INSTITUTE FOR WATER RESEARCH

IWR

2013

ANNUAL REPORT

RHODES UNIVERSITY

Where leaders learn

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RHODES UNIVERSITY
INSTITUTE FOR WATER RESEARCH
2013

Front row: Ms Daksha Naran, Mr Thabiso Mohobane, Prof Denis Hughes, Prof Tally Palmer, Ms Asiphe Sahula, Ms Ntombekhaya Mgaba

Second row: Dr Sukhmani Mantel, Ms Alex Holland, Dr Paul Mensah, Ms Juanita McLean, Mr Haden Jacobs, Mr Jai Clifford-Holmes, Dr Georgina Cundhill, Ms Lara Molony, Ms Karabo Chadzingwa

Back row: Mr Nelson Odume, Dr Neil Griffin, Ms Fox Helen, Dr Andrew Slaughter, Mr Matthew Muller, Mr Hugo Retief, Mr Ian Preston, Mr Aphiwe Ponie, Ms Louise Bryson

Front Cover (top to bottom): Profs Tally Palmer with members of the research group and Water for Dignity; Prof Denis Hughes, the recipient of the Vice-Chancellor's Distinguished Senior Research Award with family; IWR 2013 PHd graduants from left: Dr Sithabile Tirivarombo, Dr Paul Mensah, Dr Irene Naigaga, Dr Bronwyn Moore; Victoria Girls High school pupils learning about mini SASS, Botanical Gardens, Grahamstown.

STAFF AND MEMBERS OF THE INSTITUTE

STAFF

Prof Chris deWet	Professor
Mr David Forsyth	Principal Technical Officer
Dr Neil Griffin	Research Officer UCEWQ-IWR
Mr Greg Huggins	Research Officer Water for Africa
Prof Denis Hughes	Professor | Director of IWR
Ms Kwezilomso Kama	Intern
Ms Delana Louw	Research Officer IWR Source to Sea
Ms Angel Magudulela	Intern
Mr Stephen Mallory	Research Officer IWR Water Resources
Dr Sukhmani Mantel	Research Officer IWR
Ms Juanita McLean	Administration Manager
Ms Ntombekhaya Mgaba	Intern
Ms Daksha Naran	Senior Technical Officer
Prof Tally Palmer	Professor | Director of UCEWQ
Mr Tristan Peckham	Intern
Dr Andrew Slaughter	Research Officer
Ms Jane Tanner	Postdoctoral Fellow
Mrs Margaret Wolff	Part time Adminstrator UCEWQ-IWR

ASSOCIATES

Prof Jay O' Keeffe	Research associate
Mr Matthew Weaver	Research associate
Dr Victor Munnik	Research associate

REGISTERED POSTGRADUATE STUDENTS

Mr Garth Barnes	MEd (Environmental Education)
Ms Louise Bryson	MSc (Water Resource Science)
Ms Jane Burt	PhD (Environmental Education)
Mr Jai Clifford-Holmes	PhD (Water Resource Science)
Ms Athina Copteros	PhD (Water Resource Management)
Ms Helen Fox	PhD (Water Resource Management)
Ms Pearl Gola	PhD (Water Resource Management)
Ms Alex Holland	PhD (Water Resource Science)
Mr Haden Jacobs	MSc (Hydrology)
Mr Sbongiseni Mazibuko	MSc (Hydrology)
Ms Ntombekhaya Mgaba	BSc Hons (Environmental Water Management)
Mr Thabiso Mohobane	PhD (Hydrology)
Ms Lara Molony	M.Soc Sc. (Environmental Science)
Mr Matthew Muller	MSc (Water Resource Science)
Mr Nelson Odume	PhD (Water Resource Science)
Ms Boluwaji Onabolu	PhD (Water Resource Science, Awarding)
Mr Ian Preston	MComm (Management)
Mr Hugo Retief	MSc (Hydrology)
Ms Asiphe Sahula	MSc (Water Resource Science)
Ms Jane Tanner	PhD (Hydrology, Awarding)
Ms Madaka Tumbo	PhD (Hydrology); based at University of Dar es Salaam, Tanzania
Mr Agostinho Vilanculos	PhD (Hydrology; based at Eduardo Mondlane University, Mozambique

2013 GRADUATED STUDENTS

Dr Paul Mensah	PhD (Water Resource Science)
Dr Bronwyn Moore	PhD (Water Resource Science)
Dr Sithabile Tirivarombo	PhD (Hydrology)
Dr Irene Naigaga	PhD (DIFS)

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Mr Craig Thomson	Amatola Water

INSTITUTE FOR WATER RESEARCH

DIRECTOR'S REPORT

Introduction

During 2013, there have been some very positive aspects to developments within the Institute, but also some rather negative ones. Reference was made in last year's Director's report to our engagement in the discussions concerning the Rhodes University bid for a United Nations Educational, Scientific and Cultural Organisation (UNESCO) Category I Centre, and the possibility of the IWR offering a modular coursework MSc degree in Water Resources Science as a contribution to these developments. Rhodes University allocated a Senior Lecturer post to the IWR to support setting up the course, but the response to the advertisement was very poor. We did interview a suitable candidate (a PhD graduate from the IWR), but the salary and contract package being offered was not sufficient to attract the person to Rhodes. The current situation is that the post has been re-advertised, but we are less than optimistic about the outcome, and it is too late to launch the new degree programme for 2013. This is very unfortunate and has affected our plans for the next phase of the Carnegie Regional Initiative in Science and Education (RISE) programme (see later). It is also a sad reflection of the inability of the university to attract qualified academics, and poses serious implications for the near future when Prof Hughes will reach retirement age. If we are not able to address these problems, there is the very real chance that it will not be possible to find a suitable replacement for Prof Hughes, and that a proud history of 35 years of hydrology within the IWR will come to an end.

More positive developments within the IWR included the news that the Sub-Saharan Africa Water Resources Network (SSAWRN) group (led by the IWR) of the Carnegie RISE programme were awarded $850 000 for a third phase of three years from 2014 to 2016. This grant allows the Institute to recruit several more post-graduate students from Sub-Saharan Africa. All of the new students will receive full bursary and fee support. Towards the end of 2013 we also received the excellent news that the support from Unilever for UCEWQ has been renewed for a further 18 months (more details in the UCEWQ Director's report).

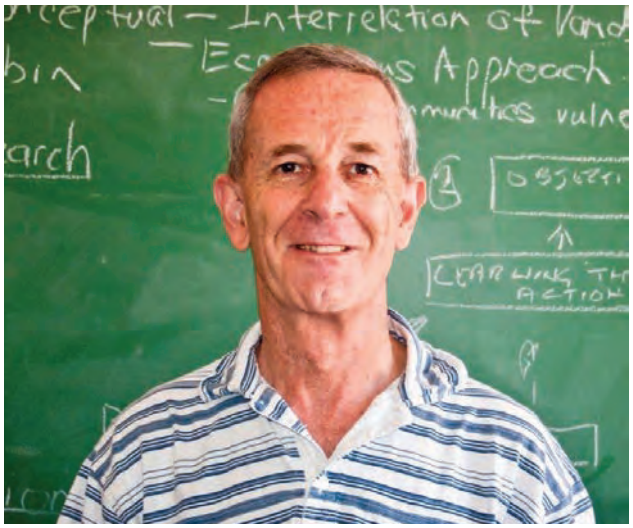
The IWR's profile at the 2013 Rhodes University Graduation ceremony was a little higher than in previous years. Not only did Prof Hughes receive the Vice-Chancellor's Distinguished Senior Research award, but we also had four PhD students graduating.

Graduation 2013: From left to right: Dr Sithabile Tirivarombo, Dr Paul Mensah, Dr Nikite Muller, Prof Denis Hughes, Dr Irene Naigaga, Dr Bronwyn Moore.

The IWR has also been successful in bidding for a R4.3 million Water Research Commission (WRC) 5-year duration project entitled "Rehabilitation of grasslands after eradication of alien invasive trees". This is a collaborative project with Dr Tony Palmer of the Agricultural Research Council (ARC), Stellenbosch University (Dr Zahn Munch) and Dr Leslie Gibson of Geohydrological and Spatial Solutions (GEOSS). Dr Mantel will be acting as the principal investigator for the IWR, and we are expecting to have two students (a PhD and an MSc) at the start of the project, and possibly two other MSc students at a later stage. The project will address issues associated with sustainable management of grasslands, improving the modelling of the water balance of grasslands, sustainable management by rural communities, providing evidence-based scientific input into the policies of Working for Water, the Department of Water Affairs (DWA) and the Department of Agriculture, Forestry and Fisheries, together with training for post-graduate students in evapotranspiration modelling and hydrology.

During December 2013, Prof Chris de Wet will move from the Department of Anthropology, where he has worked for 37 years, in order to join the IWR in January 2014. Prof de Wet's academic interests include the philosophy of social science and development, with particular expertise in development-induced displacement and resettlement. Between 2007 and 2012, he initiated and expanded an inter-faculty, integrated development programme at Rhodes University. This programme became progressively linked to the complexity-framed research projects of the IWR and UCEWQ, with Prof de Wet becoming directly involved in the SA/Netherlands Research Programme on Alternatives in Development (SANPAD) water project led by Professor Tally Palmer as of 2011. In addition to his interdisciplinary experience and interests, Prof de Wet

brings a wealth of experience in development projects. These include consulting as a social anthropologist for the World Commission on Dams, acting as the principal social specialist for Coastal and Environmental Services (a consultancy company), involvement in a resettlement-related project for the Lesotho Highlands Development Authority, a resettlement evaluator for the Komati Basin Water Authority and as the leader of a four-year international project funded by the Department for International Development on policy for resettlement programmes arising out of development situations. Prof de Wet sees the move to the IWR as an opportunity to engage in and supervise integrated development projects and to apply his experience to water-related research and practice.



Prof Chris de Wet will be joining the IWR from January 2014.

Dr Jill Slinger from the University of Technology in Delft (Netherlands) was nominated and appointed as a Mellon Senior Scholar for 2014 in order to be a keynote speaker at the 2014 IWR Open Day, assist in the formation of the Rhodes University System Dynamics working group (planned for 2014), and continue co-supervising Mr Clifford-Holmes.

The senior staff of the Institute continues to be actively involved in policy development and advisory committees at regional, national and international levels. Prof Hughes attended a number of SACNASP (South Africa Council for Natural Scientific Professions) registration meetings as chair of the Professional Advisory Committee for the Water Resources Science Field of Practice. Prof Hughes is also a Vice President of the International Association of Hydrological Sciences (IAHS) and attended the IAHS Bureau meetings during a conference in Gothenburg, Sweden during July. Prof Tally Palmer continues to chair the National Water Advisory Committee, made up of several key experts in the field of water resources management and established to advise the Minister of Water Affairs and Forestry on national policy development and implementation.

During 2013, the Journal of Hydrology, one of the most prestigious international hydrology journals, launched a spin-off journal referred to as JOH – Regional Studies. Prof Hughes has been appointed as the African regional editor of this new journal which will start publishing in 2014. Prof Hughes is also an associate editor of the Hydrological Sciences Journal, Hydrological Processes and Hydrology Research. During a recent international conference in Gothenburg, it was decided to arrange a special edition of the Hydrological Sciences Journal to promote 'African Hydrology and Water Resources Research'. Prof Hughes is one of the five individuals who will form the editorial team for this edition of the journal, and the process of collecting suitable papers was well under way at the end of 2013.

International links and conferences

IWR staff and students have managed to attend several local and international conferences over the last few years and 2013 was no exception. Prof Hughes attended the IAHS General Assembly in Gothenburg, Sweden in July and a conference on 'Facets of Uncertainty' in Kos, Greece during October. The Kos meeting was preceded by a 1-day editorial retreat for the associate editors of the Hydrological Sciences Journal, while the Gothenburg meeting included the IAHS Bureau meetings which Prof Hughes attends through his role as Vice-President.

The Unilever Centre for Environmental Water Quality sponsored Mr Odume to attend the 2013 Association of Commonwealth Universities residential school in the United Kingdom. The five day residential school, with the theme "the world in 2113" attracted postgraduate students from several Commonwealth countries to discuss issues across disciplinary, national and regional borders. Professor Rolph Payet, minister for Environment and Energy, Seychelles, and Pro-Chancellor of the University of Seychelles delivered the keynote address on what the world is likely to be like in 2113, and the key drivers of change which he identified included climate change, population growth, food, energy and water resources. He stressed the need to engage in critical thinking on how to address some of these challenges moving forward into 2113.

Prof Hughes, Dr Mantel, Ms Tanner and Dr Mensah attended the annual Carnegie RISE meeting in Johannesburg during October 2013. This was an important meeting where the plans for the final 3-year phase of the programme were discussed as well as how this very successful initiative can be continued into the future in the absence of support from the Carnegie Foundation. There were various suggestions but no conclusions were reached at this stage, and it is clear that the various network groups have a great deal of work to do over the next three years if we are to continue. Prof Hughes also attended a 1-day workshop in Dar es Salaam on the CLIVET project, which is funded from Denmark and supports an IWR registered PhD student, Ms Madaka Tumbo from Tanzania. Most of the discussions focused around the completion of the degree programme, writing papers and the organisation of a final project

conference to be held in Dar es Salaam during 2014. The focus of this conference will be on 'Environmental Change' and the links between 'Science and Practice' and 'Science and Society'. The IWR hopes to be able to send some of the Carnegie RISE students to present papers and support the discussions.

Two of the Carnegie RISE students (Mr Mohobane and Mr Odume) attended the 14th WaterNet/Water Research Fund for Southern Africa/Global Water Partnership Southern Africa international conference held in Dar es Salaam at the end of October and presented papers. Mr Mazibuko was awarded a SAVUSA – SKILL bursary to attend three courses at the beginning of 2013 (surface hydrology, data collection and processing, and data driven modelling and real time control of water systems) at the UNESCO-IHE, Institute for Water Education, in Delft, Netherlands.

Ms Tanner attended the 13th Biennial Groundwater Division of the Geological Society of South Africa conference held in Durban during September 2013. She presented a paper entitled 'Validating hydrological models in a data scarce country – getting the right results for the right reasons'.

Further details of Prof Palmer's international links and attendance at conferences and meetings can be found within the UCEWQ Director's report.

Sub-Saharan Africa Water Resources Network (SSAWRN) staff and students, RISE meeting, Johannesburg, October 2013.

Delegates at the 13th Biennial Groundwater Division Conference in Durban, October 2013.

Consultancy links

There has been much less activity in recent years within the field of consultancy than there used to be in former years. This is largely a reflection of the greater emphasis within the Institute on post-graduate training and research development and the amount of time spent by senior staff on supervision. Prof Hughes however, continues to generate some useful income from consultancy projects which provides funds for some student bursaries as well as providing additional funds for travel to conferences for staff and students. It is also important that we do not lose the links with practical problem solving which has been one of the IWR's strengths and has provided an immediate market for some of its applied research products.

During 2012, we were successful in obtaining World Bank funding as part of a United States led consortium to undertake an integrated assessment of climate change impacts within a number of large river basins in Africa. The IWR has been responsible for setting up the Water Evaluation and Planning (WEAP) model for the Congo, Orange and Zambesi River basins. The main participants on the project were Prof Hughes, Dr Desai (a former PhD student) and Mr Mohobane on the Orange River, Dr Mantel on the Zambezi River and Dr Tshimanga (former RISE PhD student now working at the University of Kinshasa, DRC) on the Congo Basin. This project provided an excellent opportunity for Dr Tshimanga to develop further research skills and a research and consultancy profile within the Sub-Saharan Africa region.

Prof Hughes has also been involved in consultancies and training related to the application of a revised model for assessing environmental flow requirements (the ecological Reserve) in South Africa. Two short training courses were held for staff of the Department of Water Affairs during November 2013.

Undergraduate teaching

The Institute continues to contribute to the Department of Environmental Science ENV302 course on water resources management, with Prof Hughes, Dr Slaughter and Dr Mantel covering water quantity, quality and legal issues, respectively. The IWR also offered a one month course on Environmental Water Quality for Geography and Environmental Science honours students. Contributions were made by Prof Tally Palmer and Dr Griffin, with

some inputs from post-graduate students, as well as a guest lecturer (Prof Grant Hose) from the Department of Biological Sciences at Macquarie University in Sydney, Australia. His research interests include ecotoxicology in surface, and more recently, groundwater systems. His visit was supported by a Key International Cooperation grant.

Post-graduate students

At the 2013 Rhodes graduation ceremony Dr Moore, Dr Tirivarombo, Dr Mensah and Dr Naigaga (RISE student from Makerere University and co-supervised by Dr Muller, formerly of the IWR) received their PhD degrees. Ms Tanner and Ms Onabolu have completed the PhD examination process and will be included on the graduation ceremony programme for 2014. We are also expecting at least two more students to be graduating in 2014, but the total number of IWR graduates (PhD and MSc) could be as high as six if all of the potential students manage to complete in time.

Ms Bryson is an MSc student in the IWR and she runs the Catchment Research Group (CRG) with a Geography MSc student, Ms Chadzingwa. They won the 2013 Rhodes University Environmental Award in the student society/ residence category. The CRG hosts monthly Water Circle Seminars, with guest presentations from students, researchers, professionals and practitioners in the water sector. The group aims to raise awareness and mobilise action amongst all water interest groups in and around Grahamstown. The CRG also organised a Rhodes Water Week from the 26th–30th of August 2013 with the theme "transdisciplinarity in the water sector".

Ms Louise Bryson accepting the Environmental Award on behalf of the CRG from Ms Nikki Kohly (Rhodes Environmental Officer).

Mr Clifford-Holmes represented the Institute at the Resilience Alliance Science Meeting in the Drakensberg in April 2013 and was involved as one of the founding members of the African System Dynamics Chapter. He has been awarded an 'Innovation Doctoral Scholarship' (2013–2014) by the National Research Foundation. He also represented the Institute and UCEWQ on national television for a Carte Blanche interview on the challenges of local government water supply (http://carteblanche.dstv.com/player/361144), partly prompted by the recent water outages that have been experienced in Grahamstown during the year.

Post-Doctoral posts

Dr Slaughter was awarded funding for a WRC project on the development of a practical water quality systems model and the income from that project has allowed the IWR to create a contract staff position for him. It is always encouraging to see the development of former students through post-doctoral positions through to staff members. However, it remains a challenge (for both Dr Slaughter and the IWR) to ensure the sustainability of such a contract research post.

Ms Tanner has been supported for part of 2013 as a Post-Doctoral Fellow by the RISE programme, but she has now been awarded a Rhodes University Post-Doctoral Fellowship for 2014 and 2015 so that she can continue to work on the understanding and modelling of surface water and groundwater interaction processes. During 2013, Dr Mensah has been working as a Post-Doctoral Fellow with Prof Tally Palmer as part of her SANPAD group and was based in Nelspruit, until Novenber 2013.

