/rehabilitation, wetland conservation/rehabilitation, soil management and siltation control – along with demand-side management, can be the most cost-effective interventions in specific instances. Despite this, decision-makers tend to favour infrastructural approaches over conservation/rehabilitation-type approaches for augmenting water supplies. Also, still to come into its own is the practice of artificial groundwater recharge, which could be particularly appropriate where water-supply boreholes already exist. Potential artificial recharge areas of South Africa have been identified, feasibility studies conducted and the cost-effectiveness of various artificial recharge options demonstrated.

The reluctance among many decision-makers to accept that catchment conservation/rehabilitation approaches and artificial groundwater recharge can be a reliable and cost-effective water augmentation option has been an important barrier to implementation. Barriers to acceptance (e.g., inadequacies in research and knowledge dissemination, capacity constraints, difficulty in institutionalising good catchment management practices and the lack of clarity regarding suitable funding models) need to be identified, researched and overcome in the interests of enhancing water security.

Climate impacts and their management

The SA water sector has had to come to terms with a highly variable climate. Extensive WRC-supported research over several decades into the impacts of floods and droughts provided knowledge for effective management of their consequences and resulted in the development and running of risk and disaster management training programmes, satisfying a requirement of the National Disaster Management Act. Ever since 1984, when the WRC developed a strategic plan for hydrological research, the water sector has also recognised the potential of climate change to impact seriously on SA's water resources. However, it required the international development of powerful Global Climate Models (GCMs) to provide the springboard for local investigations into climate change, its potential impacts, and ways of responding to these at the regional (Southern African) scale. WRC-sponsored investigations, which commenced in the 1990s, led to the development of novel and effective statistical downscaling methodologies and, following further research investment, to the use of Regional Climate Models (RCMs) for obtaining detailed simulations of present-day and future catchment-scale hydro-climatic conditions over Southern Africa. Newly-developed downscaling capabilities have provided foundations for important impact investigations and also studies on how best to respond and adapt to projected impacts, in spite of the uncertainties that continue to surround projections. Results emerging from these impact and adaptation studies have facilitated the crafting of a water sector strategy for responding and adapting to potential impacts of climate change and allowed water resource planners to start building climate-change considerations into their planning scenarios. Furthermore, the building of an exceptional scientific resource, and the growth in human capacity associated with these developments, has helped to position South Africa as a leader in Africa and beyond, and enabled SA scientists to assume leading roles in international forums such as the IPCC.

Clear avenues for further research relating to the understanding and impacts of climate change have become evident. These include sustained climate monitoring, integration of multi-method and multi-model projections, addressing uncertainty and probability in the envelope of projected future changes, integrating outputs of fully-coupled physical-system models with ecosystem and impact models and the responsible communication of appropriate climate-related information to society. Research concerning adaptation to climate change needs to focus on putting to the test options for practical adaptive management strategies that have already been suggested for important sectors (e.g., national water planners, municipalities, rural poor communities, etc.) within the broader water-related community in South Africa. In the case of extreme events, the building of resilience in potentially impacted communities is of critical importance. The resumption of the learning spiral with regard to managing impacts of floods and droughts which took place with strong WRC support over a period of some 30 years, from the mid-1970s onwards, needs to be considered.

Overcoming governance constraints to integrated water management

The widely cross-cutting interest in South African water resources, spread among various departments and tiers of government having independent and interdependent mandates, as well as the specific responsibility of the Department of Water Affairs for integrated water resource management, make integrated governance with respect to water a national imperative, especially given the crucial role that water is intended to play in social and economic growth and development. Although cooperative governance is provided for in the Constitution, and further supported by more specific enabling legislation, and despite the progress already made in unpacking its meaning and implications (*inter alia* through several WRC studies), there are still many shortcomings that have to be overcome with regard to full practical realisation of cooperative governance for integrated water resource management. One of these is the need for institutionalisation of sound, practical approaches which can be used to ensure fairness, equity and stakeholder acceptance with regard to the allocation of water-related benefits among many competing stakeholders at the scale of individuals, groups, sectors and, in the case of shared river basins, even countries.

Guidelines for the institutionalisation and wider practical implementation of cooperative governance in water management need to be drafted, taking into consideration the autonomy of institutions, legislative differences, competing mandates, areas of interface and mechanisms for cooperation, and drawing upon successes already achieved in some spheres, such as in the drafting of catchment management plans. The role of the private sector in cooperative governance, and appropriate metrics for the evaluation of cooperative governance, need to be further explored. Specific approaches to facilitate integrated water governance, such as the use of integrative bargaining to facilitate equitable sharing in water resource benefits, need to be piloted and refined to the point where they can be institutionalised.

