# INSTITUTE FOR WATER RESEARCH



# 2010

# **ANNUAL REPORT**





# STAFF AND MEMBERS OF THE INSTITUTE 2010

### STAFF

Mr David Forsyth Ms Helen Fox Ms Pearl Gola Mr Andrew Gordon Dr Neil Griffin Ms Alex Holland Mr Greg Huggins Prof Denis Hughes Mr Tarqyn Human Ms Delana Louw Mr Stephen Mallory Dr Sukhmani Mantel Ms Juanita McLean Prof Tally Palmer Ms Candice Roux Principal Technical Officer Part-Time Environmental Officer UCEWQ-IWR Jnr Research Officer UCEWQ-IWR Research Officer UCEWQ-IWR Research Officer UCEWQ-IWR Research Intern UCEWQ-IWR Research Officer Water for Africa Professor | Director of IWR Technical Officer UCEWQ-IWR Research Officer IWR Source to Sea Research Officer IWR Water Resources Postdoctoral Fellow Administration Manager Professor | Director of UCEWQ Senior Technical Officer

### ASSOCIATE

Prof Brian Allanson Dr Nikite Muller Honorary Research Fellow of Rhodes University Research Associate

### **REGISTERED POSTGRADUATE STUDENTS**

Ms Siphesihle Bukhosini	MSc (Hydrology)
Mr Ahmed Desai	PhD (Hydrology)
Ms Pearl Gola	PhD (Water Resource Science)
Mr Andrew Gordon	PhD (Water Resource Science)
Ms Alex Holland	PhD (Water Resource Science)
Mr Evison Kapangaziwiri	PhD (Hydrology)
Ms Audrey Mashao	MSc (Water Resource Science)
Mr Felike Mekiso	MSc (Hydrology)
Mr Paul Mensah	PhD (Water Resource Science)
Ms Bronwyn Moore	PhD (Water Resource Science)
Ms Irene Naigaga	PhD (Ichthyology); based at Makerere University, Uganda
Mr Nelson Odume	MSc (Water Resource Science)
Ms Boluwaji Onabolu	PhD (Water Resource Science)
Mr Andrew Slaughter	PhD (Water Resource Science)
Ms Jane Tanner	MSc (Hydrology)
Ms Sithabile Tirivarombo	PhD (Water Resource Science)
Mr Raphael Tshimanga	PhD (Hydrology)
Ms Madeka Tumbo	PhD (Hydrology); based at The University of Dar es Salaam, Tanzania
Mr Agostinho Vilanculos	PhD (Hydrology); based at Eduardo Mondlane University, Mozambique

### 2010 GRADUATED STUDENTS

Mr Bonga Zuma

MSc (Water Resource Science)

### MEMBERS OF THE BOARD OF CONTROL

Prof P Clayton	Chairman; Rhodes University, Dean of Research
Dr J Adams	NMMU, Botany Department
Mr J Dini	SANBI (South African National Biodiversity Institute)
Ms L Duys	Unilever SA
Dr J Gambiza	Rhodes University, Department of Environmental Science
Dr PW Froneman	Rhodes University, Department of Zoology and Entomology
Prof DA Hughes	Rhodes University, Institute for Water Research
Dr S Liphadzi	WRC (Water Research Commission)
Ms J McLean	Secretary to BOC and Administration Manager
Mr M Nepfumbada	DWA (Department of Water Affairs)
Prof K Rowntree	Rhodes University, Department of Geography
Mr J Venter	SANP (South African National Parks Board)
Dr A Whitfield	SAIAB (South African Institute for Aquatic Biodiversity)

Front Cover (top to bottom): Nelson Odume SASS sampling in the Swartkops River | Science Day at Yellowoods School | Neil Griffin sampling at RBM | SASS sampling during an Environmental Science field trip to the Palmiet River | Sithabile Tirivarombo at the WaterNet/WARFSA Symposium. Photos kindly supplied by IWR staff and students

# TABLE OF CONTENTS

1. IWR Director's Report	4
2. UCEWQ Director's Report	
3. Hydrology Projects	10
4. Environmental Water Quality Projects	14
5. Postgraduate Activities	20
6. Research Outputs	26



(From left to right) Back Row: H Fox, N Griffin, D Forsyth, A Slaughter Third Row: S Mantel, J Tanner, J McLean, N Muller, D Hughes, T Human Second Row: E Corrall, P Mensah, C Roux, P Gola, B Zuma, A Gordon Front Row: A Holland, S Tirivarombo, R Tshimanga, E Kapangaziwiri, N Odume Absent: A Mashao, B Onabolu

Institute for Water Research | Rhodes University | Old Geology Building | Artillery Rd | PO Box 94 | Grahamstown 6140 Tel: +27-46-6224014/2428 or +27-46-6038532/8334 | Fax: +27-46-6229427 Email: iwr@ru.ac.za | Web: http://www.ru.ac.za/iwr

# INSTITUTE FOR WATER RESEARCH (IWR)

# **1. IWR DIRECTOR'S REPORT**

### Introduction

There have been several developments in IWR staffing during 2010. The most critical change involved the resignation of Dr Nikite Muller to take up a post at Amatole Water, which left a huge gap in the management and student supervision capacity within the Institute. Fortunately, Dr Muller has agreed to become an Associate Research Officer and, as a member of the Science Faculty, can continue to supervise some of the students. Dr Muller made substantial contributions to the research and management functions of the IWR and while we were all very sorry to see her leave, we wish her well in her new and challenging career. The gap was filled in the middle of November by the appointment of Prof Tally Palmer as a full Professor and Director of the Unilever Centre for Environmental Water Quality. Since returning from Australia, Prof Palmer has been working at the NRF and we welcome her back to the IWR and look forward to benefitting from the experiences that she has gained both in Australia and dealing research administration in the NRF.

Ms Candice Roux, who occupies the university post of Senior Technical Officer, resigned towards the end of 2010 (with effect from the end of March 2011) and we have started the process of appointing a replacement in cooperation with the Rhodes Human Resources Division. We are hoping that a replacement staff member can be appointed before Ms Roux leaves so that the new person can be trained in some of the duties of the post. We are very grateful to Ms Roux for the efficient way in which she has managed the technical support tasks and wish her well in her new post as Chief Technical Officer in the Department of Zoology and Entomology.

We welcomed the youngest member of the Institute during 2010 after Ms Pearl Gola gave birth to a new potential female water scientist called Simangaliso. Pearl returned to the office environment during October after her maternity leave. In contrast to the relatively short time that Ms Roux spent in the IWR, Ms Juanita McLean has been looking after us all for just over 20 years and Mr David Forsyth has been solving our computer problems for 16 years. Given that both Juanita and David hold contract positions within the University, with all the implications of lack of job security, I believe that the Institute owes them a huge debt of gratitude for their support and loyalty that has been sustained over a long period of time.

The senior staff of the Institute continued to be actively involved in policy development and advisory committees at regional, national and international levels. Dr Muller served on the board of Amatola Water (responsible for water supply services in the East London and King Williams Town area) before joining them as a staff member, while Prof. Hughes serves on the South African Committee for the UNESCO International Hydrological Programme (IHP) and is chairperson of SANCIAHS (South African Committee for the International Association of Hydrological Sciences). Internationally, Prof Hughes was appointed as a vicepresident of the IAHS during 2009 with responsibility for developing countries. He also serves on the Scientific Steering Group for the IAHS PUB (Predictions in Ungauged Basins) programme and is regional coordinator for the southern Africa FRIEND (UNESCO) programme. Andrew Gordon continues to serve as Public Relations Officer for the Aquatox Forum Management Committee. Prof Tally Palmer has been appointed by the former Minister of Water and Environmental Affairs (Hon Ms Sonjica) to chair the new National Water Advisory Committee. Further details of this new committee will be available soon, but this is an exciting development for the IWR and for Rhodes as a whole.

### International links and conferences

It has been a very active year for staff and students in terms of attendance at workshops and conferences, both locally and internationally. Prof Hughes attended the Water Sector Skills Development conference in Port Elizabeth during February and the Kovacs Colloquium (Hydrocomplexity: New Tools for Solving Wicked Water Problems) in Paris, France, during July 2010. While in Paris, Prof Hughes also attended the Bureau Meeting of IAHS in his capacity as a vice-president. Prof Hughes attended the British Hydrological Society International Conference on the 'Role of Hydrology in Managing Consequences of a Changing Global Environment' held in Newcastle-Upon-Tyne, UK, during late July as well as the 6<sup>th</sup> International FRIEND conference (Global Change - Facing Risks and Threats to Water Resources) in Fez, Morocco during November. Dr Mantel also attended the FRIEND conference and two papers from the IWR were presented.

Prof Hughes participated in a workshop on water accounting that was organised during September in Prato, Italy by Monash University. The purpose of this workshop was to review all of the chapters that are being prepared for a book on water accounting. The IWR contributed a chapter on 'Potential for the application of the preliminary Australian water accounting standard (PAWAS) in South Africa' authored by Hughes, Corral and Muller. The book is expected to be published during early 2011 and is based on some of the work that was undertaken by Ms Esther Corral, the Spanish intern student who was with us for about 6 months between October 2009 and March 2010. UCEWQ staff and students participated in a workshop held during February with staff from the DWA Resource Quality Services aimed at investigating the potential contribution of episodic toxicity data to environmental water quality management in South Africa

Mr Andrew Gordon, Ms Alex Holland and Dr Neil Griffin attended a seminar on the management of water resources using resource quality objectives presented by DWA and Institute for Natural Resources during September. They also joined Ms Pearl Gola in attending the Aquatox Forum's seminar on risk assessment of emerging pollutants. Dr Griffin, Mr Gordon and Dr Muller were authors on a poster paper that was presented there.

Mr. Nelson Odume and Mr Paul Mensah presented oral papers at the 31<sup>st</sup> congress of the International Limnological Society held in Cape Town during August, 2010. The conference gave both students the opportunity to present their work at a conference attended by delegates from over 17 countries. In addition, the students had the opportunity to interact with leaders in their field.

For the first time since its establishment in 2008, the RISE project brought together students, academics, administrators and government representatives from its five member networks to share experiences and nurture closer collaboration among African Universities. The conference was held in Benoni during October 2010. Prof Hughes and Dr Mantel attended in their capacities as Director and Administrator of the SSAWRN network, while four of the RISE students from the IWR presented summaries of their research work at the conference. Oral papers were presented by Jane Tanner and Raphael Tshimanga while Nelson Odume and Irene Naigaga presented posters. The conference presented an opportunity for vice chancellors, other academic heads and students to interact.



RISE students from South Africa and Mozambique who attended the 11th WaterNet/WARFSA Symposium held in Zimbabwe, October 2010

One of the highlights for the RISE students was attendance at the 11<sup>th</sup> WaterNet/WARFSA symposium during October and held in Victoria Falls, Zimbabwe. The conference brought together academics, practitioners and policy makers from the water sectors from Africa, Europe and Asia. The conference objective was to enhance linkages between scientists, policy makers and practitioners. Oral papers were presented by Jane Tanner (MSc Hydrology), Bolu Onabolu (PhD Water Resource Science), Irene Naigaga (PhD Water Resource Science), Nelson Odume (MSc Water Resource Science) and Paul Mensah (PhD Water Resource Science). Poster presentations were made by Sithabile Tirivarombo (PhD Water Resource Science) and Raphael Tshimanga (PhD Hydrology). The students from the other participating universities in the RISE, SSAWRN network also presented papers or posters at the conference.

### **Consultancy links**

While some Institute staff continue to contribute to consultancy projects and we have maintained our links with consultancy groups, there has been less activity in this area than in previous years. This trend is inevitable, given the additional work load created by student supervision. It is important that we do not lose the links with practical problem solving which has always been one of the strengths of the IWR and has provided an immediate market for some of its applied research products.

### Undergraduate teaching

The Institute continue to contribute to the Department of Environmental Science ENV302 course. With Prof Hughes, Mr Gordon and Dr Mantel covering water quantity, quality and legal issues within the context of water resource management and the South African National Water Act. Additional contributions from the staff members of UCEWQ are referred to in a separate part of the report.

### Post-graduate students

Mr Bonga Zuma obtained his MSc degree at the 2010 ceremony, while Mr Evison Kapangaziwiri has successfully survived the examination process for his PhD and will graduate during 2011. At the time of writing this report (mid-November 2010) Mr Andrew Gordon (PhD), Mr Andrew Slaughter (PhD), Mr Nelson Odume (MSc) and Mr Feleke Mekiso (MSc) were all working very hard to complete their thesis documents for submission for examination before the end of the year. In the meantime Ms Jane Tanner is preparing a motivation for the Science Faculty to upgrade from an MSc to a PhD.