Dr Mensah has been an NRF grant-holder post-doctoral researcher in UCEWQ in 2013, leading the Nelspruit based group in the Crocodile River Catchment study on building a co-operative water quality management process using transdisciplinary approaches. Since, November 2013, he has moved back to Grahamstown to restart the ecotoxicology research

RISE Sub-Saharan Africa Water Resources Network

Reference has already been made to several aspects of this programme including the fact that it will be supported for another three years. At the end of 2013 we were in the process of identifying suitable candidates for post-graduate bursary support. One of the slight changes for this phase is that we are trying to link student projects (where possible) around a common theme of 'Large African Wetlands'. The idea is to get hydrologists, landscape geomorphologists, ecologists, water quality specialists and others to work together and share their disciplinary expertise. An interesting development is that Prof Hughes met with his ex-supervisor (Prof John Lewin, formerly at Aberystwyth University in Wales) after not seeing each other for over 20 years. One item discussed was the fact that Prof Lewin is currently interested in the form and processes of large rivers of the world and collaborates with several other United Kingdom research teams. There is therefore a good opportunity for the RISE, SSAWRN staff and students to link up with the United Kingdom group and share information and ideas. The other key issue for the RISE programme is to develop some ideas about how we can sustain this programme when the Carnegie Foundation funding comes to an end after 2016.

Community Outreach and Public Understanding of Science

Two learners from the Diocesan School for Girls, Jamie Brockwell and Sabrina Long, approached the IWR during the course of 2013 for advice and assistance in conducting a water related project. Within this project, Jamie and Sabrina aimed to determine the efficacy of various water filtering technologies. They tested the water quality of polluted water samples before and after treatment by: 1) boiling; 2) filtration using a Life Straw; 3) filtration using Ozone and; 4) filtration using Reverse Osmosis. Their analyses of water quality included salinity, total bacteria, pH and turbidity. Their conclusions were that in general, the Life Straw performed the best taking all water quality variables into account. The IWR assisted them in collecting water samples, providing advice and providing water quality test meters. Sabrina and Jamie's results at the regional Science Expo in Grahamstown resulted in their selection to the National Finals held in Pretoria this year, where they won a gold medal and were overall winners of their project category. In addition, they have been approached by the DWA requesting that they enter their project into a water research related competition in 2014.

Jamie Brockwell (left) and Sabrina Long (right) won a gold medal at the National Finals of the Eskom Science Expo for Young Scientists (2013).

During the "Science In Motion" themed Scifest 2013, the IWR held "Insectometer" workshops, demonstrating aquatic invertebrate adaptations and the use of mini-SASS for assessing water quality. The event was well supported by a cross section of learners.

The IWR were involved in the Rhodes Water Week this year by organising and running two water quality testing field trips to the Botanical Gardens in Grahamstown. The field trips are designed to form part of the global data collection initiative by the World Water Monitoring Day (http://www.worldwatermonitoringday.org) organisation. The World Water Monitoring Day organisation aims to 'build public awareness and involvement in protecting water resources around the world by engaging citizens to conduct basic monitoring of their local water bodies'. Two classes from the Victoria Girls' High School participated in the field trips. Also included in the field trips was a basic introduction to biological monitoring of streams, so as to make the link between the biodiversity of a stream and the overall health of the aquatic ecosystem.

Mr Matthew Muller assists learners in identifying aquatic macroinvertebrates during a Rhodes Water Week field trip.

The involvement of UCEWQ and Water for Dignity river health monitoring day with the Eloxolweni Shelter and Rotary is reported in the UCEWQ director's report.

Concluding remarks

The Institute has seen a number of changes in recent years that have included substantial growth in post-graduate student numbers initiated by the Carnegie RISE programme as well as a number of major projects started by Prof Palmer to support her transdisciplinary studies. We have seen a steady crop of students graduating each year (1 MSc in 2008, 1 PhD in 2009, 1 MSc in 2010, 2 PhD, 2 MSc in 2011, 3 PhD in 2012, 4 PhD in 2013 and expectations of more than 5 PhD/MScs in 2014). Together with the research outputs in recognised international peer reviewed journals, the IWR is making significant contributions to the Rhodes subsidy income. As noted in previous annual reports, this has been achieved with no real growth in the staff available for supervising post-graduate projects. However, externally funded contract staff (Drs Griffin, Mantel and Slaughter) make substantial contributions to student supervision, and it should be emphasised that these contributions do not cost the University anything at all. With all of the developments taking place and given the changes in the position of the IWR within Rhodes University over the last few years (many more post-grads), some strategic planning for the future is long overdue. We have to make some serious decisions about inter alia space issues, the sustainability of contract staff salaries, the pending retirement of senior staff and our relationship with the University.

The Institutes record of publishing in recognised

international journals has also been very good over the last few years and this is also a reflection of a larger group of post-graduate students and the fact that they are strongly encouraged to publish. While journal publications are recognised by the Institute as being important, the reality remains that contract staff members are also burdened with the necessity to generate research reports to funding agencies so that they can continue to attract the funding necessary to survive.

Outputs	2007	2008	2009	2010	2011	2012	2013
Peer Reviewed Journals	8	7	5	11	9	12	18
Reports	33	5	14	18	24	10	11
Conference proceedings	10	2	7	3	4	1	3

Acknowledgements

We are always very grateful for the contributions that the Board of Control make to the successful operation of the Institute. We would like to acknowledge all of the support that we receive from the various South African funding agencies and specifically the Water Research Commission (WRC) who have provided the financial backbone of the Institute for many years. We continue to enjoy a strong association with the WRC, not only through projects being undertaken by IWR staff, but also through the reference group meetings of other institution's projects and various policy and planning meetings.

Funding provided by the Unilever Foundation provides a significant contribution to the continued existence and success of the UCEWQ. This unencumbered funding allows UCEWQ staff and students to contribute to research initiatives at both local and national levels, allowing us to partner with other researchers, government and industry in the development and implementation of an integrated and holistic approach for managing environmental water quality in water resource management.

The Carnegie Foundation (through the RISE initiative) has now become a very important source of funding for post-graduate students within the Institute. We have developed excellent relationships with the fund administrators over the last six years of the project. We are also grateful to the coordinators at the other nodes of the SSAWRN (ORC, Makerere and Eduardo Mondlane universities) for their help in ensuring the success of this initiative. The IWR is very grateful to Dr Mantel for the sometimes difficult job that she does as administrator of the network.

We are also grateful for the support of the various divisions of Rhodes University including the staff of the office of the Deputy Vice-Chancellor, Research and Development, the Finance Division, the Human Resource Division and the Communications and Development Division. We are very grateful for the travel support given by the Rhodes Research Office to attend local and international conferences. Beneficiaries during 2013 included Prof Hughes and Prof Tally Palmer.

Finally, as Director, I would like to offer my personal thanks to all the members of the Institute staff (both research and support staff) and students for their hard work, enthusiasm and loyalty to the aims of the IWR. I believe that we have had several very successful years and that the future looks very secure as long as we continue to manage the operation of the IWR in a sustainable manner and as long as we get support from Rhodes University.

UNILEVER CENTRE FOR ENVIRONMENTAL WATER QUALITY (UCEWQ)

UCEWQ DIRECTOR'S REPORT

Introduction

The Centre has had a productive year characterised by growth and an expansion of activities. Securing three large contract research grants has enabled the Centre to move steadily in the strategic direction of growing the practice of transdisciplinary (TD) engaged research both at Rhodes University and in the water sector at large. This has been achieved through the consolidation of all the UCEWQ research projects into a research programme under the flagship project: "Integrated Water Resource Management (IWRM) in South Africa: towards a new paradigm". In this process we have spearheaded TD post graduate supervision at Rhodes University, and hosted a university-wide TD research group that meets monthly for two hours and has from 10 to 25 participants. We have added a civil society research practice into this arena through a ground-breaking partnership with the human rights NGO the Khulumani Support Group. During the year we have engaged in renewing and exploring a vibrant relationship with Unilever. This has involved several exploratory meetings, undertaking a specific piece of research for Unilever, and facilitating the Unilever Water Symposium in Gauteng, that attracted the attention of several leading figures. UCEWQ staff and post graduate students have thrived, publication has been strong, and there is growing evidence of our research playing a transformative role in South Africa.

Partnerships

Unilever South Africa: UCEWQ activities have always been characterised by partnerships. The core partnership that founded the Centre is, and remains, with Unilever South Africa. The UCEWQ commitment to transformative research contributing to social and environmental justice, and the Unilever Sustainability Living Plan (SLP) is our core common ground. This was the last of three years guided by a Memorandum of Agreement with Unilever. The MOA has been renewed for 18 months with three main goals. 1) We will work with Unilever SA staff to ensure they understand their business in the context of international, national, provincial and local water-related policy and practice. This contextual knowledge needs to relate directly to Unilever sustainability policy and their production practice. The first half of 2014 will see a two-day "Water Policy and Practice" course run at UCEWQ for selected Unilever staff. 2) UCEWQ and Unilever SA will work together to find relevant ways to engage actively with those policy and practice points most beneficial to Unilever SA. At present, these appear to include participating in the global CEO Water Mandate and the national Department of Water Affairs / Industry high level committee and 3) Unilever SA will actively support the UCEWQ-Khulumani Support Group Water for Dignity initiative that mobilises civil society in actions leading to a more equitable and dignified experience of water in the lives of South African residents.

In 2013 we used our Sundays River Valley research results to explore Unilever product use in relation to poorly serviced households. Research indicated that engaged TD research could catalyse more reliable water supply in poorly serviced households in a small rural town. We postulated this would result in greater use of cleaning products. In fact, further investigation revealed that local people already purchased cleaning products as a priority and that increased water supply resulted in greater convenience, but not increased product use.

A new initiative that was a substantive success was the Unilever Water Symposium. Prof Tally Palmer facilitated the symposium which included two keynote speakers: doyenne of South African water quality and pollution research Dr Peter Ashton and champion of Hartebeespoort Dam remediation Mr Petrus Venter. Delegates had the chance to engage in two of the five possible table conversations, and table hosts reported on the dialogue in plenary. Table topics were 1) Water stewardship by local people, hosted by Mr Garth Barnes (Conservation Director, The Wildlife and Environment Society of South Africa); 2) The role of big industry in securing the Vaal River system hosted by Mr Martin Ginster (Water and Environmental Advisor, Sasol Group Services); 3) "Water for Dignity" in water-scare communities hosted by Dr Marjorie Jobson (National Director, Khulumani Support Group); Science, social science and Solutions hosted by Ms Shanna Nienaber (Deputy Director: Technology Services, Department of Science and Technology); 4) Water activism hosted by Dr Victor Munnik (Independent Researcher in Water, Climate and Environmental Justice, Nature and Society, and Research Associate of the Society, Work and Development Institute, University of the Witwatersrand); 5) Top 10 strategic water issues hosted by Dr Washington Nyabeze (Director at WR Nyabeze and Associates) and 6) Behaviour change in the context of water scarcity hosted by Ms Rachel Jones (Associate of Reos Partners).

The range of topics and conversational style led to animated discussion and surfacing some of the complexities of water issues in South Africa. The emphasis was on taking personal responsibility individually and within organisational contexts for the national goals of equity, sustainability and efficiency. UCEWQ and Unilever will consider hosting a Water Symposium in the years in

between the national WISA conferences. In 2014, UCEWQ will present a session on the 'Towards a New Paradigm' project that will include showcasing Unilever's role in the programme.

Prof Tally Palmer in learning conversation with 'Water for Dignity' community group outing to Botanical Gardens (above), and in the IWR laboratory Rhodes University (below) Grahamstown.

Khulumani Support Group: The most significant new partnership of 2013 is the one developed with the Khulumani Support Group. Dr Marjorie Jobson is the National Director of Khulumani (http://www.khulumani.net/index.php), and she introduced the idea of 'Water for Dignity' to the NGO Makana and Bushbuckridge members. Both membership groups were interested in the partnership and it was initiated in Makana. Founding members are Mr Mbulelo Lipile, Mr Thandile Duda, Mr Siyabulela Saki, Ms Nosiphiwo Lipile, and Ms Xolelwa Nzwana. In the period April-November 2013 the Khulumani Water for Dignity team developed a set of goals and projects that include: 1) monitoring the local and region press for water issues; 2) engaging with Makana residents in a "one street one tank" initiative mediated by the formation of street water committees, where tanks will be secured and maintained by citizens and kept full from fire hydrants with the assistance of the Makana Municipality, for use during time of interrupted water supply; 3) clean and functional toilets health monitoring programme which will seek broader engagement with the local Kowie Catchment Campaign and the Eluxolweni Children's shelter. UCEWQ staff and students will train a civil society river monitoring group in mini-SASS in early 2014. The first substantial civil society research finding is based on a citizen report card administered in Makana and reported on a WRC deliverable in the 'Towards a New Paradigm' project. Mr Mbulelo Lipile was part of the UCEWQ research team who present the first results of the TNP project to a WRC reference group in Pretoria. This was a landmark for the WRC as the first civil society research report-back. One of the reference group members sent an email saying the TNP "proposal was one of the best I have ever read. The project looks really exciting so good luck for it!"

Research funders and industry partners: As an independently funded researcher centre, UCEWQ nurtures relationships with research funding partners carefully, ensuring attentive, adaptive and responsive proposals and effective delivery of research products and outcomes. We have long-standing relationships with the Water Research Commission, the NRF/DTI Technology and Human Resources for Industry Research Programme (THRIP), the ESKOM Tertiary Education Support Programme and Richards Bay Minerals. New industry partners include TSB Sugar Holdings, Assmang Chrome, Delta EMD Pty Ltd, Manganese Metal Company, and Coca-Cola Fortune. We have had a later but extremely productive partnership with the South African Netherlands Programme for Alternatives in Development (SANPAD) which provided the springboard for the TD engaged research initiative. The project run by UCEWQ in collaboration with SANPAD was selected as one of only four to attend the South Africa/Netherlands Knowledge and Business Day programme in the Netherlands. Prof Tally Palmer attended this programme and made useful connections and contacts.

Research partners: With our focus on TD research, the co-creation of knowledge and mutual learning, we greatly value those researchers who work with us, particularly Drs Sharon Pollard and Derick du Toit, from the Association for Water and Rural Development (AWARD); Dr Tony Palmer and Ms Andiswa Finca from the Agricultural Research Council (ARC); Professor Kevin Rogers and Ms Rebecca Luton from the Centre for Water in the Environment; and most recently Dr Victor Munnik, an independent researcher associated the Society, Work and Development Institute, all from the University of the Witwatersrand. We have worked on proposals and publications with Dr Jill Slinger (TU Delft) and Dr Suzanne Linnane (Dundalk Institute). Internally at Rhodes, we have generative partnerships with the Departments of Anthropology, Management, Economics, Environmental Science and Geography and the Environmental Learning Research Centre. UCEWQ TD research was also show-cased in a Rhodes University publication on community engagement in collaboration with the Community Engagement directorate, working closely with Ms Di Hornby, Ms Julie-Ann Lothian and Ms Heather Dugmore. The Communications directorate is assisting with planning a similar publication about the Centre, and with a re-vamped web-site.

Crocodile River project meeting, Nelspruit.

Spheres of government: Our closest relationships have been: 1) with Amatola Water, the Sundays River Valley Municipality (SRVM) and the Lower Sundays River Valley Water User Association (LSRV WUA) in the project to catalyse change in water supply and management in the SRVM. As a result of this project, there is a revitalised relationship between the municipality and the WUA, and people who for some years have had no water over weekends, have had secure weekend supply for some months. At the same time the SRVM Green Drop score for 2011 (not yet formally released) is likely to be in the region of 40%, up from 6% two years before. We are continuing work with: 1) the SRVM and extending it to the Makana Municipality - also in the Cacadu District municipality, providing an opportunity for engaging at that scale of government and; 2) the Inkomati Catchment Management Agency (ICMA) where the THRIP project to build a co-operative water quality management process for the Crocodile River project is embedded in the ICMA performance plan – and where the UCEWQ research team has offices in the ICMA in Nelspruit and are included in the ICMA water quality team. This is a real example of action research where application is part of the research process. We have initiated the formation of a new Department of Water Affairs (DWA) team to work with us on the TNP project so that progress towards a new paradigm is embossed in departmental procedures and is well understood and supported.

Performance, moves and appreciation

Highlights of 2013 included the doctoral graduation of Dr Paul Mensah, the honours graduation of Ms Asiphe Sahula and the successful doctoral completion of Dr Boluwaji Onabolu. Interns Ms Nthombekhaya Mgaba and Ms Kwesilomso Kama graduated with their diplomas in analytical chemistry and Ms Sahula was awarded Green-Matter scholarship. Dr Paul Mensah was awarded a post doctoral fellowship within UCEWQ, firstly as the on-site project leader of the Crocodile River project and then back to Grahamstown to re-ignite ecotoxicology research. Mr Jai Clifford-Holmes successfully upgraded to doctoral registration and was awarded certification in Systems Analysis by Stellenbosch University. Mr Nelson Odume benefitted greatly from the Association of Commonwealth Universities residential school meeting, held this year in the United Kingdom, using the platform for cross disciplinary discussions and fostering international partnerships under the theme "The World in 2013". Ms Athina Copteros is completing training in dance movement psychotherapy at the Queen Margaret University, Edinburgh, and will return to apply her training in doctoral research in the SRVM and Makana. The concept is that dance can be a healing and empowering activity, especially to people who have been silenced by more powerful actors in society. Ms Helen Fox continues to wrestle with an interesting TD study of social and bio-physical linkages within the Boksburg Lake area. Mr Ian Preston and Mr Hugo Retief started MSc research in 2013, and we will welcome Mr Matthew Weaver and Mr Gareth Thomson as MSc students in the new year. We expect a number of graduate completions this year and wish Mr Nelson Odume (PhD), Mrs Alexandra Holland (PhD), Mr Matthew Muller (MSc), Mr Garth Barnes (MEd) and Ms Lara Molony (MSocSci) well in the submission and examination of their theses.

Prof Tally Palmer was invited to give guest seminars and post graduate coaching at the University of Technology, Sydney in the School of Environmental Sciences and the Institute for Sustainable Futures on TD research theory and practice, and UCEWQ was visited by Prof Grant Hose (Macquarie University, Sydney) an eminent ecotoxicologist who delivered lectures to our honours students and coached post-graduate students, funded by an NRF Knowledge, Interchange and Collaboration (KIC) grant. We were sorry Dr Andrew Gordon who initiated the visit was not here with us, but Andrew is now working for DWA in Cape Town and we are looking forward to new collaborations with him. Ms Alexandra Holland, a co-presenter of the honours course, undertook most of the organisation.

Dr Neil Griffin has become a leading water quality research specialist over the past few years and was commended at his WRC reference group meeting. Neil is a key member of all UCEWQ research projects, specialising in the analysis and interpretation of water chemistry data. New to UCEWQ are Mrs Margaret Wolff and Dr Victor Munnik. Margaret is with us part-time as project manager and has made a substantive difference to the task of managing multiple projects, funders, deliverables and deadlines. Victor is an experienced researcher and activist in the field of pollution studies, specialising in the mining sector. He brings enthusiasm, new perspectives and solid social science methods experience. Victor will be running the Crocodile THRIP project and a new WRC project on mining and biodiversity. Welcome to both of you and thank you for early contributions. Mr Sandile Dlamini joined the Nelspruit team and has become an organised and effective research assistant. Mr Nick Hamer is invaluable in his part-time research as part of the Makana Project, and we are delighted to have Prof Jay O'Keeffe working again with us – also in the Makana project. This year Mr Tarqyn Human, a laboratory technician who had nurtured the ecotoxicology cultures for many years, moved on to a new career.

Profs Tally Palmer and Jay O'Keeffe on an field outing to Botanical Gardens organised with Water for Dignity, Rotary and UCEWQ.

UCEWQ was delighted to receive the Rhodes University Envronmental Award for a Department or Insititute in 2013.

Dr Neil Griffin receiving the 2013 Environmental Awards on behalf of IWR Unilever Centre for Environmental Water Quality.

