Institute for Water Research

ANNUAL REPORT

2021

RHODES UNIVERSITY
Where leaders learn

IWR

IWR: ARUA Water Centre of Excellence Hub

ARUA
African Research Universities Alliance

ARUA Water CoE

TABLE OF CONTENTS

Project partners in the Institute for Water Research

AFRICA
Addis Ababa University, Ethiopia
Amathole District Municipality, Eastern Cape, South Africa
Amatola Water, South Africa
Cheikh Anta Diop University, Senegal
Chris Swartz Water Utilisation Engineers
City for Scientific and Technological Applications, Egypt
Council for Scientific & Industrial Research, South Africa
Department of Water and Sanitation, South Africa
Federal University of Technology, Minna, Nigeria
GAIA (Groupe d'action et d'initiative pour une developement alternatif), Senegal
Kouga Local Municipality, Eastern Cape, South Africa
Makerere University, Uganda
Malawi University of Science and Technology, Malawi
Mercedes-Benz Manufacturing, South Africa
Mooi University, Kenya
National Higher School of Hydraulics, Algeria
University of Cape Town, South Africa
University of Dar es Salaam, Tanzania
University of Kinshasa, Democratic Republic of Congo
University of KwaZulu-Natal, South Africa
University of Lagos, Nigeria
University of Rwanda, Rwanda
Université Joseph Ki-Zerbo

EUROPE
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Barthauer Software, Germany
Gemeinde Ilsfeld, Germany
GIZ, Germany
IIASA (International Institute for Applied Systems Analysis), Austria
INRAE (Institut national de la recherche agronomique), France
Research Institute for Water and Waste Management, Germany
Stockholm University, Sweden
TU Delft, The Netherlands
TZW: DVGW-Technologieszentrum, Germany
University of Hohnheim, Germany
Universität Bayreuth, Germany
Universiteit Stuttgart, Germany

NORTH AND SOUTH AMERICA
CRS System, Brazil
Society for Freshwater Science, Illinois, USA

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Dr Bukho Gusha	Postdoctoral Fellow
Dr Neil Griffin	Research Officer
Dr David Gwapedza	Postdoctoral Fellow
Dr Notiswa Libala	Postdoctoral Fellow
Dr Sukhmani Mantel	Senior Research Officer
Ms Juanita McLean	Administration Manager
Ms Ntombekhaya Mgaba	Senior Technical Officer
Ms Ntombekhaya Mti	Research Assistant
Dr Chika F. Nnadozie	Research Officer
Professor Nelson Odume	Associate Professor; Director: CEWQ
Dr Kathleen Smart	Postdoctoral Fellow
Professor Tally Palmer	Professor; Director: IWR
Professor Tony Palmer	Honorary Professor / Research Officer
Dr Rebecca Powell	Postdoctoral Fellow
Dr Jane Tanner	Senior Research Officer
Dr Matthew Weaver	Postdoctoral Fellow

ASSOCIATES

Professor Brian Allanson	Honorary Research Fellow
Dr Jai Clifford-Holmes	Research Associate
Professor Denis Hughes	Professor Emeritus
Dr Paul Mensah	Senior Research Associate
Dr Nikite Muller	Senior Research Associate
Dr Eric Igbinigie	Senior Research Associate
Dr Patsy Scherman	Senior Research Associate
Dr Andrew Slaughter	Research Associate
Professor Jill Slinger	Visiting Professor

REGISTERED POSTGRADUATE STUDENTS

Mr Andrew Ali	MSc (Water Resource Science)
Ms Mary Chibwe	PhD (Water Resource Science)
Ms Asanda Chili	MSc (Water Resource Science)
Mr Jaco Greeff	MSc (Hydrology)
Mr Anthony Fry	PhD (Water Resource Science)
Mr Sakikhaya Mabohlo	MSc (Hydrology)
Ms Bawanile Mahlaba	MSc (Water Resource Science)
Ms Zintle Mtintsilana	MSc (Water Resource Science)
Ms Nandipha Ngoni	MSc (Water Resource Science)
Ms Pindi Ntloko	PhD (Water Resource Science)
Ms Anele Ntshangase	MSc (Water Resource Science)
Ms Harriette Okal	PhD (Hydrology)
Mr Miracle Osoh	PhD (Water Resource Science)
Mr Enahoro Owowenu	PhD (Water Resource Science)
Ms Mateboho Ralekhetla	PhD (Water Resource Science)
Mr Mankoe Raliengoane	BSc Hons (Environmental Water Management)
Ms Phatsimo Ramatsabana	MSc (Hydrology)
Ms Noleen Tavengwa	MSc (Water Resource Science)
Mr Stefan Theron	MSc (Water Resource Science)
Mr Edgar Tumwesigye	PhD (Water Resource Science)
Mr Peter Wasswa	MSc (Hydrology)
Mr Sinethemba Xoxo	PhD (Hydrology)
Mr Kamva Zenani	MSc (Water Resource Science)

REGISTERED POSTGRADUATE STUDENTS CO-SUPERVISED IN PARTNER DEPARTMENTS

Ms Regina Dakie	MSc (Environmental Science)
Ms Pippa Schlegel	PhD (Geography)

2021 GRADUATED STUDENTS

Mr Frank Akamagwuna	PhD (Zoology)
Ms Regina Dakie	BSc Hons (Environmental Water Management)
Mr David Gwapedza	PhD (Hydrology)
Mr Pierre Kabuya	PhD (Hydrology)
Mr William Liversage-Quinlan	MSc (Water Resource Science)
Mr Coli Ndzabandzaba	PhD (Hydrology)
Mr Yanga Njiva	BSc Hons (Environmental Water Management)
Mr Sakhikhaya Mabohlo	BSc Hons (Environmental Water Management)
Ms Sibuyisele Pakati	MSc (Geography)

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Mr Ramie Xonxa	Makana Local Municipality

IWR DIRECTOR'S REPORT

In 2021 Covid-19 became a way of life, and the IWR has adapted with resilient commitment. We have become adept at on-line and hybrid engagements, continuing to practice in terms of our values, and we have progressed the key objectives defined in the 2020 Strategic Adaptive Planning process:

Research funding

> *Objective*: To ensure that the IWR has diverse funding sources for: salaries, student bursaries, running costs, infrastructure, equipment and maintenance, workshops, well-being and investment for long-term sustainability.

IWR continued to secure and deliver on grant funding in 2021, consolidating our international funding track-record.

A critical challenge arose when the UK Research and Innovation (UKRI) £2.6M ARUA Water Centre of Excellence (CoE) projects were cut by 50% without any security of UKRI honouring the following two years of contractually agreed support. This resulted in a substantive loss of productive time - spent in re-planning, anxiety for those whose salaries depended on the projects, and tremendous administrative and research leadership load for Drs Jane Tanner and Sukhmani Mantel and CoE Manager, Juanita McLean. In November 2021 UKRI announced funding would be re-instated from April 2022 – a welcome relief, but one that also carries a second re-planning load. Jane and Sukhmani have led remarkable project delivery under demanding circumstances.

The launch of the African Water Resources Mobility Network (AWaRMN), funded by the European Union Intra-Africa Academic Mobility Scheme, has been a significant success. This €1.39M funding stream supports a new cohort of IWR postgraduate students from across Africa. Professor Nelson Odume leads the initiative, with IWR Visiting Professor, Professor Jill Slinger (Delft University of Technology), as a significant partner.

In addition to substantive AWaRMN contributions, Dr Chika Nnadozie secured a €150K grant under the European and Developing Countries Clinical Trials Partnership (EDCTP) programme.

IWR Research Associate Dr Jai Clifford-Holmes brokered a significant IWR partnership with the International Institute for Applied Systems Analysis (Austria), which resulted in a successful grant award from the Belmont Forum-NRF *Collaborative Research Action Pathways to Sustainability* call, with Professor Nelson Odume as the NRF-funded Principal Investigator.

Significantly, two new Water Research Commission projects have been awarded to Post-Doctoral fellows Drs David Gwapedza and Bukho Gusha as Principal Investigators. We are delighted to retain them in the IWR.

It is unusual to include the notion of investment in well-being in a section on funding. Perhaps the challenges of Covid-19 have brought this to the fore, and personal well-being was supported both individually and collectively. The IWR continued to Zoom-meet every two weeks, with everyone joining reliably. We included a ten-minute set of random breakaway-room "chats" to allow for some of the personal connection we have lost in this socially distanced world. At the earliest opportunity we hosted an outdoor welcome tea for new students, and later in 2021 resumed our Friday morning teas – all moves towards living with Covid-19.

Mindfulness practice has been championed by Dr Sukhmani Mantel. Four IWR staff participated in a research project: *Mindfulness for well-being and enhanced teaching in academia: A mindfulness-based program in South African higher education, co-ordinated from Wits University.* We introduced short Mindfulness practices in our IWR meetings to share a sense of what mindfulness involves, and followed-up by offering an opportunity for IWR staff and students to participate in an eight week course, run by Makhanda-based Mindfulness practitioner and trainer Alex Johnson. We had eight participants, and mindfulness practice has proved a welcome part of supporting wellbeing.

Of the elements in the objective, the one still to meet is sufficient funding to have *investment for long-term sustainability.* The IWR investments are used to provide surety to Rhodes University that University funds can be made available to IWR researchers when cash flow fails. This ensures continuity of function. However, IWR investments are not sufficient to pay salaries to staff or postdoctoral fellows whom it would be advantageous to retain in a year when insufficient grant funding has been secured.

Most grants require postgraduate student recruitment, and the most significant limitation to the growth of the postgraduate school is IWR supervisory capacity, which will be further reduced by the retirement of the Director. As always, security of employment, at least for senior research academics, would be the best pathway for the University to support and retain a vibrant IWR.

Research Outputs and Human Capability

> *Objectives*: To ensure that the IWR produces high quality, impactful outputs: highly skilled and competent students; community-engaged services; high quality publications; and vibrant research programmes. Our outputs are diverse in nature and reach different audiences including academics, community members, policy makers and civil society

Professor Nelson Odume was once again recognised as one of the most productive researchers at Rhodes University, in a year of strong IWR research productivity:

It is noteworthy that Professor Emeritus Denis Hughes is an author on eight of the articles published.

Visiting Professor Jill Slinger produced an interactive e-book published by TU Delft Open Publishing: *Building with Nature & Beyond: Principles for designing nature based engineering solutions | TU Delft OPEN Textbooks*, with Professor Tally Palmer and Dr Athina Copteros as collaborating contributors.

The innovative Tsitsa Project, funded for six years by the Department of Forestry, Fisheries and the Environment has reached the point of policy influence. Professor Tally Palmer, Dr Jai Clifford-Holmes and doctoral student Anthony Fry have authored two of the briefs in the Tsitsa Project *Practice and Policy Brief* series.

The new cohort of IWR postgraduate students have rapidly become a responsive, dedicated group, and we look forward to their contributions in our biennial Strategic Adaptive Management process in 2022. The resumption of high-quality student seminars has been welcome. IWR postdoctoral fellows have led a course in statistics, mentored ARUA Water CoE students and early career researchers in preparing publications through a Writing Community of Practice, with support from the Centre for Post Graduate Studies. Dr Sukhmani Mantel pioneered the production of narrative videos for effective, accessible communication of research findings, several of which were showcased at the ARUA biennial conference.

In an ongoing contribution to the development of water resources professionals, one Masters and four doctoral students graduated from the IWR in 2021.

Research output 2015-2021

Year	Peer Reviewed Papers & Conference Proceedings	Book Chapters	Research Reports	Conference Presentations
2015	18	4	24	24
2016	13	5	20	35
2017	19	4	24	36
2018	21	2	18	14
2019	31	1	5	15
2020	22	5	18	10
2021	40	4	12	20

Partnerships

Objective: To ensure that the IWR has strong, transparent and rich relationships with diverse local, national and international institutions. Our partnerships facilitate mutually beneficial opportunities for collaborations and the exchange

The cover of this annual report, and the project reports that follow, present the geographic spread of institutional partnerships. In 2021 the IWR actively collaborated with Universities across South Africa and Africa, as well as in the United States of America, the United Kingdom, France, Germany, Austria, and the Netherlands. We retain strong partnerships with the National Departments of Water and Sanitation and Forestry, Fisheries and Environment, and with Provincial and Local Government Departments in the Eastern Cape. We work actively with NGOs, notably with AWARD (Association of Water and Rural Development) and the LIMA Rural Development Foundation.

Technical capacity

The IWR provides access to state of the art field and laboratory equipment and enhances its technical capacity through strategic partnerships. The IWR has experience in production of software tools in several fields and the skills to work with big data and capital equipment.

The IWR technical capacity that supports success in securing research funding, academic performance and developing partnerships includes: ongoing leadership in the development and application of hydrological modelling, an emerging strength in microbiological genomics, fundamental skills in statistical analysis (using programmes such as "R"), earth observation and GIS, and the deployment of eddy covariance and large aperture scintillometer equipment used for landscape-scale water and carbon flux measurements.

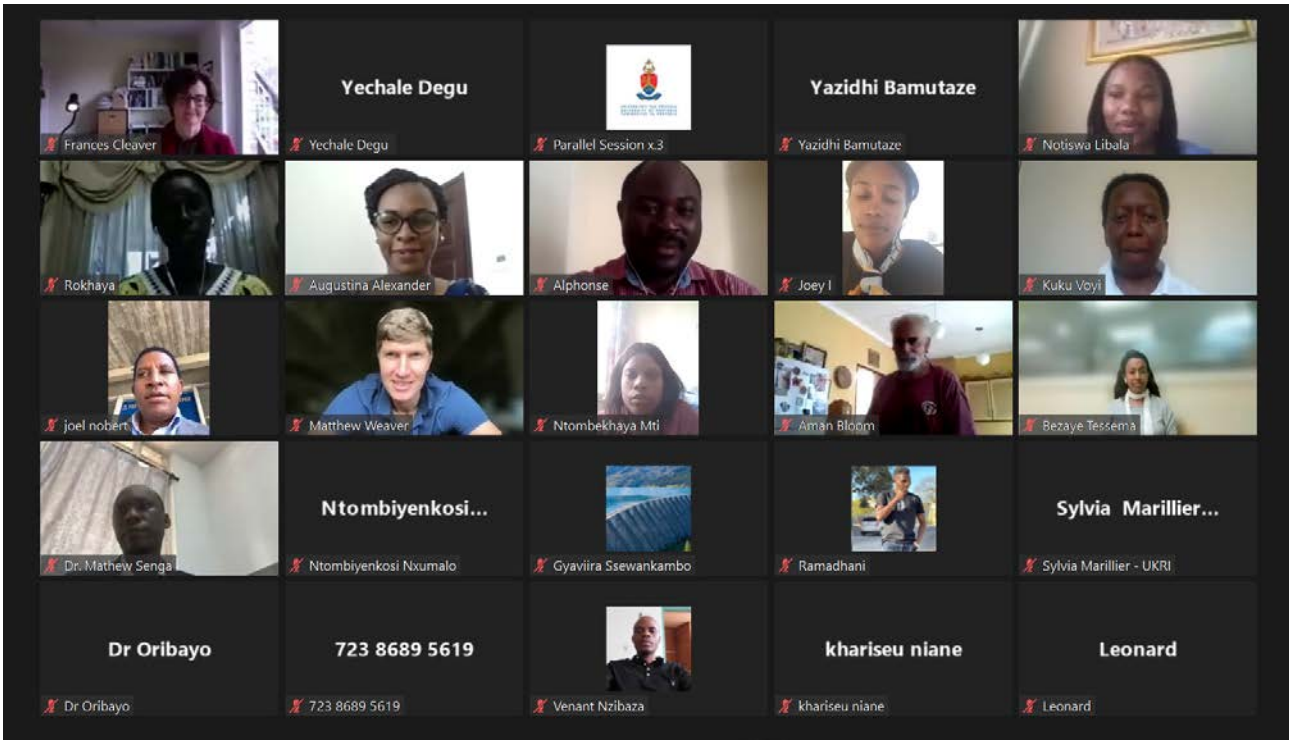
In working towards each of these objectives we have inherently progressed the final objective:

Visibility

The IWR is well-recognised across the university and beyond as a transdisciplinary Institute that fosters sustainable impact and innovation locally and globally.

Acknowledgements

Dr Jane Tanner and Professor Nelson Odume have grown in academic leadership stature. Jane leads the Hydrology Group and is a co-director of the African Research Universities Alliance (ARUA) Water Centre of Excellence (CoE). Nelson is the lead researcher in environmental water quality and aquatic ecology, and is the Director of the Centre for Environmental Water Quality (CEWQ). They have each offered me unstinting personal and



Some of the participants of the ARUA Water CoE Workshop during the ARUA Biennial Conference on 19th November 2021 professional support, and when I retire from Rhodes University and the IWR in July 2022, I will move on with confidence that the IWR will continue to grow and thrive. At this milestone in my long association with the IWR, where I completed my own doctoral studies, I pay particular tribute to previous Directors, Professors Brian Allanson and Jay O'Keeffe who profoundly influenced my research career.

IWR emeritus and visiting Professors, researchers, postdoctoral fellows, support staff and students, have continued to work hard and bravely in 2021. Across the University we have valued collaborations with the Departments of Botany, Environmental Science, Geography, Microbiology, Zoology and Entomology, and the Environmental Learning Research Centre. We greatly appreciate Dr Peter Clayton (Deputy Vice-Chancellor Research and Innovation and Chairperson of the IWR and Water CoE Boards) and Professor Tony Booth (Dean of Science). IWR Board members continue to offer sound, appreciative guidance, and we continue to receive valuable strategic and financial support from the University.

Professor CG Palmer, Director: IWR and ARUA Water Centre of Excellence

CENTRE FOR ENVIRONMENTAL WATER QUALITY (CEWQ) REPORT

Introduction

This year witnessed the official launch of the African Water Resources Mobility Network (AWaRMN), a multi-partner project funded with a grant of €1.39M by the Intra-Africa Academic Mobility Scheme of the European Union. The launch, which took place virtually on 20 October 2021 attracted over 100 participants from throughout the African continent. The launch involved two panel discussions and presentations on the benefits of intra-Africa academic mobility to achieving the AU agenda 2063 and the UN Sustainable Development Goals (SDGs). The Ugandan Minister of State for Higher Education, Dr John Chrysestom Muyingo; the South African Minister of Higher Education, Science and Innovation Dr Blade Nzimande, represented by Ms Mmampei Chaba, Chief Director: Multilateral Cooperation and Africa; the International Aid/Cooperation Officer, Regional and Multi-Country Programmes for Africa, Directorate Generals for International Partnership, Ms Eleonora Martinello, were the panellists on the first panel that spoke to the relevance of Intra-Africa Academic Mobility on achieving the AU Agenda 2063 and UN SDGs. The Vice-Chancellors and Rectors of the partner universities took part in the second panel, which addresses the criticality of internationalisation to water research in Africa. Dr Sizwe Mabizela, Vice-Chancellor, Rhodes University; Professor Abdullahi Bala, Vice-Chancellor, Federal University of Technology, Minna; Dr Hebbouche Abdelhamid Recror Higher School of Hydraulics, Blida, participated in the second panel discussion. Professor Barnabas Nawangwe, Vice-Chancellor, Makerere University; and Professor Aukje Hassoldt, Dean Faculty of Technology, Policy and Management TU, Delft, were represented in the panel. To date, the project has awarded 23 scholarship mobilities, covering 13 African countries. I would also like to welcome the AWaRMN-funded students: Ms Mary Chibwe, Ms Harriet Okal, Mr Edgar Tumwesigye, Mr Kennedy Owewenu, Mr Peter Wasswa and Mr Andrew Ali to the Institute.

During the 2021 virtual graduation, Dr Frank Akamagwuna was awarded his doctorate degree. Dr Akamagwuna was co-supervised by Prof. Odume. Ms Pindiwe Ntloko also received positive feedback on her doctoral thesis and will be graduating in the April 2022. Ms Asanda Chili has submitted her MSc thesis for examination, while Ms Noleen Tavengwa, Zintle Mtintsilana and Nandi Ngoni have all progressed well and should be submitting their theses in the second quarter of 2022.