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Overcoming capacity constraints to integrated water management

Inadequate human and institutional capacity has often been cited as one of the main factors limiting the efficient management of water resources in South Africa. Whilst a number of initiatives have been put in place to contribute towards addressing this gap, the challenge still remains. Lack of capacity to effectively participate in water resource management exists at various levels. For instance, lack of capacity amongst previously disadvantaged groups hampers progress in decentralisation of water resource management. These challenges will continue unless water management institutions make concerted efforts to transform themselves into learning organisations that are more responsive to the needs of the diverse range of stakeholders they serve, flexible to change and willing to experiment with new approaches.

At the professional level, a strong case has been presented for building capacity in transdisciplinary research among emerging water scientists. The power of research conducted across disciplines by natural and social scientists and engineers working together in harmony has been amply demonstrated in, for example, research programmes addressing environmental flows. More traditionally, however, when faced with the challenge of water scarcity, the scientific community has been driven to produce technical solutions intended to reduce vulnerabilities and impacts on people, neglecting the crucial role of the social sciences in tackling the intangible issues of trust-building, community ownership and social learning – the key to solutions being more appropriate and acceptable. Initiatives to incentivise transdisciplinarity, build the capacity of young professionals in this regard, and create opportunities to engage in the practicalities of doing transdisciplinary research, have commenced recently through the establishment and activities of the Young Scholars Forum (YSF) in Transboundary Water Governance.

Guidelines need to be developed and incentives provided to assist water management institutions to transform themselves into learning organisations fully capable of building internal capacity and responding to the needs of their stakeholders. Initiatives to promote and build capacity in transdisciplinary research and development approaches among young water professionals need to be followed up by implementing plans for ensuring sustainability of these initiatives (e.g., that of the newly instituted Young Scholar's Forum), monitoring the progress made, and evaluating outcomes in terms of the capacity developed.

Session 2: Sustainability of the water ecosystem and energy nexus

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This synthesis attempts to extract the important achievements highlighted in the conference session on 'Sustainability of the Water Ecosystem and Energy Nexus', and to make suggestions for future trajectories in research into aquatic ecosystems and into power and the water required to generate it. Although the WRC has been in existence for 40 years, for the first 20 years or so the mandate of the Commission seems to have been to fund research on technical issues such as water supply, sanitation, water quality and irrigation. Aspects relating to the biophysical environment were seldom funded until the early 1990s, when the first 'water ecosystem' projects were supported by the WRC. The first crop of reports emanating from this work were by Mark Chutter and Ralph Heath on low flows in the Letaba River; by Jackie King and Rebecca Tharme on methods for estimating instream flow requirements; by Bryan Davies, Sharon Pollard, Des Weeks, Jay Wells and André Fourie on the Sabie River in the Kruger National Park; by Helen Dallas, Jenny Day and Liz Reynolds on aspects of water quality for aquatic ecosystems; and by Mark Chutter, describing the development of the highly successful SASS water-quality monitoring system using invertebrates. From these small beginnings, the involvement of the WRC in ecosystem research has expanded to the point that the Commission now recognises Water-Linked Ecosystems as one of 5 Key Strategic Areas. The 3 major thrusts currently receiving most attention and funding are ecosystem processes; ecosystem management and utilisation; and ecosystem rehabilitation. Note that, while rivers were the focus of most of the early work in this arena, the WRC now provides significant funding for work on wetlands too.

Through the 1980s, the WRC funded the development of dry-cooling technology for coal-powered power stations. Apart from this, WRC-funded studies on power production in relation to water use began relatively recently because South Africa needs to be able to harness new sources of power, and to investigate new ways of generating it. One of the deciding factors in the choice of new means of power generation will be the water demands of the technologies involved.

Where to now?

Building on the presentations and on discussions during the conference, we try to distil the essence of the most valuable of the WRC's current activities and practices ('business as usual') and to suggest how the work of the WRC might be enhanced by new approaches: 'business not as usual'.

Key factors in the success of the WRC's 'water ecosystem' and 'energy' programmes

Several factors were mentioned by more than one speaker as being important in the success of WRC's environmental programmes. These include:

- Long-term sustained funding for specific topics, examples being research on wetlands and on estuaries, the Kruger National Park Rivers, and environmental water allocations.
- The opportunity to incorporate some fundamental research within funded projects: 'blue-water' (like 'blue-sky') research is crucial for understanding how aquatic

ecosystems 'work', and therefore how to manage them. It is also the basis of many postgraduate degrees and crucial for building a capacity for deep thinking in emerging scientists.
- The multidisciplinary nature of many of the projects.
- The emphasis on capacity building of young 'emerging' researchers. Informal mentoring by project leaders is also seen as being important.
- Opportunities for the involvement of champions and the emergence of leaders in particular fields.
- Independence of the WRC from Government departments and quasi-government institutions. Water research extends far beyond the remit of state departments and consensus is that it is **crucial** that the WRC **not** be subsumed into DWA because of the danger of reducing and trivialising the ambit of water research wherever it is not directed specifically at DWA's needs.
- Last, but not least, the very positive supportive role played by many WRC Research Managers, who work together with researchers, understanding difficulties as they arise and often pursuing the same agendas.