All members of the IWR celebrated this, together with research partners across Rhodes, and our visitor, Professor Grant Hose, at a braai hosted by Tally Palmer.

IWR staff and student celebrating the 2013 Environmental Awards at a braai.

Of course our closest partners are within the IWR, and we are always enormously grateful to Prof Denis Hughes for leadership and support, to Ms Daksha Naran for mentoring interns, supervising the laboratories and for her new contributions to activity system analysis, to Mr David Forsyth for IT support and really, most of all, to Mrs Juanita McLean who oils all wheels, embodies efficiency and brings in wonderful tea goodies. My very grateful thanks go to everyone in UCEWQ for your contribution to a vibrant and exciting team and also to the wider IWR team.

HYDROLOGY PROJECTS

During 2013, the hydrology group of the Institute consisted of Prof Hughes, Dr Andrew Slaughter (focusing on water quality modelling) and six post-graduate students; Ms Tanner (PhD), Mr Mohobane (PhD), Mr Mazibuko (MSc), Ms Bryson (MSc), Mr Haden Jacobs (MSc) and Mr Hugo Retief (MSc). Three post-graduate students are part of the Carnegie RISE programme. Other staff members contribute to some of the hydrology related projects that the Institute is involved in. Notably, Mr Forsyth continues to be involved in the development and maintenance of the Spatial Time Series and Information Modelling (SPATSIM) hydrological modelling framework software, as well as supporting other software developments. Mr Mallory and Ms Louw (Associated Research Officers) contribute to some of the research projects as well as being consultancy partners. Dr Mantel has also been assisting with the some of the hydrology projects and co-supervises some of the students. An additional two external students have been working on hydrologically related projects. Ms Tumbo Madaka (PhD) is working on hydrological modelling and climate change impacts in Tanzania (based at Dar es Salaam University and part of a collaboration with Denmark), while Mr Agostinho Vilanculos (PhD), a further RISE student based in Mozambique, is working on flood modelling of the Zambezi River. Mr Dale Tristram, an MSc student in the Computer Science Department, also made some contributions by testing some new software approaches to hydrological modelling using Graphics Processing Units to speed up the operation. Many of the hydrological projects (both research and consultancy) involve collaboration with other organisations, both within South Africa and overseas. The various projects are discussed under three main headings 'Implementing uncertainty analysis in water resource assessment and planning', 'Development and application of a simple South African water quality model for management of rivers and reservoirs under current and future development and climate change scenarios' and 'General consultancy projects'.

IMPLEMENTING UNCERTAINTY ANALYSIS IN WATER RESOURCES ASSESSMENT AND PLANNING.

Sponsor: Water Research Commission and National Research Foundation
DA Hughes and J Tanner
Collaborators: T Wagener (Pennsylvania State University, USA)

April 2011–March 2014

During 2013, the IWR were part of a partnership that was contracted to the World Bank on a project designed to apply consistent methodologies (the WEAP hydrology and water resources system model) for climate change impact assessments on water resources to a number of large basins in Africa. The IWR has been responsible for the Orange, Zambezi and Congo River basins. Prof Hughes, Dr Mantel and Mr Mohobane participated in the project, while we also sub-contracted some of the work to Dr Tshimanga (Kinshasa University in the DRC) and Dr Desai (one of Mr Mallory's employees), both who are former PhD students of the IWR.

IMPLEMENTING UNCERTAINTY ANALYSIS IN WATER RESOURCES ASSESSMENT AND PLANNING.

Sponsor: Water Research Commission
DA Hughes, J Tanner and T Mohabane

April 2011–March 2014

Uncertainty assessment has become a critical issue in hydrological and water resource estimation and is largely related to the confidence that can be expressed in the results of models and other data analysis methods. This confidence (or lack of) translates into risk when the model results are used in decision making and has largely been ignored, or not quantified in the past. The uncertainty is associated with the fact that we do not have access to perfect data and the models themselves are simplifications of reality. The current project (K5/2056) represents a continuation of a previous 3-year project (K5/1838) that was completed in March 2011 (Hughes *et al*., 2011). The previous project focussed on establishing the concepts of uncertainty analysis in a South African context as well as developing some appropriate methods for incorporating uncertainty analysis in hydrology and water resources systems models.

The current project is designed to investigate the uncertainties in surface-groundwater interactions in more depth than was covered in the previous project and will also look at a range of issues associated with the practical implementation of uncertainty including the links between uncertainty and existing methods of assessing water resources yield and various approaches to reducing uncertainty. The current status of the project is that there remains a single deliverable to produce, as well as the final report. The intention is to submit the report on surface-groundwater interactions as a separate report (Ms Tanner was finalising this at the end of 2013) and to include the more general aspects of uncertainty as a 2nd volume.

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While the project was originally designed to end in 2014, a request for a one-year extension has been made to the Water Research Commission. While we are still waiting for the WRC to make a decision, the purpose of this extension is threefold:

- Firstly, we have identified some new opportunities to investigate some issues of making decisions with uncertain information. Mr Gregory Pienaar is expected to join the IWR as an MSc student in 2014. He has several years of experience working for a United Kingdom water utility and therefore, has a background of decision making in water resources development. His project will focus on identifying and testing some new approaches to uncertain decision making and we have requested partial financial support from the WRC to cover some of his bursary costs.
- Secondly, as part of the on-going development of hydrological modelling with uncertainty, we have been testing a new approach in the Caledon River Basin which overcomes some of the previous practical difficulties. We would therefore like to apply this approach to the whole country. Part of the approach involves developing regional constraints on hydrological model outputs and we have requested some financial support for Dr Mantel's salary costs so that she can provide some Graphical Information System (GIS) expertise to the project. Mr Forsyth is currently reviewing the developments in software made by Mr Dale Tristram that allow uncertain hydrological models to run much faster. The intention is to incorporate these developments into the SPATSIM framework and make them standard analysis tools. This could be a critical development if we are to start running models for the whole country.
- Finally, there are developments in other projects led by Mr Bennie Haasbroek and Prof Geoff Pegram on improved methods of stochastic rainfall analysis and how these can be applied to climate change studies. We have therefore requested additional project time so that we can collaborate with these groups and use their outputs in hydrological modelling studies.

DEVELOPING CLIMATE CHANGE ADAPTATION MEASURES AND DECISION-SUPPORT SYSTEM FOR SELECTED SOUTH AFRICAN WATER BOARDS

Sponsor: Water Research Commission, South Africa
DA Hughes, S Mantel, A Slaughter, T Mohobane, K Stroebel, B Whiteley

April 2010–September 2013

The project aimed to quantify the likely changes in various hydro-climate variables (rainfall, evaporation, groundwater recharge, runoff, water quality, etc.), but also the uncertainty in these changes, as they will impact on future water management plans and sustainable development. The proposal had aimed to investigate climate change adaptation measures for two water boards in the context of developmental changes by developing generic estimation tools, monitoring strategies and a decision support framework. The framework needs to identify risks, vulnerabilities and adaptation strategies to climate change in order to allow the water boards to fulfil their water supply delivery mandates. The study undertook the project in cooperation with two medium size water boards in South Africa, namely Amatola and Bloem Water Boards.

The aims of this project were:

1. To identify potential impacts and threats to sustainable water services delivery posed by climate change, as well as the uncertainties associated with these, with regards to changes in water quantity, water quality and socio-economic developments. This will be done through application of existing or newly developed estimation tools that can be used to convert downscaled Global Climate Models (GCM) output data to likely changes (including uncertainties) in the variables that impact directly on the operations of water boards (water quantity and quality). Part of the estimation process will include timescales of the expected changes.
2. Develop a methodology for assessing risks and vulnerabilities (including uncertainties in predictions) to climate change for Water Boards and their capacity to fulfil their mandate on water services delivery.
3. Develop a strategy and monitoring network for water audits in order to monitor indicators of change.
4. Derive Thresholds of Potential Concerns (TPCs) for water quality and quantity issues for Water Boards related to raw and potable water, discharges, pricing effects, etc. based on the outputs of the climate models.
5. Develop a decision-support framework for an adaptive management strategy to assess and modify water services delivery and development plans of the Water Boards in terms of infrastructure repair

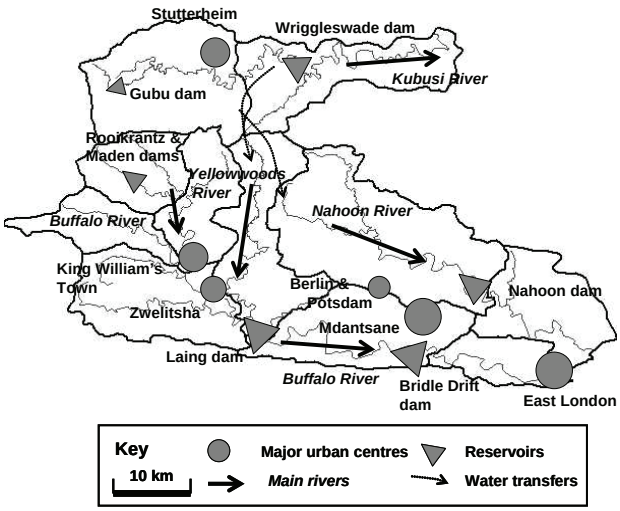
and developments, water conservation and demand management, water pricing changes and other associated issues.

The project team consisted of the Institute for Water Research (IWR) at Rhodes University and Amatola Water Board. Bloem Water Board attended the first meeting of the project but did not respond to further communication since then. However, Prof Hughes conducted climate change uncertainty estimation for the Caledon River catchments (included in the final deliverable) and a separate project (funded by Stockholm Environment Institute (SEI)) has developed a Water Evaluation and Assessment Planning (WEAP) model for the Orange River system.

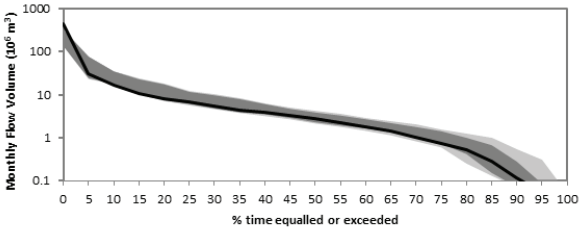
The IWR project team modelled the Amatole system (Buffalo, Nahoon and Kubusi rivers) in the Eastern Cape (first figure) using the Water Evaluation and Planning (WEAP) model, an off-the-shelf system level model for water quantity and quality. In the present project, downscaled climate data for nine GCMs were obtained from the Climate Systems Analysis Group at University of Cape Town and the socio-economic development water requirements were obtained from the Department of Water Affair's Reconciliation Strategy. Over the past year, the team finalised this project and submitted the final deliverable to the WRC which includes hydrological (using the Pitman model) as well as water availability and quality modelling results (using WEAP). In order to estimate the total uncertainty for the near future development scenarios under near future climate conditions, the results of 27 model runs (nine climate change scenarios, each in combination with three different socio-economic development scenarios) were assessed. The predicted stream flows showed greater uncertainty at low flows, particularly for the lower river reaches, in comparison to the results for climate change scenarios in isolation (second figure). Following the second workshop, the project team (Dr Slaughter and Prof Hughes) has been working on a simple water quality model Water Quality Systems Assessment Model (WQSAM) that is being interfaced with the Water Resources Modelling Platform (WReMP). The draft Decision Support System (that will be based on the WQSAM), which was included in the final deliverable, is being further developed through a two year WRC funded project being led by Dr Slaughter.

Ms Kelly Stroebel conducted a social survey of different socio-economic groups in King Williams Town as part of her Honours project in the Environmental Science Department at Rhodes University. She conducted 120 household questionnaires that focused on water use, conservation, and knowledge about climate change impacts and has recently submitted her final project report. Mr Bret Whiteley (part-time MSc student based in the USA) has been investigating the use of the Watershed Assessment Model (WAM) that has been extensively used in the United States to the Buffalo River in the Eastern Cape.

The results of the project were presented at the SASSqS 2013 conference in Arniston, Western Cape as two papers, focusing on the WEAP results, by Drs Mantel and Slaughter. The final deliverable for the project is available at http://iwr.ru.ac.za/iwr/climate/.



The Amatole system consisting of the three major rivers (Buffalo, Nahoon and Kubusi rivers) is shown with the catchments, major towns and reservoirs denoted.



Flow duration curve at a reach on the lower section of the Buffalo River under present climate conditions (solid line; 1921–2005), under the near future climate only scenarios (dark grey band of uncertainty using minimum and maximum values), and under the near future climate and development scenarios (light grey band of uncertainty).

DEVELOPMENT AND APPLICATION OF A SIMPLE SOUTH AFRICAN WATER QUALITY MODEL FOR MANAGEMENT OF RIVERS AND RESERVOIRS UNDER CURRENT AND FUTURE DEVELOPMENT AND CLIMATE CHANGE SCENARIOS

Sponsor: Water Research Commission, South Africa
A Slaughter and S Mantel

April 2013–March 2015

During the completion of a previous WRC project entitled 'Developing climate change adaptation measures and decision-support system for selected South Africa water boards', it was determined that no existing water quality models were sufficiently suitable to achieve the aims of

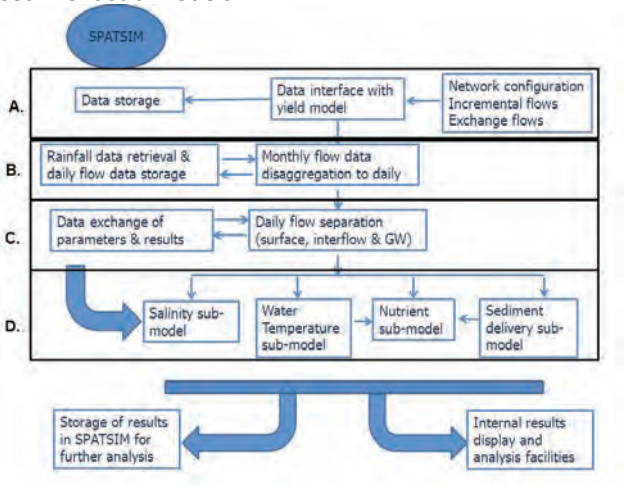
the project from a water quality perspective. Consequently, towards the end of the aforementioned WRC project, the conceptual framework behind the Water Quality Systems Assessment Model (WQSAM) was born. A new WRC project funding the development of WQSAM was awarded to the IWR within the 2013-2015 funding cycle. The overall aim of the WQSAM project is the development of a water quality decision support system with the following characteristics:

1. WQSAM would accept as input, flow output information from established and routinely used yield models such as the Water Resources Modelling Platform or the Water Resources Yield Model.
2. WQSAM would simulate only the most important water quality variables and processes from a management perspective so as to limit the complexity of the model and allow the model to be calibrated against routinely collected historical monitoring data.
3. The outputs of the model would allow water resources managers an indication of risk associated with management decisions.

The objectives of this project are:

1. The construction of a water quality systems assessment model (WQSAM) to work in conjunction with both the WReMP or WRYM yield models and the Pitman Model, to simulate the frequency of certain water quality concentration thresholds being exceeded, using predominantly available observed data, and a simplified conceptual framework.
2. Investigation of freely available remote sensing data for parameterisation and calibration of WQSAM.
3. The application of WQSAM to various catchments in South Africa, for comparison of model simulations to historical data, so as to assess the model's performance.
4. The assessment of various future development and climate change scenarios using WQSAM within the case study catchments, so as to assess the possible future impacts of development and climate change on water quality, and for comparison with results from previous studies.

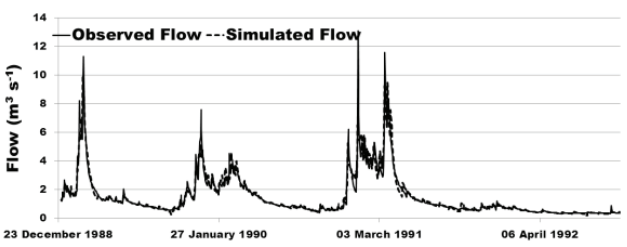
The conceptual structure of WQSAM is presented in the first figure. WQSAM is run from within the modelling framework Spatial Time Series and Information Modelling (SPATSIM), which also acts as a database where observed and simulated data, as well as model parameters can be stored. It was decided that WQSAM should be run at a daily time step, since water quality is driven by transient flow events. Since the yield models typically operate at a monthly time step, monthly incremental flows obtained from the yield models have to be disaggregated to daily within WQSAM, using a process driven by daily rainfall. WQSAM simulates water quality variable load input from the catchment by assigning water quality signatures to the incremental flow components surface water flow, interflow and ground water flow. For this reason, WQSAM breaks incremental flow into these four components. The actual water quality modelling components within WQSAM consist of the salinity, temperature, nutrient and sediment sub-models.



Conceptual representation of the model components in the Water Quality Systems Assessment Model (WQSAM): a) Input of WReMP output data and storage to the modelling framework Spatial Time Series and Information Modelling (SPATSIM) system, and replication of the nodal structure from the Water Resources Modelling Platform (WReMP) to WQSAM and SPATSIM; b) Disaggregation of simulated monthly incremental flow to daily and storage to SPATSIM; c) Base flow separation of simulated daily incremental flow to the flow components surface water flow, interflow and ground water flow; d) Water modelling components for salinity, water temperature, nutrients and sediment.

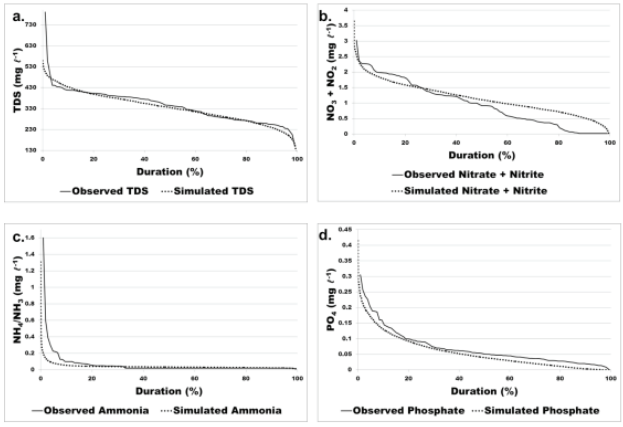
To date, the first deliverable for this project has been completed, describing the conceptual basis and technical structure of WQSAM, as well as preliminary simulation results for a case study catchment. WQSAM has been applied to the Buffalo River in the Eastern Cape to simulate historical conditions (calibration), and currently, the model is being applied to the Crocodile River Catchment. In the near future, there are plans to apply to the model to the upper Olifants Catchment as far as Loskop Dam.

An exciting outcome of the project to date is the monthly to daily flow disaggregation technique, which appears to be fairly robust and accurate. A study of the technique indicates the potential for use of regionalised parameters and satellite rainfall data, indicating the potential use of the method within ungauged catchments. A journal submission detailing the method is at an advanced state of completion. The second figure shows a short temporal segment of the disaggregation results for X22A on the Crocodile River, showing a good match between flow disaggregated from monthly flows and daily observed flows.



Results of monthly to daily flow disaggregation for the quaternary catchment X22A on the Crocodile River.

The application of WQSAM to the Buffalo River has achieved some good results for simulation of historical water quality data. The third figure shows preliminary simulation results for Laing Dam on the Buffalo River.



Preliminary simulated results for Laing Dam on the Buffalo River shown as duration curves as simulated by the Water Quality Systems Assessment Model: a) TDS; b) Nitrate + Nitrite; c) Ammonia/Ammonium; d) Phosphate.