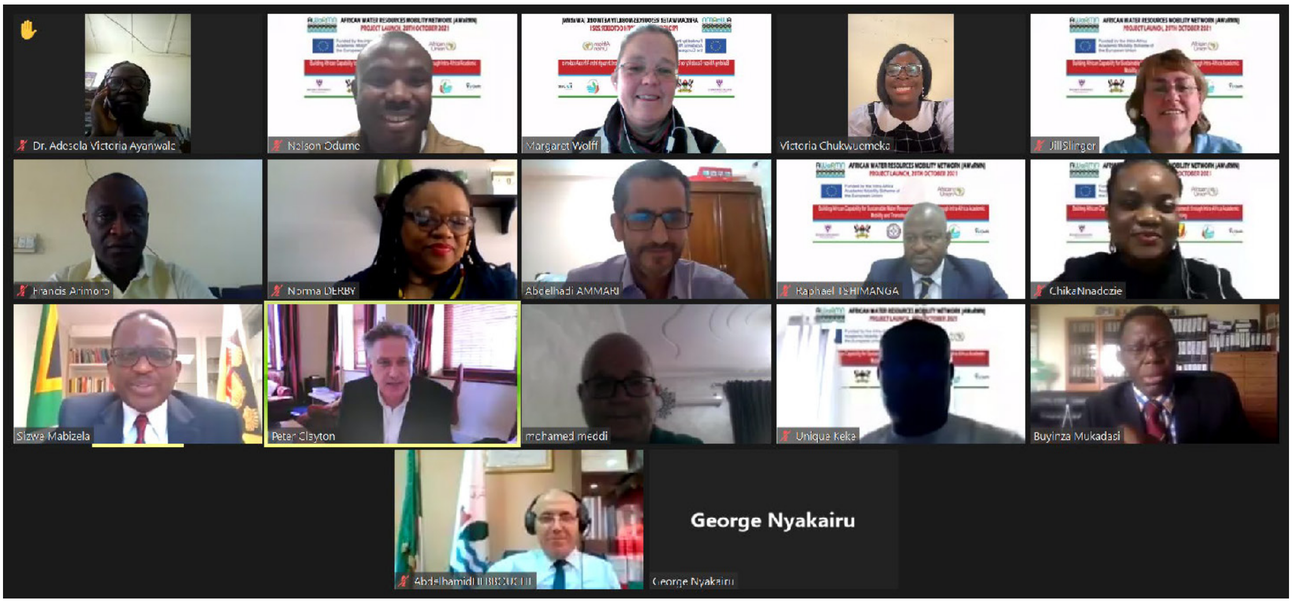


Figure 1: A cross section of the participants during the official launch of the African Water Resources Mobility Network (AWaRMN).

The Centre welcomes two new postdoctoral fellows in 2021, Dr Dennis Choruma and Dr Frank Akamagwuna Dr Akamagwua is leading the plastic research programme within the Centre, while Dr Choruma is developing leadership in the field of urban river governance, ethics, and values. Dr Bukho Gusha also works in the Centre on a sustainable development goal project funded by the Belmont Forum. Apart from the postdoctoral fellows, the Centre also welcomes four PhD students and one MSc students in 2021. I would like to welcome Ms Mary Chibwe, Mr Edgar Tumwesigye, Mr Kennedy Owewenu, Mr Miracle Osoh and Mr Andrew Ali to the Centre.

Since the arrival of Dr Chika Nnadozie, the Centre continues to develop its research capacity and capability in the field of molecular and computational microbiology. In the year under review, the Centre secured a €150K grant under the European and Developing Countries Clinical Trials Partnership (EDCTP) programme. This project is being led by Dr Nnadozie and is aimed at developing her capacity in the field of poverty-related diseases.

All our Leading Integrated Research for Agenda 2030 in Africa (LIRA) projects came to an end in 2021. The LIRA programme was jointly implemented by the International Science Council (ISC) and Network of African Science Academies (NASAC). The CEWQ was awarded two LIRA projects, which it successfully led to completion. The LIRA programme has secured additional funds to support open access publications in 2022, and we are looking forward to utilising the opportunity to publish all the scholarly work that has emanated from the two LIRA projects that the CEWQ implemented over the past two years. Through our LIRA collaborations, we have already published two papers in highly rated international journals. The first paper on science-policy-society interactions in transdisciplinary research was published in *Environmental Science and Policy*, and the second paper on the contribution of transdisciplinary research to the global sustainability agenda was published in *Sustainability Science*. We are excited about our LIRA partnership and the frontiers it has opened for the CEWQ to enable collaboration across the rest of the continent.

Through the LIRA projects, the CEWQ successfully launched a multi-party programme for the Swartkops catchment, comprising of the Department of Water and Sanitation, the Nelson Mandela Bay Metro, and communities within the catchment. The objectives of this programme are three fold: i) to mobilise capacity for sustainable governance and management of the Swartkops catchment; ii) clean up and removal of solid waste; and iii) education, awareness raising, entrepreneurship and community outreach through youth engagement.

Figure 2: LIRA Swartkops catchment champions with Prof. Odume, Drs Nnadozie and Akamagwuna during the launch of the multi-party programme for the Swartkops catchment in Uitenhage.

In the year under review, Prof. Odume was appointed the Academic Coordinator of the Rhodes University African Studies Centre. The African Studies Centre is part of the Africa Multiple Cluster of Excellence initiative funded by Bayreuth University in Germany. The Africa Multiple Cluster of Excellence aims to reconfigure African studies through partnership with African universities. The CEWQ is proud to play a lead role in this initiative and to be able to deepen its collaboration into the social sciences and humanities. Dr Dennis Choruma is funded by the Rhodes University African Studies Centre, while Dr Frank Akamagwuna is funded primarily through a project funded by the Africa Multiple Cluster of Excellence.

Research and Projects within the Centre

The Centre is currently implementing ten funded research projects in various fields of research related to water quality, water governance and ethics, sustainable development, and molecular and computational microbiology. The project on microplastics, led by Ms Khaya Mgaba, is near completion and has attracted interest as we look forward to expanding this field of research. Dr Griffin and Dr Mensah are our anchor researchers on the water quality guideline project, which is being led by our colleagues at the University of South Africa. The implementation of this project has been slow but on track. The project on water governance and ethics is also nearing completion and has generated insights on the value of ethics in reflecting on and addressing water governance issues in South Africa. The two Campylobacter projects led by Dr Nnadozie are also on track. What is evident in our research in the field of computation microbiology is the need for the Institute to invest in IT infrastructure for big data computing as this is needed to expand our research in this field. This year, we successfully completed the project, which seeks to develop a decision support system for linking the water quality component of the resource quality objectives to the discharge standards in water quality licences. The DSS developed through this project has attracted much attention from the Department of Water and Sanitation, and the bulk water users within the Vaal Barrage catchment.

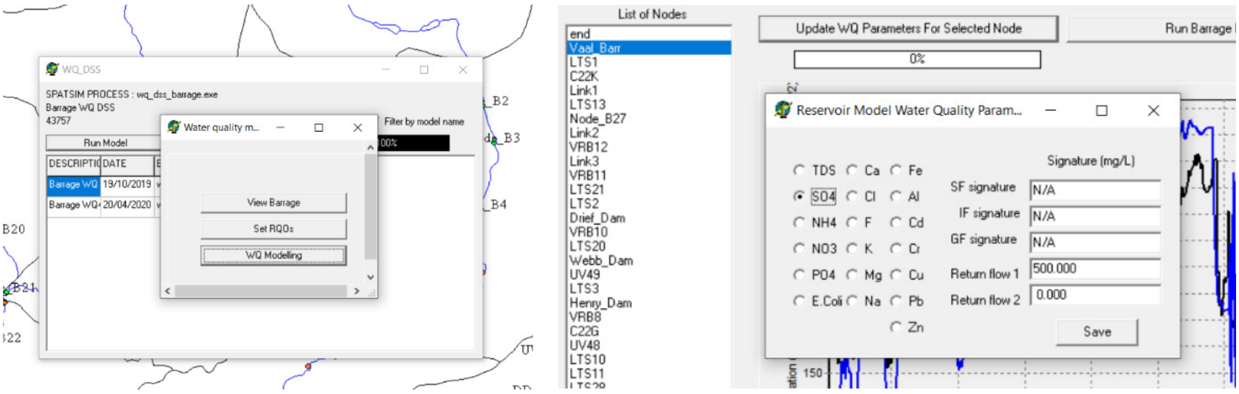


Figure 3: Launch screen of the DSS (left) and the screen for setting the water quality signature for both point and non-point sources (right).

About three years ago, the Institute made a resolution to seek more international funding opportunities to increase its international footprint, and as a response to the dwindling local funding opportunities. Since then, the CEWQ has been successful in attracting international projects through collaboration with colleagues from the rest of the continent and in Europe and United States of America. Of the ten on-going research projects within the Centre, five are internationally funded. For the first time, the Centre also attracted funding from the German agency, Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ), to implement an ecosystem-based approach to addressing climate-related and zoonotic risks in the Amathole District Municipality. We would like to express our deep gratitude to all our international partners and funders.

National, Regional and International Influence

The most notable achievement is the successful launch of the African Chapter of the Society for Freshwater Science (SFS). The CEWQ played a lead role in putting together the inaugural constitution, and setting the agenda for the chapter. Prof. Odume was also appointed as the pioneering chairperson of the Chapter. Members of SFS are leaders in the field of freshwater science, policy, and management, and we are delighted to be able to play a lead role in establishing the African Chapter, and seeing Prof. Odume being elected the pioneer chairperson of the African Chapter. The objectives of the African Chapter are to strengthen the collaboration between African scientists and the global SFS, develop and build capacity, generate critical knowledge base for the sustainable management and utilisation of African freshwater resources, facilitate exchange of ideas, equipment, and other resources between African scientists and the global SFS, and enhance the participation of African scientists in the activities of the global SFS.

An important way the Centre has continued to influence the global research communities is through the participation of its staff in influential international publications. This year, Prof. Odume joins more than 50 researchers from across the globe to publish an agenda for advancing biodiversity research. The paper, which was published in *Ecology Letters*, has attracted global attention with more than ten popular articles published in various media. Prof. Odume also participated in another global paper published in *Water*, which explores the issues of bioassessment and river rehabilitation across the world.

Despite the challenges of Covid-19, the CEWQ staff and students continue to participate in various online workshops, conferences, and symposium. Dr Nnadozie attended a three-day training workshop organised by the EDCTP programme. Prof. Odume was invited to give a talk at the knowledge lab of the Africa Multiple Cluster of Excellence. He participated in an international panel discussion on what it means to re-configure African studies in Africa and presented at the International Transdisciplinary conference.

The Centre is a key partner in the transformational NRF-funded community of practice (CoP) initiative led by Distinguished Professor Heila Lotz-Sisitka of the Rhodes University Environmental Learning Research Centre (ELRC). The CoP initiative is aimed at generating policy relevant knowledge to effect societal change in South Africa. We are proud to be associated with this initiative.

As with previous years, our community engagement initiatives led by Ms Khaya Mgaba continue to flourish. Ms Mgaba together with our students: Ms Chibwe, Ms Ramatsabana, Ms Ngoni and Mr Tumwesigye, taught learners from St Mary's School the importance of river health, and demonstrated the mini-SASS tool as part of the Scouts for SDGs water project. We believe that through these initiatives the Centre can influence and inspire the next generation of water leaders.

Figure 4: Learners from St Mary's Development and Care Centre, collecting and identifying macroinvertebrate from the Kowie River

Partnerships and Linkages

Last year, I reported that our partnership with Unilever South Africa has come to an end. We will continue to brand ourselves as the Centre for Environmental Water Quality until a replacement anchor funder is secured. The Rhodes University Communication and Advancement division has identified water as priority for institutional fund-raising efforts. To this end, we will work closely with them to approach anchor funder for the Centre.

AWaRMN and the ARUA Water Centre of Excellence are platforms the Centre will continue to make use of to deepen and strengthen its partnership and linkages within Africa and beyond. The UCEWQ has also deepened its international collaboration through the Africa Multiple Clusters of Excellence programme. We are also strengthening our partnership across Europe through various on-going internationally funded projects such as the SDG-pathfinding project.

The South African Institute for Aquatic Biodiversity (SAIAB) and CEWQ have resolved to strengthen their research collaboration, and exchange of equipment. Staff and students from CEWQ now have access to the world-class genetic facilities and ecophysiology laboratory at SAIAB. We have also been granted access to use the field vehicle at SAIAB for our field work. We are very grateful to the Managing Director of SAIAB, Dr Angus Paterson, for his interest in CEWQ and his support to date. Assured Turnkey Solutions (PTY) LTD and Scherman Environmental CC remain key strategic industry partners. We welcome Dr Scherman to the Centre as a Senior Research Associate.

In conclusion, when I reflect on the year's journey, I realise how hard all staff and students have worked under extremely challenging, and uncertain conditions. To these people, I am deeply grateful, and I wish you all a well-deserved break for the year 2021.

Professor ON Odume, CEWQ Director

HYDROLOGY REPORT

Introduction

This year was another productive year for Hydrology at the IWR. The Hydrology Group successfully graduated three PhD and one MSc students. Two Water Research Commission (WRC) projects were completed in 2021, the first led by Dr Sukhmani Mantel on Ecological Infrastructure and the second led by Dr Jane Tanner on Model intercomparison work. Five new Postgraduate students started in 2021 including two PhD students and three MSc students. The Hydrology Honours course ran for its fourth year, and one Honours student project (Mr Mankoe Raliengoane) was supervised by Dr Jane Tanner. Mr Raliengoane carried out sampling and isotope analysis of the Fairview spring and produced some interesting results. Mr Mzwanele Mkatali is leaving IWR after a long period working as a Research Assistant managing the groundwater monitoring for the University and town. A big thank you to him for his contribution.

Student Supervision

The three PhD degrees are in Hydrology (David Gwapedza, Pierre Kabuya and Coli Ndzabandzaba) while the MSc project was in Water Resource Science. Dr Gwapedza is now a Rhodes University funded postdoctoral fellow in the Institute and is project lead on a Water Research Commission (WRC) funded project on Agent-Based Modelling. Mr Sinetemba Xoxo graduated with an MSc in Water Resource Science and is now registered for a PhD in Hydrology under the supervision of Drs Jane Tanner and Sukhmani Mantel. A fourth Hydrology MSc student is submitting her thesis for examination in early 2022. She will then be moving onto a PhD in Hydrology funded by the ARUA Water CoE.

Research Directions and Collaborations

Socio-Hydrology

The scientific decade 2013–2022 of the International Association of Hydrological Sciences (IAHS), entitled "Panta Rhei – Everything Flows", is dedicated to research activities on change in hydrology and society. Emerging from this scientific decade is research contributing to the field of Socio-Hydrology. The IWR research around Socio-Hydrology has evolved through both the ARUA Water CoE engagement work throughout Africa, as well as a WRC project led by Dr David Gwapedza which aims to integrate the human dynamic into the hydrological dynamic in a more coupled way than traditional hydrological models have achieved. In terms of the ARUA Water CoE work, Hydrology and Hydrogeology are core disciplines of many of the Node partners (specifically University of Dar es Salaam, Tanzania and University Cheikh Anta Diop of Dakar, Senegal) and we are working specifically with the Tanzania partners on Systems Dynamic Modelling. This approach incorporates the full 'complex system' including, for example, sectoral development plans of local government, population dynamics, as well as traditional hydrology.

A WRC project titled *A stakeholder driven process to develop a more equitable and sustainable water resource management plan* started in April 2021. This project is led by postdoctoral fellow Dr David Gwapedza with project partners including

Figure 1: Dr David Gwapedza (PhD graduate), Dr Pierre Kabuya (PhD graduate) and Mr Sinetemba Xoxo (MSc graduate)

the Freshwater Research Centre in Western Cape and INRAE, France's National Research Institute for Agriculture, Food and Environment. The project focuses on an agricultural catchment in the Koue Bokkeveld of the Western Cape with severe water contestation issues. The project uses an Agent Based Model and a Water Sharing Model (both Socio-Hydrology models with the Water Sharing Model developed in the IWR), in an attempt to alleviate the severe water contestation (multiple lawsuits between farmers around water use), severe inequity (transformation via transfer of land to emerging farmers but without appropriate water allocation licences) and severe environmental pressure (the water is fully utilised in the dry season with the Ecological Reserve neglected). [See you tube video on the catchment and issues at https://www.youtube.com/watch?v=Bhma-WlLjYU&t=241s].

The project supports four students including PhD student Sinetemba Xoxo, who is working on the Water Sharing Model, MSc student Sakhikhaya Mabohlo, who is working on the SWAT hydrological model, MSc student Stefan Theron, working on a water balance tool for monitoring Ecological Reserve compliance and MSc student Rodney Tholanah, working on the coding behind the Agent Based Model. All the IWR researchers and students involved have submitted abstracts to present at the Scientific Assembly of the IAHS (IAHS 2022) which will take place in Montpellier, France, under the session theme Socio-Hydrology. The project has attracted some additional funding which will support the challenging project objectives. This includes Protea Funding (French and South African partnership funding through the NRF), which is a two-year project, funding travel between South Africa and France for the French partners and for the South African research team. Two student bursaries have been awarded to start in 2022 including an NRF bursary for MSc Hydrology student Sakhikhaya Mabohlo and a WRC Research, Development and Innovation (RDI) bursary for an MSc Computer Science student Rodney Tholanah. The RDI bursary is a collaborative effort between Professor Karen Bradshaw of Computer Science who will be co-supervising the student with the WRC project team. Lastly, a Rhodes University small research grant has been awarded to Dr Jane Tanner which will go towards support for the Water Sharing Model development on the project.

Figure 2: Dr David Gwapedza in the Twee River catchment of the Koue Bokkeveld

Figure 3: First workshop of the WRC Agent Based Modelling Project held in November 2021. Three more workshops are planned for 2022.

Hydrological Modelling

The IWR has an international reputation in hydrological modelling which is a legacy of Professor Emeritus, Denis Hughes. Continuing with this legacy, a WRC project titled, I concluded in 2021 (see Hydrology project descriptions for full details). The project collaborated with the South African

Environmental Earth Observation Network (SAEON), Stellenbosch University, the University of the Western Cape, the University of Cape Town and the University of KwaZulu-Natal. The WRC feedback was extremely positive and it was requested that the project team submit a follow up proposal. The follow up proposal has been funded and is titled, *Modelling uncertainty and reliability for water resource assessment in South Africa* and will run for two years starting in 2022 led by the IWR.

At the end of 2021, we met with colleagues from the Institute of Meteorology and Climate Research (IMK-IFU) at Karlsruhe Institute of Technology (KIT) in Germany who were interested in a 2018 project Professor Emeritus Hughes and Dr Tanner contributed to (led by the University of Leeds, UK). The IWR's original contribution included the validation of outputs from seven global hydrological models using local data in South Africa. The validation and comparison turned out very poorly with all seven global models determined by the testing to be unreliable for use in South Africa. These models are, unfortunately, used for water resource assessment decisions throughout data scarce regions in Africa. Colleagues from KIT are interested in taking this work further, and together with PhD student Harriette Okal (an AWARMN Hydrology student in the IWR) we are writing two publications and a project proposal with the KIT partner.

Art for communication in science

Dr Sukhmani Mantel joined the ARUA Water Centre of Excellence as Academic Manager under from mid-2020. In this role, she has taken the opportunity to expand her skills in Digital Storytelling (DST) which is a means of making research personal and accessible to communities. Mr David Forsyth and Dr Mantel attended Digital Storytelling course offered by the Rhodes University Community Engagement Division in March 2021. In the ARUA Water CoE report, you can read about a workshop at the third ARUA Biennial conference, with the theme of *Digital Storytelling of African Water Challenges* linked to human health and well-being and the Sustainable Development Goals (SDGs). The workshop showcased the videos that can enhance science communication with civil society, and as an innovative and accessible tool to generate awareness around local water challenges and to communicate scientific research findings to civil society and local water managers (see videos here: https://www.youtube.com/channel/UC4LPOYijM_CsETTKlEF8Kyw). The video created by Dr Mantel built on her South African Rivers map that went viral a couple of years ago (https://youtu.be/0Z3CvxTk_RQ). The reach of this map resulted in Dr Mantel being interviewed for SAfm-Sunrise with Stephen Grootes on 28 May 2021. Dr Mantel is pursuing this theme further in a proposal with UK and Spanish collaborators which will look at promoting public engagement using effective art-science communication outputs including and going beyond videos.