Business as usual

Solicitation of research projects on particular topics should certainly continue. It is just as important to continue funding unsolicited research projects, however, particularly because this encourages the development and exploration of new ideas.

UN-usual business: New strategic approaches

Below we present suggestions for research topics or approaches that are not currently funded.

How can the water sector contribute to the developing Green Economy?

At the inaugural Green Economy Summit in Johannesburg in May 2010, President Zuma delivered a speech that is worth summarising. He said that in a green economy we will need to recognise that functioning ecosystems underpin all economic and social activities, and that we will 'require integrated strategies and plans that balance economic, environmental and social development objectives', noting that 'we will be able to elaborate the economic case for environmental management and sustainable development'. 'Ecosystem failure will seriously compromise our ability to address our social and economic priorities... We have no choice but to develop a green economy' (http://www.southafrica.info/news/business/860407.htm). Given this clear expression of political will, the WRC has a great incentive to investigate ways of greening of the economy from a water perspective.

Valuation of ecosystem services (ESs)

Understanding of the services provided by functional ecosystems, and the monetary value that these represent to the human economy, is crucial. It is necessary to provide politicians and leaders of industry with real numbers that will bring home the value of proper management of aquatic (and other) ecosystems and the biodiversity they support, in line with the President's comments on 'functioning ecosystems underpinning all economic and social activities'. Furthermore, Catchment Management Agencies (CMAs) are currently required by law to fund themselves from the water they sell. How will CMAs support themselves financially if they manage large natural areas that are of importance to biodiversity and water conservation but that are not used for provision of water (and therefore do not generate revenue)? The only sensible solution to this thorny problem seems to be to pay the CMA for the ecosystem services provided by these economically non-productive areas.

Specific questions that can be addressed by the WRC include:
- How do we align water-related ESs with the market economy?
- What monetary and other values can we place on water-related ESs?
- How can we get decision-makers to realise the value of ecosystems as providers of ESs?
- How do we address the issue of payment for ecosystem services?

Note that South Africa has far too few resource economists and the WRC might also investigate ways of making the profession more attractive to students in Commerce faculties throughout the country.

Understanding complex systems

It would be interesting to employ the techniques of Life-Cycle Analysis (LCA) to address some of the problems of managing complex systems such as ecosystems, as well as for analysing high-impact activities, for guiding research priorities and for following improvement trajectories. Topics that might be addressed using such techniques include:
- Evaluation and evidence-based analyses of past groups of projects. What can we learn from past projects? Why have they, or have they not, worked (i.e. what did we get right and wrong)? Where should the field now be heading?
- Meta-analyses of data from groups of older projects, where we might find new understanding at minimal cost.
- How do we get to the point of actually conserving aquatic ecosystems, given the conflicting interests of 4 levels of government (including Catchment Management Agencies) and 2 state departments? What trade-offs are necessary?
- Why does technology transfer work in some cases and not others?

Both large and small, hi-tech and alternative, sources of energy and means of generating electricity need to be examined with regard to the use of water in power production. It would be valuable to expand the use of LCA to investigate the water requirements of small- and large-scale power-generating plants, and plants using new and existing technologies. Generation of hydropower from existing dam and water-distribution systems is already under way but certain aspects may need further investigation.

Various methods for generating energy from wastewater are available and different scales of implementation are possible but criticism has been levelled at the use of wastewater for this purpose, based largely on the assumption that effluents produced by power-generation processes will be detrimental to the river receiving them. Thorough cost-benefit analyses of different processes, and their environmental effects, would be worth investigating.

Biofuels can be generated from agricultural produce, from various types of organic waste, and also from suitable algae by means of aquaculture. All of these require water, particularly

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those based on crops that need irrigation. Since the amount of water available for irrigation will decrease over the next few decades, the quantity of water required by various methods for producing biofuels needs to be investigated. When this has been done it will be possible to provide guidelines regarding the suitability of the different methods **based on water requirements.**

Social issues with regard to both ecosystem- and energy research need to be identified and attention needs to be paid to the kind of research that needs to be done in this regard.

The way forward: Some practical suggestions

As a result of discussions both during and prior to the conference, a number of suggestions for modifying existing practice within the WRC have emerged.