Mr Evison Kapangaziwiri attended the University of Cape Town 2 week Winter School on 'Using climate information for adaptation and policy development' in July. This was hosted by the Climate Systems Analysis Group incollaboration with the Stockholm Environmental Institute. The course covered concepts of climate change, vulnerability and adaptation; analysis of climate data for change and variability; regional climate change scenarios; uncertainty, probability, climate envelopes and risk assessment; vulnerability, impacts and adaptation in key sectors; extreme events and threshold analysis.

Two new students joined the IWR during 2010. Ms Boluwaji Onabolu (PhD, Water Resources Science) is sponsored through the RISE SSAWRN programme, while Ms Audrey Mashao is working on a WRC project associated with climate change and water resources management adaptation strategies for South African Water Boards. Ms Mashao is participating in an UNESCO-IHE Delft online course on "IWRM as a tool for adaptation to climate change" scheduled from August 2010 to February 2011. The course modules include impacts of climate change on water and environment, on society, uncertainty in water resources, climate change adaptations and IWRM. She has scored 85% in the first module completed.

The RISE students (2 MSc and 4 PhD) attended a 4 week GIS course held by the Department of Geography, Rhodes University. It was an intensive course that provided the students with skills in the use of GIS in water resources management. During the course three of the students went on a field trip to Cape Town where they visited relevant organisations and were taught practical tools in GIS applications. Ms Onabolu was one of the students who received a Rhodes University Community Engagement scholarship award for the work carried out on a GIS group project. The Institute for Water Research has been awarded a contract for an international consultancy from November 2010 - July 2011 by UNICEF Kenya in partnership with UNICEF New York, to evaluate the Kenyan household water treatment and storage (HWTS) national programme. The main objectives are to assess the efficacy, sustainability and user adoption of technologies after external support and promotion have been withdrawn. This award will be used to support the work that Ms Onabolu will be doing for her PhD on the development of a global summary paper on HWTS for UNICEF to inform future policies, funding and decision making.

At the Waternet/WARFSA conference, Mr. Nelson Odume won one of the four distinguished young scientist awards (< 35 years) for best oral presentation. The prize is financial support for accommodation and living expenses during a period of PhD literature review in any Western Cape University of his choice. Ms Sithabile Tirivarombo was awarded a Faculty for the Future Fellowship for the 2010 academic year. She joins a network of 142 women who are currently being sponsored by the Schlumberger Foundation. The Faculty for the Future is a capacity building initiative in the education sector in emerging economies to encourage women in their pursuit of academic careers in science and technology. This grant supplements the Carnegie RISE funding for this student.

In May, Ms Tanner, Ms Tirivarombo and Mr Tshimanga, three of the RISE hydrology students, attended a catchment hydrology field school organised by the University of Kwazulu Natal and co-sponsored by Waternet, Water Research Commission of South Africa (WRC), School of Bioresources Engineering and Environmental Hydrology (BEEH) and the French Institute of Research for Development (IRD). The training mainly targeted post graduate students from Southern Africa as part of regional capacity enhancement of young hydrologists in the region. The entire field course was undertaken in the Potshini catchment at the foothills of the Drakensberg Mountains, where they were exposed to the various techniques of field measurements and data analysis with regards to infiltration and runoff generation. The main outcome of the course was an improved understanding of infiltration under different conditions of land cover and land use and the factors likely to have an impact on the runoff generation.

During June, all the RISE students (and Ms Mashao) from the Sub-Saharan Africa Water Resources Network (SSAWRN - University of Botswana, Eduardo Mondlane University, Makerere University and Rhodes University) attended a thesis writing course held at Rhodes University. The course was given by two very capable people from the University of Johannesburg and was a great success. Outcomes included enhanced networking amongst the RISE nodes and an improved understanding of the need for better research management and thesis writing skills.

While the Institute's post-graduate numbers are very healthy (11 PhD and 5 MSc students, including the RISE group) a number of problems remain. One is the ongoing difficulty of attracting suitably qualified students from within South Africa, while the second is the limited supervision capacity within the IWR. The bulk of the supervision load during 2010 rested on Prof Hughes and Dr Muller (with future inputs expected from Prof Palmer) and while the RISE funding includes funding for salary replacements, the IWR is not in a position to employ further senior staff without additional funds to guarantee a senior salary for a contract period of at least 3 years. This has always been a stumbling block for attracting staff to the IWR, but is becoming critical and is now the main factor limiting our capacity to accept further post-graduate students. During 2010 we will be adding new RISE students to the group and we desperately need to increase the supervision capacity.

### Post-doctoral posts

Dr Sukhmani Mantel joined the Institute in July 2006 and has been supported by various funds including Rhodes University Post-Doctoral bursaries. She is currently filling the role of secretary for the RISE Water Resource Network. At the end of 2010 she had managed to obtain the required South African work visa and we should now be able to process her appointment as formal contract member of staff.

### **RISE Sub-Saharan Africa Water Resources Network**

Previous reports have referred to the Carnegie RISE, SSAWRN, the first phase of which is coming to an end during the first quarter of 2011. During the RISE international conference, held in October 2010, the managers of the programme – the Science Initiative Group (SIG) of Princeton University presented some of the details for a proposal to the Carnegie Corporation of New York for a second phase lasting from 2011 to 2013. SIG expressed confidence that the continuation proposal would be successful at approximately the same level of funding as the first phase (US\$800 000 over the three year period). As the coordination centre for SSAWRN the IWR has already distributed a call for new students to apply for bursaries and placements under the 2<sup>nd</sup> phase. By the middle of November 2010 we had already received a large number of applications and we will start the selection process after the deadline for submissions in early December.

Other activities directly associated with RISE SSAWRN are referred to elsewhere in the Director's report (see International links and conferences as well as the Postgraduate students section). Individual reports on the student projects are also included later in the annual report.

During the FRIEND conference in Fez, Morocco, Prof Hughes discussed the integration of the FRIEND and SSAWRN networking activities with various members of the UNESCO FRIEND community and it was decided that this could be a good way forward and that it may inject badly needed enthusiasm into the UNESCO Southern Africa FRIEND initiative. It was also considered to be a good idea to link up with the Waternet initiative based in Harare, Zimbabwe.

### Community outreach and public understanding of science

The Unilever funded Boksburg Lake project aims to support Ekurhuleni Municipality and mobilise local people to take responsibility for Boksburg Lake, in whatever capacity they can. As part of this initiative the Boksburg Lake Day was held during September. This was a collaborative initiative between the Unilever Centre for Water Quality, Unilever and Ekurhuleni Municipality that saw approximately 230 learners from nine local schools participate in a fun, educational day at the lake. The main impact from this day seems to have been to change litterbugs into litter police, as the learners realised the impact littering causes on the lake.

During October Mr Gordon, Ms Fox, Ms Holland and Mr Human facilitated an educational activity at the Yellowwoods Primary School Science Day. The aim of this activity was to encourage young people and convince them that they are not too young to make a positive difference in this world.

### **Concluding remarks**

It is becoming very repetitive to conclude with a statement about problems of succession planning and the balance across students, young researchers and experienced staff who are getting closer to retirement with every passing year. However, the reality is that despite efforts to address this problem, the IWR is no closer to a solution than we were several years ago. In fact one of the plans to fasttract the career of a very promising hydrology student (Mr Kapangaziwiri) has failed, not because of a lack of interest or keenness on either side, but because personal family reasons have forced him to look for a job in a larger centre. Mr Kapangaziwiri will be moving to the CSIR at the start of 2011 and we wish him well as well as hoping that we will be able to find ways of collaborating in the future. The implication, from a hydrology research succession point of view, is that we start the process again from scratch.

Outputs	2005	2006	2007	2008	2009	2010
Peer Re- viewed Jour- nals	4	12	8	7	5	11
Reports	12	17	33	5	14	18
Conference proceedings	2	3	10	2	7	3

The Institutes record of publishing in recognised international journals continues to fluctuate, but the impact of having a larger group of postgraduate students is starting to reap benefits. The IWR students are starting to generate material that can be published and they have already presented some of that material at conferences during 2010. At least some of the conference papers will be developed as papers for peer reviewed journals. It should always be recognised that while journal publications are recognised by the Institute as being important, the reality of the situation is that research reports to funding agencies must take precedence if the IWR is to continue to attract the funding necessary to survive.

### 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 institutions projects and various policy and planning meetings.

Funding provided by Unilever provides a significant contribution to the continued existence and success of the UCEWQ. The unencumbered funding allows UCEWQ staff and students to contribute to research initiatives at both local and national levels, allowing us to partner 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 postgraduate students within the Institute. We have developed excellent relationships with the fund administrators over the first year of the project. We are also grateful to the coordinators at the other nodes of the SSAWRN (HOORC, Makerere and Eduardo Mondlane Universities) for their help in ensuring the success of this initiative.

The links with various research and consultancy partners are important from both development and financial points of view, but also to ensure that the IWR do not lose sight of the practical issues associated with water resource management and so that we can apply research results as effectively as possible. In the same context, we are also grateful for the excellent working relationships that we have with various directorates in the Department of Water Affairs, who are one of the main clients for our applied research outputs. We are also grateful for the support of the various divisions of Rhodes University including the staff of the office of the Deputy VC, Research and Development, the Finance Division, the Human Resource Division and the Communications and Development Division.

Finally, as Director, I would like to offer my personal thanks to all the members of the Institute staff and students for their hard work, enthusiasm and loyalty.

## UNILEVER CENTRE FOR ENVIRONMENTAL WATER QUALITY (UCEWQ)

# 2. UCEWQ DIRECTOR'S REPORT

### Introduction

2010 proved to be a dynamic year for the Unilever Centre for Environmental Water Quality as Dr. Nikite Muller, who had been director for the past 5 years departed in April to take up the newly created post of environmental specialist at the water services provider Amatola Water in East London. Nikite's contribution to the Centre since its inception has been to ensure that research undertaken has maintained a strong scientific basis. During her tenure, she widened the research expertise of the Centre in terms of algal toxicity testing, the application of sub-organism biomonitoring techniques and investigations of the biological treatment of wastewaters. She also strove to increase interdisciplinary research between water quantity and quality components of the Institute for Water Research (IWR). We do, however, anticipate maintaining a close collaboration with Nikite in terms of research and development through Amatola Water's Memorandum of Understanding with Rhodes University, and Nikite's ongoing supervision of a number of students registered through the IWR.

In a strange quirk of fate, Professor Tally Palmer, who occupied the position of Centre Director before Nikite, has returned to take on the challenge once more. Tally has brought back with her vast experience gained from running a large interdisciplinary water research unit while based at the University of Technology Sydney, Australia, and from her role as Executive Director, Applied Research and Innovation within the National Research Foundation here in South Africa. In October, Tally was appointed by the Minister of Water and Environmental Affairs to chair the new National Water Advisory Committee. The Committee is tasked with advising the Minister on all issues affecting water resources in South Africa. The Centre counts itself extremely lucky to have found a new director of this calibre. Tally officially took up her position in mid-November 2010. During the preceding 7 months, in the absence of a director and senior researcher, the staff of the Centre commendably 'kept the ship afloat', successfully completing the Water Research Commission (WRC) funded projects due in 2010, meeting biological monitoring programme obligations with our industry partners and submitting a number of proposals for future funding. Mr. Andrew Gordon played a key leadership role in these processes. With financial support provided by Unilever, and continued funding from the Water Research Commission and our industry partners, the future of the Centre is rich and challenging.

### **Research outputs**

Five WRC funded projects were completed during 2010 by Centre staff (details are provided in the section on research outputs at the end of this report). The projects cover a range of research topics, from an investigation of invertebrate physiological responses to salinisation of water resources, to research aimed at improving the ecological realism of water quality guidelines, to more applied research investigating the optimal application of toxicity tests to industrial effluents. The WRC remains an important partner to the Centre as one of our largest research project funders, and we greatly appreciate their continued support.

Consultancies for our industry partners (Sasol and Richards Bay Minerals) involve implementing biological monitoring programmes for rivers surrounding their sites. This continues to provide us with the opportunity to investigate the application of environmental water quality regulations in real world situations and thus we are able to contribute to the optimization of these regulations through research. During 2010, we completed a 3 year study for Sasol, making inputs to their draft water use licence requirements, and continued to implement a biomonitoring programme for Richards Bay Minerals.

2010 was the first year of funding received by the Centre from THRIP (Technology and Human Resources for Industry Programme), an initiative managed by the National Research Foundation and funded by the Department of Trade and Industry. The aim of the programme is to leverage industry partner funding to undertake research that is of specific interest to those industries. During 2010, the objective was to investigate the environmental realism of available compliance monitoring tools being utilised by our industry partners (Sasol, Richards Bay Minerals and Unilever). The programme operates on a three year funding cycle.