GENERAL CONSULTANCY PROJECTS

Sponsor: Various Clients
DA Hughes

2013–Ongoing

The majority of the consultancy projects are related to our partnerships with Ms Delana Louw and Mr Stephen Mallory and are frequently associated with environmental water requirement determinations. Some are relatively small projects, while others are more extensive. Prof Hughes has also been involved in training some of the staff of the Department of Water Affairs in the use of SPATSIM and the Revised Desktop Reserve Model (a model designed for rapid estimates of environmental flows).

ENVIRONMENTAL WATER QUALITY PROJECTS

RICHARDS BAY MINERALS: ENVIRONMENTAL WATER QUALITY

Sponsor: Richards Bay Minerals (RBM)
NJ Griffin, AJ Holland, TJ Human, ON Odume, M Muller, H Jacobs

April 2012–June 2013

Richard's Bay Minerals' operations may compromise environmental water quality, and subsequently ecological health, of surface waters in or near their current operations. An environmental water quality monitoring programme was developed for Richards Bay Minerals (RBM) in 2006 by UCEWQ–IWR. The monitoring programme incorporates the use of macroinvertebrates and diatoms as biomonitors, and the collection of a range of selected water quality parameters. Since 2006, samples were collected during winter, spring, summer and autumn from sites around the mine in the RBM smelter area and from the as yet un-mined Zulti South lease area. Monitoring of the Zulti South lease area was terminated in 2009 as the area is to be mined, and a biomonitoring baseline for mining site rehabilitation had been established. The smelter area is currently monitored during winter and summer only as assessment of past datasets indicated that little extra was gained by quarterly monitoring (one site only is monitored four times per year).

Monitoring of sites around the smelter assesses streams around the mine for impacts due to mining operations, small-scale agriculture, residential settlements and other anthropogenic impacts. In general, a decrease in water quality with distance downstream is indicated by both macroinvertebrate and diatom biomonitoring scores. Nevertheless, all sites have fair to good overall ecological health. In most cases, no obvious cause of impacts driving decreases in water quality could be identified. This is largely a function of the confounding effects of the number of residential settlements found along the monitored rivers. Some recent decrease in water quality in recent samples from an upstream site not associated with human settlement was also detected. The cause of this has not yet been established. Richards Bay Minerals have extended their monitoring programme to more closely assess impacts identified by UCEWQ-IWR, and have contracted UCEWQ-IWR to continue with ongoing monitoring.

AJ Holland and ON Odume sampling on site at Richard's Bay Minerals site 12.

BUILDING CAPACITY THROUGH ENVIRONMENTAL WATER QUALITY INTERNSHIPS

Sponsors: Unilever Centre for Environmental Water Quality (UCEWQ)
S Mantel and D Naran

April–February 2014

There has been a steady, emerging stream of internships opportunities, facilitated at IWR-UCEWQ, for young Analytical Water Chemistry students from two local universities, namely Nelson Mandela Metrapolitan University (NMMU) and Walter Sisulu University (WSU). The internship positions are offered to students seeking to gain practical experience in support of their Analytical Water Chemistry qualifications. Placement for these opportunities are spread through the proverbial grapevine, as success of the Analytical Water Chemistry and Environmental Water Quality (EWQ) partnering for further development through training and work based knowledge is gained by students, the option to follow such a promising career path is spread by word of mouth to their peers, with the result that IWR-UCEWQ have hosted four students, two each from NMMU and WSU in the past two years.

The partnering of students with Analytical Water Chemistry backgrounds and EWQ is most suitable for young students as it opens up options to gain biological and practical chemistry training for pursuing a career path in the water sector.

Typically, potential interns approach Prof CG Palmer for a water quality project based internship at the IWR. The option to facilitate requests for a training opportunity is evaluated internally based on projects and funding available.
This year, Angel Magudelela secured an internship position at the IWR that extends from May 2013 to February 2014, and Kwezolomso Kama joined us for a two month period from September to October 2013. Through these positions, interns will gain experience and knowledge of live shrimp culture maintenance, undertake analytical chemistry procedures including getting familiar with eco-toxicity and bio-monitoring procedures, learn and practice these scientific skills by contributing to a research project currently underway at the IWR-UCEWQ and in support of UCEWQ researchers and students, and develop and build experience in an academic research work environment.

A work-based learning experience program to develop scientific knowledge and skills based on practical (hands on) work experiences in the field of EWQ has been initiated. Internship training involves a range of scientifically based activities facilitated via supervision, mentoring, and participative learning approaches.

Training was facilitated through demonstration and practical hands on experience with aquaculture methodology. A Culture Maintenance Manual, developed by the IWR staff, served as the basis for building knowledge about life-cycle and aquaculture discourse. This activity is often a steep learning curve, as the candidates have no prior biological or laboratory culturing experiences. Progress in this area has met the goals set, as the well maintained aquaculture environment has yielded healthy shrimp populations in support of student practical and toxicological experiments.

Ms Angel Magudelela taking care of a battery of rearing tanks containing juvenile freshwater shimps (Caridina nilotica).

Ms Magudelela has also been involved in a short term (six months) field based research project to enhance the integration of theoretical scientific concepts underpinning water quality research and bio-monitoring skills. Ms Kama is assisting with toxicity experiments. Through this research project, interns are introduced to the full spectrum of scientific research activities. To date, interns have participated in field excursions with our staff and students, including planning and preparing field excursions with guidance. Interns are mentored in building competencies with laboratory based procedures leading to nutrient

analysis including nitrate, nitrite, phosphate and ammonia quantification. Mentorship also extends to developing skills to set up experiments, execute experiments following a protocol, collect and record data, manage data analysis using Microsoft Excel, and to generate data outputs.

Ms Kwezolomso Kama setting up a 96 hour toxicity experiments.

Conceptual knowledge development, including scientific writing, literature search, critical reading and writing activities and engaging with researchers, are some of the fundamentals of this program developed for the internship. This year, Ms Magudelela participated in a two week course in Entomology II, building competencies to identify aquatic macro invertebrates. During September and October, interns, attended an in-house EWQ honours course in order to further build conceptual and theoretical knowledge about the subject.

Interns are initially given an orientation by experienced interns (Ms Ntombekhaya Mgaba) (now an honours student at the IWR) in support of their accommodation and access within the Institute and within the University, and greater Grahamstown.

Ms Ntombekhaya Mgaba is now pursuing an honours degree at the IWR.

As interns are required to attend general meetings, seminars and other IWR activities, they develop further work place based skills. In particular, operational and institutional skills and knowledge are developed.

We believe that we have developed a varied and stimulating program of accomplishable goals for this internship. We are of the opinion that this intensive internship will serve to build a solid foundation for further scientific work for young students.

RHODES UNIVERSITY NOT LEFT OUT AT THE 2013 ASSOCIATION OF COMMONWEALTH UNIVERSITIES (ACU) RESIDENTIAL SCHOOL

Sponsors: Association of Commonwealth Universities and Unilever Centre for Environmental Water Quality

ON Odume

August 2013

The Unilever Centre for Environmental Water Quality sponsored Nelson Odume to attend the 2013 Association of Commonwealth Universities (ACU) residential school in the United Kingdom. The five day duration residential school, with the theme 'The world in 2013' attracted postgraduate students from several commonwealth countries to discuss issues across disciplinary, national and regional borders.

The 2013 ACU residential school held in the serene environment of the Cumberland lodge in the United Kingdom August 8-12th, attracted postgraduate students from all corners of the Commonwealth countries to engage in discussion of issues cutting across academic disciplines and national/regional borders. The theme for the 2013 residential school was 'The world in 2113'.

Professor Rolph Payet, Minister for Environment and Energy, Seychelles, and Pro-Chancellor the University of Seychelles delivered the keynote address on what the world is likely to be like in 2113 and the key drivers of change, which he identified to include climate change, population growth, food, energy and water resources. He stressed the need to engage in critical thinking on how to address some of these challenges moving forward into 2113. Participants asked questions ranging from world governance and sustainable natural resource management to citizenry participation.

The three-day event sees notable speakers, Prof Tim Unwin (Chief Executive, Commonwealth Telecommunications Organisation), Prof Graham Furniss (Pro-Dean SOAS), Prof Jeff Waaga (Director, London International Development Centre) and Jan Grasty (President, United Nations Women UK) actively engaging participants on various critical issues that are likely to face humankind in 2113. Current and future trends in communication, the survival of different languages and cultures around the globe, the

capacity of the brain to cope with the challenge of 2113, the probable nature of international development policy in 2113 and whether there will be a need for a gender policy in 2113 were some of the issues discussed. Other issues that were discussed include science and research, the role of students in shaping the Commonwealth future and the 'beyond 2015' campaign. As the Millennium Development Goals are set to expire by 2015, the beyond 2015 campaign is aimed at identifying evidence-based key issues that must be addressed by global leaders and the role of universities in doing so.

At a personal level, I found the residential school very engaging, and the opportunity as a rare one. Engaging some of the brightest young minds from around the Commonwealth countries in critical issues facing our world today and that are likely to be presenting challenges to the future generations was very rewarding.

The ACU and the Unilever Centre for Environmental Water Quality, IWR funded the trip.

I owe much gratitude to Prof Tally Palmer and the Unilever Centre for Environmental Water Quality for the part funding.

CRITICAL ANALYSIS OF ENVIRONMENTAL WATER QUALITY IN SOUTH AFRICA: HISTORIC AND CURRENT TRENDS

Sponsor: Water Research Commission (K5/2184)
CG Palmer, NJ Griffin

April 2012–March 2014

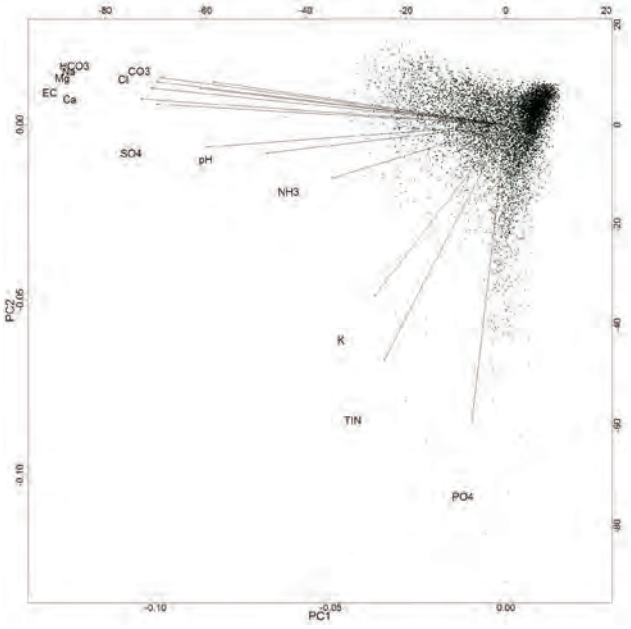
South Africa is widely recognised as having an admirable water law, and as being a leader in granting a right to water, in terms of quality and quantity, to the environment. However, the water quality of South African water resources is deteriorating rapidly despite good water quality management structures, strategies, approaches, programmes, instruments, and tools having been developed and implemented nationally over the past decade.

Some of the issues around the decrease of environmental water quality have been attributed to difficulties in meeting goals in water resource management through management practices and institutional and stakeholder cooperation and coordination. Given this background, it is desirable to approach an analysis of trends in environmental water quality in the light of changing legal frameworks and management practices and programmes.

This project has completed a review of literature on environmental water quality in South Africa, and under undertaken a review of the tools available for environmental water quality management, with a primary focus on management of rivers. This provides an overview of the various interacting processes used in water management in South Africa.

Having reviewed the management approaches and programmes, the project goes on to assess trends in a number of water quality variables in the Crocodile and Olifants River basins (the case study areas for this project). Water quality variables were selected to assess common water quality problems in South Africa, viz. eutrophication, salinisation, acid mine drainage, and microbial pollution, as well as to assess potential impacts of changes on a number of user groups. Trends with time were assessed using general additive mixed models, an approach appropriate to modelling nonlinear temporal trends with seasonal components. A number of trends were identified using this approach and major impacts in the two catchment identified.

The final part of the project will involve examination of trends that were identified in the light of management practices at a national and regional scale in an attempt to assess which approaches have been successful and which have not, and if possible to identify why this might be.



Principle Component Analysis (PCA) biplot of the first two principal components from a PCA analysis of water quality in the Crocodile River Catchment.

DEVELOPMENT AND IMPLEMENTATION OF AN INTEGRATED WATER QUALITY MANAGEMENT PROCESS (IWQMP) FOR THE CROCODILE RIVER CATCHMENT

Sponsor: DST (THRIP)-NRF, participating stakeholders
CG Palmer, PK Mensah and S Dlamini

April 2013–March 2017

Background

The Crocodile River Catchment (CRC), like many South African catchments, is over-allocated and experiencing increasing pollution of source water. The low source water quality is becoming a critical risk in terms of costs and productivity to many industries in the catchment. A previous Water Research Commission (WRC) project led by Professor Tally Palmer evaluated water stakeholders' compliance with environmental water quality criteria in the catchment. Among the priority issues from the findings were lack of compliance to environmental water quality criteria and deterioration of water quality. Most stakeholders involved in the WRC project collectively indicated the urgent need to develop and implement an integrated water quality management process (IWQMP) for the catchment.

The Inkomati Catchment Management Agency (ICMA) is responsible for water quality management in the CRC but will be unable to implement and enforce compliance without stakeholders' collective commitment. Thus, the call from the stakeholders for the development and implementation of an IWQMP was much received by the ICMA. Unilever Centre for Environmental Water Quality (UCEWQ) of the Institute for Water Research (IWR), Rhodes University in collaboration with Association for Water and Rural Development (AWARD) won a Technology for Human Resource and Industry Program (THRIP) project to partner the ICMA and stakeholders to develop and implement the IWQMP. The stakeholders include ICMA, MMC, Delta EMD, Assmang Chrome, TSB, Coke and Elands WUA. These are called core stakeholder group (CSG) members because they are paying in cash to fund the project. General stakeholder group members (GSG) are significant water users in the catchment willing to become involved but not making any cash contribution (e.g. Mbombela). The ICMA is both a CSG member and host of the project. The IWQMP is expected to reduce costs of enforcement, ensure water quality compliance, improve source water quality and thus, decrease industrial risks.

Aim and objectives

The aim of the project is to co-develop and implement an integrated water quality management process (IWQMP) for the CRC together with stakeholders. The project will serve as a prototype for application in the other Inkomati sub-catchments and then more widely to other catchments.

Achievements

- The project is now part of the ICMA's water resource protection and waste division's annual performance plan.
- Formation of a transdisciplinary Rhodes University and AWARD research team has been established.
- Formation of a Rhodes University-ICMA water quality team has been established and has been holding water quality division meetings every two months.
- A Core Stakeholder Group has been established and has held two stakeholders meeting with a third slated for 6 December, 2013. The General Stakeholder Group members attend these meetings.
- A data collection tool called the Water Quality Management Activity System was developed and used to collect the first round of data, which have been transcribed and will be mirrored back to stakeholders at the next meeting.
- The project has been presented at the Crocodile Catchment Forum.
- The on-site project team attends meetings and workshops that are conducted in the Crocodile Catchment including the Crocodile Catchment Forum.
- Water quality and flow data have been made available by the ICMA, DWA and some stakeholders to Hugo Retief (MSc student) in order to model relationships between flow and load. Asiphe Sahula (MSc student) is currently collecting data to model the activities of TSB on the river with the help of Hugo Retief.

Things to do

- Preparation for the next stakeholder meeting on the 6th December 2013.
- Preparation of year 1 progress reports.
- After initial contacts, the following have been identified as potential stakeholders to be included for year two: MPACT, Nkomati Mines, Kruger National Park, and Crocodile Major Irrigation Board.

COMPARATIVE TRANSDISCIPLINARY CASE STUDIES OF CHANGE TOWARDS ENHANCING WATER SECURITY PRACTICES IN THE EASTERN AND SOUTHERN CAPE, SOUTH AFRICA

Sponsor: National Research Foundation (NRF), Global Change Society and Sustainability Research Programme
CG Palmer, H Lotz-Sisitka (Environmental Learning Research Centre, RU), S Shackleton (Environmental Science, RU), C Fabricius (NMMU), M Mahlangu (Centre for Transdisciplinary Studies, UFH) and D Roux (SANParks)

November 2011–December 2013

This project is designed to align with the SANPAD funded project in the Lower Sundays River Valley so project progress has been reported there. Post-graduate students

supported by this grant from Rhodes University are: Jane Burt (PhD Environmental Education), Helen Fox (Water Resource Science), Lara Molony (Environmental Science), Matthew Muller (Water Resource Science), Hugo Retief (Water Resource Science), Ian Preston (Management), Athina Copteros (Geography); and from NMMU Verouschka Sonn (MSc).

A highlight has been attracting ten postgraduate students to RU through this project. This project provided most of the bursary funds and in addition associated projects funded senior research staff and running costs. The development highlight was, that the whole RU team (South African, Dutch and Irish members) put together a whole day of presentation at the first South African "Complexity Forum" – an NRF-funded initiative. The project was well received, with many positive questions and comments.

Students have commented on the value of the RU monthly research meetings, for example: i) 'The monthly project meetings for the Rhodes team that have been an excellent forum for student and staff learning for joint learning beyond their individual areas of focus towards building an understanding of the whole system' Lara Molony. ii) Jane Burt attended and presented at the International Critical Realism conference; attended and presented at the Complexity forum; is currently contributing to a chapter in a book on Transdisciplinarity and Critical Realism.

The research achievements of the whole project team include the development of a methodology for building a reflexive transdisciplinary research teams and praxis. Through the SANPAD collaboration, the Sundays River case study is being published by the Water Research Commission, and a draft report is complete.

Tally Palmer, Heila Lotz-Sisitka (RU), Mbiji Mahlangu (UFH) and Christo Fabricius (NMMU) have a manuscript in preparation on the three Universities' experience of transdisciplinary teaching, research and practice.

ENGAGED RESEARCH IN INTEGRATED WATER RESOURCE MANAGEMENT

Sponsor: South African Netherlands Alternatives in Development Research Programme (SANPAD) and a short term WRC consultancy in 2012 to support Prof CG Palmer in this research.

CG Palmer (UCEWQ, Rhodes U), C de Wet (Anthropology RU), J H Slinger(TU Delft), K H Rogers (Wits U), S Linnane (Dundalk Institute of Technology), C Burman (U Limpopo), J Clifford-Holmes (Rhodes U), R Luton (Wits U), S Shackleton (Environmental Science, Rhodes U), G Cundill (Environmental Science, Rhodes U), L Hermans (TU Delft), S Taljaard (CSIR), S Cunningham (TU Delft), S Mantel(IWR U), N Hamer(UCEWQ & Environmental Science, RU), AR Palmer(ARC), M Muller(UCEWQ, Rhodes U), L Molony (Environmental Science & UCEWQ, R U), J Gonzalez (TU Delft), G Barnes (ELRC, RU), A Finca (ARC), J Burt (UCEWQ&ELRC RU) and H Fox (UCEWQ & ELRC)

June 2011–May 2013

Getting started

Amsterdam 2010: In November 2010 The South African Netherlands Programme for Alternatives in Development (SANPAD) held a workshop in Amsterdam and The Hague in order to invite an international consortium of Dutch, Irish and South African researchers to submit a proposal for their final round of funding, in the broad arena of water and development.

Why water?