- Allocation of funds, even if modest, for long-term monitoring is highly desirable. Monitoring programmes might be run in conjunction with the South African Environmental Observation Network (SAEON).
- It would be useful to investigate the possibility of providing small amounts to allow principal investigators to follow up on technology transfer and/or implementation of successful projects, given that often it is only after a project has been completed that the best ways of technology transfer become evident.
- Some early WRC reports seem to exist only in the possession of the original researchers who did the work. These reports are not even listed in the WRC Knowledge Hub because the Commission has no record of them. Archiving old WRC reports and digitising and curating the data they contain would be valuable. Such archiving is particularly important for rivers and wetlands, where 'old' data cannot be collected again but often represent the entire historical record.
- It would be useful to investigate additional models of postgraduate funding. As things stand, postgraduate students are taken on by existing grant-holders, which means that the student has no possibility of doing a project of personal interest unless this coincides with the interests of his or her supervisor. Might students (including Honours-level students) be allowed to apply for small grants for running expenses for their thesis studies?
- In some disciplines there are so many Reference Group meetings relative to the small number of potential attendees, that each meeting is poorly attended, even though such meetings are really valuable for networking as well as for guiding research. Perhaps the WRC should investigate the possibility of meeting by means of video-conferencing, or of having 2-3-day meetings around groups of projects annually.

Session 3: Water Quality

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Early in the conference, the attention of delegates was drawn to the core set of issues facing South Africa at the initiation of the Water Research Commission in 1971. It soon became clear that the current water quality issues are essentially unchanged. There was a strong recognition that this was unsurprising in respect of water quality, because, over 4 decades, we have faced a dramatic increase in the use of water resources, associated with more waste, more water abstraction and therefore less dilution, and increased variability in all aspects of water – social and bio-physical. The conference content and discussion demonstrated that new innovations are required to face the challenge of servicing more people and supporting a vibrant economy while at the same time ensuring a continued flow of ecosystem goods and services.

Key water quality research progress

The water quality papers presented at the conference are synthesised here in the context of the broad goals of the National Water Act (Act No. 36 of 1998) (NWA): achieving equity, sustainability and efficiency through balancing water resource use and water resource protection using source-directed controls (SDC) and resource-directed measures (RDM).

New tools

A resounding success in improved water quality practice has emerged through the Green and Blue Drop processes. The Green Drop process includes a clear risk abatement programme. It seems that in all aspects of water quality management it is useful and necessary to understand, and use the language of, risk. An example is that if new water guidelines are developed they will be risk-based. Interestingly, the Blue Drop and Green Drop programmes do not fall into either RDM or SDC – they are compliance programmes that function in terms of transparent reporting and, therefore, public and government pressure to comply. This is a model that could be more widely applied.

At a similarly practical level, research has also produced:

- A water quality management manual that can be used immediately at local government level
- The practice of action research in strategic adaptive management (as applied by institutions such as SANParks and the Inkomati Catchment Management Agency)
- The practice of using a combination of water chemistry, biomonitoring and eco-toxicology for environmental water quality management

It was interesting to see an increase in use of economic methods and evaluations, with an important caution to ensure the appropriate application of economic models and approaches to a public good such as water and to ecosystem goods and services, where value can extend beyond the monetary.

Equity

There was a clear acknowledgement that there has been a rapid extension of water supply to rural communities around South

Africa using groundwater. However, the quality of that supply is much more difficult to assure. Changes in groundwater quality are slow, hidden and mainly irreversible. It is often land-use practice that affects groundwater quality and land-use control is difficult to implement and out of the water sector's domain. Water quality is the greatest risk for communities dependent on groundwater.

In terms of domestic drinking water supply, a significant advance is the recognition that water supply and water treatment technology services can be supplied in both centralised and decentralised models and at different scales – with the emerging possibility of smaller, local-scale solutions with appropriate technology use and provision.

Sustainability

Despite aquatic ecosystem research and international leadership, and the research-based development of RDM methods such as environmental flow (including water quality) methodologies, over the last decade freshwater resource condition and ecosystem health has been reported as low and deteriorating. A consistent message at the conference was that resource protection is not actually functional. The fundamental importance of the River Health Programme, with its widespread application of South African research-based rapid biomonitoring methods, was appreciated, and the fundamental importance of the chemical monitoring network was emphasised. There has been an emerging but limited use of the results of ecotoxicology research. A clear bottleneck is the practical use of the water resource classification system. There is an urgent need for an appropriately simple and accessible system which includes a sound basis for deriving resource water quality and resource quality objectives. Of aquatic ecosystems, estuaries remain sandwiched between the more extensive marine and freshwater environments. With their value as recreational resources, and starved of freshwater input, they are also a focus of water quality deterioration.

Efficiency

In urban contexts, water-sensitive urban design progress has focused on slowing water down, and efficiently retaining storm water in the urban context so as to ensuring its reuse. A previously intractable challenge to efficient water quality management was the question of quantifying and then controlling non-point source pollution. Modelling has made a major contribution in this field. However the vital step of ensuring the use of the models by managers remains to be taken.