A number of additional smaller research projects are being undertaken, funded by a variety of sponsors. Dr. Neil Griffin is currently undertaking the mammoth task of georeferencing and digitising upwards of 16 000 seaweed specimens housed within the Albany Museum's Selmar Schonland Herbarium. This project, funded by the South African Biodiversity Information Facility, will contribute to an existing database of South African seaweeds available through the Global Biodiversity Information Facility. Neil was also involved in a project investigating the responses of aquatic biota to alien riparian clearance. Andrew continues to investigate the application of sublethal biomarkers for ecological monitoring of estuaries, funded through the Joint Research Committee at Rhodes University.

### **Teaching and training**

Undergraduate teaching by Centre staff was provided to the Department of Environmental Sciences. Neil lectured a three week long 2nd year course on water resource management, focusing on global environmental problems and policies. Andrew lectured a week long 3rd year course on environmental water quality within integrated water resources management. The professional short course on managing environmental water quality, traditionally provided annually by the Centre, was not undertaken in 2010 due to limited staff capacity during most of the year. It is anticipated that the course will resume in 2011.

Full time postgraduate students associated with the Centre include Mr. Nelson Odume (MSc), Mr. Paul Mensah (PhD) and Ms. Irene Naigaga (PhD) funded under the Carnegie Rise programme, Ms. Bronwyn Moore (PhD) funded through a grant from Anglo Platinum, and Mr. Andrew Slaughter (PhD)(partially funded by Unilever). Nelson and Paul had the opportunity of presenting oral papers at the 31st congress of the International Limnological Society held in Cape Town in August. Their attendance was cofunded by the conference organizers and the Joint Research Committee at Rhodes University. Both these students also presented oral papers at the 11th WaterNet/ WARFSA symposium in October, where Nelson won one of the four distinguished young scientist awards. Staff development remains an important function of the Centre, with Mr. Andrew Gordon (PhD), Ms. Pearl Gola (PhD)(partially funded through the ESKOM Tertiary Support Programme), Mrs. Alex Holland (PhD) and Ms. Helen Fox (MSc)(funded by Unilever through the Boksburg Lake Project) all currently registered for higher degrees.

Congratulations to Mr. Bonga Zuma who graduated with an MSc degree in Water Resource Science. He is now undertaking a PhD within the Department of Pharmaceutical Sciences at Rhodes University.

### **Community engagement**

Helen continues to practice her innovative approach to water resources management through the Boksburg Lake Project (a Unilever funded initiative). The project aims to encourage people to seek responsibility for the water resources of the catchment within which they live. In other words, how to become agents for the change they'd like to see occurring around them. The Boksburg Lake Project is,

at present, focusing on learners from schools based within the area, providing them with a week-long resource module (developed by Helen) on the management of urban catchments and the role that people living and working in the catchment can make towards it's optimal management. The module has been integrated into the learner's curriculum, and this year approximately 230 learners from nine schools were involved. In September this year, in collaboration with Ekurhuleni Municipality and various NGOs active within the area, the Boksburg Lake Day was held, where the learners came together at the lake to undertake practical components of the module. The event was extremely successful, managing to energise and excite the learners with regard to water resource management and giving them the opportunity and confidence to play a role in attaining the kind of environment in which they'd like to live.

In October, Helen, supported by Centre staff took part in the Yellowwoods Primary School Science Day. Every second year, this rural school in the Eastern Cape interior organises a fun and educational day for its learners and those of surrounding schools aimed at creating enthusiasm for science related topics. The aim of the Centre's contribution was to give these young people the confidence to realise they have a voice, a stake in how their environment is managed and the ability to make a positive difference in this regard.



Ms Helen Fox with some of the scholars at Yellowwoods Primary School Science Day



Mr Tarqyn Human and Mr Andrew Gordon from UCEWQ assisting Ms Fox at the Yellowwods Primary School Science Day

Closer to Grahamstown, Alex and Mr. Tarqyn Human continued to undertake regular biological monitoring of the Bloukrans River as part of the Centre's contribution to raising awareness of the state of water resources in and around the town. Results are routinely made available to the Kowie Catchment Campaign, a local NGO, for further dissemination and awareness raising.

A number of national academic workshops or seminars were also attended by Centre staff. Attendance of these meetings is made possible through funding from Unilever, as part of Unilever's contribution to the capacity development of the water sector in South Africa. In February, Centre staff and students participated in a workshop held with staff from Resource Quality Services (Department of Water Affairs - DWA) aimed at investigating the potential contribution of episodic toxicity data to environmental water quality management in South Africa. In September, staff attended a seminar on the management of water resources using resource quality objectives presented by DWA and the Institute for Natural Resources, and in November the Aquatox Forum's seminar on risk assessment of emerging pollutants was attended. Neil, Andrew and Nikite were authors on a poster paper that was presented there.

### Laboratory/Research facilities

The new water quality lab has been established during the course of this year and is running smoothly under the guidance of Alex. All nutrient analysis protocols have been changed to fit the use of our in-house micro-plate reader and are in the process of being validated. The only machine not being housed within our water quality lab is the fluorometer at the Department of Zoology. We are thankful to Prof William Froneman (Department of Zoology) for letting us use this machine for our chlorophyll-a analysis for yet another year. We would also like to extend our thanks to Dr. Roman Tandlich of the Faculty of Pharmacy for his advice and assistance regarding optimisation of the nutrient analysis protocols.

Tarqyn has once again improved on our freshwater shrimp culture (Caridina nilotica) through optimizing the availability beneficial algae and diatoms within the tanks, thus ensuring extra food provision for the shrimp. Furthermore, culture tanks are now sealed with glass plates, eliminating the coffin fly infestation that had appeared at the beginning of this year. Our shrimp culture currently comprises 12 culture tanks and 15 rearing tanks. Tarqyn has also started four new tanks with a limpet culture, which are thriving under ideal conditions in our stream laboratory.

Results for the nation-wide comparison of our Daphnia pulex toxicity tests (PTS – proficiency test scheme) have been very close to the overall mean LC50 of all participating laboratories in South Africa this year, meaning that the toxicity testing facilities of D. pulex at the Centre are of a very high standard yet again.

### Conclusion

2010 marks the 10th year of the partnership between Unilever and the Unilever Centre for Environmental Water Quality based within the IWR at Rhodes University. The Unilever global commitment to doubling productivity while halving environmental impact serves as a challenging context within which the Centre will work. The Rhodes University initiatives to explore hosting a Type 1 UNESCO institution; and the Environmental Education Department's "Environmental Commons" focusing on transdisciplinary research practice activities offer exciting opportunities for Centre growth and involvement.

# 3. HYDROLOGY PROJECTS

The hydrology group of the Institute currently consists of Prof. Hughes and four post-graduate students; Mr Kapangaziwiri (PhD), Mr Tshimanga (PhD), Ms Tirivarombo (PhD) and Ms Tanner (MSc). The last three are part of the Carnegie RISE programme, while Mr Kapangaziwiri is supported from IWR funds. Mr Kapangaziwiri's PhD thesis was accepted during the course of 2010 and will graduate at the 2011 ceremony. While we had all been hoping that he would remain with the Institute as a post-doctoral fellow (and eventually a member of staff), he will be moving to Pretoria to join the CSIR at then end of 2010. We wish him well in his new post. Other staff members contribute to some of the hydrology related projects that the Institute is involved in. Notably, Mr Forsyth continues to be very involved in the on-going development of the 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 is co-supervising Audrey Mashao, an MSc student working on the WRC climate change and adaption project. An additional four external students have been working on hydrologically related projects. Ms Sihle Bukhosini (MSc) is working on the WRC uncertainty project, Mr Ahmed Desai (PhD) on the development of the hydraulic sub-model for a revised desktop Reserved determination model, Mr Feleke Mekiso on natural isotope and geochemical tracers for assessing wetland processes and Ms Tumbo Madaka on climate change impacts in Tanzania (based at Dar es Salaam University). 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 four main headings 'Uncertainty assessment for hydrological and water resource estimation models', 'Developments and applications of the SPATSIM hydrological modelling framework software' and 'Developments in environmental water requirement methods' and 'Climate change adaptation strategies'. The hydrology group has also been involved in various consultancy projects during 2010, mostly associated with Reserve determinations.

### UNCERTAINTY ASSESSMENT FOR HYDROLOGICAL AND WATER RESOURCE ESTIMATION MODELS

Sponsor: Water Research Commission and National Research Foundation DA Hughes, E Kapangaziwiri, S Mallory, J. Smithers (UKZN) and T Wagener (Pennsylvania State University, USA) April 2008 – March 2011

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 core research is supported by a Water Research Commission (WRC) project that started in April 2008 entitled 'Identification, estimation, guantification and incorporation of risk and uncertainty in water resources management tools in South Africa' (K5/1838 – project duration of April 2008 to March 2011). This project is a collaborative effort with the School of Bioresources Engineering and Environmental Hydrology at the University of KwaZulu-Natal and the consultancy company IWR, Water Resources (led by Mr Stephen Mallory). A parallel project is supported by the NRF under the Key International Science Capacity (KISC) initiative for the same 3 year duration. The NRF project is designed to increase the awareness of water resource estimation uncertainty amongst South African practitioners through an exchange programme with Dr Thorsten Wagener (a recognised authority on uncertainty analysis) of Pennsylvania State University. The project is also designed to support the organisation of workshops, training programmes and student exchange.

During 2010 a third workshop was organised in Pretoria and attended by 18 people including Dr Thorsten Wagener. The workshop focused on three main issues: the tools required to quantify uncertainty, communicating uncertainty to water resources managers and reducing uncertainty (the focus area of deliverables 9, 10 and 11). Deliverables 7 to 10 were finalised during the year and submitted to the WRC. Deliverable 11 will be submitted before the end of 2010, leaving the final report as the only outstanding commitment. All of the deliverable documents are available on the IWR website at (<u>http://</u> www.ru.ac.za/static/institutes/iwr/uncertainty/).

As this project comes to an end it is interesting to note that many of the concepts and methods that have been developed are being applied in other research projects, specifically student projects and projects related to climate

change and uncertainty. One of the final sets of analysis that is being undertaken is an assessment of the use of stochastic rainfall uncertainty combined with model parameter uncertainty (within a hydrological model) compared with the more traditional use of hydrological inputs into a water resources yield model and the use of stochastic stream flow ensembles. The stoachsotic rainfall/ parameter uncertainty approach involves the generation of 250 000 possible model ensembles. A filtering program extracts a representative sample of 500 ensembles from the 250 000 which are then used by the water resources yield model to determine a yield probability curve. An example of the application of this approach is currently being run for the Midmar (KwaZulu-Natal) dam in collaboration with Mr Bennie Haasbroek, Prof Geoff. Pegram and Mr Stephen Mallory.

The uncertainty framework has been used to look at climate change scenarios in the Okavango River basin and the Amatola system (Buffalo River catchment near East London) and some of this work has either been published or is in the process of being published.

This project has already generated two PhD's from Rhodes while Ms Tanner, Mr Tshimanga and Ms Tirivarombo (all RISE students) are applying some of the methods to their student research projects. During 2010, the IWR submitted a proposal to the WRC to continue with the hydrological uncertainty research and in mid-November we were informed that this proposal has been successful (R600 000 for a further 3 year period). The focus of the new project will be reducing uncertainty in surface-ground water modelling (partial support for Ms Jane Tanner), further investigations into the use of stochastic rainfall ensembles and improving the communication to and use of uncertainty by water resources managers. This project is expected to link up with several other ne WRC projects on improving our understanding of surface-ground water processes that will start during 2011.

Three papers based on the outputs of the hydrological uncertainty research have been submitted to the organisors of the IUGG General Assembly to be held in Melbourne during June/July 2011.

### DEVELOPMENTS AND APPLICATIONS OF THE SPATSIM HYDROLOGICAL MODELLING FRAMEWORK SOFTWARE

Sponsor: Department of Water Affairs, Water Research Commission and National Research Foundation DA Hughes, DA Forsyth, BEEH (UKZN), E Kapangaziwiri and University of Mauritius April 2008 – March 2011

This is a collaborative project with the School of Bioresources Engineering and Environmental Hydrology (BEEH) at the University of KwaZulu-Natal to develop an improved version of the SPATSIM software which will extend its applicability and sort out some of the design faults associated with the first version. These developments were initially funded by the Water Research Commission, while the current development programme is funded by DWA through the WRC. Part of the focus is on enhancing the use of the framework by the RDM (Resource Directed Measures) office of DWA (or their consultants) for ecological Reserve determinations and implementation. The other focus is on incorporating the ACRU model into the framework (being undertaken by BEEH). After some delays it is expected that the software will be ready for general distribution at the end of 2010.

The focus of the work undertaken by Prof Hughes and Mr Forsyth during 2010 has been to ensure that the software is robust and error free and that all of the facilities and models that are essential for efficient use in Reserve determinations have been moved across from the older version of SPATSIM. Mr Forsyth is also in the process of developing a check-out/check-in procedure that allows the DWA to release the most up-to-date version of the RDM database to consultants (check-out) and then update the main database with the results generated by the consultants at the end of a specific Reserve determination (check-in). A great deal of care is necessary in the design of this approach to ensure that the National RDM database does not get corrupted by any changes made by consultants in error.