Ecological Infrastructure

Land use and land degradation impact the way water moves through a catchment, with changing land use impacting water retention in a catchment (leading to increased flood risk and reduced low flows in dry seasons). A WRC funded project on Ecological Infrastructure concluded in April 2021 (see Hydrology project descriptions for full details). The project supported two MSc students, Mr Sinetemba Xoxo (who graduated in October 2021) and MSc student, Ms Bawinile Mahlaba (who is in the process of making changes following the reviewers' comments). During the final reference group meeting, the steering committee provided encouraging comments about the products generated. The project also allowed the team to collaborate with Dr David le Maitre at CSIR who is now an Extraordinary Professor at Stellenbosch University. This research theme will continue to be explored at the IWR with a number of proposals submitted and links to postdoctoral fellow, Dr Kathleen Smart's work on carbon and water flux movements.

General

Continuing with the ongoing collaboration between Hydrology at IWR and German water utility OOVW and Technical University of Braunschweig (TUB), a final go-CAM project workshop was held titled *Climate change and water security in the Buffalo City Metropolitan Municipality*. Dr Jane Tanner was a panellist on the closing panel discussion. The workshop was held on 5 July 2021 and was hosted by Oldenburg-East Frisian Water Board (OOWV), Technical University of Braunschweig (TUB) and Buffalo City Metropolitan Municipality (BCMM).

Conferences and Contributions

Dr Jane Tanner and PhD student, Pippa Schlegel, both presented papers at the Wetlands Indaba which was held online from 20 to 21 October 2021. Dr Tanner presented a paper during the opening plenary session on her work on the hydrological functioning of Palmiet wetlands in the Eastern and Western Cape, while Ms Schlegel presented on her PhD work on sediment dynamics in floodplain wetlands in the Tsitsa River catchment (detailed under student projects). Ms Schlegel also presented her work at the Eastern Cape Wetlands Forum in December 2021. Dr Mantel presented a paper on: *Ecological infrastructure (EI) as a sustainable* *solution for water security*: *Research from South Africa*, at the online Twenty65 Conference hosted by Sheffield University from 15 to 18 March 2021. Mr Sinetemba Xoxo submitted a video to Rhodes University 3-minute thesis competition in September 2021, titled: *More droughts? Okay, let's go back to basics*.

Dr Jane Tanner remains on the Environmental Committee and Water Task team at Rhodes University, as well as on the technical advisory board of the Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON), and on the advisory board of the ARUA Notions of Identify Centre of Excellence based at Makerere University in Uganda.

Lastly, a big thank you to all hydrology researchers and students who continue to enhance the profile and reputation of Hydrology at Rhodes University through their hard work and reach for excellence.

Dr JL Tanner

Postdoctoral Fellow activities

African urban complexities and the governance challenges of urban rivers – a systemic-relational inquiry

ON Odume, FC Akamagwuna, DJ Choruma and CF Nnadozie

March 2021 - April 2023

Sponsor: **African Multiple Cluster of Excellence**

Collaborators: **GO Omovoh, Federal Ministry of Environment, Nigeria; BN Onyima, Anthropology, Nnamdi Azikiwe University; Okeja Uchenna, Philosophy Department, Rhodes University**

The trajectory of urbanisation in Africa is complex, presenting potentially intractable governance challenges of natural resources such as urban rivers. Part of this intractability arises because of insufficient appreciation by urban planners and policymakers in Africa of the interconnectedness and interdependence between ecological and social subsystems within an urban landscape (Grimm, 2000). In Africa, urban river systems are often seriously degraded, and recent empirical evidence suggests the accumulation of novel pollutants such as macro- and microplastics in such river systems (Grimm et al., 2000). However, healthy urban rivers can support sustainable urban development by supplying desired and valued ecosystem services (Wangai et al., 2017). In this project, we argue that if the trajectory of African urban rivers is to be on an ecologically sustainable path, then a paradigm shift towards an approach that recognises the complexity of the interconnectedness and dynamic interactions between social and ecological systems within African urban landscapes is required. We build on our existing projects on water ethics and governance challenges and ways of enhancing African urban ecosystem health, which suggest that urban rivers pose unique governance challenges because of their location within urban catchments and consequent severe ecological degradation. Thus, we propose to use the systemic-relational (SR) ethically grounded approach (see Odume and de Wet, 2019), as an analytical perspective for investigating the governance and ecological dimensions of urban river systems. The approach recognises that ecological and social-economic components of urban landscapes together form an integrated and dynamic complex system of urban river catchments and that these two major components are in ongoing complementary and co-supportive interactions, with multiple, cross-scale dynamic feedbacks. Further, the SR approach recognises the centrality of values and the potential role of ethics in negotiating and constructively balancing conflicting values in order to realise healthy urban river ecosystems in African urban landscapes (Figure 1).

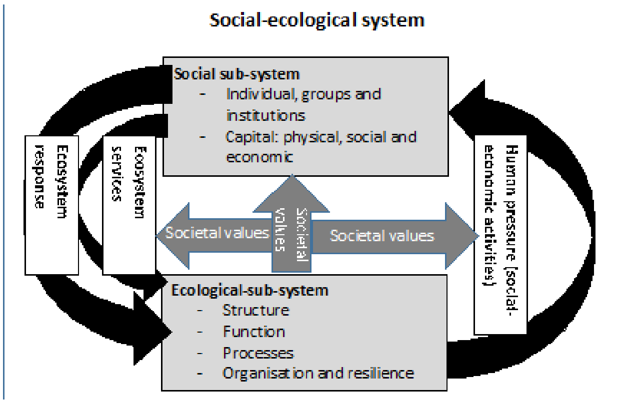


Figure 1: An SR SES framework with explicit recognition of the centrality of societal values (Odume and de Wet 2019).

The proposed project covers two important grounds i) contributing empirical evidence to policy on urban river governance challenges and their ethical implications, considering the multi-faceted issues associated with African urban complexities, and ii) contributing important ecological data on the dynamics of emerging pathogens, biota and macroplastics. Altogether, our intention is staying put in particularly urban river catchments long enough to shift policy and practices regarding i) the governance of urban river systems, ii) institutional and societal values informing behaviour towards urban rivers, and iii) the management of novel pollutants. Overall, these contributions will be achieved through the following research objectives:

i) Examine the concept of African urban complexity through an investigation of urban river governance challenges e.g. the regulatory system and cooperative governance and their ethical implications in the selected Metros (Nelson Mandela Bay in South Africa and the Federal Capital Territory in Nigeria).
ii) Investigate the influence of bio-habitat complexity on the dynamics of macroplastics and the distribution of biota in the selected rivers
iii) Examine whether macroplastics support the establishment of emerging pathogens, relative to the surrounding aquatic habitats.

Assessing performance of livestock production in communal rangelands of the Eastern Cape, South Africa.

B Gusha and AR Palmer

Sponsor: National Research Foundation

In South Africa, communal rangelands are regarded as being on the brink of ecological collapse because they are vastly overstocked compared to commercial agricultural enterprises. In the traditional areas of the Eastern Cape, livestock continue to supply many different goods and services, making a significant contribution to household livelihoods. Villagers invest heavily in livestock production, of which cattle production alone accounts for 80 – 90% of assets value. Rural people and their urban-based household members continue to own considerably high livestock numbers in these communal areas, which is perhaps mostly related to the high esteem that is associated with cattle ownership as well as the absence of other saving methods such as banks that leads to thousands of rural people to own livestock as store wealth. However, the excessive numbers of livestock in these communal areas are having a deleterious effect on the condition of communal grazing resources through overstocking and overgrazing leading rangeland degradation, which saw communal famers faced with mandatory destocking in the past. Even though excessive deterioration of the grazing resources still continues in the communal rangelands, high livestock numbers are still maintained. This study has mobilised communities to form livestock associations governed by a constitution formulated by livestock members to inform rangeland management plans. This rangeland management plan allows for rangelands to be rested and grazed at certain periods of the times and allow re-generative growth and improved vegetation cover, where land degradation is hoped to be reduced. During resting, livestock are allowed to graze in other areas and moved back to rested rangelands at times where grazing resource has improved. This management improves livestock conditions and enables farmers to achieve better/higher livestock offtakes during marketing and reduce costs that are associated with buying additional feed by livestock dependent households.

Dr Bukho Gusha assessing the condition of a communal rangeland where livestock grazing takes place.

Postdoc chronicles: a transition from doctoral to postdoctoral research

D Gwapedza and JL Tanner

In the final year of my PhD (year 2020), Dr Tanner and Dr Mantel had made it clear that they were keen to host me as a postdoctoral fellow. Therefore, we set out to identify funding sources and an appropriate research topic.

Dr Tanner insisted that she wanted my postdoctoral research to be impactful in the scientific fraternity and beneficial to my career as an academic. There were two research paths available for me to pursue:

i) A continuation of my PhD research in erosion and sediment yield modelling.
ii) Pursuing a project based on Agent-Based Modelling (ABM) as a continuation of my ABM training in France.

Because I could not decide, I applied for both – submitting two project proposals to the Water Research Commission based on the two themes. I also submitted two postdoctoral funding applications to two different funding streams on the two themes. When the outcome of the applications came, both the applications based on theme two were funded, while the ones for theme one were rejected. Therefore, when the year 2021 began, I began preparing to take on responsibilities as a postdoctoral fellow and lead researcher of a project titled "A stakeholder-driven process to develop a more equitable and sustainable water resource management plan".

The project includes research partners from the Freshwater Research Centre (South Africa) and the National Research Institute for Agriculture, Food and the Environment (France). The project has a total of six researchers and four postgraduate students (three Masters and one Doctorate).

Apart from my direct postdoctoral research work, I have been involved in several other projects and consultancies. Firstly, I am assisting with the supervision of a Uganda based masters student under the African Research Universities Alliance project. This work enables me to pursue sediment modelling work, which I forfeited because of funding. Secondly, I am involved in the "modelling Intercomparison" project that compares various hydrological models applied in South Africa. This project enables me to build capacity and be grounded in hydrology research. Finally, I conducted some hydrological modelling consultancy work with Dr Tanner which involved modelling an arid Sudanese catchment. The work provided some insights on arid catchments hydrology.

As demonstrated previously, a postdoctoral fellow's work in the IWR is far from straightforward. The Institute is fast-paced and dynamic placing postdoctoral fellows in the frontlines of research and administration. As a postdoctoral fellow in the Institute, I find myself given roles to lead, teach and supervise postgraduate students. Additionally, the Institute funding model encourages postdoctoral fellows to seek out research funding. Therefore, I have been involved in numerous grant applications for myself, students and as part of a collaborative application effort. Such conditions allow a postdoctoral fellow to sharpen some of the essential skills needed in the academic field. My transition from doctorate to postdoctoral fellow has not been without challenges, but it is a testament to an environment that allows and nurtures growth.

Project team members have a discussion during a field visit in November 2021 (From left: Sinetemba Xoxo, Bruce Paxton, Jane Tanner, Sukhmani Mantel, Stefan Theron and David Gwapedza)

Supporting the ARUA RESBEN Project's nodes: Lagos and Rwanda

N Libala and CG Palmer

Sponsor: Africa Research Universities Alliance

Overview of my role in ARUA project

My main role is operational support, assisting and guiding Research Assistants from Lagos and Rwanda Nodes in their paper writing process, organising and facilitating Node meetings, and close contact and feedback. I am also responsible for organising the Writing Community of Practice sessions and I am involved in organising and facilitating workshops.

Activities in 2021

ARUA (Africa Research Universities Alliance) Water Centre of Excellence workshops

For the year 2021/22, I am working as a Postdoctoral Researcher in the ARUA Water Centre of excellence, funded by the UK government. This is a collaborative project that involves researchers from Rwanda, Nigeria, Tanzania, Uganda, South Africa, Ethiopia, Senegal and the United Kingdom. As a part of this project, we are required to conduct workshops for the six Nodes. The purpose of the workshops is to refine case study research toward outputs that are achievable in a year. For the past months I have been involved in the planning and running of the Bound and Adaptive Planning Process workshops for all the Nodes.

ARUA Writing Support Community of Practice (CoP)

The RESBEN Postdoctoral fellows have established a paper Writing CoP which is facilitated by Rhodes University departments that specialise in paper writing, I am responsible for leading the Writing CoP. Each case study Node is required to submit a paper for their involvement in the RESBEN project by January 2022. The purpose of the CoP is to provide support to help make this commitment a reality. The core contribution of the Writing CoP will be to provide capacity development and mentorship for the development of the selected paper commitments of each Node. The RESBEN Postdoctoral fellows are driving this process, working closely with Research Assistants.

Progress to date on the paper Writing CoP

On the 27th August 2021, we had an orientation session with all the Research Assitants. We introduced the Writing CoP, paper authorship and submission dates, roles and responsibilities, how to access the courses, and the RESBEN Writing CoP Principles of Engagement.

On the 17 September 2021, we had session one on Plotting the paper and focusing your contribution to knowledge. Research Assitants were given a task to share their papers and write about who their audience is, what the focus or angle of their paper is, and why they think this is an important paper to write at this time. What contribution will they make to knowledge?

On the 1 October we had session two on choosing a journal and working on your argument. We looked at how to create a journal shortlist for the paper and why this is important to do early on. We also talked a bit more about arguments and how we move a step further in plotting, outlining, and beginning to structure a paper we can write and submit for consideration. Research Assistants were given a task to create the outline for their papers.

Storytelling course

I attended a storytelling course facilitated by Rhodes University. Digital Storytelling (DST) is a modern approach to the ancient art of storytelling that combines photos, video, and audio to create short stories. The purpose of the course was for ARUA Water CoE Early Carrier Researchers to develop stories about land and water issues and connect their case studies to the SDGs. The storytelling video I created will be featured at the ARUA Biennial Conference in November 2021.

Water Research Commission Projects

I am a reference group member of two Water Research Commission (WRC) projects. The first one is looking at promoting the adaptive capacity of rural communities to climate change, and the other one is looking at monitoring of SDGs in South Africa. I am also involved in a WRC project that focuses on using citizen science to protect natural untreated drinking water sources.

SDGs summit workshops

I attended three SDGs Summit workshops that were hosted by UCT on the 20 and 21 June and 20 July 2021. The purpose of the Summit was to mobilise collaborative efforts that will accelerate African-led activities in support of a common development agenda. The contributions from the three workshops were presented at the Sustainable Development Goals in Africa Summit from 13-15 September 2021.

National Skills Summit hosted by Rhodes University

I attended the NRF Early Career Researchers CoP Conference Workshop on 8 September 2021. I was also a part of the workshop's preparation and organisation team. The goal of the workshop was to bring together a group of young, vibrant early career researchers from various fields of environmental education, water, biodiversity, and climate change to create a platform for young practitioners who will form part of a wider community of practice in the sustainability sciences space.

Research and funding related activities undertaken during 2021 for the ARUA-UKRI Water COE grants

R Powell, JL Tanner and SK Mantel

Sponsor: ARUA-UKRI GCRF Programme

Summary of activities

- Supporting ARUA-UKRI Water CoE African Nodes research
- Funding Applications: Submissions and Support
- Coordination of ARUA Biennial Conference Water CoE Symposium

Introduction

The ARUA Water Centre of Excellence hosted in the IWR, Rhodes University was established in 2019. The centre secured a multi-million Rand Research Excellence Grant (RESBEN) and a smaller Water for African SDGs Capability Grant (SDGs), funded by the ARUA-UKRI GCRF Programme in 2019/2020. One of the aims of the RESBEN project is to foster strong and long-lasting research collaborations with African partners towards understanding water management related challenges in African contexts, and how to address these effectively. Our team at present works with six African Universities or research 'Nodes'. In 2021, I was appointed as a postdoctoral fellow and project administrative support on both RESBEN and SDGs ARUA-UKRI Projects. In this report I summarise the research and funding related activities I contributed to during 2021.

1. Supporting African Node Research

As a postdoctoral research fellow, I have worked with research teams from two of the six African Nodes- Tanzania (University of Dar Es Salaam) and Senegal (University of Cheikh Anta Diop). My role in each of these cases, with inputs from Dr Jane Tanner and Dr Ana Porroche-Escudero from the CoE, has been to provide guidance on case study research design and implementation. Both case studies are investigating issues of access to adequate and safe water by local rural communities and aquatic ecosystems, influenced by the way in which water is being managed by various agencies. The goal is to assist each Node team to publish their research in an African journal in 2022.

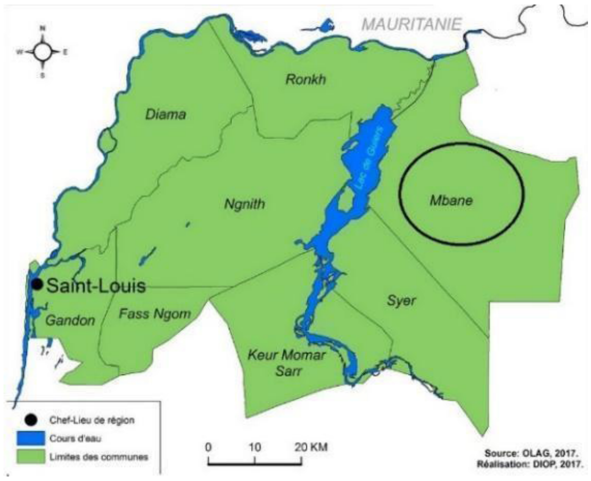


Figure 1 Lake Guiers along the Senegal River showing the study site circled in black, 'Mbane'. (Source: OLAC: https://www.olac.sn/reseau-hydrographique/le-lac-de-guiers)

In Senegal, the water challenge being investigated is access to water by small irrigation farmers located around Lake Guiers, a tributary of the Senegal River Basin. Due to time constraints, the study will focus on one of the five communities in the area, the commune of Mbane (Figure 1). The aim of the research, as proposed by the Senegalese team, is to analyse the levels and forms of power exercised by local water organisations to manage and regulate access to water for irrigation agriculture.

These organisations include local community and government organisations. "This study is important because the water-related problems encountered at the communal level are often poorly known, or the representativeness of the actors involved in solving these problems is often weak or poorly organized." (Ms Rokhaya Diop- UCAD, Senegal Researcher).

In Tanzania, the water challenge being investigated relates to tensions between water availability and increasing water demands in the Ruaha River Basin located in the Great Rufigi Basin. Increasing demands for water, and poor management of water allocation, has resulted in insufficient water availability for small water users (such as small-scale farmers) and the ecosystem of the Ruaha National Park. There are several larger water users who have greater power in accessing water, including local industries and hydropower.

The aim of the research paper is to **investigate the extent to which local stakeholders such as water users can participate and influence decisions within the Sub-Catchment Water Committee (SCWC) (comparable to a catchment management agencies in South Africa), to influence water management for the Ruaha Basin.** The SCWC has real agency to exercise power as delegated from the RBWB (Ruaha Basin Water Board). The paper will also discuss the usefulness of using the WEAP model (Water Evaluation and Planning Model) - a model used to develop optimum water allocation scenarios– to contribute to decision making for more equitable water allocation in the basin.

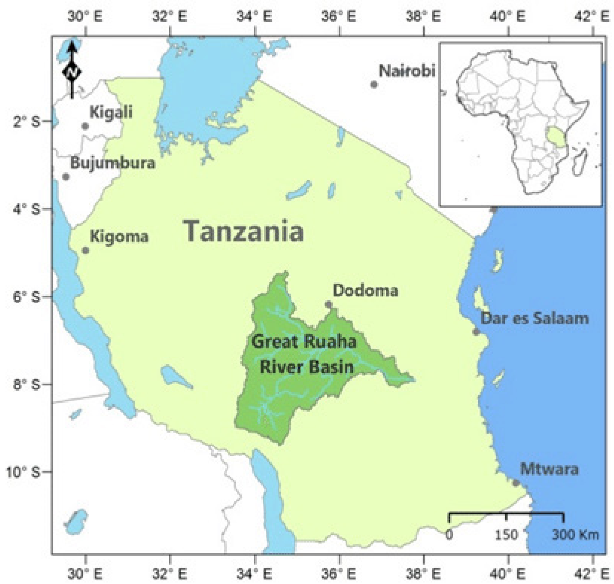


Figure 2 The Ruaha Basin located in central Tanzania. (Source: Liwenga et al. 2015)

2. Funding Applications: Submissions and Support

During the year I worked on and supported several applications for funding opportunities that would potentially secure funding for my postdoctoral work and continuation of the ARUA-UKRI Grants beyond 2021. These are summarised below.