The most critical current issues

The water quality session identified that, at present, the most critical water quality challenges in South Africa are:

- Assurance of safe drinking water in smaller urban, and rural contexts
- Deterioration of ecosystem water quality (rivers, wetlands, dams/lakes, estuaries and aquifers)
- Compliance with, and enforcement of, water quality regulation
- Acid mine drainage
- Eutrophication
- Salinity
- Sediments
- Microbial contamination (the risk to human health from pathogens in irrigation water is underestimated)
- Unmonitored and emerging pollutants (for which nanotechnology may be both a source and a solution)

Responding to the challenges

The planned initiative to develop a new generation of **risk-based water quality guidelines**, linked to the classification system, was welcomed. There was a timely reminder of the need for a sound research basis and simplicity in practice.

The clearest call to change and action was for an accelerated and well-supported **process for knowledge flow into action**: for research to be used rather than to remain potentially useful. The initiation of the 'knowledge flows' Directorate in the WRC was welcomed, and the concept of action research, with users being actively involved in the research throughout the research process, was aired. There were also ideas for supporting the rapid recognition of acutely-needed research outcomes into the user or policy development arena. For example, when DWA engages in major strategic projects such as water law revision, institutional alignment reviews and the development of a new national water resource strategy, current water research outcomes could be accelerated into the practice-arena (as was done during the 1996-1998 Water law Review process).

There is always a cry for **investment in monitoring** – and this is the hardest research resource to maintain. For water quality, the monitoring of water chemistry combined with biomonitoring and the continued development of an eco-toxicity database is critical. Partnership with SAEON was recommended and the role of monitoring in the strategic adaptive management process was emphasised.

The crucial and emerging arena of **integration** was addressed. There was a constant thread running through the session of the need for trans-disciplinary research – and for research that recognises and focuses on integrated, and complex, social-ecological systems. The use of general complexity theory is quite new in the South African water sector, but it is growing, along with the use of concepts such as social learning and resilience. Critical interfaces that require integration include:

- Surface water-ground water interactions
- Water quality and water quantity management (perhaps, in particular, integrated licensing)
- Process of RDM and SDC
- Water conservation and water demand management with water quality issues
- In the research arena, natural science-social science-humanities interfaces, mediated through a deep understanding of trans-disciplinary research

Then we come to the question of 'how'. The water quality session provided an excellent example of occasions where there is more heat than light. In this instance it related to acid mine drainage (AMD). It has become quite clear that the AMD debate in South Africa has not been enhanced by transparent access to all available knowledge, use of the best possible expertise, and a clear and neutral exposition of issues together with prioritised and motivated solutions. The South African research community can make itself heard in calling for transparency, and in contributing to knowledge flow by making available a clear risk-based understanding of the AMD issue.

This clearly lies in the domain of a public understanding of, and engagement in, **knowledge flows**, a space in which the WRC plays a crucial role. Items which would benefit from transparent debate include the proliferation of small desalination plants (their location, design and capacity) and the risk to human health from pathogens in irrigation water.

Towards a robust research community

Finally, the water quality session addressed issues pertinent to a healthy and robust research community. After an inspiring review of aquatic ecosystem research and of leading researchers over 8 decades, 5 guidelines for healthy researchers in a vibrant research community were offered:

- **Slow down***:* Scientists and managers in senior positions seem to have no buffer time at all. How do you respond to sudden changes or opportunities if your space is so crowded? How do you inspire postgraduate students, serve as a role model and influence the future if you only fight fires and do not have time for quality reflection?
- **Strive for excellence***:* Excellence and relevance in science can be mutually reinforcing attributes. We need excellence both in pushing the frontiers of disciplinary understanding and in skills that enable integration and implementation, e.g. leadership, communication and facilitation skills.
- **Rediscover the noble purpose***:* Discovery and stewardship are essentially noble causes. Have we allowed ourselves to be caught up in a just-another-business mentality? John Philip said: 'All too often today scientists seem forgetful of their calling and submit passively to being overmanaged into a state of creative impotence'.
- **Learn with others**: Amidst rapid and ongoing change as well as multiple and often contrasting perspectives, we simply have to keep learning – purposefully and with others. Co-learning is much more than knowledge transfer or public participation. It is a process of participative and iterative reflection through the sharing of experiences and ideas with others. As such co-learning serves as a mechanism for facilitating shared understanding and collective action among diverse but interdependent parties.
- **Have fun**: You have fun when you are so excited about your latest discovery (results from the field or laboratory) that you cannot wait to present it at the best conference in the world. Jane Lubchenco said **'...** we relish the fun and challenges of problem-solving, and we wish to contribute something useful to current and future generations'. However, most workers seem to be waiting for retirement so that they can hopefully rekindle some of that fun – their current workload seem to have very little to do with why they got into science in the first place.

Session 4: Water use efficiency

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South Africa is a water-scarce country. Rainfall is low, erratic and very inefficient. Runoff is low and erratic. Runoff is geographically strongly skewed, with 50% of the total runoff generated from only 9% of the land surface along the eastern seaboard. It is therefore imperative to maximise water use efficiency.