A training workshop was held for about 25 people from DWA and other organisations during October 2010. The main purpose of this workshop was to introduce existing (old version) SPATSIM users as well as new users to the software system and give them an opportunity to learn about some of the basic facilities.

Prof Hughes has been involved in several ad hoc consultancy type projects to support some of the users of the SPATSIM system. One example is the use of the system by a major consulting group (Atkins) to undertake a water resources assessment for the whole of Malawi. The IWR has also submitted a proposal to the government of the Dominican Republic (with a local partner) to set up the SPATSIM system as a water resources management tool for their country.

As part of an NRF supported project under the Regional Cooperation Fund for Scientific Research and Technological Development, the IWR has been collaborating with the University of Mauritius to establish SPATSIM and associated water resource estimation models for the whole island. We have experienced a number of problems with communication and have found it very difficult to gain access to the data necessary to establish examples that can be used for training. Mr Kapangaziwiri has been in contact with Mr R Dhurma (a PhD student in Mauritius) who visited the IWR during October 2010 and brought some new rainfall data to the project. Mr Kapangaziwir is trying to finalise the modelling and a report to the NRF before the end of 2010.

### DEVELOPMENTS IN ENVIRONMENTAL WATER REQUIREMENT METHODS

Sponsor: Water Research Commission DA Hughes, D Louw, N Kleyhans (DWA), A Birkhead (Streamflow Solutions) and A Desai (PhD student) April 2008 – March 2011 (after 1 year extension)

One of the models available within that is used extensively is the Desktop Reserve model that is able to provide a rapid, but low confidence, estimate of an ecological Reserve requirement (equivalent to an environmental flow requirement or EWR). This project was initially a 2 year project designed to improve the Desktop model through the inclusion of hydraulic and ecological sub-models (a collaborative project involving the consultancy groups Water for Africa and Streamflow Solutions, DWAF and the IWR). At present the model is largely based on hydrology data and some empirical relationships between hydrological variability characteristics and ecological response that were developed some years ago.

The project was designed to incorporate a great deal of the science underlying the determination of environmental water requirements that has been developed over the last few years and yet still ensure that the model can be used for rapid assessments making use of regionalised and readily available data. The project has not progressed as quickly as originally intended, partly because of the complexity of the relationships between hydraulics and ecological response and partly because of difficulties in regionalising hydraulic channel cross-section parameters.

A prototype version of the final model has, however, now been developed (deliverable 7) and is currently being tested on a range of rivers. The approach is very different to the original Desktop model and is based integrating hydrological, hydraulic and fish habitat response information. Thus far in the project, it has been necessary to go ahead without the fully complete development of the regionalised hydraulic parameters and only using fish habitat requirements as the key ecological indicator. The project team hope to be able to include the hydraulic parameter estimation process into the model (the focus of Mr Desai's PhD work) before the end of the project, while integrating other ecological indicators may have to be included as a later development. We have also largely ignored the high flow requirements of the Reserve and have only focused on the low flows. While this was the original intention of the project, it will be necessary to look at adding high flows in the future.

Some of the initial tests of the model suggest that the results can be quite different to the Reserve requirements determined from either the previous version of the Desktop model or through detailed (comprehensive) Reserve studies. Further testing is necessary to investigate the implications of these differences from the point of view of future rapid estimates of Reserve requirements.



Ecological sub-model of the revised Desktop Reserve model.

Mr Slaughter is working on a PhD project (supervised by Prof Hughes and Dr Muller) with the objective of developing methods for improved integration of water quality and quantity in Reserve determinations. Part of this project involves testing and developing relatively simple water quality/quantity models that can be used in data scarce situations and yet will still generate sensible results that can assist in making management decisions. Mr Slaughter is in the final stages of writing up his PhD and has also drafted papers for publication in international journals.

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

Sponsor: Water Research Commission DA Hughes, SK Mantel, AK Gordon, E Kapangaziwiri and A Mashao April 2010 - March 2013

The present project aims 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 proposed project aims 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 will identify risks, vulnerabilities and adaptation strategies to climate change in order to allow the water boards to fulfill their water supply delivery mandates. The study will undertake the analysis in cooperation with two medium size water boards in South Africa, namely Amatola and Bloem Water Boards.

The aims of this project are:

 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.

- 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.
- Develop a strategy and monitoring network for water audits in order to monitor indicators of change.
- 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.
- 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 first deliverable of the project was submitted to WRC in June 2010. The report presented the results of the first annual workshop with the two water boards held at the Bloem Water facility on 12<sup>th</sup> May 2010. The meeting was attended by the representatives of Amatola Water Board, Bloem Water Board and the Institute for Water Research (IWR). The main aims of the workshop were to gain guidance on how the project should proceed, to clarify the study areas, to discuss the preliminary climate data available and uncertainties, and to place climate change in the context of other developmental changes. The major outcome of the workshop was deciding on the potential sources of data required for water quantity and quality modelling, and which of the three groups would take responsibility for gathering the data.

Since the first workshop, the project team at IWR is working on calibrating off-shelf water quantity and quality models that have been identified to be useful for the project. The models are being calibrated for present day conditions using water quantity and quality data that are available from DWA or have been provided by the Amatola Water Board. Downscaled climate data for 9 Global Circulation Models (GCMs) are being obtained from the Climate Systems Analysis Group at UCT.

# 4. ENVIRONMENTAL WATER QUALITY PROJECTS

### DATABASE OF SOUTH AFRICAN SEAWEEDS: PHASE 3

 Sponsor: South African Biodiversity Information Facility NJ Griffin (project leader)
 Collaborators: JJ Bolton (UCT), N Barker (RU), RJ Anderson (DAFF) and ML Gründlingh (CSIR) Feb 2010 - March 2011

### **Rationale and objectives**

South Africa's coast has approximately 900 species of seaweeds, of which 40% are endemic to temperate Southern Africa. The taxa found in South Africa make up more than 10% of the world's seaweed flora. Information on the biodiversity and biogeography of South African seaweeds has historically been relatively scarce, with some improvement made since 1980. Most locality-based specimen records are housed in seaweed collections in various herbaria across the country. Most major seaweed collections in herbaria across the country have been georeferenced and digitized and the data made available via African Node of the global Ocean Biogeographic Information System (AfrOBIS), from where they are available to the Global Biodiversity Information Facility (GBIF).

The Pocock collection, housed at the Albany Museum's Selmar Schonland Herbarium (GRA), is the remaining major seaweed collection in South Africa. The Pocock collection, together with other smaller collections of seaweed also housed at GRA, is made up of 18000-35000 records (depending on sources). Specimens in the Pocock collection are largely drawn from the Eastern Cape and therefore from the overlap between the temperate Southern African region (roughly, Western Cape and Namibia) and the tropical Indo-West Pacific (roughly corresponds to KwaZulu-Natal and regions further north). This is an area where seaweed biodiversity is relatively little studied. This project aims to georeference at least 16000 specimens from the Pocock collection and to upload the data for global access.

### Progress

About 15000 specimens have been digitized so far. Data will be transferred to AfrOBIS once digitization and georeferencing are completed.

### RICHARDS BAY MINERALS: ENVIRONMENTAL WATER QUALITY

Sponsor: Richards Bay Minerals (RBM) AK Gordon (project leader), NJ Griffin, AJ Holland, R Tandlich and TJ Human July 2010 - May 2011

### **Aims and Objectives**

Richards 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 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 have been collected in winter, spring, summer and autumn from sites around the mine in the RBM smelter area and from the as yet unmined Zulti South lease area. Monitoring of the Zulti South lease area was terminated in 2009 as the area is to be mined. The Smelter site is currently monitored in winter and summer only as assessment of past datasets indicated that little extra was gained by quarterly monitoring.



SASS sampling at Site 10 on the Manzamnyama River adjacent to the smelter

Monitoring of sites around the Smelter assesses streams around the mine for impacts due to mining operations, residential settlements and other anthropogenic causes. In general, a decrease in water quality with distance downstream is indicated by both macroinvertebrate and diatom biomonitoring scores. However, overall water quality in the area sampled is fair to good.

### **Progress and Future**

Two field trips to RBM were undertaken during 2010. Biannual monitoring of sites around the RBM smelter will continue in 2011.

### EVALUATION OF METHODS FOR ASSESSMENT OF ECOTOXICOLOGICAL RISK DUE TO COMPLEX EFFLUENT DISCHARGE

Sponsor: Water Research Commission NJ Griffin (project leader), WJ Muller, AK Gordon, A Slaughter and TJ Human. Collaborators: H Pearson and C Loots (Toxsolutions Kits and Services) April 2007 - December 2010

### **Aims and Objectives**

The Department of Water Affairs and Forestry (DWAF) have acknowledged that substance-specific methods are

However, there is a lack in South Africa of trained staff and accredited laboratories able to complete ecotoxicity tests. Quality assurance of endpoints is however crucial for legally defensible decisions relating to effluent control, and ISO standardisation particularly for international trade. The introduction of commercial toxicity test kits that use standard laboratory organisms, and are reported to be easy to use and to produce defensible endpoints may alleviate many practical problems with implementation of the DEEEP.



Effluents assessed during this study showing colour cast

DWAF have called for revision of the water quality guidelines with ecologically sensitive species relevant to South Africa, as standard laboratory organisms may not give applicable ecologically protective endpoints. This project aims to compare standard culture-based toxicological methods with tests that use toxicity test kits, as well as with tests that use native or indigenous taxa as test organisms. Comparisons are made on the basis of test endpoints and ease of use, as well the costs of deploying tests in a laboratory.

### Progress

An analysis of costs involved in toxicity testing using commercial test kits and indigenous organisms is complete. Test costs vary considerably. Costs of tests using indigenous organisms are affected mainly by capital costs of equipment and ongoing costs of maintaining cultures of test organisms. Test kits mostly have relatively low capital costs and equipment requirements, but ongoing costs of purchasing kits may make this option less economical where testing rates are high. Toxicity testing of four complex effluents using six test kits and seven tests using indigenous organisms is complete, and test sensitivities and endpoints have been analysed. No differences in results were found when the same tests were undertaken using commercial kits and standard culture-based methods. Potentially promising tests using South African native or indigenous taxa were identified. Problems encountered in obtaining endpoints to tests were noted for consideration in future methodological specifications. The report on this project is currently being finalized. The results will be used in building capacity and awareness in technical staff of the local municipality and of industries from whom the samples were taken.

### ENVIRONMENTAL ASSESSMENT IN AN AREA WHERE ONGOING DDT SPRAYING OCCURS

**Sponsor**: Water Research Commission WJ Muller, AK Gordon, AJ Holland, TJ Human and H Bouwman (North-West University) April 2007 - July 2011

This project is assessing possible impacts of DDT on riverine macroinvertebrates in the Luvuvhu River, Limpopo Province where ongoing DDT spraying occurs to control malaria. The focus is to determine possible endocrine disruption effects of DDT on freshwater snails, frogs, birds and riverine macroinvertebrates by comparing wild-caught species from malaria control areas (DDT impacted) and reference areas (outside the spray area).

Fieldtrips were undertaken to measure riverine health using the South African Scoring System (SASS) Version 5 macroinvertebrate index as well as collecting macroinvertebrate samples to determine whether metrics that use measures of diversity and abundance could be used to identify whether sites were potentially impacted by DDT. SASS and ASPT data do not discriminate between DDTspraying and non-spraying areas. Looking at differences in biotopes most of our data show high variability at each site which might have to do with different seasons sampled in.



Alex doing SASS in the Luvuvhu River.

Data are divided into pre-spray season (August 2008) and post-spray season (March 2009) for further analysis. In addition, samples of freshwater shrimp *Caridina nilotica*, a key species in tropical freshwater ecosystems, were collected to determine whether there was DDT accumulation and / or acetylcholinesterase (AChE) inhibition. Levels of DDE were found in these shrimp caught in the DDTsprayed area and their levels of AChE were lower that at the reference site.



Toxicity test exposing freshwater shrimp, Caridina nilotica, to DDT

Bird eggs were collected by North-West University to determine levels of DDT and its breakdown products DDE and DDD and were sent to Norway for analysis. The results show very high levels of DDT especially in sparrow and chicken eggs. Sediment analyses of pools where snails were collected showed high levels of DDT and its isomers in the DDT-sprayed areas. Histology sections for snail gonads are finalised and result interpretation is well under way.

Multivariate analysis of macroinvertebrate counts is underway. Acute toxicity tests using DDT and DDE have been conducted and samples resulting from these tests are being analysed for AChE levels in order to compare these with levels in field-collected animals. Chronic toxicity tests on the freshwater shrimp *Caridina nilotica* are planned for early 2011.