In his workshop keynote address, Prof Hamanth Kasan from Rand Water, South Africa, painted a gloomy and disturbing picture, with alarming global statistics of water-related human death and deprivation, and environmental degradation. After further presentations and conversations, researchers from Rhodes University, South Africa; the Delft University of Technology, the Netherlands; Trinity College, Ireland; and the Dundalk Institute of Technology, Ireland agreed to submit a proposal. The core idea was that in the last decade or so, a wide range of methods and approaches have emerged to augment, enlarge, and support the use of traditional science and engineering in actively engaging with the world's considerable and pressing problems with fresh water.

The project team aimed to identify and engage with a set of such problems, bringing to bear novel and interesting combinations from the range of new approaches.

Tackled playfully

Our first insight was that the enormity of the task could only be tackled playfully. That with so much to learn and so much that was new and daunting, we could best envisage ourselves as children, learning new skills in a playground of swings and climbing frames – challenged by each other and by the elusive holy grail of sustainable, just, integrated water resource management. The metaphor has the added power of humility. The first draft title was: *Crafting the water playground: learning to breach implementation barriers and blockages.* This was too playful for the funders and was sobered down to: *From policy to practice: enhancing implementation of water policies for sustainable development*. However, the metaphor of the playground remained powerful within the project team for the duration of the project. Finally, with the firm aim of research being 'used' rather than just potentially useful – we are currently in the process of producing a guide to a research practice that engages with difficult water resource problems.

Building a Transdisciplinary (TD) team

Delft 2011: A driving thrust of the research was for a group of researchers, colleagues and students to work to

bring together research, citizenship and IWRM practice across a range of customary divides – including context, experience, language, terminology, conceptual framing and, perhaps the most divisive, methods. This process was to be rigorous: an intellectual and practical wrestling with coherence, not a facile patching over of differences. The process of integration was to be concurrent – that is researchers, practitioners and case-study participants would work together concurrently – rather than independently on separate disciplinary-based aspects, for later integration. Practically, this concurrence had to be managed within the constraints of discontinuities (such as different people together in time and space). However, the commitment to concurrence served to encourage repetition and re-telling, so as to build a functional redundancy of insight, as a more whole understanding and practice emerged.

The TD work aimed to open up opportunities for new insights out of intersections of thinking and practice, so as to offer new ways of grappling with being human on plant earth.

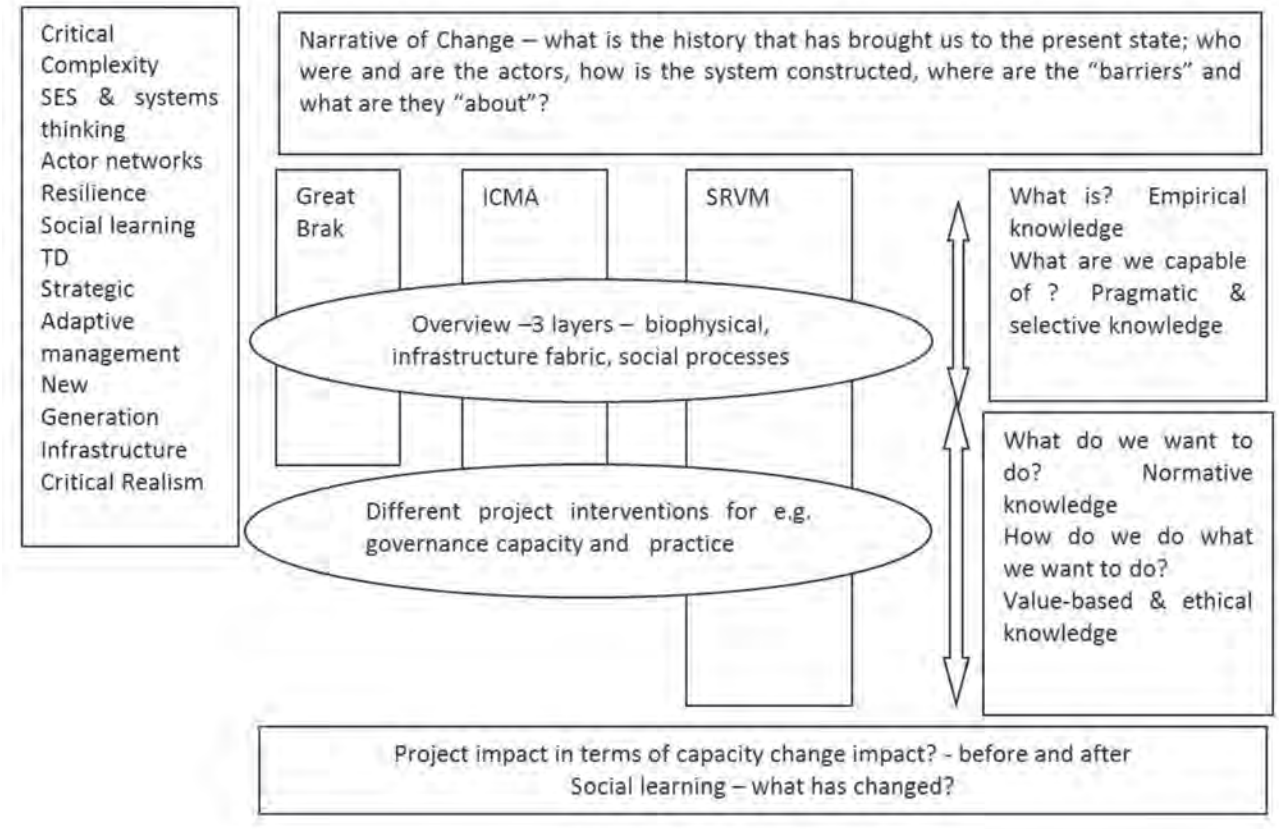
Case studies and the co-creation of knowledge

The integrating work was to be tackled in the context of case studies, with participants co-creating new knowledge, drawing on disciplinary and life experience. The process of assembling the project team and selecting case studies comprised part planning and part serendipity. This is consistent with our understanding of being part of a complex system with feedbacks, lags and unanticipated connections. SANPAD brought together the initial members (Palmer, Slinger, Linnane and Carmody). Others were invited to join the team because of experience with complex social-ecological systems (SES) and an action research approach to IWRM research (Rogers and Luton); an interest in the links between the social and the ecological in SES (de Wet, Clifford-Holmes, Burman, Shackleton); and later more students joined as additional funds were leveraged (Muller, Molony, Barnes, Gonzales, Burt and Fox). Additional researchers made contributions to specific case studies (Palmer, Finca, Cundill, Hamer, Taljaard, Hermans, Cunningham).

Most of the authors and several collaborators from other Dutch institutions gathered in Delft in June 2011 to initiate the project. Each participant was asked to write a 1-2 page outline of their research and practice perspective, or to share a key paper, report or proposal, and email it to rest of the team before workshop. Team members were also asked to prepare a 15 minute presentation, or to lead discussion on their tried and tested approaches and methods that could be applied at the IWRM coal-face.

Workshop documents introduced team members to a set of principles for TD engagement derived by Palmer and others in an Australian TD team building project:

- "Tolerate discomfort and unresolved tensions" as they are often a gateway to a new level of knowledge, understanding, and trust.
- Be sensitive to "aha" moments (insights), they emerge out of irritation as often as from consonance.



A conceptual model for the project.

- Engage with balanced generosity: enquiring, listening and sharing. Managing contribution and constraint is closely linked to listening.
- Practice tolerance and trust - exploring the nature of conflict before making judgements.
- Be sensitive to "arrivals" physical and meta-physical - ideas, opportunities and people "arrive".
- Create and use reflective opportunities.
- Manage discontinuities (e.g. time intervals, purpose, discipline focus, team composition).
- Sustain enquiry - engage in the concrete question, sustain reading, discourse and attention.
- Remember everyone involved in the research is a multi-faceted person, with the potential to engage with their whole self and many ways of knowing."

Case studies and methodology

The five-day Delft workshop set the tone for the unfolding project. Later on, people would admit to nervousness, anxiety, uncertainty and a sense of "grappling in the dark" during this workshop – but also to a sense of excitement at the shared ideas and an unfolding sense of purpose. From the start, open communication and a willingness to trust and explore, characterised the team. As days passed the similarities, differences, connections, disconnections, challenges and agreements among team members created a vibrant ebb and flow of ideas, as well as pointers to, and examples of, practice.

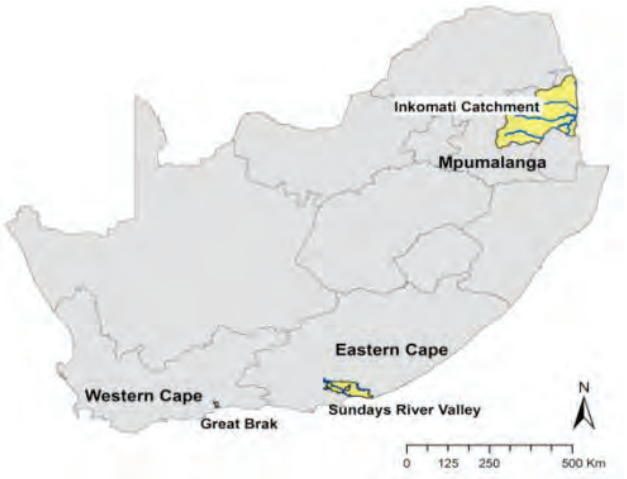
By the end of the workshop we shared an agreed conceptual model for the project (see figure on page 23).

On the left of the model diagram is a block with guiding integrative concepts which have associated methods. With the exception of critical realism, which was brought into the project later, each of these was presented and discussed in Delft. This is the intellectual scaffolding we used to build a common understanding by discussing the content and use of each concept and using these to derive the structure and function of the project.

The top horizontal block of the model diagram acknowledges that history shapes the present context. This provides an example of the way the concepts guided the research activities: given an acceptance and understanding of general complexity thinking (which provides a characterisation of the ways in which complex systems operate), and of the complex nature of the social-biophysical systems that comprise planet earth, we decided that the first step for each case study was to characterise the pathway to the present. This was described as the narrative of change. It brings to the fore the recognition that structure and function/relationships, only make sense in context – and that one of the primary contextual processes is through time. The narrative of change is given focus by leading questions related to IWRM: What is the history that has brought us to the present state; who were and are the actors, how is the system constructed, where are the barriers and what are they about?

Selection of the case studies

This brings us to the selection of the case studies. Again, drawing on understandings of complex social ecological systems, we accepted the importance of scale. Time and spatial scales affect the nature of system structure and functional/relational processes. Therefore as the various researchers presented the what, how and where of their research, we sought to stratify characteristics of the potential case studies by bio-physical and institutional scale.



Selection of scale for the case studies: considering spatial scale as projected in the Catchment Areas.

Smaller scale: The Great Brak River estuary is situated in the southern Cape. The estuary is at the bio-physical scale of a reach, and the social-institutional system of the estuary mouth emerges from a relatively small community of residents. The IWRM challenge is the inflow of freshwater into the estuary, released from an upstream dam.

Medium scale: The Lower Sundays River Valley in the Eastern Cape is at the bio-physical scale of a sub-catchment, and the associated social-institutional system is the Sundays River Valley Municipality (SRVM) municipality. The sub-catchment comprises the lower reaches of the Sundays River catchment, from the point where it receives an influx of water from an inter-basin transfer from the Orange River, via the Fish River. This once seasonal river is now perennial and supports a thriving export citrus industry. In contrast, many people living in the SRVM have poor quality drinking water and a frequently interrupted supply. The IWRM problem scenario is one that is common in south Africa: well serviced agriculture and poorly serviced people.

Larger scale: The Inkomati River catchment or basin in the north-east of South Africa spans South Africa and Mozambique. It comprises four sub-catchments, and the IWRM institution is at the scale of a catchment management agency (CMA) - a new institutional model in South Africa, which emerged from the reformed water policy and legislation after democracy. The challenge was

to support the Inkomati Catchment Management Agency (ICMA) to effectively practice IWRM.

Two phases of research

For each of the case studies, the two central ovals on the conceptual model diagram indicate two phases of research. The first is an empirical and descriptive phase where particular bio-physical, and social processes, and the associated infrastructure are recorded and analysed. In the second phase the project researchers and case participants work together on a particular aspect of the IWRM problem to move towards loosening the problem and opening up new choices and capacities for action.

Loosening problematic areas

It is important to note the language used. In complex systems there are no solutions – we work to loosen problematic areas and to create new perspectives and capacity so that a actions can be selected from a range of possibilities. The cycles of strategic adaptive management enable decision making and action in line with negotiated and agreed goals. These goals can also be shifted adaptively through time.

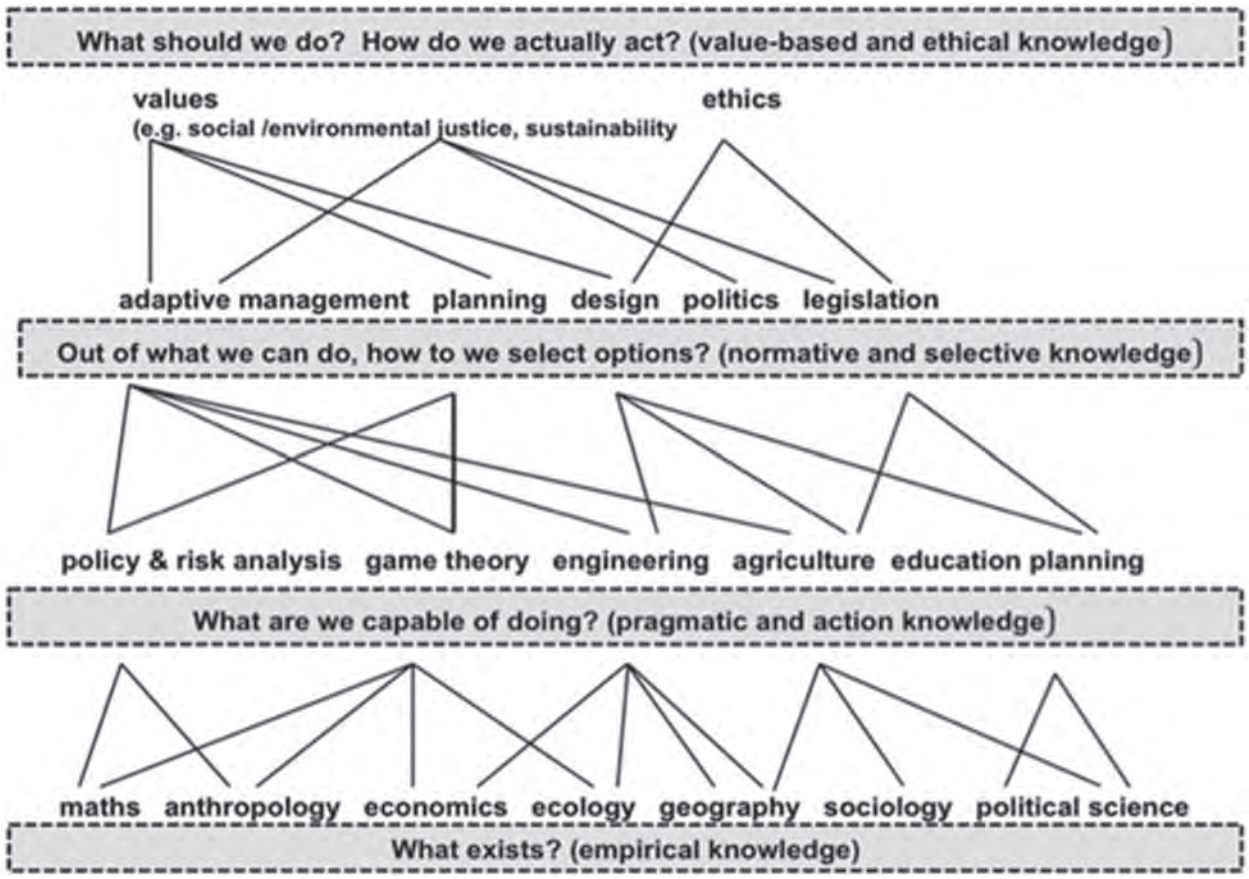
The two phases represented by the ovals in the model diagram can be related to the two blocks on right of the model diagram, a summary of the transdisciplinary theory of Max-Neef who envisaged different disciplines contributing to a hierarchy of human skills.

What has changed?

Finally, the project is underpinned by the question: *What has changed?* This is reflected in the bottom block of the project model diagram. If this way of thinking and of practising research is to be transformative, something needs to change. Problems are not shifted by a repetition of the same processes. So throughout the project we worked to reflect personally, and shared reflections among team members as to how we were changing and what we were learning. We asked project participants to do the same. This process of encouraging and tracking social learning is well developed in the literature but in this project we added it in after the Delft workshop and it was not embedded in the research practice to any of the case-study leaders. This is one of the overall project lessons – attention to social learning needs to be embedded from the start, with careful attention to monitoring, if we are to make our learning conscious and shared as we seek to undertake research in ways that facilitate social transformation.

Catalytic individuals

A crucial factor in engaged research, as exemplified by the Sundays River Valley Municipality process was the involvement of a Master's student, Jai Clifford-Holmes. In future research we will pay attention to the role of catalysing individuals in the process of engaged research. Clifford-Holmes has an undergraduate background in history and philosophy and a student-activist history of involvement in local community water matters. He



Max-Neef's theoretical transdisciplinary contributions within a hierarchy of human skills.

started in the project as a Masters student in Integrated Development Studies, and has recently changed to a doctoral research in Water Resources Science. He lived in the SRVM, becoming an integral part of SRVM activities, following an ethnographic methodology, and using actor network analysis, and systems analysis to build an understanding of water management within the SRVM. The other emerging lesson for TD practice is the value of the co-supervision of graduate students across disciplinary boundaries. Clifford Holmes' supervisors were from Anthropology, Water Resource Science and Soft Systems Engineering – and everyone learned a great deal.

Jai Clifford-Holmes, catalysing individual in the process of engaged research.

The knot metaphor

Have you ever walked along a beach and picked up a piece of tangled fishing line? Perhaps with some seaweed and a fish hook mixed in? Have you started to pick at it – seeking to untangle it? As you pull on a piece of line – it tightens elsewhere and it is hard to see where to start, and what is connected where. The first step is to loosen – to pull at the knotted pieces until a place to unravel becomes apparent.

We liken difficult water problems to the knotted line, and our research process to the loosening process. Loosening is followed by some unravelling which we see as the opening of opportunities to reduce tangles and engage with problem areas. This loosening and unknotting takes time, patience, attention and nimble fingers.
Likewise, engaging with knotty water problems takes time, attention and skilful facilitation and engagement.

At our Sunday River Valley Municipality (SRVM) workshops four knots were identified: 1) bulk water supply and storage; 2) treatment of water to drinking quality; 3) reliable distribution of safe water to households; and 4) waste water (sewage) treatment works and their effects on human and environmental health. Finance was seen as a multi-faceted issue that was part of each of the knots.
Clifford Holmes' research focussed on knot 1 - how to get reliable water from the plentiful inter-basin transfer supply to people. As a direct result of this work, in July 2013, the SRVM and the LSRV-WUA have agreed to work together to develop a common understanding of the water supply system, and to translate that understanding into a step by step water supply process they can jointly run.

Several other graduate students have undertaken research that is contributing to loosening knots and building conceptual understanding:

Matthew Muller has worked on knot 4, managing waste water. He participated with the SRVM in the Green Drop process which measures performance in waste water treatment. At the same time he monitored the stream into which the sewage effluent flows. His key finding is that if the municipality continues to improve its Green Drop score and to meet its licence conditions, the stream condition is likely to improve to the level required by the National Water Act.