Proposal Submission: WRC 2021/2022 Research Development and Innovation Call:
Proposal submitted as lead researcher with Dr Jane Tanner (Water CoE): KSA3: Thrust 1: Water Sensitive and Resilient Settlements; Proposal Title: ***Improving water supply management with augmentation at Makhanda (Grahamstown)***

Funding Calls Support

- **WADI-IDIQ II (Water and Development Indefinite Delivery, Indefinite Quantity) Programme –** Assisted IWR to join the **ASU (Arizona State University) Consortium** pre-proposal application for the WADI IDIQ II Programme, which falls under the USAID Bureau for Resilience and Food Security.
- **ARISE-PP (African Research Initiative for Scientific Excellence Pilot Programme) 2021 Call** - Contributed to the proposal submitted by Dr Notty Libala (Water CoE) for the call; Proposal Title: **Applying the Adaptive Systemic Approach as a methodology to improve water related human health issues in African countries** (still awaiting feedback)
- **Horizon EU 2021 Call** – Supporting application for the call:
  Development of high-resolution Earth system models for global and regional climate change projections (still awaiting feedback)

- **Wellcome Trust Discovery Awards 2021 Call** - Supporting proposal development for this call (still in draft phase).

3. Coordination of ARUA Biennial Conference Water CoE Symposium

The ARUA Water CoE is hosting a symposium on 19 November 2021 for the ARUA Biennial Conference: ***Global Public Health Challenges: Facing them in Africa.*** I am supporting the coordination of the symposium together with Dr Sukhmani Mantel which is titled, ***Digital Storytelling of African Water Challenges: Links to Human Health and Well-being.*** Each of the African Water CoE Research Nodes under the ARUA-UKRI Grants (described in the introduction of this text) will be showcasing a digital story of the particular water challenge they are investigating. The presenters will be asked to briefly discuss the role of digital storytelling in enhancing research communication and stakeholder engagement around a particular water issue, as well as the possible approaches and solutions to addressing the challenges highlighted.

Digital Storytelling (DST) is an approach to the ancient art of storytelling that uses modern technologies to create short stories comprising photo, video, and audio features. DST has multiple uses within the University environment such as, collecting narratives and data, monitoring and evaluation, reflection and healing, and disseminating research findings to create awareness around a particular topic.

Acknowledgements

The ARUA Water CoE and UKRI Grants have seen a lot of change during 2021, especially related to adaptation to Covid-19 impacts. Our Water CoE core team and the African Nodes have been exceptional in pulling together to continue navigating these challenges in the international research and funding space. I'd like to personally thank Dr Jane Tanner, Dr Sukh Mantel, Prof. Tally Palmer, and the rest of the Water CoE core team for the support and encouragement they have provided me during the year.

Determine water use of the cannabis tree in the Eastern Cape and Kwazulu–Natal provinces

K Smart and AR Palmer

April 2021 – March 2025

Sponsor: Water Research Commission
Collaborators: Alistair Clulow, Samson Tefsay, Richard Kunz, Shaeden Gokool, Kershani Chetty and Tafadzwa Mabhaudhi

Who is involved

This is an exciting project led by the IWR working with members from the Centre of Water Resources Research Unit at the University of KwaZulu-Natal which will determine the water use efficiency of *Cannabis sativa*.

The changing legislation about the use and production of Cannabis in South Africa mirrors that of the rest of the world, and opens up opportunities for small- and large-scale growers to move into fibre, seed and oil production. To date there is no work done in South Africa on the quantities of water that will be required to produce various Cannabis products – we are going to fill this gap!

Kamva Zenani is the IWR student who will be measuring the water use by Cannabis in the Eastern Cape. Kamva will be combining different measurement approaches for an exciting Masters degree in Water resource science and hydrology.

The UKZN team will be using micrometeorological instruments in the field combined with growth in a controlled greenhouse facility to generate water use measurements which are comparable to the Eastern Cape field trial. These measurements will be complimented by modelled water use estimates using the FAO's AquaCrop model. Once the crop model runs have been completed, crop coefficients will then be calculated for each quinary catchment for non-stressed growing conditions. These crop coefficients will be used as input for the ACRU agro-hydrological model to assess the impact of *C. sativa* production on downstream water availability. The purpose of the hydrological model run is to 1) quantify the stream flow reduction potential of *C. sativa* on available water resources in South Africa, and 2) assess the feasibility of declaring this crop as a potential stream flow reduction activity (SFRA).

The identification of suitable crop growing areas will be led by UKZN postdoctoral researcher, Shaeden Gokool, who will be using the MaxEnt bioclimatic model and supervised classification using the Google Earth Engine platform and Sentinel-2 Multi-spectral Instrument Level 2-A imagery.

In a training session a team from the IWR comprising

Kamva Zenani, Tony Palmer, Kathleen Smart, David Forsyth and Bukho Gusha installed a Kipp Zonen Large Aperture Scintillometer (LAS) and other micrometeorological instruments at the field site where Kamva will be working (Figure 1). The LAS is designed for measuring the path-averaged evapotranspiration (Figure 1).

Why is this work important?

This work will inform us about whether Cannabis can be grown as a dryland crop and the productivity that can be obtained with and without irrigation. This will be the first data on the water use by the crop which is fundamental to informing which water use activity under The National Water Act (NWA, 36 of 1998) the crop falls into. In turn, this will contribute to enabling farmers to apply for Water Use Licences.

Figure 1: Setting up the weather station at Firglen. (a) Tony Palmer, Bukho Gusha and Kamva Zenani installing the NR Lite radiometer, (b) Kamva Zenani installing the temperature and humidity sensor surrounded by a radiation shield.

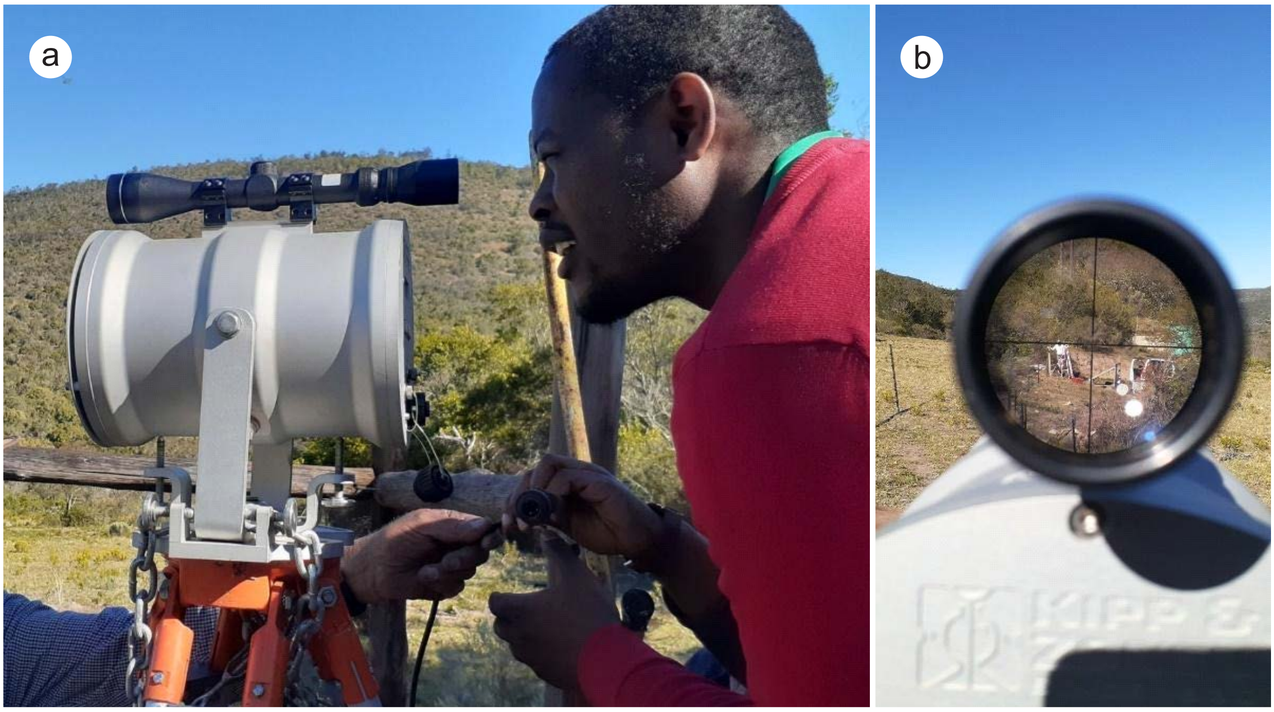


Figure 2: MSc student Kamva Zenani using rifle scope to align the sight path between (a) the LAS receiver and (b) the transmitter.

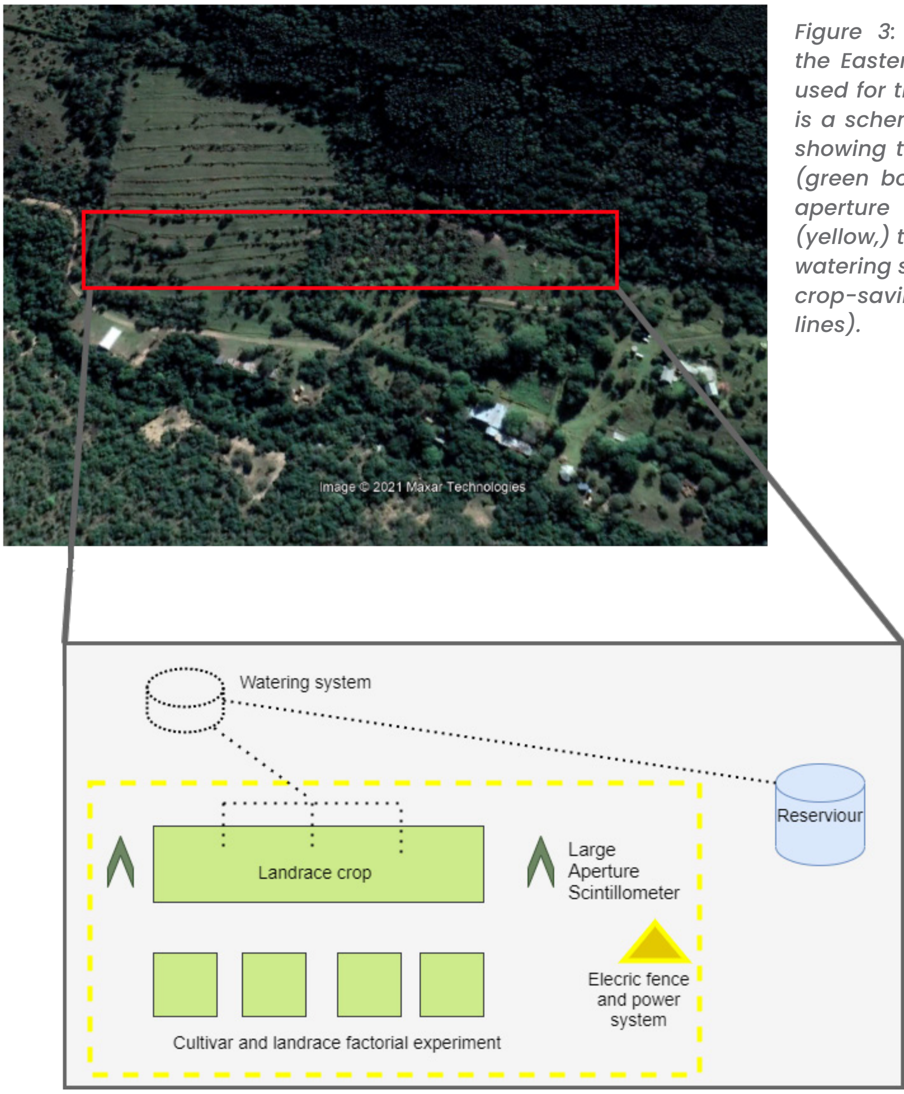


Figure 3: A Google Earth image showing the Eastern Cape field site and the portion used for the experiment boxed in red. Below is a schematic (not to size) of the field site showing the layout of the planned planting (green boxes), the placement of the large aperture scintillometer, the electric fence (yellow,) the current reservoir (blue) and the watering system currently being installed for crop-saving watering interventions (dotted lines).

Carnegie Early-Career Research Fellowship

B Tessema, CG Palmer and JL Tanner

Sponsor: Carnegie ECR Fellowship through ARUA hosted by ARUA Water CoE, IWR - Rhodes University

Introduction

I am Bezaye G. Tessema awarded the Carnegie Early Career Research fellowship through ARUA and hosted by the ARUA Water CoE for one year beginning October 2021 under the supervision of Prof. Tally Palmer and Dr Jane Tanner. I am an Environmentalist and have been conducting research on Sustainable Land Management and Terrestrial Carbon Sequestration, using Integrated watershed management approach, water pollution and its impact on ecosystem and human health in Ethiopia. I earned my PhD in Terrestrial carbon from the University of New England, Australia, MSc in Environmental Sciences and BSc in Plant Science from Addis Ababa and Haramaya Universities Ethiopia, respectively. I have always been keen and passionate about contributing to the research and development efforts for viable social impact and towards food and water secure communities, sustainable development, climate change adaptation and mitigation. I believe this can be promoted through networking, partnerships, innovation, and active participation of stakeholders including institutions and communities at large. I am currently interested and heading toward more inclusive, transdisciplinary, adaptive and systems thinking research approaches to better use and manage resources and achieve SDGs and hope to work more on these themes during my time with the Water CoE.

Overview of my role at IWR, Rhodes University

During my time in the Institute, I will work on water related research and capacity development initiatives under the Water CoE Research Excellence. Under the RESEBEN project I will support the Ugandan Node as a postdoctoral fellow from the hub; function as an integral member of research teams, delivering presentations and participating in technical workshops with fellow researchers and other stakeholders. I will also assist in creating and bolstering partnerships between the ARUA Water CoE and African and European research and innovation units. My work will therefore contribute significantly to the intellectual vitality of the IWR and the Water CoE.

Summary of Activities Nov2021 – Jan2022

1. Discussant on the First biennial symposium of African research on water resilience
2. Support ARUA-UKRI Water CoE African Nodes
3. Facilitation in the ARUA Biennial Conference Water CoE Symposium
4. Funding Applications support proposal development

1. Discussion on the First biennial symposium of African research on water resilience

On 4 November 2021, attended and presented my work on the first biennial symposium of African research on water resilience as a visiting postdoctoral research fellow at the IWR Water CoE through the ARUA/Carnegie research fellowship from the Ethiopian Node was one of the selected few (Figure 1) who have attended the first biennial symposium of African research on water resilience in association with the ARUA Water CoE. The symposium was intended as a multidisciplinary space in which academics can share their research, strengthen connections for future collaborations and develop new insights into the foundations of water resilient towns, cities, and communities in Africa. The discussion was held on two themes: 1) Materiality of water (quality and volumes) and 2) Trust, values and governance. Discussants were from various universities such us University of Cape Town, Addis Ababa University and Rhodes University, Cardiff University, UK, Gollis University, Somaliland, Addis Ababa Science and Technology University.

2. Supporting the ARUA Water CoE and Nodes Research

Tanzania Node: supported organisation and facilitation of the stakeholders APP workshop in Tanzania entitled *Adaptive Planning Process for water resources management* which was conducted on 1 – 2 December, 2021 (Figure 2). As a postdoctoral research fellow, I have been involved in the Tanzania (University of Dar Es Salaam) APP workshop planning, co-organising and face-to-face participation on the stakeholder's workshop.

Figure 1 First biennial symposium of African research on water resilience participants

Figure 2: APP group photo of all workshop participants (top), Stakeholders group discussion (bottom-left) and workshop organisers and facilitators (bottom right)

Uganda Node: the water challenge under investigation at the Uganda Node is the role of sediment transport, microplastics and who pollutes the lake/catchment ecosystem. The Node operates in the following catchments (Figure 3): IMB is located on the northern shores of Lake Victoria with a watershed size of 282 km^2. Drainage basins (sub-catchments): Nakivubo (40 km^2) in northwest, Kansanga (15.9 km2) and Gaba (Kyetinda) (7.0 km^2) in the west, Kinawataka (35.9 km^2) and Portbell (2.3 km^2) in north, Namanve (86.7 km^2) in northeast, Nakiboga (17.5 km^2) and Zirimiti (78.3 km^2) in the East. Currently, I have taken over the task of a postdoctoral fellow from the hub supporting Uganda Node to push the activities forward towards outputs and since funding from April 2022 is restored I have been involved in planning meetings, writing minutes and take part in the upcoming planning and implementation of activities such as conducting APP. I will be involved in the Uganda Node Research Assistants writing works and will co-publish the papers. The goal is to assist each Node team to publish their research in an African journal in 2022.

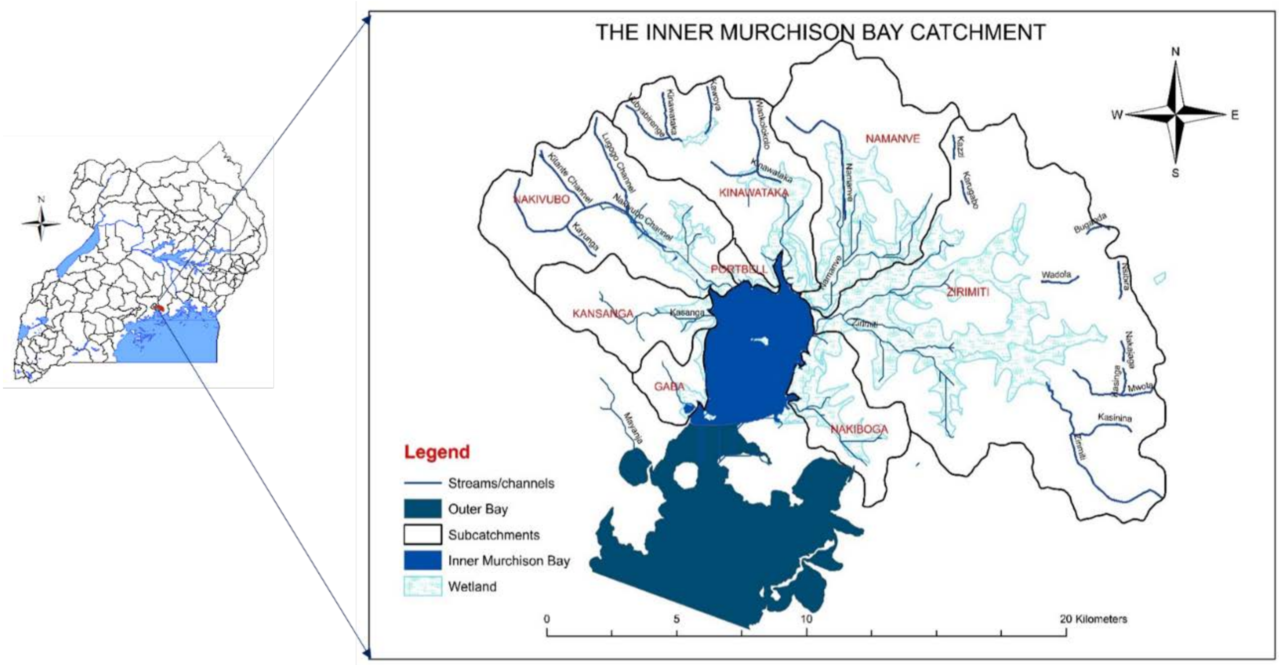


Figure 2. Uganda Node study area

3. Facilitated a storytelling session at the ARUA Biennial Conference Water CoE Symposium

The ARUA Water CoE hosted a session on 19 November 2021 on the ARUA Biennial Conference entitled *Global Public Health Challenges*: *Facing them in Africa*. I was supporting the coordination of a storytelling session together with Rebecca Powell, Sukhmani Mantel and Prossie (Ugandan Early Career Researcher) which was titled, *Digital Storytelling of African Water Challenges*: *Links to Human Health and Well-being*. Early Career Researchers and Research Assistants from Rwanda, Tanzania, Nigeria, UCT, Rhodes, Uganda and Senegal presented and showcased a digital story of their particular water challenge, and I was privileged to facilitate the first half storytelling session on water quality challenges.