### OSMOREGULATION IN FRESHWATER INVERTEBRATES IN RESPONSE TO EXPOSURE TO SALT POLLUTION

**Sponsor:** Water Research Commission WJ Muller, AK Gordon and AJ Holland April 2005 - December 2010

The current methodology for water quality assessments includes boundary values for specific salts, although biological effects data are scarce for the majority of these salts. Riverine macroinvertebrates and fish are excellent indicators of water-borne pollutants as they are in constant contact with the water column through which they are exposed to pollutants at all times. Macroinvertebrates have been shown to be suitable laboratory-test organisms. Methods are currently being developed by UCEWQ for generating chronic toxicity test data for selected indigenous species, at both organism and sub-organism levels. However, accurate interpretation of toxicity test results remains elusive as very little is known of the biology, and physiology, of these indigenous toxicity test species. Therefore, fundamental research is necessary to establish the osmoregulatory properties of organisms currently being evaluated as chronic toxicity test species.

The following inorganic salts were used as test substances: sodium chloride (NaCl), sodium sulphate (Na<sub>2</sub>SO<sub>4</sub>) and magnesium sulphate (MgSO<sub>4</sub>). Toxicity tests were conducted using these salts on three different species of mayflies in artificial stream systems with mortality as endpoint, on two species of fish in static non-renewal tests (respirometers) with oxygen consumption as endpoint, and on the freshwater shrimp Caridina nilotica in respirometers with haemolymph osmolality as endpoint. Mortality values for the three mayfly species tested reveals that their LC<sub>50</sub> values do not differ significantly from each other. According to these data the boundary values for MgSO<sub>4</sub> currently applied in Reserve assessments in South Africa seem conservative and restricting. Results on fish showed that oxygen consumption could be used as a physiological respons variable to exposure with inorganic salts. Measurements of haemolymph osmolality in C. nilotica revealed that this crustacean is a hyper-hypoosmoregulator. Osmoregulatory capacity seems to be a good indicator of hyper- or hypo-regulation and will be evaluated as an indicator of exposure to inorganic salts.

The water quality boundary values for the selected inorganic salts are being evaluated in light of results of this project. The final report is in preparation and due at the beginning of December.

### SASOL: ENVIRONMENTAL WATER QUALITY ASSESSMENT

### Sponsor: Sasol

AK Gordon, NJ Griffin, WJ Muller, AJ Holland, TJ Human January 2008 - March 2010

The objectives of this project were to:

- undertake environmental water quality monitoring of selected sites on the Leeuspruit, Taaibosspruit and Vaal rivers in order to meet the draft Water Use License (WUL) requirements issued to Sasol by the Department of Water Affairs (DWA), and gain a better understanding of the ecological processes and ecological significance of changes in water quality at selected sites
- investigate the development of an appropriate, tiered, site-specific monitoring programme for the selected sites, that would inform the refinement of the current WUL requirements toward more practical and environmentally realistic objectives
- identify research needs to be undertaken in order to successfully implement the site-specific monitoring programme.

The current draft WUL requirements were found to be impractical in most instances and consequently a number of alternative approaches to measuring and managing the aquatic ecological impacts of Sasol's operations on the three identified rivers were investigated:

- the derivation of an appropriate reference condition for the Leeuspruit against which downstream sites could be compared, reducing reliance on the inappropriate upstream site
- using SASS score and ASPT to derive an ecological cate-

gory for each site, and comparing results obtained against a recommended ecological category defined by the ecological Reserve for the catchment in which the sites occur

- highlighting the need to take account of inherent variability in the SASS sampling methodology
- investigating the use of only the marginal vegetation biotope to measure potential impacts between up and downstream sites
- applying the complementary approach of concurrent macroinvertebrate and diatom biomonitoring.

### EVALUATING THE POTENTIAL CONTRIBUTION OF EPISODIC TOXCITY DATA TO ENVIRONMENTAL WATER QUALITY MANAGEMENT IN SOUTH AFRICA

### **Project Sponsor:** Water Research Commission AK Gordon, SK Mantel, WJ Muller April 2009 - March 2010

Organisms in the environment are rarely exposed to environmental or anthropogenic stress on a continuous basis at constant levels. Instead, these stresses fluctuate in magnitude (e.g. chemical concentration), frequency (the number of exposure events) and duration (the time of the exposure event). However, the episodic exposure of organisms to chemical stress is almost never considered in the application of water resources management.

The approach of this project (WRC project K8/851) was to undertake a desktop literature review with the aim of addressing the following questions:

- What are the quality and quantity of episodic toxicity data available in the aquatic environmental water quality literature?
- What are the philosophical and practical constraints limiting their inclusion in environmental water quality management procedures and guidelines in South Africa?
- How could these data be incorporated into the current development of a risk-based approach to deriving water quality guidelines for aquatic ecosystems?

The major product emanating from this project was an aquatic episodic toxicity database for utilization in environmental water quality management. Due to its size, the database could not be produced in hardcopy format, but can be downloaded as an Excel file from the IWR website (http://iwr.ru.ac.za/iwr/download). A report accompanies the database providing supporting documentation and a summary of observed trends.

### TOWARD DEVELOPING A REFERENCE CONDITION FOR *RHABDOSARGUS HOLUBI* IN THE APPLICATION OF SUBLETHAL BIOMARKERS FOR ECOLOGICAL MONITORING OF ESTUARIES

Project Sponsor: Joint Research Committee, Rhodes University AK Gordon and TJ Human January 2009 - December 2010

Biological monitoring of South African estuaries currently relies on the use of community indices to infer the ecological health and assess possible pollutant contamination. While this approach is scientifically sound it does have the disadvantage of only identifying problems once effects have already impacted the fish community structure of the estuary. The measurement of sublethal responses (biochemical changes in organs and cells) in an organism exposed to harmful levels of contaminants or stressful environmental conditions can give an indication of potential risk before individual organisms die and species are lost. Two biomarkers: acetylcholinesterase (AChE) inhibition (inhibition indicates possible neurological misfunction) and lipid peroxidation (LPx) (indicates damage to cellular membranes) have been successfully applied using the indigenous fish Rhabdosargus holubi to give an indication of estuarine health (Richardson et al. 2010). This study highlighted however, the need for a reliable reference condition for the above biomarkers to be established (ie AChE and LPx concentrations that reflect a natural or unimpacted environment) against which results from surveyed estuaries could be compared. This would be particularly important if a national monitoring program was established. During the course of 2009 and 2010, R. holubi juveniles were collected from the West Kleinemonde estuary on a seasonal basis. Captured fish were dissected and excised body tissues frozen in liquid nitrogen in the field and then transported to Rhodes University for analysis.

Results to date indicate no significant variation in biochemical markers AChE and LPX over the various seasons sampled, suggesting environmental factors such as seasonal temperature variation do not affect these markers. This is a desirable trait in a biomarker of pollution.

### RIPARIAN ALIEN CLEARANCE AND RESPONSE OF AQUATIC BIOTA

SR Lowe (project leader, SAIAB) Collaborators: NJ Griffin and FC de Moor (Albany Museum) 2007-2010

Riparian zones are particularly vulnerable to invasion by alien (non-native) plants which typically alter the physical characteristics of rivers and reduce availability of water for aquatic ecosystems and human use. In South Africa, nationwide clearing of invasive plants has been undertaken to increase water security, conserve indigenous ecosystems and provide employment. In this study, aquatic invertebrates and periphyton were sampled and habitat and water parameters determined so as to assess the influence of Acacia mearnsii invasion on aquatic biota and to determine the effectiveness of rehabilitation efforts in the Kouga River catchment, Eastern Cape Province. Invertebrate communities recovered rapidly after rehabilitation, leading to increased taxon abundance and diversity. Diatom communities were slower to recover and community structure reflected the history of invasion several years after clearance. A number of environmental parameters were found to change with invasion and rehabilitation and some of these were correlated with biotic community structure.

- Task 1: the standard biomonitoring tool SASS5 was assessed against multivariate approaches, in order to obtain a better understanding of ecosystem relevance of results obtained using this standard assessment tool.
- Task 2: A key component of biomonitoring assessments is comparison against an appropriate reference, or unimpacted, site. In many instances, industries are operating in areas that have been impacted for decades and therefore finding relevant reference sites is not possible. In this task, available data were used to investigate the development of site-specific reference conditions,



NMDS ordination of abundance of diatom taxa overlaid with contours showing when riparian Acacia mearnsii was cleared, current cover of A. mearnsii, and density of A mearnsii before clearance.

### THRIP – TECHNOLOGY AND HUMAN RESOURCES FOR INDUSTRY PROGRAMME

Sponsors: National Research Foundation, Sasol, Richards Bay Minerals and Unilever AK Gordon, NJ Griffin, AJ Holland, NP Gola, TJ Human and WJ Muller 2010-2013, renewable annually

The THRIP initiative is managed by National Research Foundation (NRF) and funded by Department of Trade and Industry. The aim of the programme is to promote development of technology and human resource skills, whereby the NRF contribute a third of the funding originally provided by UCEWQ's industry partners Sasol, Richards Bay Minerals and Unilever, toward specific THRIP objectives. The project was initiated because, for some time, these industries have been questioning the ecological relevance and application of results obtained through the compliance monitoring methods that are used to evaluate and manage their impacts on the environment.

The overall objective of this project is to investigate the environmental realism of available compliance monitoring tools being utilised by industries. The aim is to develop compliance monitoring tools that better reflect the actual ecological impacts occurring, resulting in water resource management that is not too stringent so as to prevent social and economic development, but effective enough to reduce the negative impact of industrial processes on the environment and allow long-term ecological protection. The workplan for 2010 was as follows: thus enhancing the interpretation of biomonitoring results.

### BOKSBURG LAKE AND WETLAND PROJECT

Project Sponsor: Unilever H Fox, AK Gordon and WJ Muller Renewed on an annual basis

Boksburg Lake is situated in the city centre of Boksburg, an industrial and mining town in the East Rand. It is a shallow 150 000 square meter man made lake, built by the mining commissioner, Montague White and given to the community as a recreational resource in the 1800s. It falls under the Ekurhuleni Metropolitan Municipality, in the Gauteng province of South Africa. Between the 1960s-90s this Lake was the social centre for Boksburg and held high value to the local people.

However, current problems associated with the lake now reflect Beck's (1992) exposition of the 'risk society'. Boksburg has experienced the "social production of wealth" through extensive industrial and mining enterprises but this has "systematically being accompanied by the social production of risks" (Beck 1992: 19). It is an urban water catchment at risk and the lake reflects this in serious water pollution, crime, deterioration of infrastructure and aesthetics and is now little used by local people. The local risk includes +-300 000 tons of toxic sludge in the lake (Gordon 2008), and the area has been declared a hazardous zone where extensive fish kills, rape and murder are not uncommon.



Pollution at Boksburg

The Boksburg Lake and Wetland Project is a community driven project aimed at creating partnerships between local residents, local industry and local government (Ekurhuleni Metropolitan Municipality (EMM). The goal is to make Boksburg Lake a safe and pleasant recreational resource for residents, a landscape feature of which the Municipality can be proud, and an ecological resource contributing to the long-term ecological sustainability of Boksburg Lake's catchment and downstream watercourse.

Over the past five years, funding from Unilever has led to the development of an integrated water quality management plan (IWQMP) which has provided guidance and structure to the project, identifying problems affecting the lake and wetland and suggesting solutions. An ongoing goal of the project has been to encourage the EMM to adopt and implement the IWQMP. Progress was made toward achieving this goal when the project was listed as one of the Mayoral Projects in 2007 and allocated a budget of R1.4 million. Over the last five years the project has also been building up a database of information regarding the lake and wetland's ecological integrity. This information will support the decisions made in implementing the IWQMP and provide a benchmark against which to measure the success of remedial tasks undertaken. In mid 2008 the importance of civic engagement in this process was recognised. A pilot environmental education strategy involving schools was piloted with the aim of generating enthusiasm and a groundswell of support for effective implementation of urban catchment management within Boksburg. In 2009 an evaluation of this strategy was undertaken and the insights gained have informed the process into 2010.

Objectives for 2010 were to:

- Implement, improve and expand the environmental education strategy
- Continue to facilitate the implementation of the IWQMP for Boksburg Lake and Wetland (and overall improvement of the lake and wetland areas) through participation with Ekurhuleni Metropolitan Municipality, local industry and other interested stakeholders

### Progress

In 2009 there were encouraging signs that the EMM were beginning to the goals of this project and become significantly involved. In addition to the R1.4 million budgeted by EMM for various remedial actions in 2007, they allocated

R24 million to remedial tasks such as dredging the lake of noxious sludge and installing litter and sediment traps and aerators. Progress on these various tasks has, however, been slow. Since 2009 an investigation of how to remove the sludge was underway, while the EIA for the litter and sediment traps is complete and installation scheduled to begin. A dredger had been bought and plans were to start dredging the lake in early 2010. Unfortunately a variety of delays have stalled this process and dredging of the lake has not yet begun. The local media has focussed on this lack of action and communication with a variety of local people indicates that they are anxious to see the dredging begin.