Lara Molony engaged with local residents with regard to knot 3, and explored the relationship between access to housing and water. She has provided valuable insights into the realities of life with, at best patchy, domestic water supply. Additional domestic water supply research by Andiswa Finca, Prof Tony Palmer and Dr Sukhmani Mantel contributed to understandings of the use of rainwater tanks.

Jane Burt is using the project team as her case study, and she is directly investigating the process of transdisciplinary research, and she, Dr Georgina Cundill and Clifford-Holmes are writing about the social learning processes within the case study.

Helen Fox is exploring engagement and participation of scholars with urban water resources, and has brought in the concepts and methods associated with critical realism which will add to the options presented in the guide.

The Guide: In its final form the guide will comprise a set of principles of practice – supported from the theoretical and case study work with associated methods. The final report will also consider the project outcomes, products and ways of going forward.

A transformative process: Each of the project case studies has offered experience and learning in practising engaged research. Research that is predicated on knowledge co-creation and sharing across and among disciplines, practices and life circumstances. The outcomes show

early promise that research activities can be catalytic and that **engaged research can realistically be viewed as a transformative process.**

The results have been sufficient encouraging for the team to have been awarded a Water research Commission project: *Towards a new paradigm in South African Integrated Water Resource Management*, where the "new paradigm" is this practice of engaged research and the sharing of new knowledge into the adaptive, inclusive way of actively practising Integrated Water Research Management.

Capturing 'knotty' water problem; water cycle, catchment activities, biophysical processes-generated through group discussions.

WATER RESOURCES MANAGEMENT IN SOUTH AFRICA: TOWARDS A NEW PARADIGM

Sponsor: Water Research Commission
CG Palmer, J O'Keeffe, N Hamer, K Rogers, V Munnik, D du Toit, S Pollard, M Jobson, C van Ginkel, C de Wet, Water for Dignity group.

April 2013–March 2016

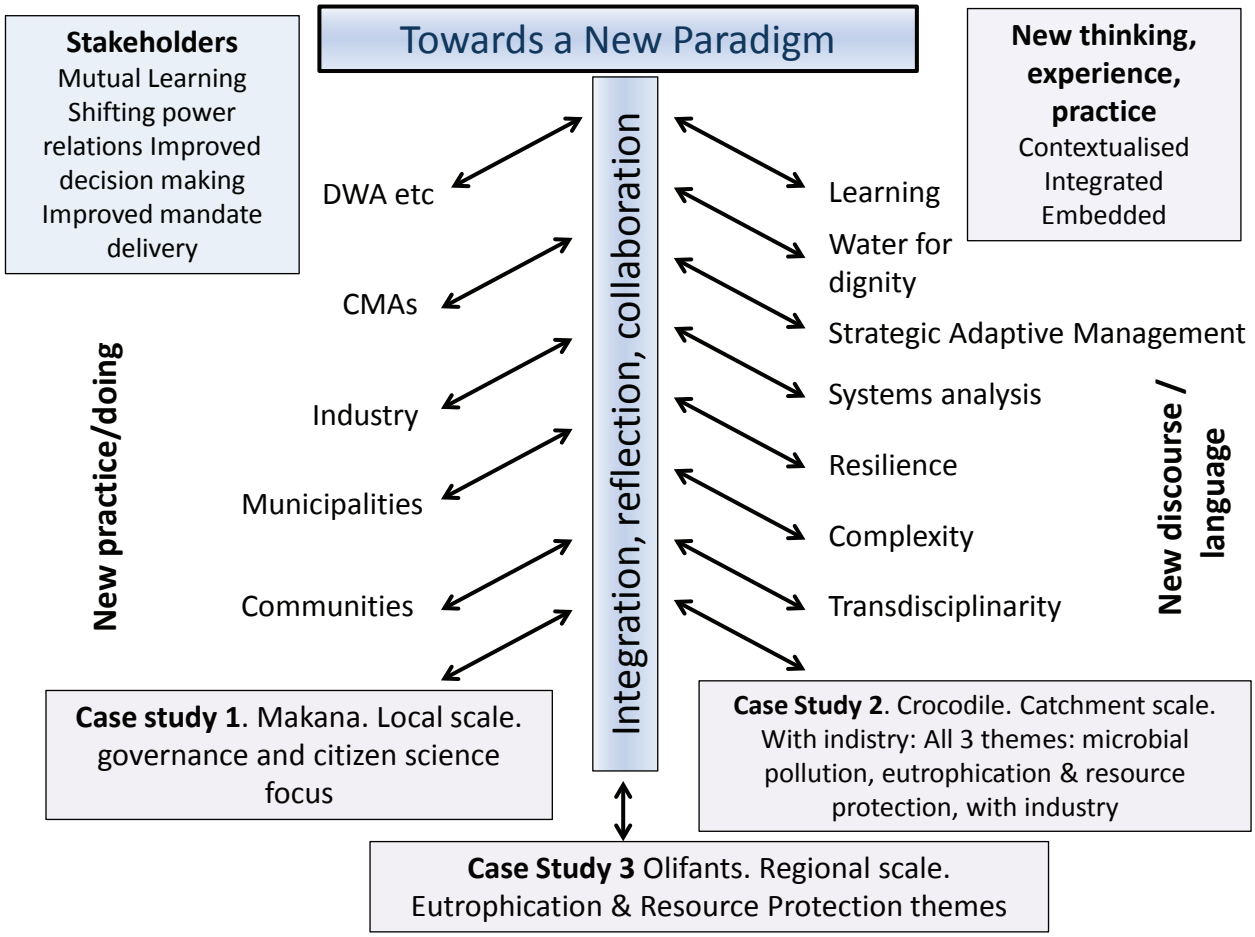
The Towards a New Paradigm, four year project launched in April 2013 with funding from the WRC. At a recent meeting held with all stakeholders and team members in Pretoria, the WRC showed their confidence in the project by agreeing to continue to fund the project for the full four years. One of the core processes of this project is to ensure DWA participations and this is being co-ordinated by Ms Marie Brisley, Chief Director: Policy and Strategy, DWA. This working group will meet every two months with case-study leaders in order to ensure the new paradigm thinking is embedded in the planning and policy making of the DWA from the very beginning of the process and that team members and interested parties work together in finding workable solutions to IWRM.

Case studies:
Case studies provide three focal areas where greater depth, and the experience of new paradigm practice will be explored, this method was successful in the SANPAD and WRC funded project on IWRM implementation in difficult circumstances three case studies: in the Sundays River Valley (Rhodes University and Wits University), the Great Brak estuary (Rhodes Univesity and TU Delft) and the Inkomati Catchment (with Wits University and AWARD)) experience (this foundation has been provided by previous WRC and SANPAD funded research).

Eastern Cape: This case study will focus on governance at the local and district municipal scale, and at the quarternary catchment scale. The process developed over the previous two years for the Lower Sundays River Valley (LSRV), and Sundays River Valley Municipality will be extended through the Cacadu District Municipality. This case study will provide insights into local government governance and institutional arrangements, and will include integration of best practice microbial pollution approaches into New Paradigm practice.

Crocodile River (Inkomati Catchment): This study will pilot the development of an Integrated Water Quality Management Process (IWQMP) at the secondary catchment scale (the Crocodile River is a relatively simple secondary catchment), requiring local and regional government participation, inclusion of the catchment forum, and links into the Inkomati catchment and the ICMA. The ICMA is a full, contributing partner and will use the process as their water quality management development process. As the project progresses consideration will be given to the other Inkomati catchments (Komati, and Sabie-Sand). Success will depend on effective local government participation, so the experience from the LSRV and Case 1 will integrate into this. Several water users, including agriculture, mining, industry, and water service providers and water user associations in the Crocodile River catchment have committed partnership funding for this case study, and others have agreed to collaborate. Leveraged funding from THRIP (NRF) R1.3M was secured for 2013, and further funding provisionally approved for 2014-15. (THRIP funding ultimately depends of industry cash contributions being received).

Olifants River: This case study will pilot integrating water quality into the practice of IWRM using a systems analysis approach at a complex secondary catchment scale (including multiple tertiary catchments), but with no



Toward a New Paradigm-Project structure

CMA, and therefore at the regional and local government scales, and with a catchment forum. Leveraged funding from USAID (R2.8M) has been secured for 2013-17. This case study is focussed primarily on Resource Protection, and provides a eutrophication focus at river reaches up and downstream of Loskop Dam.

The Makana: This case study includes Jay O'Keeffe, Nick Hamer, the Water for Dignity group, Marjorie Jobson and MSc student, Matthew Weaver. The Crocodile River Case Study includes MSc students Asiphe Sahula, Hugo Retief and Gareth Thomson.

POSTGRADUATE ACTIVITIES

AN EXPLORATION OF THE WAY IN WHICH VALUES AND VALUING PROCESSES MIGHT STRENGTHEN SOCIAL LEARNING IN WATER STEWARDSHIP PRACTICES IN SOUTH AFRICA

Student: Mr G Barnes
Supervisor: Profs CG Palmer and H Lotz-Sisitka
Degree: MEd (Environmental Education)

This qualitative study is located within a current global narrative that describes the scale of human impact on our Earth systems that rivals other geophysical processes: the Anthropocene. These impacts are setting humanity on a trajectory that threatens to place us beyond the safe operating spaces called planetary boundaries, which focus on the biophysical processes of the Earth system that determine the self-regulating capacity of the planet. For humanity to live within these safe operating spaces – one of which is global freshwater use –will take a new way of relating to the environment called Earth Stewardship, which calls for a new ethic of responsibility towards Earth systems.

It is at the local level of stewardship within a global approach to water resources management called Integrated Water Resources Management (IWRM) that this qualitative study is contextually bound. Two case studies, located in the catchment management forums (CMFs) of the Upper Vaal catchment of Gauteng, South Africa, are used in an exploration of the way in which values and valuing processes might strengthen social learning in water stewardship practices in South Africa. The meta-theory of critical realism is used to help explore this relationship between values, practice and social learning. The data were collected using the analysis of seven years of forum minutes, semi-structured interviews and observation.

The study differentiates between held and assigned values and identifies that there is a strong altruistic held values tendency that characterises forum participants who practice water stewardship in the two case study sites. It also finds that even though biospheric values are not prolific, they do appear to have influential power in driving practice. Most water stewardship practice, identified in the case study sites, manifests as compliance activities in the public – or forum – space, while private-sphere environmentalism is mostly left to the confines of the individual's private household. Lastly, the CMFs seem to have the potential of providing a space for social learning that is not yet maximised.

Drawing from these key findings, the study's major recommendation is that forums that facilitate learning, either utilising the current CMF structure or creating new opportunities, need to be provided as a conduit for social learning and reflexivity so as to make the existing boundaries between private and public forms of water stewardship more porous. This social learning may then expand social practice and thus effect social change.

A DISTRIBUTED EROSION AND SEDIMENT DELIVERY MODEL FOR SOUTH AFRICAN CATCHMENTS

Student: Ms L Bryson
Supervisor: Prof DA Hughes
Degree: MSc (Water Resource Science)

Water resource management is an important issue in a semi-arid region such as South Africa where increasing suspended sediment loads in rivers and reservoirs, due to increasing water erosion, have brought water quality to the forefront of management problems. Effective management calls for a practical water quality estimation tool. A simple sediment model is proposed which incorporates sediment availability, storage and delivery. To determine daily sediment availability, probability distribution theory is used with the Modified Universal Soil Loss Equation (MUSLE) and a runoff component from a daily disaggregation of the Pitman rainfall-runoff model. A storage and delivery component would be applied to the high, moderate and low runoff zones of the catchment as well as for the main channel. According to runoff events there will be daily outputs of erosion and sediment delivery. The model will be validated against sediment accumulation records from two small farm dams as well as annual sedimentation records from a larger storage reservoir in the Karoo, of the Eastern Cape of South Africa. The sediment model deals with the issue of scale effectively and can be used in small catchments as well as larger areas, indicating that it would have a broader applicability for management. The attributes of this new sediment model are its simplicity, effectiveness and practicality for water resource managers.

EXPLORATIONS AND REPRESENTATIONS OF THE EMERGENCE OF INTER/TRANS-DISCIPLINARY PRACTICE IN THE WATER SECTOR IN SOUTH AFRICA.

Student: Ms JC Burt
Supervisor: Profs CG Palmer, H Lotz-Sisitka and Dr L Price
Degree: PhD (Environmental Education)

At the beginning of this year I converted from a full time to a part time PhD student as I was offered a job to work for the Association of Water and Rural Development on a catchment based project (RESILIM – Resilience in the Limpopo Basin) funded by USAid. The project adopts a trans-disciplinary framework and is one of the case studies for the WRC's "New Paradigms" project run through the IWR, Rhodes University. The project work will form one of four case studies for the PhD. I am contracted to Theme four of the project which is responsible for capacity building, media and communication.

One of the key focuses of the PhD is researching the practice of trans-disciplinarity in two case studies:

- SA/Netherlands Research Programme on Alternatives in Development (SANPAD)/Global Change, Society and Sustainability Research Programme (GCSSRP) case in the Sundays River Valley
- Resilience in the Limpopo Basin (RESILIM) Olifants catchment
- Social learning and mediation in Cata

Thus, the main PhD activities for this year have been process documenting the start-up of the RESILIM project. This has included contributing to the conceptual framing of Theme four as well as participating and documenting numerous trans-disciplinary meetings.

Working with Ray Ison at Reference Group meeting, October 2013

A TRANSDISCIPLINARY INVESTIGATION OF WATER GOVERNANCE IN THE LOWER SUNDAYS SUB-CATCHMENT OF SOUTH AFRICA

Student: Mr JK Clifford-Holmes
Supervisor: Profs CG Palmer, C de Wet, and Dr J Slinger (Delft University of Technology, the Netherlands)
Degree: PhD (Water Resource Science)

This research investigates water governance in the Lower-Sundays sub-catchment in the Eastern Cape province of South Africa. The study uses the water services provided by the Sundays River Valley Municipality (SRVM) as the focal point of the research, emphasising the interlinked relationship between the SRVM and the Lower Sundays River Water User Association (WUA) in the area. In 2013, this research was upgraded to a doctoral study, from being a Masters in Integrated Development that was previously entitled "Knotted Pipes: A Transdiscinplinary Exploration of Interventions into Water Supply Aspects of the Sundays River Valley Municipality's Water Services". The primary aim of the doctoral study can be summarised as follows:

To explore and understand the use of transdisciplinary, practice-based research in engaging local water authorities in a process of institutional change that increases the likelihood of equitable water supply in the Lower Sundays sub-catchment, Eastern Cape, South Africa.

This research utilises a multi-method approach that incorporates actor analysis, institutional analysis, and systems analysis. The systems analysis component of this research has been extended in 2013 through the increased incorporation of the discipline of System Dynamics (SD). The increased use of SD is additionally relevant given the formation of the African System Dynamics Chapter in 2013, and the planned establishment of a SD Working Group at Rhodes University in early 2014 (which is foreseen as operating within the context of the existing Rhodes University Transdisciplinary group pioneered by the SANPAD project). The focus of the action research component of this study remained on developing an operational agreement between the SRVM and the WUA, which is aimed at assisting in alleviating the current water shortages experienced in Kirkwood – the main town and commercial center of the SRVM.

PARTICIPATORY ACTION RESEARCH INTO WAYS IN WHICH DANCE MOVEMENT PSYCHOTHERAPY CAN PROMOTE PERSONAL AND SOCIAL CHANGE IN A SOUTH AFRICAN COMMUNITY EXPERIENCING WATER-RELATED INJUSTICE

Student: Ms A Copteros

Supervisors: Profs CG Palmer, R Fox (Geography, Rhodes University) and Dr V Karkou (Edge Hill University UK)
Degree: PhD (Water Resource Management)

This research investigates how Dance Movement Psychotherapy (DMP) can be a means of connecting to sensory experience, nature and an embodied sense of belonging within the personal, cultural and/or collective unconscious in order to bring about healing and greater connectivity within the area of Integrated Water Resource Management (IWRM).

The goals of the research

- To reflect on how the experience of DMP training in the UK can be translated into a culturally appropriate practice in South Africa;
- To apply DMP to a South African project on effective IWRM;
- Jointly with participants, to develop a model of DMP related action that has personal and social meaning towards desirable change;
- To determine how insights offered by DMP in a transdisciplinary research team can assist in bringing about more effective IWRM in selected complex social-ecological system/s.

The core of the study resides in the individual experience of psychotherapy within a DMP group. Participatory Action Research will be used. Khulumani Support Group (KSG) is a Non-Government Organisation that represents and helps people across South Africa who suffered under apartheid. Members of KSG are citizens who want to take responsible action and hold government to account in the realisation of 'a better life for all' and this includes the equitable distribution of water for all. Working with KSG and the researchers from a range of disciplines engaged in transformative IWRM research as part of a transdisciplinary project, focusing on the ways in which DMP can promote personal and social change provides the framework for the study.

THE INFLUENCE OF STRUCTURE AND AGENCY ON THE VALUE AND HEALTH OF SOCIAL-ECOLOGICAL SYSTEMS: A CASE STUDY FROM BOKSBURG

Student: Ms H Fox
Supervisor: Profs CG Palmer and R O' Donoghue
Degree: PhD (Water Resource Science)

This thesis is based on a case study of a complex social-ecological urban water catchment system in the East Rand, Gauteng. The focus is on Boksburg Lake, a social-ecological system that had high value from the 1920s till 1990s and perceived ecological health but is now a severely degraded ecological and social system. An environmental education initiative was started in 2009, focusing on local schools with the aim of catalysing local people to reclaim the lake through a process of collectively re-imagining possibilities, shaping identities, gaining knowledge and developing human agency to improve the lake and surrounding catchment.

This social-ecological system is used as a case study and platform to explore the primary question: what key generative mechanisms enable and/or constrain the Boksburg Lake social-ecological system from being valued and healthy? This question begins an exploration of key generative mechanisms that affect the health and value of modern social-ecological systems.

Critical Realism (Bhaskar 1978) provides the philosophical framework and necessary conceptual tools to address this question in the context of the Boksburg Lake social-ecological system:

- It provides a thorough ontology and epistemology that grounds this study in the reality of the social-ecological context of Boksburg Lake's catchment, while enabling the researcher to take up both a truth-searching and emancipatory perspective.
- It provides the necessary tools to research key generative mechanisms that affect both the social and natural aspects of this integrated social-ecological system and allows extrapolation into the wider processes occurring in modernity.
- Working with a critical realist perspective and tools opens up a space for an interdisciplinary approach that is used in this study. Qualitative and quantitative methods are thus used to generate data on different aspects of this social-ecological reality.

THE USE OF INDIGENOUS ALGAL SPECIES IN TOXICITY TESTS FOR APPLICATION IN WATER RESOURCE MANAGEMENT

Student: Ms NP Gola
Supervisor: Dr WJ Muller
Degree: PhD (Water Resource Science)

This study investigated the use and application of locally isolated South African freshwater micro-algae in toxicity tests for water resource management. It was carried out in three phases and addressed the following aims:

Phase 1: Developing capacity to use South African freshwater algae in toxicity testing. This was done by isolating and selecting suitable local micro-algal species for use in toxicity tests using pre-defined criteria.
Phase 2: Refining the toxicity test methods for using South African taxa in toxicity tests. This refinement was achieved by exposing selected locally isolated species and the standard toxicity test species *Pseudokirchneriella subcapitata* to reference toxicants in order to assess the ability of the local isolates to grow under the prescribed toxicity test conditions.
Phase 3: Assessing the application and value of using the

selected local micro-algal species in toxicity testing for use in water resource management in South Africa. In this phase, the sensitivity of the local micro-algae to a range of carefully selected toxicants (reference toxicants, salts and effluents) was assessed.