Water use in dryland cropping

South Africa's dryland (rainfed) cropping potential is low due to a combination of low, erratic and inefficient rainfall and poor quality soils. According to internationally-used norms South Africa can feed only marginally more than 35 million people.

Dryland cropping uses only 'green water', i.e. rainwater that is stored in the soil profile and which can be used only by plants growing in the soil. Dryland cropping does not compete directly with sectors that use 'blue water' (runoff and underground water).

Several management strategies and practices can be used to improve water use efficiency in dryland cropping, such as

- Conservation tillage to improve infiltration, increase the amount of rainwater stored in the soil and reduce runoff. This is important since South Africa has large areas with soils with strong crusting (surface sealing) tendencies, which limit infiltration strongly. At the local level efficient runoff reduction sometimes leads to problems for users depending on adequate runoff.
- Practices to reduce surface evaporation, e.g. mulching.
- Elimination of soil compaction to enable crops to utilise subsoil water.
- Longer fallow periods that
  - Improve yields – by up to 30%
  - Improve rainwater use efficiency (kg yield/mm rain)
  - Reduce crop failure risk.

Special practices can be used to improve water use efficiency in small-scale dryland cropping. South African studies include deep trenching and rainwater harvesting, both ex-field (runoff-runon) and in-field. Unfortunately there is resistance from communities to adoption of the latter. Adoption and effective implementation of these could, in some cases, locally lead to problematic reduction in river flow.

Growing of indigenous and indigenised crops that are able to withstand drought stress is a further option, especially in small-scale agriculture. These crops mostly also have high nutritional value.

Water use in commercial irrigated agriculture

Irrigated agriculture is the largest user of blue water. It consequently seems to be targeted as the big villain when it comes to the use of blue water. Statistics regarding the amount of water used by irrigated agriculture are often presented in misleading and unfair ways. It is, for example, commonly stated, that 'agriculture uses 62% of South Africa's water', referring to irrigated agriculture. This is a distortion of figures given in the National Water Resource Strategy (NWRS) of 2004. According to the NWRS, irrigated agriculture used 7 900 million m^3 runoff water in the year 2000, representing 62% of the 12 900 million m^3

water used by all sectors in that year and less than 40% of the NWRS's estimated 20 000 million m^3 exploitable annual runoff. Irrigated agriculture is less productive than industry in terms of both gross income and number of jobs created per unit of water. From an economic point it is therefore seen as inevitable that water will in future be transferred from irrigated agriculture to industry.

Potential negative impacts of transferring water away from irrigated agriculture

The potential negative impacts of water transfer away from irrigated agriculture cannot be ignored. These include:

- **Consequences regarding food security and food prices.** Since, *inter alia*, 90% of our fruit and vegetables, 80% of our potatoes and (most importantly) 30% of our wheat are produced under irrigation this impact can be huge. According to the 2007 food cost review major new investment in irrigated agriculture is actually needed.
- **Economic, socio-economic and social consequences for rural areas that are presently based around irrigated agriculture.** The National Planning Committee expects agriculture to create nearly a million jobs in rural areas in the next few years and most of these will have to come from irrigated agriculture.

Studies are required regarding the balancing of economic, socio-economic and social impacts should water be transferred from irrigated agriculture to industry. Such studies should not only consider impacts at national and provincial level, but also at local level.

Potential for increased water use efficiencies and water savings in irrigated agriculture

There is huge potential for increased water use efficiencies and water savings in irrigated agriculture without negative effects on crop yield and quality. In this way significant amounts of water can be released for use in other sectors and/or for expansion of irrigation. There is a large body of research information available in South Africa, mainly from WRC-sponsored projects, which can be used to achieve this. Unfortunately adoption has been disappointing, despite the large benefits gained by those who have adopted and implemented this knowledge. Actions required to achieve increased water use efficiencies and water savings include:

- **Correct crop water requirements must be used as basis for planning irrigation development and management.** This can be achieved by using the SAPWAT (presently SAPWAT3) model. It is scientifically sound, has been developed in South Africa for local conditions and has achieved great success where it has been implemented. It is not a rigid 'black box' model, but is flexible in making provision for differences between regions/localities. Correct crop coefficients are key to its application. These differ widely between crops and for the same crop between regions/localities. Further studies are required to refine crop coefficients for different crops for different regions/areas.
- **Water losses and non-beneficial water use between the source and the field edge must be minimised.** This will help to maximise beneficial use of the water released at the source, e.g. dam wall. It can be achieved by implementing the Water Administration System (WAS) and the 'Standards and guidelines for improved efficiency of irrigation water use from dam wall release to root zone application'.
- **In-field beneficial water use must be maximised by selection and design of appropriate irrigation systems for each case according to soil, climate, crop and management capability of the irrigator.** This is also captured in the above mentioned 'Standards and guidelines'. It is of utmost importance to take into consideration the role of the extreme crusting (surface sealing) nature of most irrigated soils in South Africa. On some, even drip and micro-irrigation result in ponding and extreme evaporation losses. Good South African data, including that from a WRC-sponsored project on adaptation of overhead irrigation design to soil, are available, but are not used in planning. Good local data on successful alleviation of soil crusting with soil conditioners are also available. A WRC project showed that infiltration under dynamic flow conditions (flood/furrow irrigation) can be orders of magnitude higher than 'static' infiltration, showing that sometimes these systems could be the preferred ones on strongly crusting soils. Better use of the available data and further research on the aspects mentioned above are urgently needed.
- **Irrigation water use efficiency by crops can be maximised by optimising root zone water management based on the 'profile-available water capacity' (PAWC) concept of Hensley.** PAWC gives the maximum amount of water that can be extracted before 'first material stress' sets in and irrigation has to be applied. Stretching the intervals between irrigations reduces non-beneficial evaporation water losses, thus increasing irrigation water use efficiency. Combining 'deficit' irrigation strategies, i.e. where full irrigation is not applied, with PAWC gives further increases in irrigation water use efficiency, *inter alia*, by maximising use of rainfall. Large amounts of data on PAWC and deficit irrigation, and successful application of these, are available in several WRC reports. These form the core of the BEWAB irrigation management model, but are, in general, used very little in irrigation planning and management. More attention should be given to their potential use. More studies on PAWC and deficit irrigation are urgently needed for more crops and in more climatic regions. Strategies like 'regulated deficit irrigation' and 'partial root zone drying' are widely used overseas in irrigation planning and management at farm level. Some research has been done on these in South Africa, but a lot more research should be done, given their potential to increase water use efficiencies.
- **Application of correct, efficient irrigation scheduling, i.e. applying the correct amount of water at the correct time, which is key to maximising irrigation water use efficiency**. This requires effective soil water management, used in combination with the above-discussed parameters and strategies or by integrating soil water modelling with measurement. Atmospheric parameter approaches can also be used in irrigation scheduling, but, as indicated for SAPWAT, these must be carefully adjusted, especially for areas with extremely hot, dry climates. Adoption of objective irrigation scheduling is still low in South Africa, thus leaving large potential for improvement and significant water savings. Research aimed at improving adoption of objective scientifically-based irrigation scheduling should be a high and urgent priority.

Water use in small-scale irrigated agriculture

The most important limiting factors on smallholder irrigation schemes are management and conflict. Schemes are diverse and plot-holders on any specific scheme are diverse. Thus, notions that blanket solutions and approaches could apply across schemes and within schemes are fallacies. Complex designs and sophisticated technologies are recipes for failure. Yet, the latter are the preferred routes for provincial governments. Research aimed at finding strategies to bring about a mindset change at decision-making level should be a priority.

Successful techniques to increase food production in home garden systems include, *inter alia*:

- Rainwater harvesting, used in runoff-runon systems or for filling tanks to provide irrigation water during dry seasons
- Treadle pumps
- Tower drip kits
- Keyhole gardens for the use of greywater

Unfortunately the most potent water-saving irrigation system for garden systems, viz., clay pot irrigation, does not feature in South Africa. It is used widely in Africa and elsewhere, including nearby countries like Zambia and Zimbabwe. Proven water savings of between 50 and 70% have been found in vegetable production systems. Studies on this technology should receive very high priority.

In a home garden study a large difference in adoption was found between 2 geographical areas studied. The area with high adoption was characterised by a population with a long history of successful crop production and a high aptitude for growing crops, whereas this was not the case in the area with low adoption. Such differences between different population groups are well-known throughout Africa and need to be taken into consideration in such studies.

Subsistence aquaculture is not viable, but fisheries have potential to develop rural livelihoods.

Economic modelling in irrigated agriculture

Research has been conducted regarding whole-farm economic modelling of irrigated agriculture and the costing of irrigation water, using 2 approaches, viz., simulation modelling and mathematical programming. The shortcoming of simulation modelling is that that the opportunity-cost of limited resources (water, capital, labour) is ignored. The shortcoming of mathematical programming is that simplification of the soil-crop-water subsystem is required. Whole-farm modelling of small-scale irrigated agriculture is limited and often does not represent the decision-making process of small-scale farmers. More research into the latter is required.

Water use in the domestic, commercial and municipal sectors

Use of greywater for irrigating home gardens has great potential for improving food security in poor communities, especially in peri-urban areas. Guidelines have been developed for the use of greywater for irrigation. Dual water reticulation enables the use of less expensive non-potable water for home garden irrigation, but its implementation is very limited in South Africa. Cleaner production enhances the potential for non-potable water use.

Awareness among the public, building profession and municipalities regarding water-conservation devices that can be used in the domestic and commercial sectors is low. Government is a major building owner and should lead by example.