Boksburg Lake Day

The environmental education strategy is showing great promise. This process aims to mobilize civic society to become an environmental citizenry engaging in social activism and responsible action through social learning in schools and churches while partnering with a range of stakeholders (e.g. Ekurhuleni municipality, WESSA, Boksburg Historical Association, RandWater and the South African Faith Communities Environmental Institute (SAFCEI)). In 2010 the school based strategy had two main foci:

- A refined resource pack that mirrors the risk of Boksburg's urban water catchment and provides important knowledge to understand the dynamics of this catchment. This resource pack supports the curriculum and is used within the classroom context.
- The Boksburg Lake Day, held on the 17<sup>th</sup> of September, where + 220 learners from the participating schools spent a day engaging in a range (eight) of educational (knowledge, inquiry and action) activities based at the lake. The participating schools each prepared a statement to hand to the municipality to indicate their support to see the lake improved. These were handed to councillor Doug Scholtz after the public march around the lake. The Unilever Centre for Water Quality, Unilever factory and Ekurhuleni municipality collaborated in organising this event.

The aim of this process has been to represent the risk to

learners, re-couple action to consequence (increase a sense of responsibility) and increase agency for meaningful sustainable action.

### Feedback indicates a number of key results from this process:

- The learners have felt empowered and have begun to take ownership of the process of restoring the lake. The role they are taking up is to become positive agents of change in their community.
- By giving the learners a physical experience, the knowledge that they learnt through the resource pack has become real to them. An important impact is that learners have made connections between their actions and the consequences of these.
- The children are enthusiastic about what they learnt and are applying this knowledge to their daily lives
- Learners expressed a positive change in their littering habits and many have changed from being litterbugs to litter police
- The learners have realised that they are part of a wider community working towards seeing the lake restored
- Teachers are inspired to bring about positive environ-

mental change in their school setting

• A number of schools have started engaging in sustainability activities, including recycling initiatives and addressing litter problems in their school

The church based strategy is being developed as a collaborative process. An eco-congregation workshop was held on the 23rd of October with the aim of supporting churches to adopt an environmental focus and participate in learning actions and projects to improve Boksburg Lake. Twenty participants attended, including church leaders, from five local churches in the area. Kate Davies from SAFCEI was invited to lead the workshop as she has developed a framework to support churches to become eco-congregations. The outcomes of this workshop hold a lot of promise. It was an important time of networking and developing an action plan for 2011. Local churches are now planning to raise environmental awareness amongst their congregations and have a combined 2011 Easter service at the lake, which will also include a public demonstration of their desire to see the lake restored as well as picking up litter.

# **5. POSTGRADUATE ACTIVITIES**

### BIOLOGICAL TREATMENT OF ACIDIC PRECIOUS METAL REFINING WASTEWATER

Student: Ms B Moore Supervisor: Dr WJ Muller Degree: PhD (Water Resource Science)

Precious metal refining generates a number of waste streams which cannot be discharged into water courses and are for the most part recalcitrant to simple physicochemical treatment techniques. As a result expensive treatment methods are being employed to reduce the quantity of the waste before it is sent to landfill. An opportunity to recover the water in these wastes exists if biological methods are employed during treatment. Anglo Platinum (Rustenburg) generates approximately 15m<sup>3</sup> of acidic wastewater a day. Historically this wastewater was housed in evaporation dams with the intention recovering metal rich salts over time. Unfortunately evaporation has proven to be unsuccessful and alternate methods have been employed to recover the metals and the water. One of these methods includes the co-treatment of the acidic wastewater with municipal wastewater. Bench scale studies have shown promise in treating the water to a level which may be satisfactory for use in other processes. Cur-



Demonstration plant for the co-treatment of municipal and acid effluent generated by Anglo Platinum Precious Metal Refinery

rently a 240 L demonstration is being commissioned to assess whether similar or improved results can be replicated at a larger scale. The final aim is for treated water generated in the process to be sent to the concentrator and for solid material wasted from the treatment system to be delivered to the smelter for recovery of any metals bound to the biomass.

### INVESTIGATING THE RESPONSES OF SOUTH AFRICAN AQUATIC INVERTEBRATES TO LAUNDRY DETERGENT EXPOSURE

Student: Mr AK Gordon Supervisor: Dr WJ Muller Degree: PhD (Water Resource Science)

In many rural areas of South Africa, clothes are washed near to or in rivers and streams, resulting in the potential direct input of a commonly used anionic surfactant, linear alkylbenzene sulfonate (LAS) to the aquatic environment. Little is known about the resulting in-stream concentrations or potential effects caused to these rural water courses. In this study, the fate and effects of LAS are investigated in a reach of the Balfour River (Eastern Cape Province, South Africa) which is regularly used as a site for laundry activity. As the use of only one hazard assessment tool or technique rarely provides the adequate information to make a confident assessment of ecological impact, multiple assessment tools will be applied in this study and integrated and evaluated as part of a weight of evidence approach. Samples of river water have been collected upstream of the main washing site and at a number of locations downstream for LAS analysis. In addition, a household survey of the nearby village has been conducted to ascertain washing practices and the amount of detergent

used. Macroinvertebrate biomonitoring surveys have been undertaken at the river water sampling sites, investigating various macroinvertebrate community level responses, and sub-organism level biomarker responses in specific macroinvertebrate taxa. Lastly, the tolerances of various indigenous invertebrates at different levels of biological organisation (population, individual and sub-organism levels) to LAS exposure have been determined in the laboratory and, together with relevant international data, will be used to derive a preliminary guideline for LAS for South African fresh waters.

### AN INVESTIGATION INTO THE SENSITIVITY OF INDIGENOUS ALGAL SPECIES FOR APPLICATION IN WATER RESOURCE MANAGEMENT

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

The standard micro-algal toxicity test with *Pseu-dokirchneriella subcapitata* has been used locally and internationally as part of a battery of tests to assess the hazardous effects of effluent and wastewater discharges, as well as to evaluate environmentally safe levels of chemicals that could potentially enter aquatic ecosystems. Although toxicity tests with the standard species are highly reproducible and generate much needed toxicity data, tests with species isolated from local aquatic sources are more environmentally realistic and relevant to specific sites. No single algal species has consistently emerged as most sensitive to a variety of chemicals, and because of this uncertainty regarding sensitivity, there have been recommendations internationally to change algal toxicity testing from using a single standard species to using a battery of species. Further suggestions, are to use indigenous species in addition to the standard toxicity test species, *P. subcapitata*, in order to obtain ecologically relevant and environmentally realistic data.

This research is therefore specifically aimed at isolating and culturing locally isolated species to be used in toxicity tests with single chemicals and complex effluents, and comparing the sensitivity of these local isolates to that of the standard toxicity test species P. subcapitata. Different micro-algal species have been isolated and cultured from different aquatic sources (rivers and streams) around South Africa. There are 41 identified and un-identified axenic/uni-algal cultures (Table 1) being maintained in our laboratory and from these, suitable species will be selected and used in toxicity tests with two reference toxicants, CdCl<sub>2</sub> and NaCl, as well as in-stream and industrial effluents. This research will be applicable to the Direct Estimation of Ecological Effects Potential (DEEEP), which is a tool put forward by the Department of Water Affairs to assess the ecological hazard of complex effluents and wastewater discharges. The DEEEP methodology is said to be flexible, ensuring that techniques and parameters are revised and updated from time to time, and leaving room for gradual increase in environmental realism. Different algal species generally respond variably to chemical stressors, therefore using locally isolated algal species, in addition to the standard species that is already in use for the DEEEP methodology, could add environmental realism to this tool.

 Table 1: Laboratory cultures of indigenous micro-algae isolated

 from different sources around South Africa.

Source/River	Province	Total no. of cultures
Palmiet	Eastern Cape	4
Keiskamma	Easterm Cape	4
Luvuvhu	Mpumalanga	9
Knysna	Western Cape	10
Sundays	Eastern Cape	14
Total		41

### USE OF FLUCTUATING ASYMMETRY AS A BIOINDICATOR FOR ENDOCRINE DISRUPTION IN AQUATIC BIOMONITORING

### Student: Ms AJ Holland Supervisor: Dr WJ Muller Degree: PhD (Water Resource Science)

Situated between biomonitoring and physiological biomarkers is the morphological measurement of fluctuating asymmetry (FA) - deviations from the near-perfect symmetry of naturally bilateral-symmetrical characteristics of an individual - as an indicator for environmental stress. FA is said to be easily estimated, and inexpensive to measure. Even preserved specimens (e.g. museum specimens) can be used to measure the change in river condition over time.



Second pereiopod basal segment of C. nilotica, left body side

Measuring multiple traits (e.g. legs and antennae) is suggested, since some traits seem to respond to certain anthropogenic impacts whereas other traits seem to respond to physical stressors like temperature. Research on mouthpart deformities in chironomid larvae which develop at the endocrine-regulated molting stage after exposure to pollutants suggests fluctuating asymmetry as a potential bioindicator for endocrine disruptors. Acute toxicity tests exposing the freshwater shrimp *Caridina nilotica* to DDT (and DDE a breakdown product of DDT, both known to be endocrine disruptors), have been undertaken. Molting rates seem to be higher when exposed to DDE than when exposed to DDT. Preliminary measurements of fluctuating asymmetry are under way and chronic toxicity tests are planned for early 2011.

### DEVELOPMENT OF CARIDINA NILOTICA LIFE-CYCLE TOXICITY TEST PROTOCOL IN ORDER TO DERIVE WATER QUALITY GUIDELINES FOR ROUNDUP HERBICIDE IN SOUTH AFRICA

Student: Mr PK Mensah Supervisor: Dr WJ Muller Degree: PhD (Water Resource Science)

Herbicides as toxic agents are known to cause deleterious effects in aquatic ecosystems. South African farmers, as well as organizations interested in protecting the country's water resources often use Roundup and other glyphosate formulated herbicides to control weeds or invading alien plant species. These herbicides ultimately end up in water bodies indirectly through drifting, leaching, and surface runoff, or directly by foliar spray of these nuisance plants. Unfortunately, there is a paucity of ecotoxicological data on the impacts of these herbicides on the aquatic biota. The freshwater shrimp Caridina nilotica is an indigenous species often used for aquatic ecotoxicological tests in South Africa. Currently, there is no ecotoxicological data for Roundup (or any other glyphosate based herbicide) on C. nilotica. Furthermore, there is no life-cycle toxicity test protocol for C. nilotica although there are protocols to test some specific life-stage. Thus, the study seeks to fill these gaps. The overall aim of this study is to develop a water quality guideline for Roundup herbicide that can be used to manage environmental water quality as part of integrated water resource management. Preliminary studies involving range finding and definite acute toxicity tests with neonate, juvenile and adult shrimps have been done. Both short-term (96 hour) and long-term (21 days) Sublethal tests have also been done. These tests include the effect of the herbicide on gonad development, acetylcholinesterase and growth. Currently a test is ongoing for the effect of Roundup on lipid per oxidation, which is a cellular level toxicity test. All these will contribute to the next phase of the study, which involves the full life cycle test. Quantitative analysis of the test chemical using high performance liquid chromatography (HPLC) is at an advance stage.

### A COMPARATIVE ASSESSMENT OF THE PERFORMANCE AND DETERMINANTS OF POINT OF USE WATER TREATMENT TECHNOLOGIES IN A RURAL COMMUNITY CONTEXT OF SUB SAHARAN AFRICA

Student: Ms B Onabolu Supervisor: Prof. CG Palmer Degree: PhD (Water Resource Science)

The purpose of this research is to assess the performance of selected household water treatment technologies in real life (post trial) situations in rural communities of South Africa and Kenya and examine the behavioral determinants of performance in relation to adoption, compliance, promotion and sustained use.

Although much research has been conducted in the area of household water treatment, there is an absence of rigorously obtained scientific evidence of sustained use, positive health impact and water quality improvement over extended periods of use by the different POU technologies. Furthermore, most information on effectiveness are obtained from experiments/efficacy studies which do not reflect the actual post trial situations i.e. water treatment chemicals or products are provided at subsidized rates and usually accompanied by aggressive promotion (Luby et *al*. 2008; Sobsey *et al.*, 2008).

The proposed study addresses the gap in knowledge about :

- The comparative effectiveness of household water treatment and storage (HWTS) versus source water treatment
- The sustained effectiveness of point of use water quality interventions outside field trial situations particularly as a sizeable number of the studies have been efficacy and not effectiveness studies
- The human behavioral determinants of adoption, compliance, post trial sustained and large scale use of these water treatment technologies.