In Phase 1, eight single species that could out-compete the rest in terms of growth were successfully isolated and cultured in the defined culture conditions. Three of the eight species satisfied the selection criteria (*Scenedesmus bicaudatus*, *Chlorella sorokiniana* and *Chlorella vulgaris*) by growing relatively well under the defined conditions, being unicellular and forming homogenous suspensions in the defined test medium. The limitation was that the selected species were green algae (Chlorophyta). The ideal scenario would have been to obtain species from different taxonomic groups (green, blue-green and diatoms). Green algae are generally easy to culture and are used in toxicity bioassays more than other taxonomic groups. Species of *Chlorella* and *Scenedesmus* are the most common, well known and widespread of the green algal species.

The algal bioassay in South Africa uses the algal growth inhibition test with the standard species *P. subcapitata* as it is the most widely used algal bioassay internationally. There are established standardised and routinely used test protocols of this bioassay (US EPA 1978, OECD 1984, ISO 1989, Slabbert 2004). The standard species *P. subcapitata* is not necessarily encountered in the local environment and therefore the data obtained from these tests may not realistically describe responses under natural conditions. **In Phase 2**, the standard algal growth inhibition bioassay protocol was adapted and refined to support the growth of the locally isolated species. Two out of the three selected species (*C. vulgaris* and *C. sorokiniana*) satisfied the conditions of potential toxicity test species. *S. bicaudatus* was eliminated as a potential toxicity test species due its high variability in growth. Constant and uniform growth was a prescribed requirement of toxicity test species in this study and *S. bicaudatus* failed in this regard. However, it should be clarified that although *S. bicaudatus* was eliminated as a toxicity test species for the test protocol prescribed in this study, it may be a useful toxicity test species for other test methods with different experimental conditions and endpoints.

In Phase 3, the indigenous species *C. sorokiniana* and *C. vulgaris* were exposed to a range of selected toxicants; widely used reference toxicants ($K_2Cr_2O_7$ and $CdCl_2$), inorganic salts of water quality concern in South Africa (Na_2SO_4 and NaCl), coal-based effluents from important industries in the country (power plant and petro-chemical industry) as well as a commonly used glyphosate based herbicide (Roundup). The toxicants were selected to increase the applicability, site-specificity and environmental realism of the study by considering the potential of using of the selected local micro-algae in routine toxicity testing to determine the impact of these toxicants on local aquatic resources. The response and sensitivity of these local species to these toxicants was compared to that of the standard toxicity test species *P. subcap*itata and a species obtained from a culture collection *Chlorella protothecoides*. *C. sorokiniana* was the most sensitive species to $CdCl_2$ and NaCl *C. vulgaris* was the most sensitive species to $K_2Cr_2O_7$, and *P. subcapitata* was the most sensitive species to Na_2SO_4 (both indigenous species were relatively tolerant to this salt) The stimulation of algae was shown by both selected effluents. All the species were stimulated by the effluent from the petrochemical industry. *Chlorella protothecoides* was stimulated at a much higher concentration than the rest of the species. The power-plant effluent stimulated the standard species *P. subcapitata* and *C. protothecoides* at all concentrations. The effect of this effluent on the indigenous species was slightly different. The indigenous species were both stimulated at low concentration and inhibited at high concentrations. This phenomenon was more pronounced on *C. vulgaris* than *C. sorokiniana*. *C. vulgaris* was therefore more sensitive to this effluent than *C. sorokiniana.*

The two indigenous species *C. vulgaris* and *C. sorokiniana* showed different responses to the herbicide (Roundup®). The growth of *C. vulgaris* was slightly stimulated by Roundup® while the growth of *C. sorokiniana* significantly inhibited at all the tested concentrations of the herbicide. There was obvious growth inhibition of *C. sorokiniana* and *P. subcapitata* by Roundup, although the EC_{50} values to could not be determined due to practical challenges. *C. protothecoides* was also inhibited by the herbicides with an EC_{50} of 1.2 mg/l.

The use of a battery of single species in toxicity test is important for comparative purposes, especially when dealing with complex effluents which consist of different components. Using a battery of single algal species in routine toxicity testing is more representative of the ecosystem and is preferred by many countries. The use of a battery of micro-algae (that includes indigenous micro-algae) for toxicity tests in programmes that assess discharge and in-stream effluent in South Africa would assist in alerting operations and managers of any changes in effluent composition. Single species toxicity tests have been used as the source of biological data for hazard assessment internationally, and it is recommended that South Africa follows this trend.

ASSESSMENT OF FLUCTUATING ASYMMETRY AS A BIOINDICATOR OF WATER QUALITY DEGRADATION

Student: Mrs AJ Holland
Supervisor: Drs WJ Muller and AK Gordon
Degree: PhD (Water Research Science)

Bilateral organisms develop symmetrically along a bilateral axis. Both sides of the body develop from the same genome as well as (usually) under the same environmental conditions; hence, both sides should be exact mirror images

of each other. However, this expected developmental outcome (i.e. perfect symmetry) can change through the random nature of cellular developmental processes - such as diffusion, metabolic rates, cell division, cell growth etc. These random variations of cellular developmental factors are called developmental noise. Developmental noise acts locally so that cells in one side of the body can show small perturbations whereas cells on the other side of the body stay undisturbed. These cellular perturbations accumulate on each side separately during development and can result in small structural differences between both sides (i.e. small deviations from perfect symmetry). The ability of an organism to buffer against developmental noise through compensatory mechanisms is called developmental stability. Developmental stability is indicated by an organism's developmental precision - the more precise the development the more perfect the symmetry and the higher the developmental stability. Fluctuating asymmetry is a measure of developmental instability - the further the asymmetry departs from perfect the less the organism is able to buffer against developmental noise. Fluctuating asymmetry (FA) has been proposed as a bioindicator for water quality degradation and is being investigated in the current study in the freshwater shrimp, *Caridina nilotica*.

Stained samples of C. nilotica (left) collected from the Luvuvhu River (right).

Shrimps were collected from rivers from different provinces in South Africa: Bushman's River (Eastern Cape), Vaal and Taaibos rivers (Free State), Mpisini and Mdibi rivers (KwaZulu-Natal) and Luvuvhu River (Limpopo). Each river posed a different water quality impact, e.g. industrial, agricultural and pesticides. FA levels were determined by dissecting and mounting pereiopod pairs onto microscope slides, photographing each pereiopod, measuring selected parts in image analysis software and finally comparing measurements from left and right side of the organism's body. Results were transformed into internationally acceptable FA indices, e.g. FA1, FA8, FA10b and FA14. These were compared between sites along each River to establish differences in FA from reference sites as a result of degrading water quality. FA indices were then compared across provinces in order to determine the severity of FA as well as natural levels. FA indices were then correlated with water quality variables as well as biomonitoring indices in order to detect possible relationships. Advantages and disadvantages of the FA method were then critically analysed as possible tool for use in biomonitoring in South Africa.

SIMULATING NUTRIENT FATE AND TRANSPORT IN A LOW ORDER STREAM INFLUENCED BY POINT SOURCE AND DIFFUSE SOURCE POLLUTION: AN INVESTIGATION OF COMPLEXITY IN WATER QUALITY MODELLING

Student: Mr HM Jacobs
Supervisor: Prof DA Hughes and Dr AR Slaughter
Degree: MSc (Hydrology)

Rivers worldwide are put under increasing stress due to pollution. The most widespread water quality problem is eutrophication, which is the presence of excessive amounts of nutrients in water. Eutrophication leads to increased algal growth and increases the occurrence of harmful algal blooms. The main contributors of nutrients to river systems are agriculture and urban discharge. Urban areas contribute nutrients through surface runoff and from the treated and sometimes untreated sewerage effluent from sewerage treatment works. Due to human reliance on water resources, it is necessary to protect and manage natural ecosystems. In order to effectively manage water systems, water quality models are used as management tools to simulate the transport and fate of nutrients. The first figure illustrates the fate of nutrients in a water body that water quality models attempt to simulate. Not illustrated is downstream transport of nutrients.

The aim of this study is to investigate the ability of a simple water quality model to simulate water quality trends in the Bloukrans River, Eastern Cape, South Africa. Simple models are favoured when there is low data availability, there are few stakeholders affected by the issue and thus low importance is placed on the accuracy of the modelling results or there is a small budget for the modelling project and thus time and resources are limited. From a management perspective, the best model is one which provides an acceptable answer with the lowest data and parameter input. Developing countries often do not have water quality monitoring schemes for the rivers and thus, simpler models have to be used due to the lack of data. The South African Department of Water Affairs (DWA) does monitor water quality in some of the rivers, but the monitoring is not comprehensive enough to be used for water quality modelling of the rivers and many rivers are not monitored by DWA. The study will look at the short comings of either end of the complexity scale in water quality modelling by running and comparing a relatively complex model (QUAL2K) to a simple model. A mass balance nutrient model was constructed in-house to

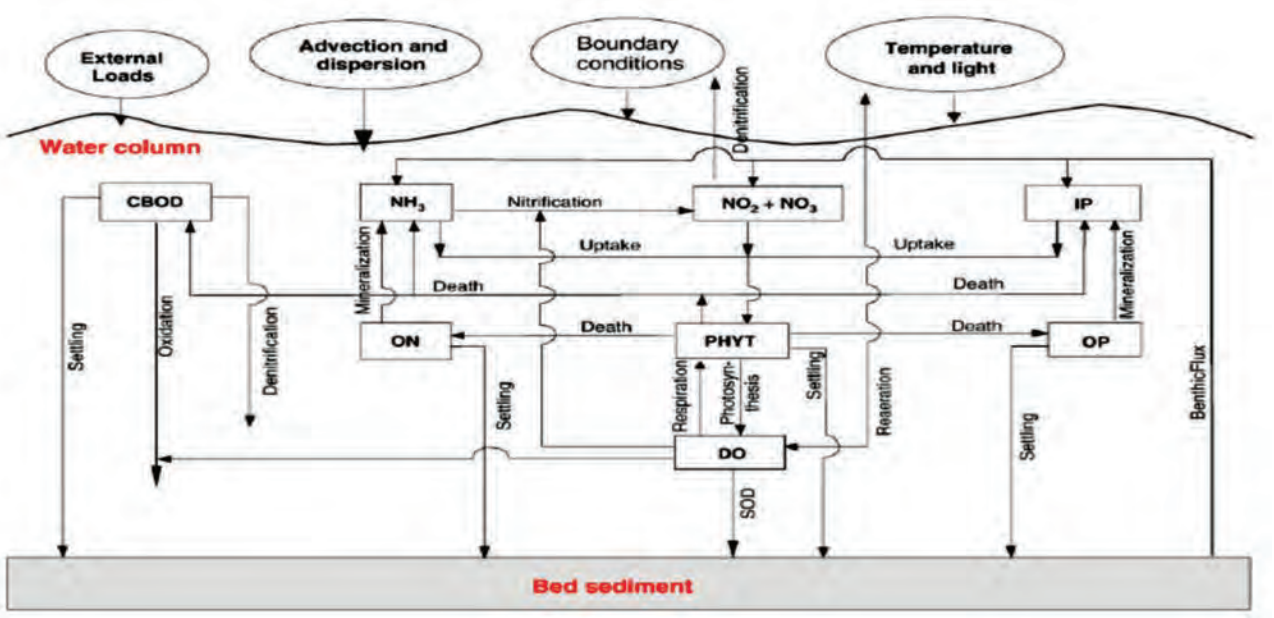


Illustration of the fate of nutrients in water (Hu and Li, 2009).

represent the simple model. The simple model requires minimal nutrient data when compared to QUAL2K and is more flexible in its use and can be used as both a fate and a dynamic model. Qual2k proved difficult to calibrate and confirmation results were poor, however, general trends in nutrients fate were represented. When used as a fate model the simple model provides more accurate simulations than QUAL2k, which is a fate model. However the simple model can be run as a dynamic model, simulating nutrient input from the entire catchment. The simulation of nutrient transport from the urban area of Grahamstown proved difficult due to the nature of the degraded municipal infrastructure. However, through using stochastic modelling techniques to represent the leaking pipes in Grahamstown and the Belmont Valley Waste Water Treatment Works, an acceptable simulation of the entire system was accomplished.

ASSESSING MODIS EVAPOTRANSPIRATION ESTIMATES FOR HYDROGICAL MODELLING APPLICATION IN SOUTH AFRICA.

Student: Mr S Mazibuko
Supervisor: Prof DA Hughes
Degree: MSc (Hydrology)

Evapotranspiration (ET) plays a key role in hydrology studies as ET represents a loss of water from a catchment. Although ET is a second largest consumer of catchment water balance, direct measurements of this important component of the hydrological cycle at the various temporal and spatial scales are still challenging and mostly, point estimates are used. This is as result of deficiency of adequate monitoring systems, especially in the developing countries or because measurements cannot be done in all catchments. In addition, potential evapotranspiration (PET) input for hydrological models is often simplified compared to the detailed estimates of catchment average precipitation used. This situation has an impact on proficient applications of hydrological prediction tools. In the current situation where water resources are threatened and demands are rapidly increasing, there is a great need for improved understanding and knowledge about hydrological components and its processes, for example catchment evapotranspiration dynamics. Hydrological predictions from hydrological models necessitate a great need for reliable and adequate hydrological data to improve predictions and to constrain model output. The use of remote sensing techniques has gained attention in Earth Sciences for their ability to provide hydrologic variable data at the scales required for modelling purposes. The aim of this study is to assess the potential use of evapotranspiration estimates, both actual and potential, from the Moderate Resolution Imaging Spectrometer (MODIS), MOD16 products, in driving the Pitman Model processes and constraining its simulation output in catchment of different climatic condition in South Africa. A method of extracting and generating a time-series of actual and potential evapotranspiration from MODIS areal data with the ultimate goal of reducing uncertainties associated with evaporation demand input was developed and applied to drive the Pitman Model. In testing MODIS data capabilities in improving model simulations, it was discovered that the overall impact of driving hydrological modelling with MODIS PET did not have significant differences when compared with model simulations using monthly distribution of potential evaporation from the A-pan. Noticeably, the model slightly underperformed when using MODIS PET while,

on average, the flows were to some extent increased. When constraining the ET output with MODIS ET, in few catchments that are slightly forested, this exercise had less success where the simulation of streamflow proved to be difficult due to the overestimation of ET. In most dry catchments, MOD16 ET was extremely underestimated making it impossible to simulate any realistic streamflow. However, the uncertainties in the MOD16 products were identified. While this study showed some potential of using spatially averaged MODIS PET data to drive hydrological processes, a challenge remains in identifying conditions that these data can perform better and to address the loopholes of MOD16Et overestimation.

MACROINVERTEBRATE-BASED BIOMONITORING OF THE BLOUKRANS RIVER, EASTERN CAPE, SOUTH AFRICA

Student: Ms N Mgaba
Supervisor: Prof CG Palmer
Co Supervisor: Mr ON Odume
Degree: BSc. Honours (Environmental Water Management)

Discharges from wastewater treatment works (WWTW), agricultural run-off and run-off from informal settlement are major sources of environmental pollution, affecting the ecological health of freshwater resources. The Bloukrans River, in the Eastern Cape of South Africa, receives wastewater effluent and run-off from the surrounding informal settlement as well as agricultural run-off, which impacts on its ecological conditions.

This project aimed to evaluate aspects of the ecological health of the river using macroinvertebrate-based single biotic index score, the South African Scoring System version 5 (SASS5) approach and a multimetric approach. Additionally, effluent from the Belmont Valley wastewater treatment work was characterised to ascertain green-drop compliance status. The study was undertaken at Bloukrans River and Belmont Valley wastewater treatment works (WWTW) between April and September 2013. Macroinvertebrates were sampled using the SASS5 protocol at one reference site (Site 1) in the Palmiet River and five sites in the Bloukrans River. Concurrently, water chemistry variables were measured. SASS5 scores and Average Score Per Taxon (ASPT) values in the reference site revealed good a water quality category, whereas water quality as indicated by both SASS5 scores and ASPT values were in the fair to very poor water quality range between Site 2 and Site 6, with improvement downstream of the effluent discharged point. In terms of green drop compliance, the results indicated that during the study period, effluent was not compliant. In addition, physicochemical variables indicated poor water quality from upstream to downstream of the river.

In conclusion, the study showed that the Bloukrans River water quality was affected by run-off and effluent from the WWTW. Appropriate management of both run-off and untreated effluent before discharge into the Bloukrans River should be initiated to improve the river's ecological status.

SIMULATING THE HYDROLOGY OF THE CALEDON RIVER USING THE PITMAN AND WEAP HYDROLOGICAL MODELS

Student: Mr T Mohobane
Supervisor: Prof DA Hughes
Degree: PhD (Hydrology)

The current research deals with simulating past and current hydrological regime of the Caledon River as well as predicting future hydrology under the influence of climate change. While this study takes into consideration the various changes affecting the water resources in the Caledon River Basin, it also focuses on the impacts of climate change. As it is widely accepted that quality and quantity of water resources are impacted by regional climate variability and change, the prediction of the future status of water resources is fundamentally reliant upon the predictions of future climatic conditions. Adequate understanding and reasonable simulations of the current state of water resources dynamics are a necessity to achieving reliable predictions of the future.

The main objective of the study will be achieved through the following specific objectives:

- Accounting for natural and artificial factors affecting the quantity of water within the basin.
- Assessing the skills of the climate models in simulating the average monthly historical rainfall.
- Simulating the past and the present hydrological regime of the basin influenced by the current and past state of the physical environment, observed climate conditions and estimated water use and demand.
- To predict the future status of water resources in the basin and to evaluate the impacts of climate change under predicted future climate conditions.
- Identify and assess major sources of uncertainty related with the use of both the hydrological and the climate models.
- Establish methods of reducing the uncertainties at various stages of the prediction process.

WATER SECURITY AMONGST IMPOVERISHED HOUSEHOLDS IN SUNDAYS RIVER VALLEY: COMMUNITY EXPERIENCES AND PERSPECTIVES

Student: Ms L Molony
Supervisor: Dr S Shackleton (Environmental Science)
Co Supervisor: Prof CG Palmer
Degree: M.Soc.Sci (Environmental Science)

This study is in its final stage and forms part of two broader projects within the Lower Sundays River Valley (LSRV) that are based in the Institute of Water Research funded by SANPAD[1] and GCSSRP[2] respectively. The LSRV forms part of this project as a study focusing on a catchment scale, and deals with the management of water resources by the Sundays River Valley Municipality (SRVM) and other stakeholders. These research projects grew out of the need to understand the complexities of water resource management at a municipal level. This specific study provided an understanding of the local context and community perspectives and experiences of the realities of water security, and explored the linkages between social water scarcity, water security and livelihoods within the SRVM.