4. Funding Applications: Support

I recently participated on proposal writing as a working group team member for funding. The proposal entitled "*Improving integration in a continental level, transdisciplinary complex social-ecological systems project with multiple case-studies*: *a critical review followed by adaptations to enhance equitable outcomes*". The proposal was submitted to the Southern African Resilience Academy (SARA) - Building equitable resilience in southern Africa".

Acknowledgements

I would like to acknowledge the Carnegie ECR fellowship scheme for supporting my stay at Rhodes University and Institute for Water Research for hosting me for the period of 12 months to get the time to focus on research and to collaborate with the IWR in general and ARUA Water CoE team in particular for further future efforts which can strengthen the institutional and cross country collaborations.

Social learning facilitation, capacity development and evaluation in two multi-collaboration research projects: The ARUA and Tsitsa projects.

MJT Weaver and CG Palmer

Overview of my role

My research interest lies in sustainable landscape transformation. This mostly involves working with complex resource problems located at the interface(s) of social and ecological systems. Learning, particularly learning that is social, transformative and transgressive is central to catalysing transformation and making a difference at these interfaces. Through my postdoctoral fellowship, I have been fortunate to drive, support and research learning processes in two multi-collaboration research processes. I am contributing to several linked transdisciplinary research processes related to social learning facilitation capacity development and evaluation, strategic adaptive management, governance, capability expansion, and integrated landscape rehabilitation planning. Below I briefly outline the highlights of my involvement in the RESBEN and Tsitsa Projects.

The Tsitsa Project

On 6 October 2021 we held the graduation ceremony that capped off the online certificate Course (NQF Level 5): *Facilitating Social Learning and Stakeholder Engagement in Natural Resource Management Contexts - Introductory Course (Training of Trainers)*. The name of the course speaks to its purpose, however if you wish to find out more click or follow this link to access an introductory video about the Course: https://youtu.be/YQbWjbqUX74). My role was as lead coordinator, curriculum design and facilitator. I was supported by a coordination group and a dedicated team of 15 tutors and 22 dual-participant tutors who collaborated in small

Figure 1: Some of the participants who completed the Course, the tutors who supported learning (center block collage) and the coordination and facilitation team (surrounding encircled faces).

tutorship circles to enable and mediate online learning. The impact of the Course was far greater that we initially anticipated. Of the 80 participants who completed the course 48 received certificates of competence and 32 certificates of participation. To be adjudicated as competent participants were required to develop as series of four assignments that culminated in the implementation and evaluation of a stakeholder engagement or social learning process. Of the 276 assignments submitted 44 learning processes were implemented resulting in sustainability impacts in their contexts. Impact areas related to sustainable livelihoods, landscape management and stewardship, environmental pollution, environmental education, sustainable agriculture and green economy and water resources and service delivery. This was the first iteration of this Course and there has already been another iteration solicited and currently underway for the Energy and Water Sector Education and Training Association (SETA), with calls for further iterations from various environmental sectors. A small research team is conducting evaluative research drawing on the Value Creation Framework to further explore the different forms of impact of the Course.

I have drawn much learning from my experience in the Tsitsa Project into my research role in theRESBEN Project, particularly related to evaluation method and praxis.

The RESBEN project

I am leading evaluative research with and of the Resilient Benefits (RESEBEN0) Project driven by the ARUA Water Centre of Excellence. The research is entitled: *Exploring the impact of learning catalysed from participation in the Resilient Benefits Project: A value creation approach*. This research project aims to explore the value catalysed for coordinators, facilitators, participants and stakeholders from their involvement participation in the Project. The RESBEN Project implementation is informed by the Adaptive Systemic Approach (ASA). The ASA is being effected through a series of social learning engagements, which cumulatively seek to support engaged social-ecological research processes across six African Case studies. The impact of the Project can be evaluated by exploring the different forms of value catalysed for participants as they engage in the collective social learning engagements facilitated through the course of

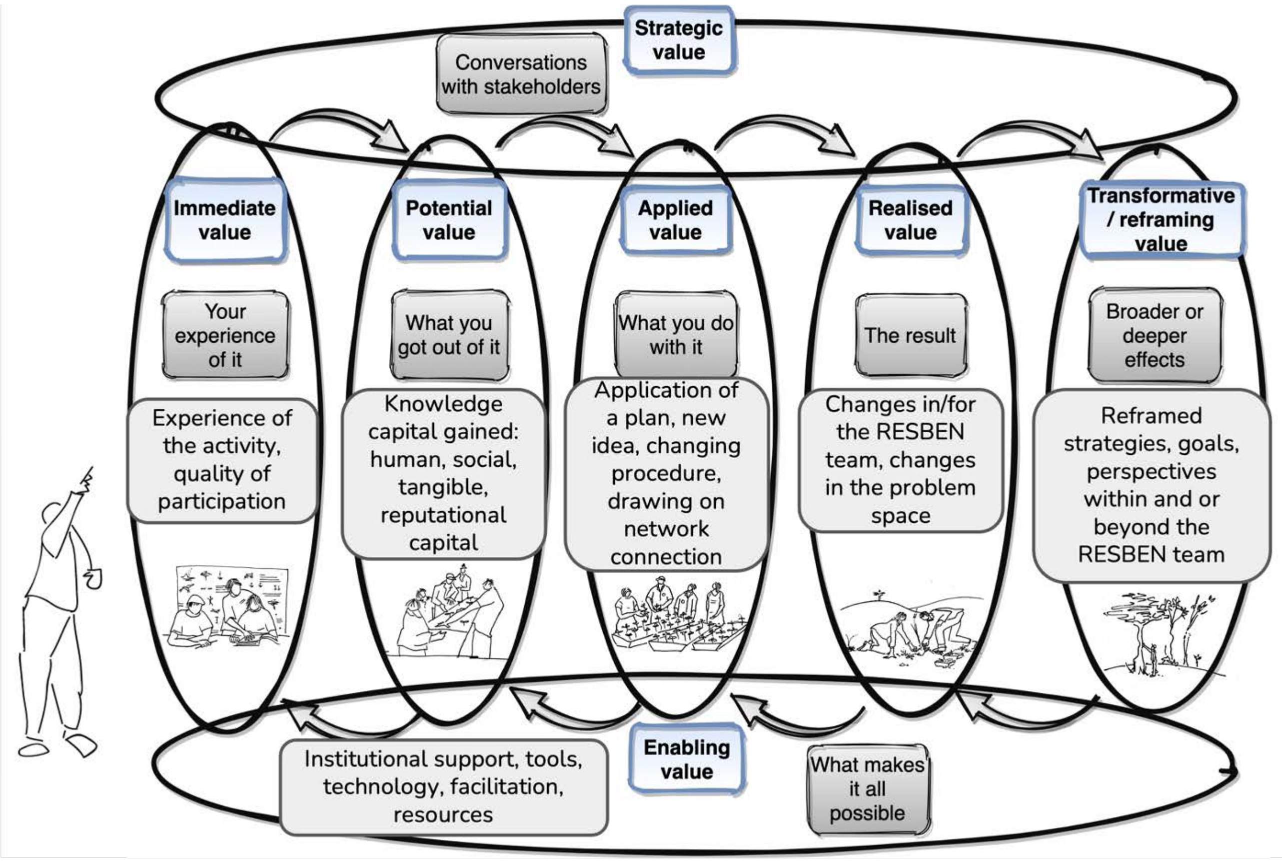


Figure 2: The Value Creation Framework and different indicators of value catalysed by social learning processes. We are exploring the value catalysed from project members participating in social learning processes facilitated by the RESBEN Project.

the Project (Figure 1). We understand value as individual and collective experiential, potential, application, impact, enabling, transformative and strategic benefits gained by participants through their engagement in the Project. Value creation-related data is being collected through observation within group engagements, reflection survey results after engagements, analysis of project outputs and key informant interviews. This research will provide a fine grained and nuanced understanding of value catalysed by the Project beyond what was outlined in the objectives and what was promised as deliverables.

My other significant activities in the Project include: building Adaptive Planning Process (APP) facilitation capacity of Centre's Node teams and supporting the design and facilitation of Node-based APP-informed stakeholder workshops; and coordination of publication capacity development and support for Node paper-writing teams.

Lastly, I am supervising a second year Masters student, Ms. Anele Tshangase, with Prof. Tally Palmer. Anele is based at the IWR and conducts her research within the Tsitsa Project. She is exploring the value of ecological infrastructure related to participatory governance processes in the Tsitsa River catchment.

Hydrology projects

Critical catchment model intercomparison and model use guidance development

JL Tanner, DA Hughes and D Gwapedza

June 2019 – August 2021

Sponsor: Water Research Commission
Collaborators: South African Environmental Earth Observation Network, University of the Western Cape, University of Cape Town, Stellenbosch University and University of KwaZulu-Natal.

Catchment hydrological modelling has become a critical component of water resource management in South Africa. Models are regularly used across a range of applications, including predicting inflows to water supply reservoirs, estimating flows for ungauged catchments, and assessing probable impacts of land cover and climate changes. A plethora of modelling tools is available, each with differing approaches and structures for representing hydrological processes. Given the existing and growing reliance on modelling to inform catchment and water management, there is a need for continuous research and capacity building that enables the water sector to take advantage of, and make wise-use of, the diversity of strategies and tools. This project aimed to contribute by producing informed and accessible guidance that can assist modellers in the process of selecting and applying modelling tools for typical use-cases. This was informed by reviewing the structural differences across several commonly used modelling tools in South Africa and exploring implications of these differences in various settings.

Project Objectives

Review and compare the structures and structural options in a selection of catchment modelling software tools commonly used in South Africa.

- Apply a set of catchment modelling software tools to a set of case study catchments and change scenarios across a diversity of settings to allow for more quantitative exploration of the implications of structural differences.
- Capture and document user experiences with the different tools being compared and reviewed through workshops and surveys.
- Synthesise the resulting information to produce guidance materials for modellers.

The modelling tools and versions selected for inter-comparison in this project were:

- **ACRU**, Agricultural Catchment Research Unit model, ACRU 4 version (Schulze, 1986, 1995; Schulze and Davis, 2018)
- **WRSM-Pitman**, Water Resources System Model, WRSM2000 version (Bailey, 2015; Bailey and Pitman, 2015; Pitman, 1973)
- **SPATSIM-Pitman**, modified Pitman Model run through the SPatial And Time Series Information Modelling platform, SPATSIM v3 version (Hughes, 2013, 2019; Pitman, 1973)
- **SWAT**, Soil and Water Assessment Tool, SWAT2012 implemented with the ArcSWAT2012 interface (Arnold et al., 1998; Neitsch et al., 2011)
- **MIKE-SHE**, Système Hydrologique Européen, MIKE-SHE and MIKE-Hydro 2019-2020 versions (Abbott et al., 1986; DHI, 2019; Refsgaard and Storm, 1995)

The number of tools included was limited to allow for depth in review and make case-study modelling across the set tractable. These specific tools were selected for several reasons. They are all already being used in the South African water sector, with WRSM-Pitman, SPATSIM-Pitman, and ACRU used widely, and SWAT and MIKE-SHE having more limited use to date. They are all appropriate for modelling at the meso-catchment scale, or quaternary catchment scale, needed for most water resource management applications (Uhlenbrook et al., 2004). As a set, they encompass a variety of modelling approaches and structural types, and were developed both locally and overseas under both proprietary and open-access settings. Tool familiarity in the project team and the availability of local advising experts was also considered. The versions of the software tools used were generally the most recent versions and/or the most public facing.

The project accomplished its primary objectives in completing an in-depth comparison of structural options for the focus tools, applying the tools to four case studies, conducting a model-user survey online, and synthesising learnings from these steps into a 'wiki' website (https://hydromodel-sa-wiki.saeon.ac.za/) that can continue to be updated and improved through input from users. Methods and outcomes are summarised in sections below.

The focus tools were used to build models of four case study catchments selected to cover a variety of climate, geomorphological, and land cover settings. These were the Mistley catchment in the upper Mvoti River in KwaZulu-Natal, the Upper Berg River catchment in the Western Cape, the Upper Kromme river catchment in the Eastern Cape, and the Middle Letaba catchment in Limpopo (Table 1, Figure 1). For each, one or more alternative scenarios were applied to assess how differently they predicted the response to the change. These were land cover scenarios for the Mistley, Berg, and Kromme, and a change in irrigation water sources in the Letaba.

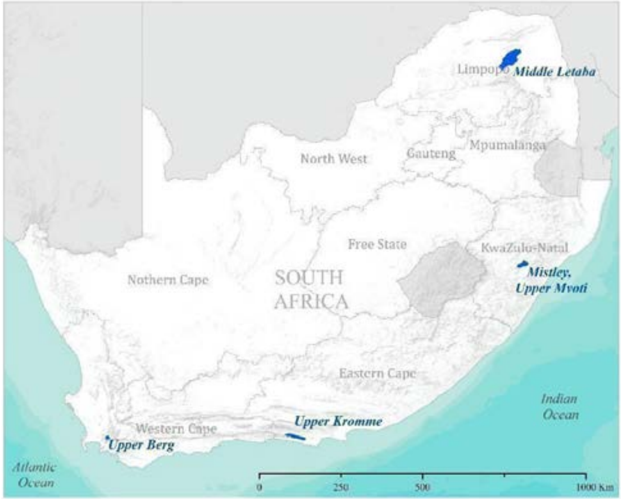


Figure 1: Map indicating case study catchments

Table 1: Case study catchments, use-case demonstration scenario types, and highlighted process representation issues encountered in model building

Case-study catchment	Climate type	Geology, geomorphology, natural vegetation	Scenario types	Highlighted representation issues
Mistley, upper Mvoti (U40A), KwaZulu-Natal	Summer rain, sub-tropical	Shale & dolerite, rolling hills, Grassland	Commercial forestry extent & riparian/wetland buffers	Riparian zone processes
Upper Berg (part G10A), Western Cape	Winter rain, sub-humid/semi-arid, Mediterranean	TMG quartzite, steep mountain, Fynbos	Invasive alien tree extent & location	Interflow in steep, rocky mountains
Upper Kromme (K90A,B), Eastern Cape	Bimodal rain, semi-arid	TMG quartzite - steep mountain + floodplain alluvium, Fynbos	Invasive alien tree extent, Wetland extent	Spatial rainfall distribution & flow connectivity interact with subcatchment delineation; Valley bottom wetland representation
Middle Letaba (B82A-D), Limpopo	Summer rain, semi-arid, temperate	Gneiss & granite, relatively flat, Woodland	Irrigation amount & irrigation from groundwater	Irrigation from groundwater, from multiple sources; Numerous small farm dams; Channel transmission loss

Working across the documentation and interfaces of the different tools it was clear that each tool has its own 'language'. It was often the case that different terms were used for the same concept across different tools (e.g. what is called "interflow" in WRSM-Pitman is called "lateral flow" in SWAT). Alternatively, there were cases where the same term, or a very similar one, was used for different concepts across tools (e.g. 'groundwater outflow' referring to subsurface flow of groundwater between neighbouring subcatchments in SPATSIM and flow from an aquifer into a channel in SWAT). This is not surprising and wouldn't pose a challenge to a user of a single tool. However, it required extra care in the context of this project.

Viewed at a very basic level, the five focus tools are similar in some notable ways. However, despite their high-level similarities, there are numerous differences in how the tools allow users to discretise and represent various components of catchments, in terms of scales, unit types, and connections (overview in Table 2 below), as well as in the process algorithms used to calculate flows in and out of the different modelled units. These differences have implications for what a model can represent explicitly and the model-building decisions (discretisation into subcatchments and other model units, parameterisation, etc.) needed to represent what is intended.

Table 2: Structure overview across modelling tools

Structure characteristic	WRSM Pitman	SPATSIM Pitman	ACRU4	SWAT2012	MIKE-SHE Semi-distributed, more conceptual	MIKE-SHE Distributed, more physical
Timestep	Monthly* *(Daily versions exist. Limited use to-date)*		Daily	Daily, subdaily	Daily, subdaily* *(Dynamic timesteps by process. Outputs saved for selected step)*	
Spatial discretisation	Modules connected by routes *('runoff modules' + special area modules + channel modules create subcatchments)*	Subcatchments + limited internal sub-area types	HRUs within subcatchments		Gridded surface & soils + zones within subcatchments: overland flow, interflow, 'baseflow reservoirs'	Gridded (3D), no subcatchments *(topography is explicit: flow dictated by gradients)*
Spatial model units for:						
Climate input	Modules	Subcatchments	Subcatchments or HRUs* **laborious*	Subcatchments	Grid cells or zones	Grid cells or zones
Surface & shallow subsurface processes	'Runoff modules' + special area modules	Subcatchments (+ internal special sub-areas)	HRUs		Grid cells + overland flow zones + interflow reservoir zones	Grid cells
Groundwater processes	'Runoff modules'	Subcatchments	HRUs	Subcatchments	Baseflow reservoir zones	Grid cells
Channel processes	Channel 'modules', flexible connections to other modules	Single channel unit within a subcatchment	Channel units with flexible connections to HRUs & dams within a subcat	Single channel unit within a subcatchment	Spatially & topographically explicit channel reaches between nodes, connect to bordering landscape units (surface & subsurface), flexible spatial layout	
Waterbodies (optional)	Reservoir 'modules', flexible connections to other modules	Single reservoir at outlet of subcat channel (not for irrigation) + single/lumped dam internal to subcat (can irrigate)	Dam units with flexible connections to HRUs & channels within a subcat	Single reservoir at outlet of subcat channel (can irrigate) + 'pond' & 'depression' units internal to subcat (not for irrigation)	Storage created with explicit bathymetry cross-sections in channel reach set-up (can irrigate) OR Simple storage unit attached to reach (not for irrigation)	

Some of the structural differences across the tools manifest as differing capabilities in terms of what processes or aspects of spatial or temporal variability can be explicitly represented. A summary of capabilities across tools is presented in the final report. All the tools have most of the capabilities listed, while no one tool had all of them. In other cases, the differences were in how a process is represented rather than whether it can be explicitly represented or not.

The specific implications of the differences across tools and their real importance for a modelling project will differ across use-cases. These will be dependent on the combination of the type of catchment, the changes that are to be modelled, the data available, and the types and scales of model outputs that are needed. This makes it challenging to generalise about the relative importance of particular differences; however, the case study modelling exercises helped to highlight some issues that may come to a fore in common use-cases.

A key finding of the case study modelling was that models could be built across all the tools with comparable levels of performance against observed streamflow, while the predicted water balances of these models could differ fairly substantially. This occurred even though the model set-ups were all informed by the same set of catchment property data and information. Differences in the predicted balances of canopy interception, ET from soil and groundwater, surface flow, interflow, aquifer outflow, and storages across the baseline models showed differences in process representation, which meant that their streamflow predictions became more divergent when the scenarios were applied. There was no consistent pattern of over- or under-prediction across the different tools across the different case studies. A pattern was not expected as model performance is function not only of the capabilities of the tool to represent local processes, but also the input and performance evaluation data being used and many decisions made by the modellers. Because of the practical challenges in extracting and processing various water balance outputs, water balances were only compared across the models post-hoc. The exercise highlighted the importance of assessing the modelled water balance against other information sources beyond catchment outlet streamflow to validate it as part of the calibration process.