This study is based on existing interventions and will use a multi method approach which includes literature review, water quality tests, cross sectional survey, questionnaire administration, Key Informant Interviews (KII), and Geographical Information Systems (GIS). The information obtained will enable policy makers, technocrats and funding agencies make informed decisions about the types of household water treatment technology to invest in for sustained impact and scaling up of these interventions.

### MODELLING OF THE RELATIONSHIP BETWEEN FLOW AND WATER QUALITY IN SOUTH AFRICAN FRESHWATER SYSTEMS

Student: Mr A Slaughter Supervisor: Dr WJ Muller & Prof. DA Hughes Degree: PhD (Water Resource Science)

The National Water Act (Act 36 of 1998) provides for an ecological Reserve as the quantity (flow) and quality of water needed to protect aquatic ecosystems. While there are methods available to quantify the ecological Reserve in terms of flow, methods of linking flow to water quality are lacking. Therefore, the research presented in my Ph.D. thesis investigated various modelling techniques to estimate the affect of flow on water quality. Simple Q-C regressions of flow and water quality were investigated using Department of Water Affairs (DWA) historical monitoring data. It was found that while flow versus salinity regressions gave good regression fits in many cases, the Q-C regression approach is limited. A mechanistic/statistical model that attempted to estimate the point and diffuse signals of nutrients in response to flow was developed using DWA historical monitoring data. The model was verified as accurate in certain case studies using observed point loading information. Statistical models that link land cover information to diffuse nutrient signals in response to flow using DWA historical data were developed. While the model estimations are uncertain due to a lack of data, they do provide an estimation of the diffuse signal within catchments where there is flow and land cover information available. An existing mass-balance salinity model was extended to estimate the effect of saline irrigation return flow on in-stream salinity. The model gave accurate salinity estimates for an ephemeral stream with little or no irrigation within its catchment, and for a permanently flowing river within a catchment used extensively for irrigation. The ability of the in-stream model QUAL2K to estimate nutrient concentrations downstream of point and diffuse inputs of nutrients was investigated. It was found

that the QUAL2K model can give accurate results in cases where point sources dominate the total nutrient inputs into a river. However, the QUAL2K simulations are too uncertain in cases where there are large diffuse source inputs of nutrients as the load of the diffuse inputs is difficult to measure in the field. Finally, a modelling method to estimate the reaction coefficients involved in nitrification using only DWA historical monitoring data was investigated. Here, the model used flow information to estimate the residence time of nutrients within the studied river reaches. While the model obtained good estimations of nitrification for the data it was applied to, very few DWA data sets were suitable for the model. This research highlights the problem of data scarcity in terms of temporal resolution as well as the range of constituents measured within DWA historical monitoring data for water quality. This thesis in addition argues that the approach of applying a number of models is preferable to applying one model to investigate the research aim, as particular models would be suited to particular circumstances, and the development of new models allowed the research aim of this thesis to be explored more thoroughly. It is also argued that simpler models that simulate a few key processes that explain the variation in observed data, are more suitable for implementing Integrated Water Resource Management (IWRM) than large comprehensive water quality models.

### CLIMATE VARIABILITY AND CHANGE IN WATER RESOURCES MANAGEMENT OF THE ZAMBEZI RIVER BASIN

Student: Ms S Tirivarombo Supervisor: Prof. DA Hughes Degree: PhD (Water Resource Science)

Climate variability and climate change mainly result in alterations to climatic variables such as precipitation, evaporation and temperature. Water resources are the most vulnerable to these impacts due to changes in river flow patterns and these will affect all water users. The most vulnerable regions will be affected the most and extreme events will worsen the food security situation. This research project aims to explore ways of incorporating climate change and variability into water resources planning and management of the Zambezi river basin, the overall objective of the study being to establish the relationship between climate variability/change and the hydrology of the Zambezi river basin. Expected outcomes of the research include an enhanced understanding of the interaction between the climate and hydrologic systems, translation of climate change signals into the hydrological component of the basin, assessing climate related vulnerabilities and identifying possible adaptation strategies for the Zambezi basin. The ultimate goal is to assist water resource managers and practitioners in taking informed decisions on sustainable basin water management. The main activities during the year 2010 involved undertaking a comprehensive regional drought analysis of the Zambezi basin and calibrating the Pitman rainfall runoff model. Data collection has always been a challenge for the southern African

region and it remains an ongoing process with the view of improving the research results.

### REGIONAL APPLICATION OF THE PITMAN MONTHLY RAINFALL-RUNOFF MODEL IN SOUTHERN AFRICA INCORPORATING UNCERTAINTY

Student: Mr E Kapangaziwiri Supervisor: Prof. DA Hughes Degree: PhD (Hydrology)

Hydrological predictions in ungauged basins in South Africa have generally been based on regionalisation of parameters derived from calibration on a limited recorded streamflow database. The outputs from such approaches have always been accepted to be uncertain though no attempts to quantify and analyse this uncertainty have been attempted. The impact of this uncertainty is therefore largely unknown as there has not been any inclusion of uncertainty in water resources development decision making. This study explores the propagation and impact of uncertainty of an a priori parameter estimation method for the Pitman monthly model in South African basins.

Uncertainty in hydrology manifests itself in three major areas of the modelling chain; the input data used to force the model, the parameter estimation process and the model structural errors. While the literature abounds with uncertainty estimation techniques, most of these are dependent on observations and are therefore unlikely to be easily applicable to the southern African region where there is an acute shortage of such data. This study advocates the development of an *a priori* parameter estimation process for the Pitman model and uses indices of hydrological functional behaviour to condition and reduce predictive uncertainty in both gauged and ungauged basins.

An uncertainty model-independent framework is also proposed. The framework is made up of a number of components related to the estimation of the prior distribution of the parameters, used to generate output ensembles which are then assessed using regionalised indices of basin behavioural responses. This is premised on such indices being based on the best available knowledge covering different regions.

This study reports on the preliminary work on the development and testing of the framework components based on South African basins. Uncertainty into the parameter estimation process was incorporated by assuming uncertainty in the physical and hydro-meteorological data used to directly quantify the parameters. This uncertainty was represented by the range of variability of these basin characteristics and probability distribution functions were developed to account for this uncertainty and propagate it through the estimation process to generate posterior distributions for the parameters. The results show that the framework has a lot of potential and can be improved on. In general, the estimated uncertain parameters managed to produce hydrologically realistic model outputs capturing the expected regimes across different hydro-climatic and geo-physical gradients examined. The regional relationships for the three indices developed and tested in this study were in general agreement with existing knowledge and managed to successfully provide a multi-criteria conditioning of the model output ensembles. The feedback loop included in the framework enabled a systematic reexamination of the estimation procedures for both the parameters and the indices when problems arose. However, there is need to carefully examine the issues and problems that may arise within other basins outside South Africa and develop guidelines of the use of the framework.

This PhD work was submitted for examination in early 2010 and the degree was awarded, but will be conferred at graduation in April 2011.

### HYDROLOGICAL UNCERTAINTY ANALYSIS AND SCENARIO-BASED STREAMFLOW MODELLING FOR THE CONGO BASIN

Student: Mr R Tshimanga Supervisor: Prof. DA Hughes Degree: PhD (Hydrology)

The hydrology of the Congo basin is poorly understood, yet it is crucial to understanding the dynamics of water resources in Africa. This situation is caused by a lack of hydrological information, further exacerbated by absence of real basin data and experimental research. In recognition of uncertainties such as the impact of climate change, anthropogenic activities and land use changes, surrounding the availability of present and future water resources, there is need to adequately quantify and understand the dynamics of the hydrological processes in the Congo basin. The current research project aims at establishing a framework of identifiability and uncertainty analysis with regards to data development and conceptual modelling of the Congo basin. The study will also analyze a set of scenarios for future development options of water resources in the Congo basin.

Given the absence of adequate hydrological and climate data for the Congo basin, the preliminary work consisted of identifying various sources (local, regional and global) of data, necessary to develop reliable hydro-climate baseline information. These data were then used to establish the Pitman rainfall runoff model for the whole basin, representing 3,680,000 Million Km<sup>2</sup>. The preliminary assessment of the model performance through a framework of sensitivity and uncertainty analysis helped indentify the area for improving the conceptual understanding of the hydrological processes in the basin. This area is the focus of the current work and it includes an exploration of the behavioral parameters in the context of all available basin physical property data (topography, soil types, vegetation, geology and hydrogeology).

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

### Student: Ms JL Tanner Supervisor: Prof. DA Hughes Degree: MSc (Hydrology)

The research aims to evaluate whether the Pitman rainfallrunoff model can accurately represent surface water and ground water interactions in South African basins. Quantification of surface and ground water interactions is essential for the facilitation of appropriate decision making and resource management. The Pitman model, which has been modified to incorporate ground water routines, aims to combine surface water and ground water estimation approaches which have developed separately from each other. The MSc research included the development of conceptual hypotheses about surface water and ground water interaction processes (using available data from ground water studies undertaken in South Africa) and then assessing the ability of the model to represent these processes.

The overall conclusion is that the model is able to simulate the interactions between surface and ground water in a realistic manner. However, a large degree of uncertainty still exists for the values of the various simulated components of the ground water balance. It is planned to upgrade the MSc degree to a PhD degree in January 2011 which will focus on reducing this uncertainty by testing the model in more example sites with more depth of analyses. This work will include collaboration with a number of institutions (both universities and consultancies) carrying out field investigations. To reduce the uncertainty and increase confidence in the model we need a better conceptual understanding of surface and ground water interaction dynamics and observed data to support the conceptual understanding. The literature review for the MSc has been completed and a PhD proposal is underway. Work completed to date includes two example sites analysed using the Pitman model, and a number of other case studies in progress and planned as part of the PhD work. If the uncertainty can be reduced by an improved interpretation of existing information coupled with observed data collected by simple field investigations, then it may be concluded that the model has a potential to contribute to integrated water resource planning and management.

### CHIRONOMIDAE LARVAL DEFORMITIES AS INDICATORS OF ANTHROPOGENIC IMPACTS IN THE SWARTKOPS RIVER

Student: Mr ON Odume Supervisor: Dr WJ Muller Degree: MSc (Water Resource Science)

Growing human population, increase urbanization and industrialisation have led to pollution of already stressed freshwater resources and consequent deterioration in environmental water quality. The Swartkops River is an important freshwater ecosystem in South Africa but owing to its strategic location, draining several industrial and residential areas, it suffers various kinds of anthropogenic impacts. As a result, there is need for a holistic assessment of the impacts of anthropogenic activities on in-stream biota in the Swartkops River.



(a) normal mentum of Chironomus spp. ( b) Chironomus spp. mentum with missing teeth

The project employs different levels of macroinvertebrate based biomonitoring approaches to assess the impact of deteriorating environmental water quality on in-stream biota in the Swartkops River. The approaches include the use of a single biotic index (the South African Scoring System version 5), a multimetric approach and screening of deformities in Chironomidae. By applying different approaches that incorporate information from different levels of taxonomic resolution, i.e. family, genus or species and biological organisations, i.e. community, population, organismal and sub-organismal levels allow for a holistic means of quantifying impacts of anthropogenic activities on in-stream biota in the Swartkops River. The research provides useful information needed improve management of the Swartkops River water resources.

### EVALUATING THE THREATS TO SUSTAINABLE WATER SERVICES DELIVERY RELATED TO ENVIRONMENTAL CHANGE: A CASE STUDY OF THE AMATHOLE DISTRICT

Student: Ms AM Mashao Supervisor: Prof. DA Hughes and Dr SK Mantel Degree: MSc (Water Resource Science)

This research project was developed as part of the climate change project granted by the Water Research Commission of South Africa to the Institute for Water Research in April 2010. The main aim of this IWR project is to develop adaptation measures and decision-support framework for the Amatola and Bloem Water Boards. The purpose of this MSc project is however, to evaluate how environmental change, particularly climate change, may affect sustainability of water services delivery in the Amathole District area where Amatola Water Board serves as the main potable bulk water supplier. Conducting this study is important because the expected future climate change conditions may negatively impact on water quantity and quality, and consequently on the water supply. Amathole District in the Eastern Cape Province was selected for undertaking this study because so far no research on how the expected environmental change may affect sustainability of water supply services was conducted. Historical and present hydrology and quality data from the Department of Water Affairs are used as well as data from the study area e.g. data on dams, population sizes, pollution generation sites etc. This gap in knowledge is addressed by application of various models including Patching flow data model and Pitman rainfall-runoff model in SPATSIM, and WEAP water quality model. Patching model was used to patch for missing data periods (hydrology data) for data obtained from the Department of Water Affairs. After patching, the data were used together with data from the study area, for simulations of water quality, flows and water demands for multiple water uses in the study area through application of WEAP model i.e. for historical scenarios. The data were also used for WEAP model calibration, and will also be used for simulations of present scenarios. Pitman rainfallrunoff model will be applied to simulate future flows which will then be used for simulations of future scenarios.