Potable water losses in municipal distribution systems are significant. South Africa has a world-class water supply network, but it is deteriorating. Water distribution management needs basic inputs (sufficient people working in the field) and not always sophisticated models (one person behind a computer). Water distribution management has a huge potential for job creation – 'working to save water'.

Session 5: Water technology

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The session on Water Technology comprised 5 papers which addressed the following topics:

- Saline sewage treatment and urine separation for more sustainable urban water management
- Membrane technology: past, present and future
- Water and nano-science
- Irrigation water measurement for both voluntary management and regulatory purposes
- Software-assisted irrigation canal water management

Sewage disposal and treatment

It was emphasised that the water contained in wastewater has a much greater value than that of energy embedded in the wastewater. The preservation of public health and water quality is much more important than any energy savings or recovery from the wastewater. Moreover, the per-capita environmental burden associated with the supply of water and treatment of wastewater is much lower than that associated with most other essential human activities such as transportation. However, hugely beneficial as it may be, wastewater treatment technology would be of no value if there were not the skilled people required to understand and use the technology in maintaining and operating wastewater treatment works.

New developments in wastewater treatment were envisaged. Simplification of the wastewater treatment process could be effected through separating urine at source, which has added benefits from a resource recovery perspective and from the smaller land and energy requirement of the simplified treatment processes. In water-scarce coastal situations, the sewage disposal system could be separated from the potable water system and seawater used for toilet flushing instead of consuming huge quantities of potable water for this purpose. In Hong Kong a treatment process is being developed in which the biological nutrient removal processes are being modified to operate on high-sulphate water. This system could be considered for new coastal developments as a substitute for the installation of seawater desalination plants. It was suggested that microbiologists begin to look for sulphate-reducing organisms that could be acclimated to this treatment process.

In order to take advantage of these new developments in wastewater treatment, emphasis was placed on the need to develop researchers with a deep knowledge in particular fields so as to exploit the interconnectedness between fields (for example, knowledge gained from research into high-sulphate mine-waters has been applied in seawater sewage system development).

Membrane technology

Following a review of the advances in membrane processes in South Africa, it was stated that membrane usage had 'come of age' and was now considered as standard practice for a range of applications. The membranes themselves have become commodity items and are available from a range of manufacturers. Parties previously involved in membrane research are now undertaking the commercialisation of membrane systems.

The control of the quality of the feed to a membrane process remains as important as ever, as excursions in quality can cause the rapid decline in performance and result in the need for membrane cleansing. With regard to the desalination of seawater for potable use, a number of small systems have been installed and more are in the planning phase. The first direct water reuse system (sewage to potable water) that uses membrane technology has been commissioned and is in operation in Beaufort West. Within the industrial sector, membranes are becoming common for the production of boiler feed water, ultra-pure water and water for the food and beverage industry. The use of membranes for industrial effluent treatment has not proceeded as rapidly, notwithstanding the installation of Amcoal Billiton's globally innovative 26 Mℓ/d 'mine-water to potable-water' plant at eMalahleni.

With regard to the production of potable water, the quality of the product water is a function of the membranes only and not of the feed water. It was contended that there is still a great potential for this market to expand, with regard to both centralised and decentralised plants.

Nanotechnology

The conclusion reached from a review of the status of research in the field of nanotechnology in South Africa was that a watching brief should be kept by the water research community on developments in nanotechnology, as it cannot be predicted where beneficial new applications will arise. Small water-related nanotechnology projects should be undertaken so as to be able to alert the water research community of new developments in this field.

Irrigation water measurement

There is a great need for accurate volumetric data to facilitate efficient management and allocation of irrigation water. Increases in the price of electricity (and thus pumping costs) are becoming a large driver for the more efficient use of irrigation water. Methods and difficulties associated with the practical measurement of water flows and volumes in irrigation systems were described. Different applications require different measuring techniques and there is no single best technique.

Software-assisted irrigation canal water management

The Water Administration System (WAS) software was developed over a period of about 15 years. It has evolved into a sophisticated system that uses real-time information related, for example, to the monitoring of water flow and the ordering of water for irrigation. The WAS system is now used by a number of large irrigation schemes (comprising about 28% of the irrigated area). It results in greatly improved water use efficiency, with potential savings of about 30% of irrigation water with proper implementation. The challenge is to roll it out to smaller schemes. This change in emphasis would make the approach much more resource intensive than in the case of the larger irrigation schemes. The evolution of WAS shows the need for the development of such systems to be supported over a period of decades as opposed to years.

Another lesson from the development of WAS is that, in order to develop a simple system, a whole range of more complex models need to be developed, evaluated and modified. The WAS-associated irrigation models (based on the interplay between climate, crop water demand and yield) have been built on a very limited experimental dataset and, with wider use, this dataset will need to be improved and extended.