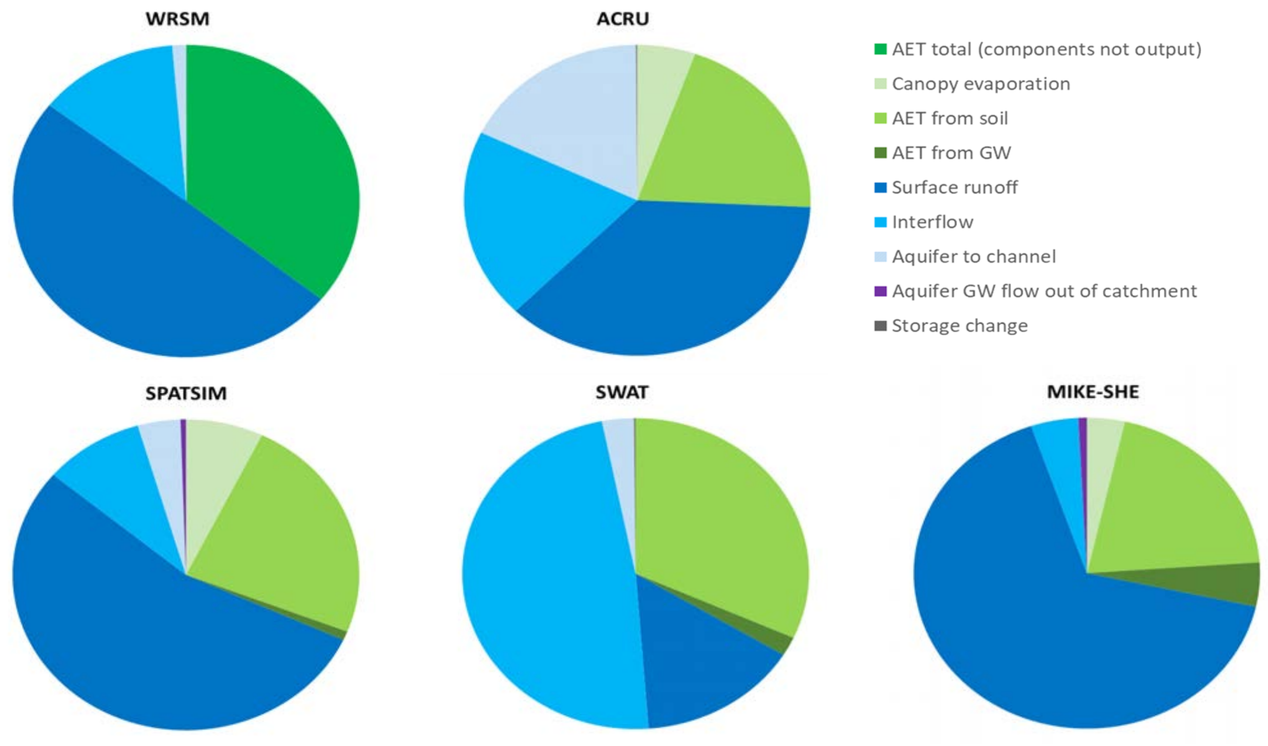


Figure 2: Modelled mean annual water balances for the Upper Berg catchment for 2006-10-01 to 2018-09-30, predicted using five different modelling tools shown as proportions of catchment mean annual precipitation (NB: not all fluxes are modelled or output by all tools)

It is hoped that this project and the HydroModel SA 'wiki' site will contribute to growing the number of hydrological modellers by helping people engage with the modelling tools and to foster the practice of 'looking under the hood' of models to ensure they are put to appropriate use. The intercomparison highlighted the need to not only consider parameter uncertainty, but also model structural uncertainty, and the need to go beyond assessing modelled streamflow outputs and evaluate the modelled water balance where possible before extending models to scenarios. This would entail additional process data such as measurements of actual evapotranspiration, soil moisture, or groundwater levels. While field data may not be readily available on these values a growing number of remote sensing products could be brought to bear. Material on operationalising this would make for a useful addition to the wiki content.

Role of Ecological Infrastructure (EI) in mitigating the impacts of droughts

SK Mantel

April 2019 – March 2021

Sponsor: Water Research Commission
Collaborators: JL Tanner (IWR), D le Maitre (CSIR), A de Vos (Department of Environmental Science, Rhodes University)

South Africa is an arid country with a mean annual rainfall of less than 500 mm, only 9% of which ends up as water in rivers and aquifers, so every drop is scarce, and it is imperative that water is optimally used. Water supplies are unevenly distributed, only 8% of the land area yields about half the runoff, and these major Strategic Water Source Areas (Figure 1) need to be managed to protect the quality and quantity of the water they provide. South Africa is currently experiencing a severe drought, and this has resulted in crop losses, imposition of water restrictions and significant impacts on water and food security. Droughts are likely to become more intense and more frequent in the future due to changing climatic regimes; at the same time, energy, land and water demands are expected to increase globally. This has implications for associated impacts on the availability of grasses for livestock, and water and food security (affected by crop losses and water availability). South African society needs to respond more appropriately to droughts through timeous and transformative interventions, moving away from responses that do not yield long-term gains, to optimise the supply of water resources.

The aims of the WRC project were:

1. To explain how well-managed ecological infrastructure can help to mitigate the impacts of droughts on human livelihoods and well-being and to propose strategic responses that will maintain and enhance the value of this service that people will embrace and implement.
2. Assessment of ecological infrastructure presence, current state and prioritisation in three focal catchments.
3. To provide an assessment of how the ecological infrastructure facilitates drought mitigation.

We interrogated these aims using four target ecological infrastructure (EI) land cover types in three catchments. The EI land cover types were selected primarily based on their recognition by the SANBI *Framework on Investment in Ecological Infrastructure*. Maintenance and restoration of these areas will support the flow regulation ecosystem services. These target EI land cover types are grasslands/rangelands, riparian zones, wetlands, and abandoned croplands. The last category has been added as previous research has identified them as focal areas for invasive alien plant invasion, which are well known for their large water use as well as a source and cause of erosion. Notably, the SANBI Framework provides the foundation for linking the investment in EI to the National Development Plan 2030, specifically critical action 7 (*public infrastructure investment focused on transport, energy and water that takes account of disaster risk reduction and protection of freshwater ecosystems*) and critical action 8 (*interventions such as restoration and maintenance for ensuring environmental sustainability and resilience to future shocks*). The case for the value of EI is supported by research done in South Africa, specifically hydrological, restoration and monetary evaluations. One of the outcomes of the project is a Fact Sheet on the value of maintaining and restoring EI that can be used to support knowledge sharing of the importance of these infrastructures (Figure 2). The project supported two MSc students, Mr Sinetemba Xoxo and Ms Bawinile Mahlaba, who researched the three study catchments: Tsitsa, Cacadu and Crocodile River catchments.

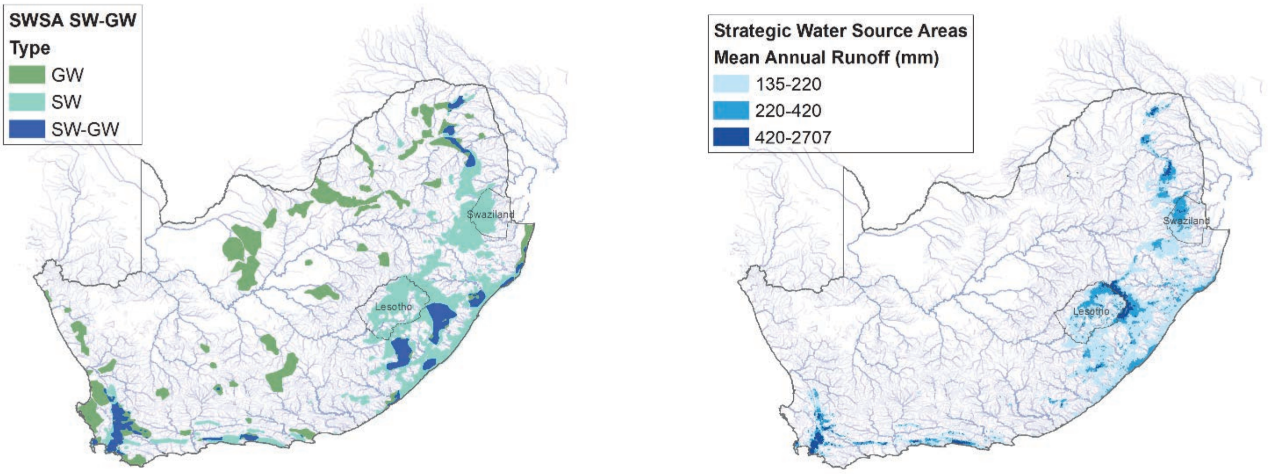


Figure 1: South Africa's Strategic Water Source Areas (SWSAs) for surface water (22 SWSA-sw areas) and groundwater (37 SWSA-gw areas) that generate relatively large quantity of mean annual surface water runoff for their size and/or high groundwater recharge

The Sustainable Development Goal (SDG) 15.3.1 indicator was used to identify the location of land degradation in the three catchments using the Trends.Earth plugin in QGIS. The SDG 15.3.1 degradation indicator aims '*to monitor the proportion of land that is degraded over the total land area*'. The results found that a large proportion of the pixels are in stable state in the Cacadu catchment and <17% has degraded over the assessment period of 2000 to 2015. In comparison, approximately 41% of the land is degraded in the Tsitsa catchment, particularly the lower parts, and 34% in the Upper Crocodile catchment.

Under Aim 3, four anthropogenic induced land modifications, defined as afforestation, cropland expansion, expansion of settlements, and eroded surfaces, were detected. The Pitman hydrological model was applied in two focal catchments – White Kei and Tsitsa, and the simulated impacts of land use under 1990 and 2018 land covers were evaluated. The results clearly demonstrated that land modification in these environments reduces the catchment's capacity to delay rainfall from quickly reaching streams during the wet season.

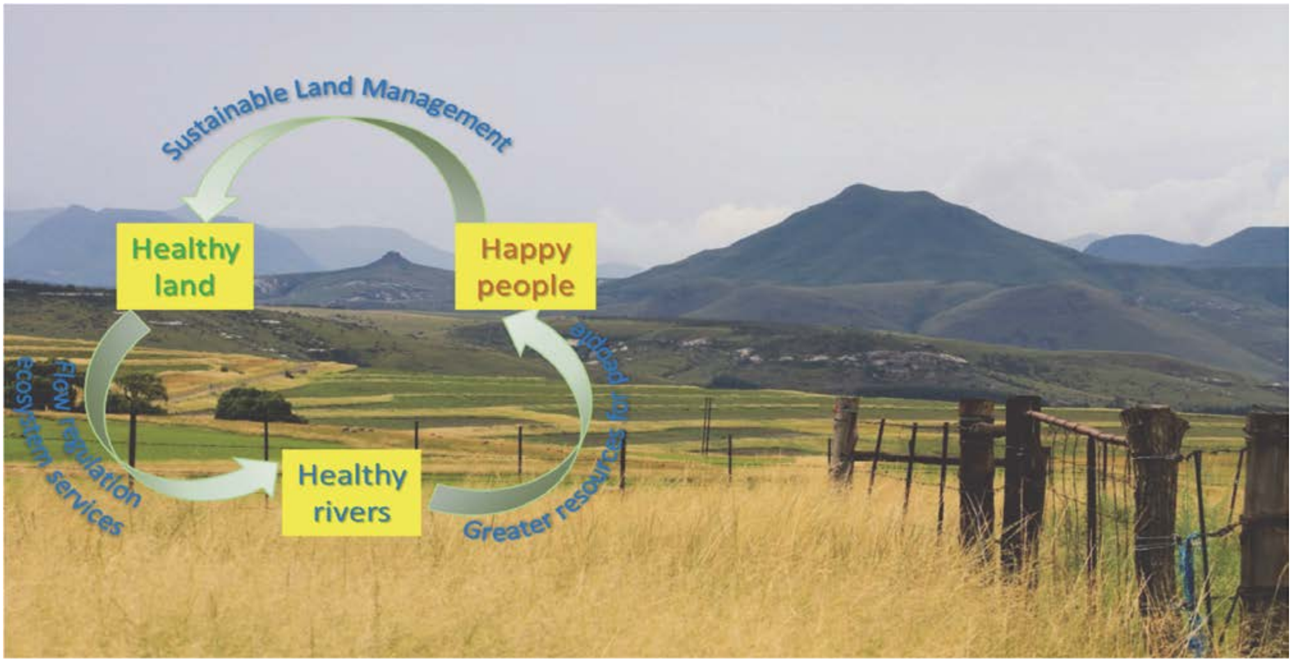


Figure 2: An image from the Fact Sheet produced by the project team on the value of investing in ecological infrastructure.

Key findings from the final project report

There are several key findings from this project. Firstly, we have brought together literature which shows that investing in ecological infrastructure is beneficial from the point of views of flow regulation and finances. Secondly, we have built a case for supporting the argument that investment in ecological infrastructure enhances water security through promotion of strong flow regulation in the catchment. We propose that the methodology adopted by our project (as in some others) of integrating stakeholder feedback with spatial information allows for a more meaningful and transformative research that can be implemented because of the buy-in of the stakeholders that is a result of the process of allowing and recognising the preferences of the local community.

The project results are aimed both at decision-makers in the government at both national and provincial level (particularly, the Department of Agriculture, Forestry and Fishery and the Department of Water and Sanitation) who are responsible for the policy and financial allocations to implement the SANBI Framework in the catchments. The results are also aimed at NGOs, citizen scientists and other scientists who provide the oversight and feedback on protection and restoration programs on the ground.

In terms of strategic response, public-private partnerships are showing the way of successfully implementing sustainable management programs. A good example is the LandCare programme that was initiated by the former Department of Agriculture (now DEFF) with the aim to mainstream biodiversity in agriculture, forestry and fisheries policies in cooperation with NGOs, private sectors and provincial government practices. This form of public-private partnerships has also been used by DEA-NRM (e.g., uMzimvubu Catchment Partnership Program, Umngeni Ecological Infrastructure Partnership, Tsitsa Project, WRC Green Village), and is being promoted through partnerships between the private sector and NGOs (e.g., WWF, Meat Naturally, AWARD). Participatory partnerships such as these offer the affected people agency and capacity, which are essential bottom-up initiatives that should be coupled with top-down support, for a way forward that supports sustainable land management and the building of sustainable livelihoods.

A stakeholder driven process to develop a more equitable and sustainable water resource management plan

D Gwapedza, JL Tanner and SK Mantel

April 2021 – March 2024

Sponsor: Water Research Commission
Collaborators: B Paxton (FRC, South Africa), O Barreteau (INRAE, France), B Bonte (INRAE, France)

Water scarcity is a significant problem in South Africa. Low average rainfall results in limited water available for human and environmental needs (DWAF, 2013). The water availability situation has received further shocks from droughts (Wolski, 2017) and the increasing impacts of climate change. The South African National Water Act (Act 36 of 1998) and Water Services Act (Act 108 of 1997) were instituted to manage human water uses and protect the environment by establishing Environmental Water Requirements (EWR). Environmental Water Requirements's stipulate the amount of water needed to ensure that a river system remains functional and sustainable. However, due to low rainfall in many areas, water holding areas (catchments) retain too little water in rivers and reservoirs, barely meeting human and environmental needs. Consequently, competition for water resources is increasing and has resulted in water-related conflicts among the various water users in many areas of South Africa. Unfortunately, when competition for water use exists, EWR's are often ignored, thus impacting the health of riverine ecosystems. This project responds to this problem by negotiating a shared water management strategy that achieves equity in water access and respects EWR. While the problem exists in many regions of South Africa, the project focuses on the Koue Bokkeveld (KBV) region, Western Cape, where the problem is prominent. Conflicts are rife between upstream farmers who have initial access to river water and downstream farmers who are forced to use what remains after upstream users satisfy their needs (Paxton and Walker, 2018). Unfortunately, the numerous dams have led to a depletion in EWR and threaten riverine ecosystems and the various plant and animal species that depend on the river systems (Paxton and Walker, 2018).

The situation entrenches inequality and fuels conflict and, if left unmanaged, may turn into an environmental disaster (e.g. there are several endangered endemic fish species in the rivers) and lead to a breakdown in the farming community. Additionally, the potential loss in agricultural productivity will affect food security and the livelihood of the thousands of farmworkers who work in the area. Therefore, effective water management is vital to ensure equity in water access to foster shared growth, reduce water conflicts, promote ecosystem health and prevent biodiversity loss. This project aims to assist KBV stakeholders in co-developing a water resources management strategy that results from a shared understanding of the catchment. The specific aims are:

1. Work with/build relationships between stakeholders while expanding their understanding of the bigger picture of water resource use and management in their catchment.
2. To negotiate a sustainable and equitable water management plan that observes environmental water requirements and protects riverine biodiversity.
3. To explore scenarios of future water demand under growing agricultural development and water availability under climate change to adapt the water management plan to a set of anticipated scenarios to ensure sustainability under change.

A mixed-methods approach will be adopted in this research following multiple disciplines. Hydrological, ecological, social, and computer sciences converge to fulfil the project aims. Hydrological and ecological data will be used to set up an Agent-Based Model (ABM) model (branch of computer science), the principal tool used for negotiation support within the project. Social science principles will be adopted in stakeholder engagement through various methods that include workshops and interviews.

Three institutions will collaborate on the project. The Institute for Water Research-Rhodes University, South Africa specialises in hydrology and water governance. The Freshwater Research Centre, South Africa specialises in ecology, conservation and stakeholder engagement within the KBV. The National Research Institute for Agriculture, Food and the Environment (INRAE), France specialises in the development of ABM models and agricultural sciences. The project is for three years. Three postgraduate students (Mr Sinetemba Xoxo (PhD), Mr Sakikhaya Mabohlo (MSc) and Mr Stefan Theron (MSc) are part of the project. All students are in the initial stages of their projects. Reports that describe students' projects and progress are provided in their reports.

Progress so far

Some progress has been made towards the development of the ABM model. Initially, hydrological modelling testing was done for hydrology students. The following training was an ABM training facilitated by the French collaborators. IWR IT technician Mr David Forsyth joined the training, and he will be vital in coding the ABM model. During the training, we developed a conceptual model that we later formalised using the Unified Modelling Language. Additionally, the team was trained on methods of involving stakeholders through the ABM development and application process. The project's next stage is to complete hydrological modelling, complete another ABM training, and conduct a workshop in the catchment before the end of the year.

Figure 1: Image showing the students working together during the ABM training week.

Evaluating trade-offs from intensified practices in communal livestock systems in South Africa using an integrated farming systems approach (TOCASA)

AR Palmer
April 2019 – March 2022

This interdisciplinary research project, funded by the UK's BBSRC, involves researchers from Coventry University, Rothamsted Research (UK), with partners from three separate institutions in South Africa namely Conservation SA, the Institute for Water Research and Stellenbosch University. The project aims to better understand the social-ecological systems (SES) of communal grazing areas in South Africa for the past 20 years, focusing on governance of communal grazing systems as common property regimes and the links between governance and degradation of communal rangeland. Using a large aperture scintillometer, Prof. Tony Palmer, has been determining the water use of the wattle trees which have invaded the hill-slope seeps of the Drakensberg foothills. The grasslands associated with these hill-slope seeps have been invaded by silver wattle (*Acacia dealbata*), whereas black wattle (*Acacia mearnsii*) was historically planted for woodlots, and has subsequently invaded upland areas and the riparian zone. Both these landscape habitats had been grasslands and important grazing resources, and this has now been replaced by unpalatable wattle trees. The TOCASA project includes a component that evaluates the potential use of these wattle trees as forage for livestock. In addition, the water used by these trees has radically altered catchment run-off, reducing the water available to downstream communities living in the villages. The IWR component of the project has determined that approximately nine percent (274 km^2) of this geographic region was invaded by woody shrubs, and this represents an annual use of approximately 253000 ML of water used by invading trees.

Figure 1: Prof. Tony Palmer installing the larger aperture scintillometer, with wattle invasions of hillslope seeps clearly visible in the background.

Assessment of ecological infrastructure degradation: a case study of cultivated land abandonment in rural areas of the Tsitsa River Catchment

Student: RN Dakie
Supervisor: A de Vos and SK Mantel
Degree: MSc (Environmental Sciences)

Cultivated land abandonment is a growing phenomenon, with many studies conducted in European countries, followed by studies in Southern Africa. In Southern Africa, the focus has been mainly on understanding the drivers, patterns, and consequences of this phenomenon in the affected areas. Studies have shown that cultivated land abandonment arises through people's interaction with the environment, and its consequences may affect people living in those environments. The consequences associated with cultivated land abandonment may be positive or negative, which makes it difficult to decide how these lands can be managed. Positive consequences may include water retention, soil recovery along with nutrients cycling and increased biodiversity, while negative consequences may include encroachment by invasive alien plants, land degradation in the form soil erosion and soil fertility and reduced agricultural income which will increase dependency on governmental support. Given various complex interactions and trade-offs of abandoned lands, what are the best sustainable land management practices to implement? There may not be a one-size-fits all approach, which is why understanding land abandonment in social-ecological context is critical. This study, therefore, aims to determine what sustainable land management practices could be put in place to improve/rehabilitate abandoned cultivated lands such that they may benefit livelihoods positively while also protecting the environment. This study will be focusing on two villages, Sigoga and Ntatyaneni, in the Tsitsa River catchment. The study will use a mixed-method approach including remote sensing data, interviews, and scenario development on assessing the extent of the abandonment, its drivers, consequences and explore possible future perspectives.