Progress made in this project so far includes:

- formulation and presentation of research proposal;
- literature review on the subject matter and study area;
- hydrology and water quality data collection as well as data defining study;
- application of Patching flow data model;
- WEAP model setup for the area and model calibration; and
- interpretation of first results on simulations of historical scenarios (in progress)

# 8. RESEARCH OUTPUTS

### PEER REVIEWED JOURNALS AND CONFERENCE PROCEEDINGS

- Dudgeon D, Cheung FKW, Mantel SK (2010) Food-web structure in small streams: do we need different models for the tropics? *Journal of the North American Benthological Society* 29: 395-412.
- Hughes, DA (2010) Unsaturated zone fracture flow contributions to stream flow: evidence for the process in South Africa and its importance. *Hydrological Processes* 24: 767-774.
- Hughes, DA (2010) Hydrological models: mathematics or science? Hydrological Processes 24: 2199-2201.
- Hughes, DA, Kapangaziwiri, E and Baker, K (2010) Initial evaluation of a simple coupled surface and ground water hydrological model to assess sustainable ground water abstractions at the regional scale. *Hydrological Research* 41(1): 1-12.
- Hughes, DA, Kapangaziwiri, E and Sawunyama, T (2010) Hydrological model uncertainty assessment in southern Africa. *Journal of Hydrol*ogy 387: 221-232.
- Hughes, DA and Louw, D (2010) Integrating hydrology, hydraulics and ecological response into a flexible approach to the determination of environmental water requirements for rivers. *Environmental Modeling & Software* 25(8): 910-918.
- Hughes, DA and Mantel, SK (2010) Estimating the uncertainty in the impacts of small farm dams on stream flow regimes in South Africa. *Hydrological Sciences Journal* 55(4): 578-592.
- Hughes, DA and Mantel, S (2010) Estimating uncertainties in simulations of natural and modified streamflow regimes in South Africa. *Global Change – Facing Risks and Threats to Water Resources* (Proceedings of the Sixth FRIEND World Conference held in Fez, Morocco, November 2010), *IAHS Publications 340*: 358-364.
- Hughes, DA, Tshimanga, R and Tirivarombo, S (2010) Simulating the hydrology and water resources of large basins in southern Africa. *Global Change – Facing Risks and Threats to Water Resources* (Proceedings of the Sixth FRIEND World Conference held in Fez, Morocco, November 2010), *IAHS Publications 340*: 591-597.
- Mantel SK, Hughes DA and Muller WJ (2010) Ecological impacts of small dams on South African rivers: I. Drivers of change water quantity and quality. *Water SA* 36(3): 351-360.
- Mantel SK, Muller WJ, Hughes DA (2010) Ecological impacts of small dams on South African rivers: II. Biotic response - abundance and composition of macroinvertebrate communities. *Water SA* 36(3): 361-370.
- Richardson N, Gordon AK, Muller WJ, Pletschke BI, Whitfield AK (2010) The use of liver histopathology, lipid peroxidation and acetylcholinesterase assays as biomarkers of contaminant-induced stress in the Cape stumpnose, *Rhabdosargus holubi* (Teleostei: Sparidae), from selected South African estuaries. *Water SA* 36: 407-415.
- Sawunyama T and Hughes DA (2010) Using satellite-based rainfall data to support the implementation of environmental water requirements in South Africa. Water SA 36(4): 379-385.

### IN PRESS AND SUBMITTED ARTICLES

- Hughes, DA (2010) Regionalisation of models for operational purposes in developing countries: An introduction. *Hydrological Research* (in press – part of a special edition).
- Hughes, DA, Kingston, DG and Todd, M.C. (2010) Uncertainty in water resources availability in the Okavango River Basin as a result of climate change. *Hydrology and Earth Systems Science Discussions*, 7: 1-32.
- Lowe SR, de Moor FC and Griffin NJ (2010) Recovery of aquatic biota following rehabilitation of mountain streams invaded by riparian trees in the Cape fold mountains of South Africa. *Hydrobiologia* (submitted).

### REPORTS

- Gordon AK, Griffin NJ, Holland AJ, Gola NP and Muller WJ (2010) Annual progress report to the Technology and Human Resources for Industry Programme (THRIP).
- Gordon AK, Griffin NJ and Holland AJ (2010) Environmental water quality monitoring for Richards Bay Minerals: Smelter Site Area. Annual Report.
- Gordon AK, Griffin NJ, Muller WJ (2010) Environmental water quality monitoring for Sasol. Final Report.
- Gordon AK, Mantel, SK and Muller WJ (2010) Evaluating the potential contribution of episodic toxicity data to environmental water quality management in South Africa. Final report for the WRC project K8/851, Water Research Commission, Pretoria, South Africa
- Gordon AK and Muller WJ (2010) Developing sediment quality guidelines for South Africa. Phase 1: identification of international best practice and applications for South Africa to develop a research and implementation framework. Final report for the WRC project K8/793, Water Research Commission, Pretoria, South Africa.
- Griffin NJ, Muller WJ and Gordon AK (2010) Evaluation of methods for assessment of ecotoxicological risk due to complex effluent discharge. WRC report K8/748.
- Griffin NJ (2010) Database of South African seaweeds: Phase 3. Progress report period 01 January 2010 30 June 2010.
- Griffin NJ (2010) Database of South African seaweeds: Phase 3. Mid-year review and technical report.
- Holland AJ and Muller WJ (2010) Environmental assessment in an area where ongoing DDT spraying occurs (WRC Project K5/1706). Deliverable No. 5: Rhodes University report on all fieldtrips.
- Hughes DA, Mantel SK (2010) Developing Climate Change Adaptation Measures and Decision-Support System for Selected South African Water Boards: Deliverable 1. Project Number K5/2018. The Institute for Water Research. Report submitted to the Water Research Commission.
- Hughes DA, Smithers J, Kapangaziwiri E and Frezghi M (2010) Identification, estimation, quantification and incorporation of risk and uncertainty in water resources management tools in South Africa (WRC Project K5/1838). Deliverable No. 7: Second report on hydrological model uncertainty quantification.

- Hughes DA, Kapangaziwiri E and Mallory SJL (2010) Identification, estimation, quantification and incorporation of risk and uncertainty in water resources management tools in South Africa (WRC Project K5/1838). Deliverable No. 8: Report on integrating hydrological model and system yield uncertainties.
- Hughes DA, Kapangaziwiri E and Mallory SJL (2010) Identification, estimation, quantification and incorporation of risk and uncertainty in water resources management tools in South Africa (WRC Project K5/1838). Deliverable No. 9: A report on techniques and tools for quantification of uncertainty.
- Hughes DA, Mallory SJL and Kapangaziwiri E (2010) Identification, estimation, quantification and incorporation of risk and uncertainty in water resources management tools in South Africa (WRC Project K5/1838). Deliverable No. 10: A report on communication strategies required to relay uncertainty information to stakeholders.
- Hughes DA, Mallory SJL and Kapangaziwiri E (2010) Identification, estimation, quantification and incorporation of risk and uncertainty in water resources management tools in South Africa (WRC Project K5/1838). Deliverable No. 11: A report on reducing uncertainty.
- Hughes DA, Desai A and Birkhead A (2010) Development of a revised Desktop Reserve estimation model (WRC Project K5/1856). Deliverable No. 4: Prototype version of the hydraulic sub- model.
- Hughes DA (2010) Development of a revised Desktop Reserve estimation model (WRC Project K5/1856). Deliverable No. 5: Design recommendations for the revised, integrated desktop Reserve model.
- Hughes DA, Kleynhans CJ, Louw D and Birkhead A (2010) Development of a revised Desktop Reserve estimation model (WRC Project K5/1856). Deliverable No. 7: Prototype version and testing of the revised, integrated desktop Reserve model.
- Moore BA, Burgess JE and Muller WJ (2010) Confidential quarterly progress reports.
- Rivers-Moore NA, Mantel SK and Dallas H (2010) Temperature Metrics Guidelines to classify water temperature time series into ecologically meaningful metrics. Report Number 1799/15. The Institute for Water Research and The Freshwater Consulting Group. Report submitted to the Water Research Commission.
- Rivers-Moore NA, Mantel SK and Dallas H (2010) Water Temperatures and the Ecological Reserve: Development of a spatial framework for managing water temperature. Project Number K5/1799. The Institute for Water Research and The Freshwater Consulting Group. Report submitted to the Water Research Commission.

### CONFERENCE PROCEEDINGS

Hughes DA and Muller WJ (2010) Hydrological model and data analysis support for climate change adaptation strategies within a South African water board. In: Role of Hydrology in Managing Consequences of a Changing Global Environment, Proc. 3rd BHS International Symposium, Newcastle, UK.

### CONFERENCE PRESENTATIONS

Griffin NJ, Muller WJ and Gordon AK (2010) Kits versus cultures, standard versus indigenous test organisms: a comparison of methods for toxicological assessment of complex waste. Poster presented at the South African Aquatox Forum's seminar on risk assessment of emerging pollutants in the environment, University of Johannesburg, Johannesburg, South Africa, 23 November 2010.

- Hughes DA (2010) Groundwater-surface water interaction: The need for a common understanding. Baseflow. Invited presentation at the Water Institute of Southern Africa (WISA) Biennial Conference, Durban, April 2010.
- Mensah PK and Muller WJ (2010) A preliminary water quality guideline for Roundup herbicide in South Africa: assessment factor approach. A paper presented at the 31st Congress of the International Society of Limnology (SIL), Cape Town, South Africa, 15-20 August 2010.
- Mensah PK and Muller WJ (2010) Acute toxicity of the herbicide Roundup to three life stages of the freshwater shrimp Caridina nilotica. A paper presented at the 11th Waternet/WARFSA/GWP-SA Symposium, Victoria Falls, Zimbabwe, 27-29 October 2010.
- Naigaga I, Kaiser H, Muller WJ and Ojok L (2010) Biomonitoring of water quality using fish as bioindicator species: a case of Lake Victoria Wetlands, Uganda. Poster presented at the RISE International conference, Benoni, South Africa, October 2010.
- Odume ON and Muller WJ (2010) Mentum and ligula deformities in Chironomidae (dipteral) larvae as indicators of anthropogenic impacts in the Swartkops River, South Africa. Paper presented at the 31st Congress of the International Limnological Society, Cape Town, South Africa, August, 2010.
- Odume ON and Muller WJ (2010) Assessment of nutrient enrichment in the Swartkops River – Multimetric approach based on macroinvertebrates. Poster presented at RISE International conference, Benoni, South Africa, October, 2010.
- Odume ON and Muller WJ (2010) Diversity and structure of Chironomidae communities in relation to water quality changes in the Swartkops River. Paper presented at the 11th WaterNet/WARFSA/GWP-SA Symposium, Victoria Falls, Zimbabwe, October 2010.
- Onabolu B, Jimoh OD, Igboro SB, Sridhar MKC, Onyilo G, Yaro J and Adewole J (2010) Establishment of an integrated water quality monitoring system, in Katsina Nigeria. Paper presented at the 11<sup>th</sup> Water-Net/WARFSA/GWP-SA Symposium, Victoria Falls, Zimbabwe, October 2010.
- Tanner JL and Hughes DA (2010) Surface and groundwater interaction modelling – a case study from South Africa using the Pitman Model. Paper presented at the WaterNet/WARFSA/GWP-SA Symposium, Victoria Falls, Zimbabwe, October 2010.
- Tanner JL and Hughes DA (2010) Quantifying interactions between groundwater and surface water using the Pitman Hydrological model. Paper presented at the RISE International Conference, Benoni, South Africa, October 2010.
- Tirivarombo S and Hughes DA (2010) Regional Droughts and Food Security Relationships for the Zambezi basin. Poster presented at the 11<sup>th</sup> WaterNet/WARFSA/GWP-SA Symposium, Victoria Falls, Zimbabwe, October 2010.
- Tshimanga RM and Hughes DA (2010) Quantifying water resources of the Congo basin. Paper presented at the RISE conference on strengthening higher education in Africa, South Africa, October 2010.
- Tshimanga RM, Hughes DA and Kapangaziwiri E (2010) Initial calibration of the Pitman rainfall runoff model for the Congo Basin. Poster presented at the 11th WaterNet/WARFSA/GWP-SA Symposium, Victoria falls, Zimbabwe, October 2010.

Annual Report layout done by Candice Roux (Senior Technical Officer)

Back Cover (top to bottom): Tarqyn Human assisting with sampling in the West Kleinemonde River | Environmental Science field trip to the Palmiet River | RISE students during a Hydrology field course (Potshini catchment, Drakensberg) | RISE students at the WaterNet/WARFSA Symposium | Getting stuck into field work downstream for the Barrage on the Vaal River during a Sasol Field Trip. Photos kindly supplied by IWR staff and students