The overall aim of this study was to provide a lens into the water security experiences of two poor township communities in the SRVM; Nomathamsanqa in Addo and Aquapark in Kirkwood. This was done through assessing water security patterns amongst Reconstruction and Development Programme (RDP), township and informal settlement households serviced by the SRVM. Differential experiences amongst these three groups with regard to securing, accessing and negotiating the use of water were explored as well as household water needs, uses, water quality concerns, experiences of service delivery and coping strategies. This study found that both township communities are faced with water security problems, specifically it was found that communities face problems with water shortages and cuts in municipal water supply, water quality problems, issues surround the payment for water and dissatisfaction with water service delivery. Therefore, this study concluded that these communities within the SRVM experience great challenges in securing safe water and these are due to social water scarcity and the difficulties the municipality is faced with, in regards to water service delivery.

Leakages and broken taps are common in Nomathamsanqa (picture 1) and Aquapark (picture 2 and 3)

A older women fetching water: she complains about the distance from the community standpipe to her house as it takes her about 20 minutes (left), Many residents have to walk a far distance to find available water (Nomathamsanqa, 2012 (right).

[1]*SANPAD: Water and Sustainability*, assessing how water resource researchers, practitioners, users and policy developers most effectively collaborate, using knowledge, to realise the goals of equity and sustainability in the practice of water resources management and development in southern Africa. [2]GCSSRP: *Water and Society*. A transdisciplinary research programme of case studies is the Eastern and Southern Cape regions in South Africa, specifically the Sundays River Catchment. The goal is to develop knowledge of, and model small rural municipal functionality in governance, service delivery and adaptive planning to ensure water security in contexts such as the Sundays River Catchment.

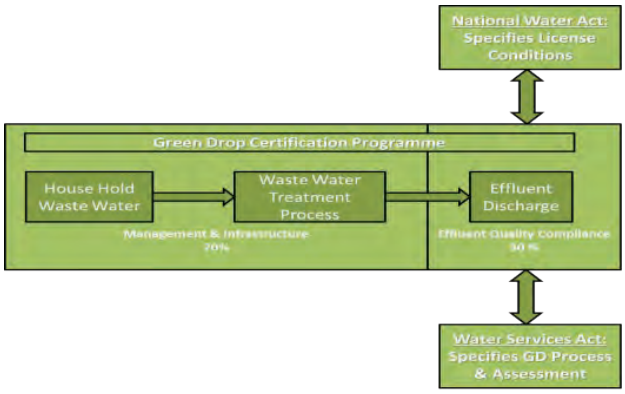
LINKING INSTITUTIONAL AND ECOLOGICAL PROVISIONS FOR WASTEWATER TREATMENT DISCHARGE IN A RURAL MUNICIPALITY, EASTERN CAPE, SOUTH AFRICA

Student: Mr M Muller
Supervisor: Prof CG Palmer and Ms A Holland
Degree: MSc (Water Resource Science)

With the inception of democracy in South Africa in 1994, there was a need to address the vast inequalities to access and use of water resources and services around the country. The need to address the social inequalities more so than environmental protection saw the Water Services Act (No. 108 of 1997) (WSA) and the National Water Act (No. 36 of 1998) (NWA) drafted as separate acts instead of a single act. This creates a divide between protection of water and the environmental (NWA) and the delivery and use of water and sanitation services (WSA). Ideally these acts should have been combined as a single act to be used by water managers around South Africa which would help South African water managers embraced the ideals of Integrated Water Resource Management promoted

by the NWA. The focus of this research was to assess whether Green Drop, an incentive based monitoring programme for wastewater treatment works, can act as a linking tool between the two acts. Green Drop (GD) is an initiative facilitated by DWA towards the improvement of the wastewater sector. Although GD is an incentive based programme, it is not optional for municipalities to participate. Municipalities, as Water Service Authorities, are legally required to participate through submission of data (section 62 and 82 of WSA).

The Green Drop programme assesses the entire business of wastewater treatment from the consumer to the environment and the operational and management procedures in between. A small percentage (30%) of this score examines the quality of the effluent being discharged into the river. It is this 30% which determines whether a wastewater treatment works is complying with its license conditions, which are covered by the NWA and the WSA. The other 70% examines the day to day running of the plant, emergency protocols and long term plans. This is illustrated in the figure below.



Areas that are covered by the Green Drop Programme and linkages to political tools; the NWA (No. 36 of 1998) and the WSA (No. 108 of 1997).

Little work has been done on the effects of domestic wastewater treatment works on small rivers in South Africa. Thus, the project conducted an assessment of the compliance of a small domestic wastewater treatment works as well as the effects of its effluent on the Uie River, a small tributary of the Sundays River. The motivating question behind the research was "if the treatment works met its license conditions, would the river meet its eco specs?". The basic ecological category for the river was determined using biomonitoring (SASS data which were input into the Macroinvertebrate Response Assessment Index), habitat (Integrated Habitat Assessment Index) and water chemistry data which were collected monthly over the period of a year. The data were collected from three sites, namely a reference site, a site downstream of the discharge point and a recovery site further downstream. The instream data were then compared to the effluent quality data to assess the magnitude of the impact of the wastewater works on the river. The overall conclusion was that the wastewater treatment works was not meeting its license criteria which meant the magnitude of the effect on the river health was greater than it would have been if the plant was complying.

The second part of the project examined whether GD is an effective tool in bringing about improvement in the wastewater treatment sector by linking the NWA and the WSA. The changing criteria for each assessment make it difficult for struggling municipalities, or municipalities which have not participated in every assessment, to perform well. There are often suites of compounding issues outside of the Green Drop assessments which slow this improvement in wastewater treatment performance. Assistance from the Department of Water Affairs tends to be presented in a generic manner and needs to be more site specific. However, it was concluded that the programme shows a lot of promise, and that municipalities which have participated from the start have seen continuous improvement.

INTEGRATED ENVIRONMENTAL WATER QUALITY MANAGEMENT OF THE SWARTKOPS RIVER, USING WATER CHEMISTRY, WHOLE EFFLUENT TOXICITY TESTING AND MACROINVERTEBRATE-BASED BIOMONITORING

Student: Mr ON Odume
Supervisor: Prof CG Palmer
Degree: PhD (Water Resource Science)

Increased pollutions of freshwater ecosystems have adversely affected their capacities to provide clean and reliable sources of freshwater, maintain the natural hydrological cycle and ecosystem attributes including structures, functions and processes. Although there are several sources of pollution of South Africa's surface freshwater resources, a major contributor is the discharge of wastewater effluents into receiving rivers and streams. Wastewater effluent discharges, which constitute over 50% of the downstream river flow of the Swartkops River during low flow periods, are a major contributor to the observed elevated nutrient levels, metal concentrations, faecal contamination, and excessive algal and macrophyte growth in the river system.

To minimise the impacts of discharged effluents on receiving freshwater bodies, the South African Department of Water Affairs (DWA) in 2008, introduced an incentive-based Green Drop regulation programme, which seeks to regulate the management and operations of all wastewater treatment works to ensure final effluent quality compliance. Although some progress has been made, the water quality of most effluent receiving rivers and streams including the Swartkops River continue to degrade. Therefore, to ensure that discharge wastewater effluent has minimal ecological impacts on receiving water resources, there is a need to develop an integrated approach for measuring and monitoring effluent quality,

and quantifying effluent effects on in-stream biota.

The overall aim of this study was to develop an integrated approach for managing environmental water quality in the Swartkops River, using water chemistry, ecotoxicology and macroinvertebrate-based biomonitoring. The following objectives were set to achieve this overall aim: I) to established macroinvertebrate distribution, ecology and function in the Swartkops River, using both taxonomic and traits measures; II) to develop a novel chironomid species trait-based approach to biomonitoring in the Swartkops River, with potential for use in other similar river systems; III) to develop a model stream ecosystem approach suitable for ecotoxicological investigation of long-term effluent effects on macroinvertebrate communities; IV) to develop a chironomid deformity-based sub-lethal bioassessment tool for monitoring the Swartkops River with potential for use in other river systems and; V) develop a conceptual framework for integrated environmental water quality management of the Swartkops River.

WATER SUPPLY INFRASTRUCTURE DECISION-MAKING IN SOUTH AFRICA

Student: Mr IR Preston
Supervisors: Profs L Louw, CG Palmer and JN Blignaut
Degree: MComm (Management)

South Africa is a semi-arid country that has a well-developed network of water supply infrastructure. Dams have been built in nearly all of the economically viable locations in South Africa, and further dams will have to be built in the less desirable and more costly locations. The water quality of many rivers in South Africa is declining due to pollution, high abstraction, increasing eutrophication and alien invasive fish and plants. It is predicted that climate change will exacerbate these aforementioned issues.

This study aims to better understanding the decisions, which need to be made when developing water supply, for the improved long-term management of South Africa's finite water resources. It also aims to make available useful data and a decision-making framework to inform discussion amongst water supply development decision makers.

The purpose of this study will be achieved by determining what the key costs, benefits and decisions are that should be taken into account when faced with choices concerning raw water supply in a South African context. More specifically, this study will have a historical focus on the construction costs and environmental management (through looking at ecosystem services) of selected dams, with the decision-making findings being applied to a catchment in which a dam is currently being implemented.

It has been found that construction cost data are not readily available for dams built in South Africa, especially those dams built more than twenty years ago. The cost data in question include estimated costs; actual costs; and operations and maintenance costs. Estimated cost data for some dams were available in white papers; actual cost data were much more difficult to get hold of and tricky to compare between dams. A breakdown of operations and maintenance costs does not exist at a per dam level, however national totals do exist.

A further finding is that there is a trend that the actual costs of dams are significantly different to the estimated costs. This trend has been found after taking inflation into account. The reasons for this trend still need to be scrutinised and explained.

INVESTIGATING INTEGRATED CATCHMENT MANAGEMENT SCENARIOS USING A "SIMPLE" WATER QUALITY AND QUANTITY MODEL: A CASE STUDY OF THE CROCODILE RIVER CATCHMENT, SOUTH AFRICA.

Student: Mr DCH Retief
Supervisor: Prof DA Hughes and Dr A Slaughter
Degree: MSc (Water Resource Science)

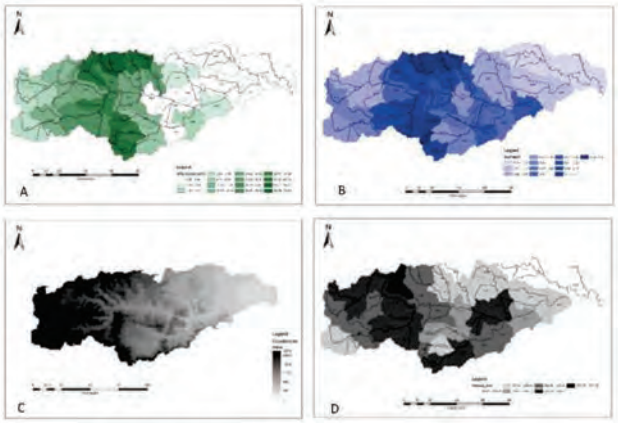
The Crocodile River Catchment, which is located within the Mpumalanga Province of South Africa, has been experiencing a decline in water quality as a result of the point source input of a cocktail of pollutants, which are discharged from industrial and municipal wastewater treatment plants, as well as from diffuse source runoff and return flows from the extensive areas of irrigated agriculture and mining sites (Deksissa, et al., 2004). The decline in water quality has profound implications on a range of stakeholders across the catchment. The major implication is the financial repercussions incurred by stakeholders particularly that rely on high water quality for production, as they must face the increase in costs of treating water extracted from the Crocodile River. Even more importantly the Crocodile River flows out of the catchment into a bordering country, Mozambique, and South Africa is governed by international treaties to regulate the quantity and quality of rivers leaving South Africa (Palmer *et al*. 2012).

One of the research requirements on the status of water quality in the Crocodile River Catchment (CRC), as identified from the research conducted by Palmer *et al.* (2012) based on results of stakeholder engagement, is that there is a need for understanding the relationship between surface water flow and water quality to be able to determine compliance (or non-compliance) of water users within the catchment. Therefore, this research will attempt to understand the relationship between quantity and quality of surface water in the Crocodile River Catchment (CRC) with the use of the Water Quality Systems Assessment Model (WQSAM) model. This research will contribute to a larger project with the aim of building a co-operative,

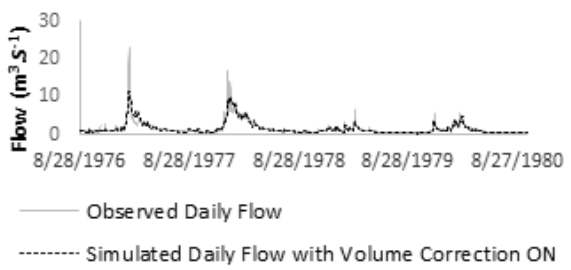
implemented and integrated water quality management process (IWQMP) in the CRC.

The year 2013 involved consolidating all data (rainfall, land use maps in the first figure showing catchment characteristics and observed daily flows, required for disaggregating simulated monthly incremental flows (an output from the Water Resources Modelling Platform (WReMP)) to daily simulated incremental flows. Other data consolidated include all observed water quality measurements for monitoring stations across the CRC including air temperature datasets used for water temperature modelling. Many challenges have been encountered throughout the process of consolidating data. These include gaps in all the observed data sets obtained as well as the variations in data set format. A number of methods were implemented to identify gaps as well as to streamline processing of all datasets in the required format.

Seven of the CRC quaternary catchments and one from the Buffalo River Catchment were disaggregated for and will be used in the development of a regionalisation model to disaggregate for ungauged catchments (see first figure). Results for the disaggregation process had Nash-Sutcliffe model efficiency coefficients ranging from 0.494 – 0.862, observed vs. simulated daily flows are presented in in the second figure.



Land use characteristics to be used in the regionalisation model for disaggregation for the Crocodile River Catchment, A) Afforestation as a percentage of land surface coverage, B) Aridity as a ratio of Mean Annual Precipitation and Mean Annual Evapotranspiration, C) Elevation in meters above sea-level, C) Mean elevation change (m).



Observed vs. simulated disaggregated flow for quaternary X22A in the Crocodile River Catchment

AN EXPLORATION AND CRITICAL ASSESSMENT OF THE DEVELOPMENT OF AN INTEGRATED, PARTICIPATIVE, WATER QUALITY MANAGEMENT PROCESS FOR THE CROCODILE RIVER CATCHMENT, FOCUSING ON THE SUGAR INDUSTRY

Student: Ms A Sahula
Supervisor: Prof CG Palmer
Co-Supervisors: Dr S Mantel and Mr V Munnik
Degree: MSc (Water Resource Science)

Water quality deterioration is reaching crisis proportions in South Africa (CSIR, 2010; Ashton and Dabrowski 2011). Many South African catchments are over-allocated, and decreasing volumes of source water mean increasing concentrations of pollutants. Low source water quality is becoming a critical risk in terms of costs and productivity to many industries. The Crocodile River Catchment in Mpumalanga province in South Africa is faced with the deterioration of source water for water users in the catchment. Low water quality is becoming a sufficiently acute concern for stakeholders and they need to co-operate to develop a process that will assist with compliant control of their water use and waste disposal. This will reduce costs of enforcement, and industrial risks will decrease as water quality compliance, and therefore source water quality improves.

Businesses in the Crocodile catchment are facing direct risks and costs to profitability. These risks and current costs include the following: low source water quality escalates the costs of in-house treatment for mining, sugar milling, water boards, and beverage and paper manufacturers (Deksissa et al., 2003). It also reduces the productivity of sugar cane and citrus crops and this is a risk to the export quality of citrus and sugar. This study aims to critically explore the development of an integrated, participative, water quality management process for the Crocodile River Catchment, focusing on the sugar industry. The sugar industry is downstream within the Crocodile River Catchment and thus affected by the activities of upstream water users, and dependent on the stakeholders upstream participating in the effective management of the resource. This study looks to examine how the sugar industry can work together with other stakeholders in the Crocodile River Catchment to least affect the Instream water quality of the Crocodile River. This research will contribute to a larger project with the aim of building a co-operative, implemented and integrated water quality management process (IWQMP) in the Crocodile River Catchment.

A view of TSB Malelane Sugar Mill, Nelspruit, spray dams to cool water used in phases of sugar manufacturing before it is released back into the resource (at Stingspruit channel into the Crocodile River).

ASSESSMENT OF THE SURFACE AND GROUND WATER INTERACTION COMPONENTS OF THE PITMAN RAINFALL-RUNOFF MODEL

Student: Ms J Tanner
Supervisor: Prof DA Hughes
Degree: PhD (Hydrology)

The connections between surface water and groundwater systems remain poorly understood in many catchments throughout the world and yet, they are fundamental to effectively managing water resources. Managing water resources in an integrated manner is not straightforward, particularly if both resources are being utilised, and especially in those regions that suffer problems of data scarcity. This study explores some of the principle issues associated with understanding and practically modelling surface and groundwater interactions. In South Africa, there remains much controversy over the 'best' type of integrated model to be used and the way forward in terms of the development of the discipline; part of the disagreement stems from the fact that we cannot validate models adequately. This is largely due to traditional forms of model testing having limited power as it is difficult to differentiate between the uncertainties within different model structures, different sets of alternative parameter values and in the input data used to run the model. The approach used in this study is focused on fundamental understanding of hydrological systems rather than calibration based modelling and promotes the use of all the available 'hard' and 'soft' data together with thoughtful conceptual examination of the processes occurring in an environment to ensure as far as possible that a model is generating sensible results by simulating the correct processes. A number of South African case studies were used to examine the types of data typically available and explore the extent to which a model is able to be validated considering the difficulty in differentiating between the various sources of uncertainty. While the lack of appropriate data means there will always be considerable uncertainty surrounding model validation, it can be argued that improved process understanding in an environment can be used to validate model outcomes to a degree, by assessing whether a model is achieving the right results for the right reasons.

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Palmer CG, du Toit D, Griffin N and Pollard S (2013) Building a co-operative, implemented Integrated Water Quality Management Process (IWQMP) in the Crocodile River Catchment. 10th annual Savanna Science Network Meeting, Skukuza, Kruger National Park, South Africa 5-9 March 2013.

Palmer CG (2013) Transdisciplinary research practice within social ecological systems. Invited seminars in the School of Environmental Science, and the Institute for Sustainable Futures University of Technology, UTS Sydney, Austrialia. September 2013.

Palmer CG (2013) Water for people and people for water. National Sustainabiliy Week Conference. Sandton City, Johnnesburg, South Africa. October 2013.

Slaughter A and Hughes DA (2013) Linking a water quality model to an existing water resources yield model. Paper presented at the IAHS General Assembly, Gothenburg, Sweden, July 2013.

Slaughter AR, Mantel SK and Hughes DA (2013) Water quality implications of uncertain future climate and development in the Amatole System, Eastern Cape, South Africa. Paper presented at the SASSqS 2013 conference on Catchments, Coastal Interfaces and Communities, Arniston, South Africa, 30 June-4 July 2013.

Tanner JL and Hughes DA (2013) Validating hydrological models in a data scarce environment-Getting the right results for the right reasons. Paper presented at the *Biennial Conference of the Groundwater Division of the Geological Society of South Africa*, Durban, South Africa 11-19 September 2013.

Back Cover
(top to bottom): Ms Louise Bryson and Dr Neil Griffin with the 2013 Environmental Awards on behalf of IWR Unilever Centre for Environmental Water Quality and CRG; At the IWR Open day, with Prof Denis Hughes, Mr ET Myalato (Acting Municipal Manager and Technical Director of the Makana Municipality) and Prof Tally Palmer; Eluxolweni Shelter children learning about mini sass and water quality during an outing organised with Water for Dignity, Rotary and UCEWQ; Prof Tally Palmer and research group outing to Botanical Gardens, Grahamstown.

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