The aim of the project is to assess the role of abandoned cultivated land in the spread of invasive alien plants in the Tsitsa River Catchment.

The specific objectives of the study are:

1. To determine the extent of cultivated land abandonment in the catchment
2. To determine the change in the landcover after the abandonment of the cultivated land
3. To determine if abandoned cultivated lands are susceptible to disturbances by invasive alien plants.

Figures 1 and 2 summarise the drivers and consequences of cultivated land abandonment based on a literature review.

Figure 1: Drivers of cultivated land abandonment

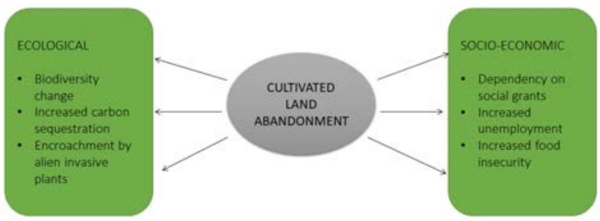


Figure 2: Consequences of cultivated land abandonment

Integrating multiple earth science methods to develop an overview model to be used in groundwater exploration

Student: Jaco Greef
Supervisor: JL Tanner and S Buttner
Degree: MSc (Hydrology)

Many parts of South Africa are experiencing water shortages. Increased urbanisation and industrialisation have placed enormous pressure on water resources, making it more difficult to regulate, manage and allocate appropriately. During current drought conditions in South Africa, available renewable groundwater volumes are estimated to be around 7500 million cubes per annum of which only half of this is said to be utilised.

The research is looking at using different earth science investigative techniques to assist with groundwater exploration, and potentially increase groundwater utilisations through borehole establishment.

This part-time study is currently in its second year of which most of the time was spent studying the structural geology to the south of Makhanda. The strata covering this area are quartzitic sandstone, mudstone, and shales from the Witteberg Group of the Cape Supergroup. The Cape Supergroup are strongly folded along a west-northwest (WNW) to east-southeast (ESE) trending fold axis as a result of Cape Fold Belt (CFB) tectonics. Initial field investigations showed evidence of overturning within the first order anticline at Featherstone Kloof with evidence of thrust faulting found within the topographical lows of Featherstone Kloof towards the lithological contact between the Witpoort Formation (Quartzite) and Weltevrede Formation (Shales). Joint sets and quartz veins within Featherstone Kloof and along mountain drive have shown an initial 'preferred' alignment, striking at ~130 degrees. Research into the structural characteristics of Featherstone Kloof will continue in 2022.

It is expected that most of the structural geology focussed fieldwork will be concluded in 2022, after which stereonets and conceptual cross sections across Featherstone Kloof and into Makhanda can be drawn using multiple suites from Rocscience. This will help determine the orientation and locations for the geophysical assessment.

Initial hydrological assessment of the area will be based on remote sensing using Landsat8 imagery from USGS and among other, the Normalised Difference Moisture Index (NDMI) to compare seasonal moisture levels and Normalised Vegetation Wetness Index (NDVI) to highlight vegetation which receives more water. It is still unclear at this point what outcomes can be expected from the remote sensing, but it is likely that select ground truthing will be critical in determining the accuracy of these outputs. Once structural interpretation, geophysical assessment and remote sensing is completed, attempts can made at formulating a baseline model to be used for exploration of groundwater.

Figure 1: Striations between bedding layers indicating sheer sense movement at one of the potential thrust zones

Figure 2: Quartz veins in the Witpoort Quartzites showing a preferred strike of ~130°

Application of SWAT hydrological model to simulate catchment water balance: a case study of Twee and Leeu River, Western Cape

Student: S Mabohlo
Supervisors: JL Tanner and D Gwapedza
Degree: MSc (Hydrology)

The availability of water in South Africa is affected by numerous and diverse factors. These factors include not only temporal and spatial distribution of rainfall and high evaporation rates (Taylor, 2001; Molobela, 2011) but also competition for the limited water resources from expanding irrigated agriculture, industrial and domestic water use sectors (Guug et al., 2020). Water demand from competing water users results in overexploitation of water resources. A study by Swatuk (2015) reveals that as water resources become more limited, the water-related conflicts among water use sectors become more frequent. Conflicts are also known to arise within a single water use sector, such as when water use allocations are questionable (Kramer, 2004; Swatuk, 2015). For instance, in the agriculture sector, which is the largest (63%) user of available freshwater, water-related conflicts largely centred among commercial farmers are commonly experienced. When such conflicts occur, emerging farmers are left without a fair share (Paxton and Walker, 2018; Gwapedza et al., 2020) and the flows are abstracted without considering environmental requirements (Tessema, 2011).

Proper planning and effective management of water are required to balance water demands among farmers and other water users, thereby reducing water conflicts and ensuring that ecological reserve requirements are met. Planning and management for balancing water demands need a detailed understanding of the dynamics of water resource availability at a catchment scale. Hydrological models are applied to represent various inputs, storages, and outputs of a catchment's water balance and the additional impacts of human

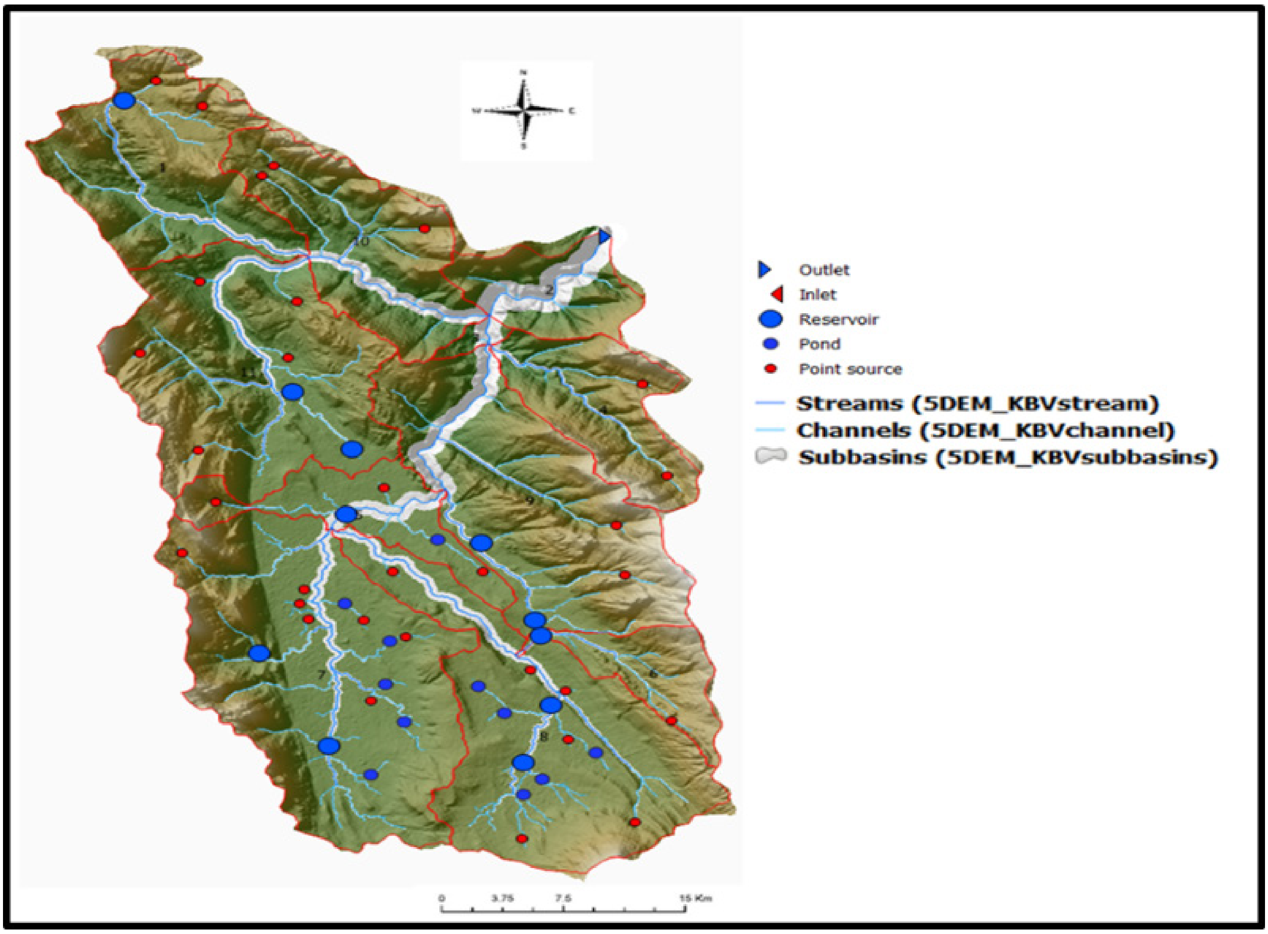


Figure 1: Study catchment delineated by SWAT model.

influence (Guug et al., 2020). Therefore hydrological models assist in acquiring sufficient knowledge of catchment dynamics.

This current study aims at improving the quantitative understanding of detailed water balance and future flow scenarios of the Kouebokkeveld catchment. The specific objectives below are established and will be followed to achieve the main aim of the study:

- To analyse the rainfall information from farmers and weather stations to produce a reliable rainfall surface
- To set up and evaluate SWAT model performance in simulating water balance for the Twee and Leeu River catchment, Western Cape, where there are significant abstractions for irrigation purposes
- To apply a calibrated SWAT model to simulate future flow scenarios under changing climate.
- To assess the need for a physically-based daily hydrological model in an environment where precision water management is occurring considering the high data and time costs

Input data for the model set up is obtained from Geosmart and Stellenbosch University, Department of Agriculture and Rural Development, Agricultural Research Council, South African Weather Services, Department of Water and Sanitation, and Cape Farm Mapper of the Western Cape Department of Agriculture. Projected climate data for simulating future flow scenarios will be extracted from CORDEX.

This study forms part of a broader project setting up an Agent-Based Model (ABM). Therefore, the results of this study will be used in the ABM development. It is anticipated that the calibrated hydrological model developed in this study will be transferred to the catchment managers for use in day-to-day catchment management. Furthermore, the outcome of this study will be used to support decision-making regarding equitable water allocation among farmers. Additionally, the information that the study will provide on current and future water availability will assist catchment managers in making informed decisions about how water management could be adapted to changes in water availability.

The assessment of degradation state in ecological infrastructure and prioritisation for rehabilitation and drough mitigation in the Tsitsa River Catchment

Student: B Mahlaba
Supervisors: SK Mantel and JL Tanner
Degree: MSc (Water Resource Science)

Ecosystem degradation is a serious concern globally, including in South Africa, with approximately 38% of its population living in ecologically degraded areas. Increasing threats from land transformation, overexploitation, and invasive alien species are resulting in potential adverse impacts on food security, livelihoods, climate change, biodiversity, ecosystem goods and services, and hydrological alteration, which in turn has a negative impact on water availability. So, assessment, monitoring, maintenance, and restoration of degraded lands are important for sustaining ecosystem services. This study aimed to assess how Ecological Infrastructure (EI; specifically wetlands, grassland, abandoned cultivated fields, and riparian zones) can facilitate drought mitigation, and assess the land degradation status and identify priority EI areas that can be restored to improve the drought mitigation capacity. The study adopted the South African National Biodiversity Institute (SANBI) Framework of Investing in EI to prioritise the restoration of degraded ecosystems and maintain ecosystem structures and functions.

The Trends.Earth tool was used to assess the current state of degradation and change since the year 2000 in the Tsitsa River catchment (see Figure showing the land cover of the catchment), through assessment of Sustainable Development Goal degradation indicator (SDG15.3.1) at a resolution of 300m. The degradation indicator uses information from three sub-indicators: Productivity, Landcover, and Soil Organic Carbon to compute degraded areas. The degraded areas need to be restored and rehabilitated to maintain the flow of essential ecosystems services provided by EI. The Analytical Hierarchy Process (AHP), a useful decision support system that considers a range of quantitative and qualitative alternatives, was used for prioritisation. The AHP was used in the ArcGIS platform to prioritise suitable key EI restoration areas with high potential to increase water recharge and storage, and to contribute to drought mitigation and ecosystem services for the catchment.

The major causes of land degradation are woody encroachment in grasslands, invasion of alien plants on abandoned cultivated fields and soil erosion in the catchment. The land degradation indicator showed that approximately 54% of the catchment is stable, 41% is degraded land, and 5% of the area has improved over the assessment period (15 years). The degradation status of the EI suggests that more than half (>50%) of each EI category is stable, but there are areas showing signs of degradation, with 43% of grasslands degraded and 39% of wetlands, cultivated lands, and riparian zones also degraded. The AHP analysis identified more than 39% areas (of the degraded EI indicated by the Trends.Earth analysis) as suitable for restoration, because key EI plays a significant role in flow regulation and people's livelihoods, especially when they are managed, maintained, or restored to healthy conditions.

The most suitable EI areas recommended for restoration are those natural resources near local communities, which provide essential ecosystem services to sustain their livelihood. Therefore, current degraded EI in the Tsitsa River catchment should be restored and maintained to improve livelihood and mitigate drought impacts. The study pointed out how the key selected ecological infrastructure can help mitigate the impacts of droughts and improve human livelihood. By mapping and identifying changes in the Tsitsa River catchment, this study contributes to the prioritisation of EI for ecological rehabilitation planning. Moreover, assessing the health of the Tsitsa River catchment EI contributes to the field of climate change adaptation for local communities, especially in times of drought.

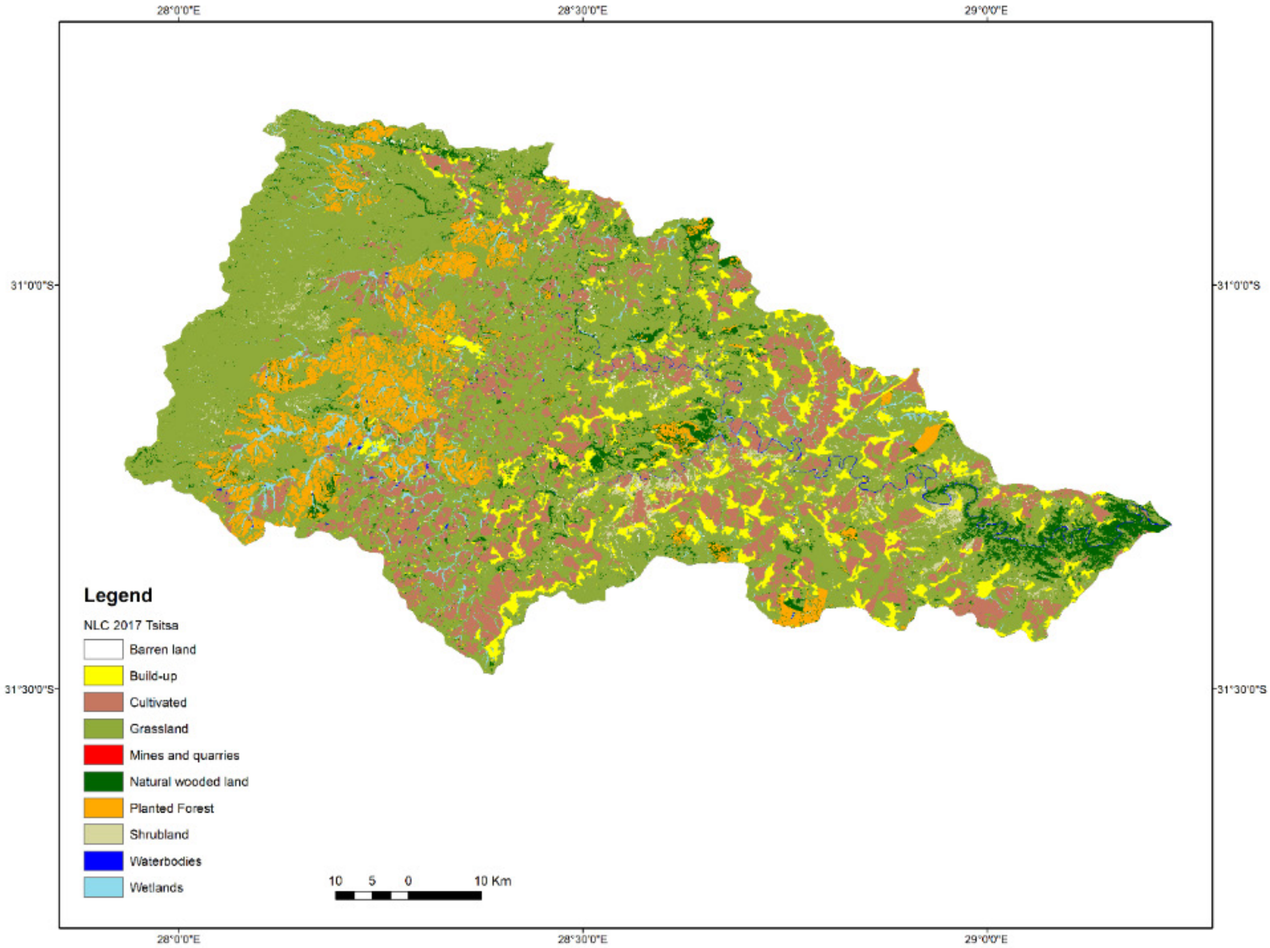


Figure 1: Land cover of Tsitsa River catchment derived from the National Land Cover 2017-2018 database.

Integration of satellite data in reducing hydrological modelling uncertainty for sustainable water resources management in Sub-Saharan Africa

Student: HA Okal
Supervisors: J Tanner and SK Mantel
Degree: PhD (Hydrology)

Africa is blessed with a lot of water resources, which are a major source of economic development within the continent. However, these resources are unevenly distributed and are constantly under threats from climate change, urbanisation, population pressure, pollution, and over-abstraction among others, resulting in a widened water supply and demand gap. Added to water availability threats -now and into the future, is the fact that many countries have scarce and poorly monitored hydro-climatic variables (precipitation, temperature, evapotranspiration, surface and ground water etc.) and water use information.

In understanding the hydrological variations and predicting future scenarios in a watershed, hydrological models (HMs) have proven to be vital especially in data-scarce environments. These models are therefore necessary for addressing water resources management issues under their unpredictable environments. They are a simplification of a real-world system that relies on reliable data. However, the uncertainties that come with these models remain a challenge as evidenced by the scanty literature available on hydrological modelling uncertainty within many river basins in Africa. This is largely attributed to concerns on measurements of climate, hydrological variables, land-use change and water use within these basins. Significant uncertainties in available data result in highly uncertain model outputs being used in the assessment, planning, and management of water resources in Sub-Saharan Africa (SSA). Unfortunately, many decisions on water resources development in Sub-Saharan Africa are made with data that are erroneous, unreliable, and/or simply non-existent. Yet these data are vital in understanding the environmental, atmospheric and hydrological dynamics of any watershed. Twelve major river basins have been identified for this study (Figure.1) with the focal points being; areas with no initiative or hydrological modelling (HM) yet, areas where large scale HM have not been done, and areas with no regular hydrological information updates for the past ten years.

With the emergence of satellite data that use measurements of the electromagnetic spectrum to characterise the landscape, or infer its properties, or in some instances measure the actual hydrologic state variables, different satellites provide unique information about properties of the Earth's surface and sub-surface. Resultantly, Remote Sensing techniques have proven to be reliable due to their spatio-temporal data availability. But, which and how can Remote Sensing products be used in bridging this hydrological modelling uncertainty gap? Therefore, this PhD aims to evaluate the integration of satellite data in HM to reduce uncertainty and produce reliable hydrological indices in SSA using the modified Pitman model. The specific objectives are to (i) identify regions in Sub-Saharan Africa that have high levels of hydrological uncertainty, (ii) identify useful and reliable RS products for hydrological modelling purposes in Sub-Saharan Africa and (iii) use relevant Remote Sensing products and existing Pitman Model setups to produce a list of key hydrological indices for WRA in Sub-Saharan Africa.

The study is primarily computer-based, where data collection, management and analysis will be done on a desktop (Figure 2). For objective 1, an extensive literature review on hydrological modelling and uncertainty sources and levels will be done on the twelve basins. To realise objective 2, a thorough literature review on reliable and useful Remote Sensing products for hydrological modelling purposes will be conducted with validated products inferring to those that have been successfully applied in HM within the continent, while, invalidated products representing products that are potentially reliable yet have not been used within the Sub-Saharan Africa. Data derived from the identified products will then run within the Modified Pitman model set up to produce a list of key hydrological indices for water resource assessment and to support evidence-based decision-making concerning water resources for the overall sustainability of water resources in Sub-Saharan Africa.

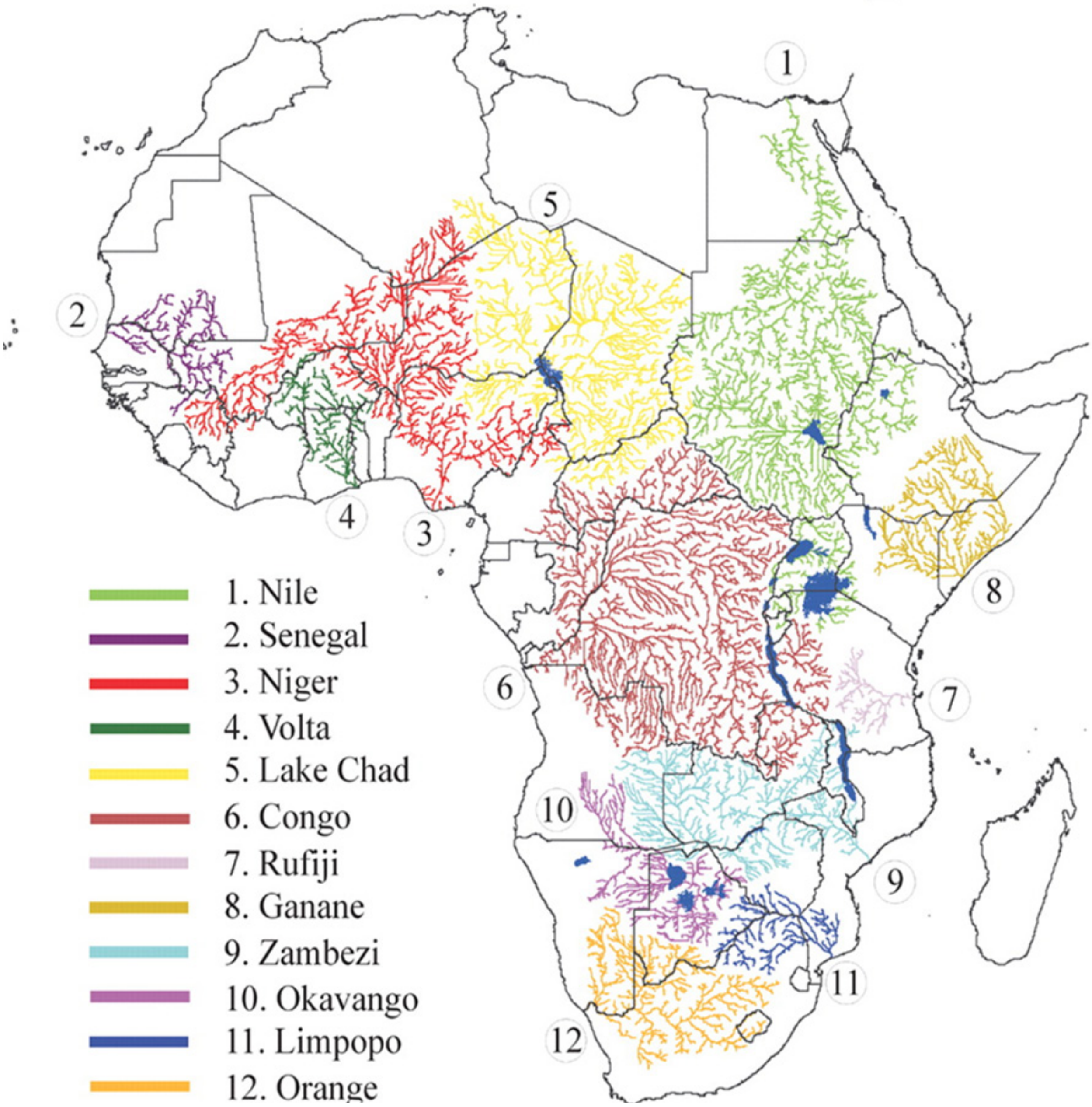


Figure 1: Study Site

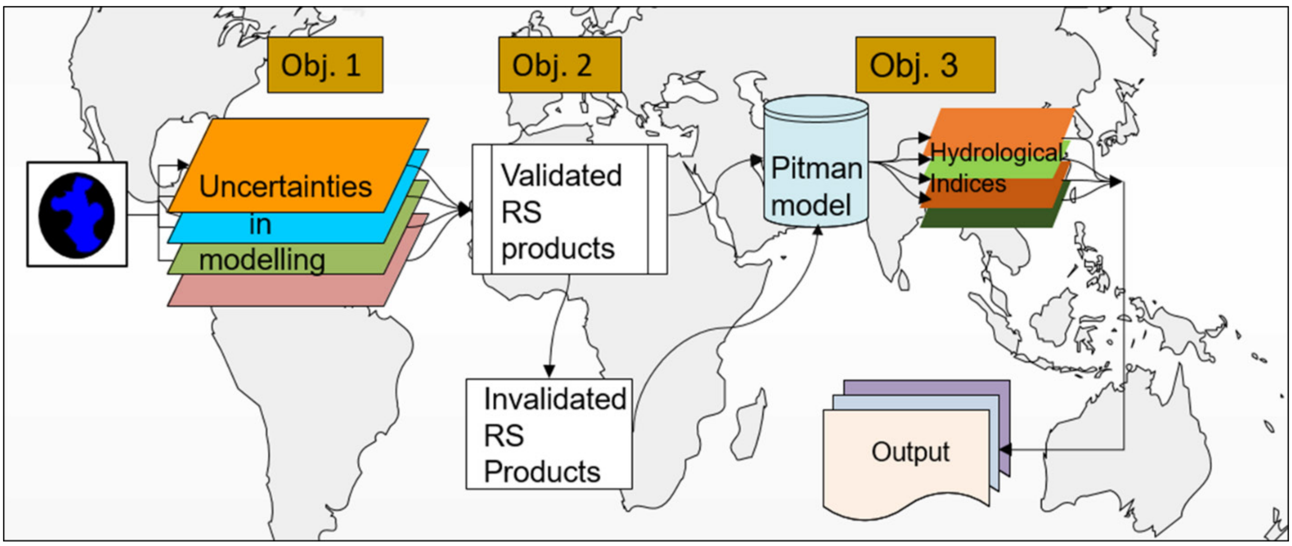


Figure 2: Methodological Framework

Identifying the sources of water discharging at the Fairview Spring using isotopic and geochemical tracers

Student: M Raliengoane
Supervisor: JL Tanner
Degree: BSc Honours (Environmental Water Management)

Groundwater resources have become an important natural water supply to residents in rural areas. In South Africa, the Cape Fold Belt Geology in the Western and Eastern Cape Provinces holds significant groundwater resources in particular; however, this groundwater resource is complicated by complex aquifers. There are numerous springs found along the Cape Fold Belt Geology and this study focuses on improving understanding of one of these springs in Makhanda, Eastern Cape. The Fairview Spring has maintained a relatively constant discharge even though Makhanda is experiencing severe drought. The previous work undertaken at the spring developed a number of conceptual models to try to explain the sustained spring discharge and one of these studies used geophysical survey methods and identified a shale layer beneath the spring. This was a significant clue to the workings of the spring, however, there remains significant uncertainty over the sources of water discharging at the spring as well as the sub-surface spring dynamics. Previous work also identified two spring response mechanisms, a slow stable groundwater response, as well as a fast response to rainfall (interflow) which increases discharge significantly but which recedes quickly as well. This current project aimed to use spring discharge measurements, groundwater level measurements, isotopic and geochemical tracers to identifying the sources of water discharging at the spring, to better understand the ratio of interflow to groundwater, and how this ratio changes during drier and wetter periods. The understanding of flow mechanisms at Fairview Spring will contribute to previous work and aid in better understanding aquifer dynamics in Makhanda and the Eastern Cape, as well as improving general information on the numerous springs found in the Cape Fold Belt geology. Using rainfall, spring, and groundwater isotopic signatures it was hypothesised that the previously identified shale layer has a much larger extent than was previously thought, resulting in a large sub-surface reservoir. This reservoir is recharged during high intensity or duration rainfall events (predominantly summer rainfall) and high mixing of both summer and winter rainfall occurs resulting in a consistent isotopic signature at the spring. The spring is also hypothesised to be supported by a local groundwater contribution.

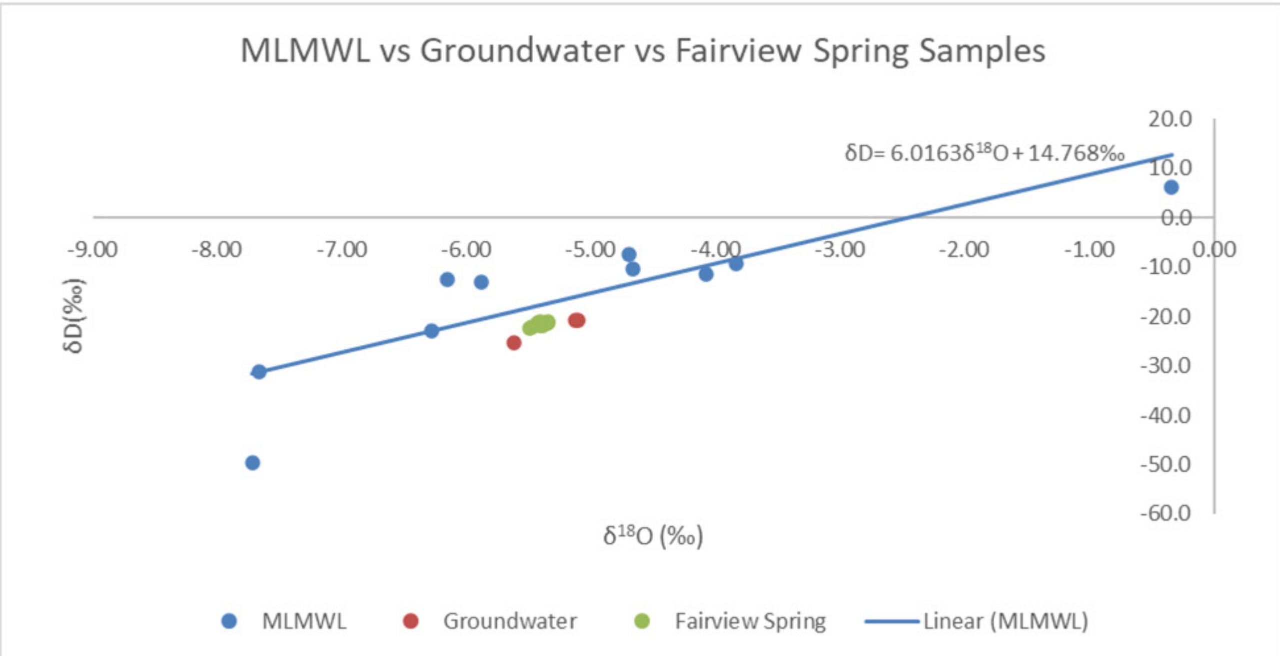


Figure 1: Isotope sampling results: Local meteoric water line (Winter rainfall) shown in blue, against groundwater and spring discharge samples.

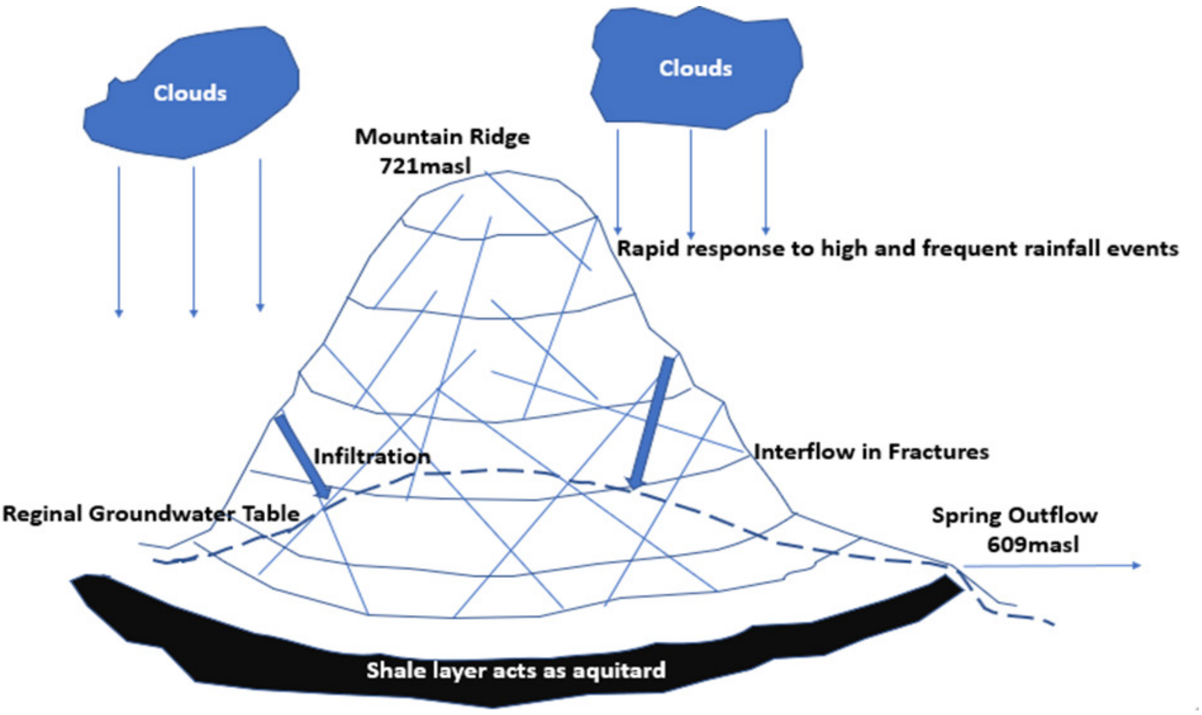


Figure 2: Conceptual model produced from results of project

Modelling and assessment of surface water-groundwater interactions in the Lake Sibaya Catchment, South Africa.

Student: P Ramatsabana
Supervisor: JL Tanner and SK Mantel
Degree: MSc (Hydrology)

Surface water (SW) resources in South Africa are limited, more than 60% of the major rivers are experiencing significant declines (Department of Water Affairs. As a result, groundwater is becoming increasingly relied on. Expanded utilisation of groundwater highlights the need for careful management, bearing in mind the fact that aquifers too have finite storage. Understanding and quantifying interactions between surface water and groundwater is essential for the sustainable management of both resources. Describing either of the components as a residual of the other ignores the crucial importance of interactions with the consequence of highly uncertain water resource estimations. Integrated hydrological models simulate the combined surface water -groundwater system as a continuum and thus, can appropriately support integrated water assessments.

Considering the high heterogeneity and widespread occurrence of complex fractured rock environments in South Africa, it is preferable to utilise physically-based models which are the most suited to capture these heterogeneities more explicitly. However, the lack of adequate data frequently restricts the use of the more complex process-based models in favour of relatively simpler conceptual approaches. Models with simpler structures have the benefit of fewer data requirements but are limited in their capacity to reflect the full complexity of hydrological processes. For this study, the modified Pitman model was selected to assess how well a moderately detailed conceptual model can characterise surface water -groundwater interactions. The key questions for successfully applying the Pitman model are whether processes can be adequately represented at broad spatial scales and whether a robust conceptual understanding can help to reduce some of the uncertainties associated with parameter estimations within the context of a highly data-scarce region.

The model was set up for the Lake Sibaya catchment which is a predominantly groundwater-driven system and thus, provides an important opportunity to interrogate different aspects of uncertainty in both the conceptualising and quantifying interaction processes. Lake Sibaya is mainly recognized as one of the several lakes, swamps and lagoons that fall within the iSimangaliso Wetland Park, a UNESCO World Heritage Site (Figure 1). Recent activities, such as the establishment and expansion of plantations around the lake, have increased the demands on this ecologically sensitive area with significant impact on lake levels. Due to its conservation significance and position as a critical source of water for rural and urban supply, the continued trend of declining lake levels in Lake Sibaya has prompted considerable research interest focused on various aspects of the lake, including the groundwater component.

Overall, the Pitman model performed better than expected as it was able to simulate the lake's water balance correctly enough such that the influences of dominating components (evapotranspiration, groundwater seepage, and abstractions) were sensibly reflected in variations in streamflow and lake levels.

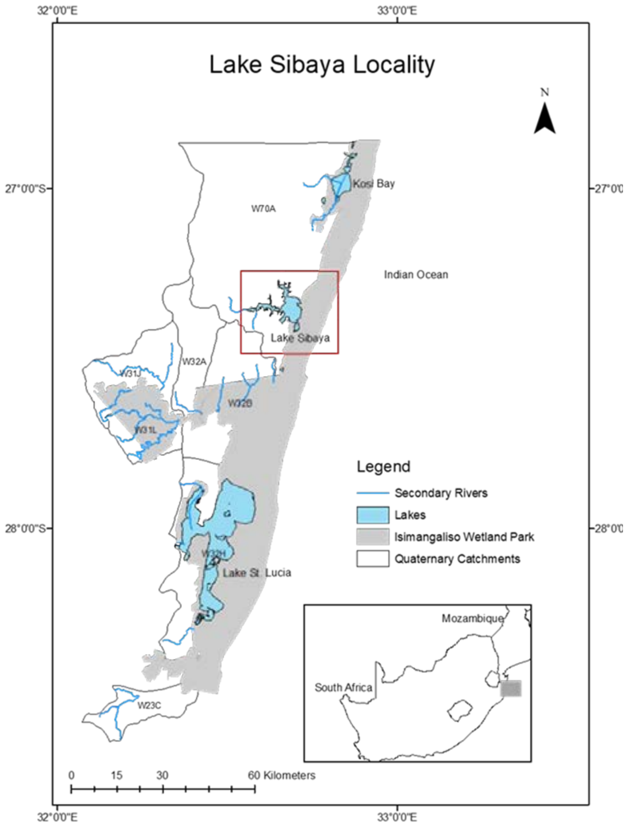


Figure 1: Locality map showing the location of Lake Sibaya within the iSimangaliso Wetland Park boundary (WR2012)

Sediment dynamics in floodplain wetlands in the Tsitsa Catchment: implications for floodplains in southern Africa

Student: PK Schlegel
Supervisors: B Van der Waal and JL Tanner
Degree: PhD (Geography)

Two wetlands namely Gatberg wetland and the Minnehaha wetland are part of this project. During 2019 to 2020 seven field trips were conducted. Topographical surveys were conducted along the longitudinal profile as well as five monitoring cross-sections across the floodplain of the Gatberg and Minnehaha floodplain systems. A further ten meander bends were chosen for each wetland for detailed cross-sections of the channel and banks. To document the deposition of sediment and sediment-associated nutrients and contaminants by flood events on the two floodplain systems, Astroturf artificial grass mats (Lambert & Walling, 1987) and small time-integrated samplers were placed at locations representative of both varying distance from the channel and different topographic units within each floodplain system. Further, at each of these locations a vegetation assessment was done as well as the collection of surface sediment samples. The number of sites was considered large enough to provide a representative assessment of the spatial variation of sediment and sediment-associated nutrients and contaminants in the floodplain systems during overbank flooding events. Within the meander bend cross-section three surface sediment samples were collected (point bar, cut bank and channel bed) and surface sediment samples were taken along the longitudinal profile. Six sediment cores were taken at each floodplain system in different geomorphic units, these have been analysed and dated with Pb 210 and Cs137.

All Field work is complete, and all equipment has been retrieved.

Laboratory analysis: All sediment samples were oven-dried and gently disaggregated. The samples were then analysed for particle size distribution using the Mastersizer 3000, organic matter content using the loss-in-ignition method, percent clay, and nutrient and contaminant content using various appropriate methods.

Laboratory work is mostly complete. A few samples from the last field trip need to be completed.

Presentations: I presented my research at the Wetlands Indaba 2021 and the Eastern Cape Wetlands Forum December 2021 meeting.

Papers: One paper is in the final review process for publication in "Wetlands Ecology and Management".

2022: According to the NRF website I have been awarded the extension funding for my research. Statistical analysis and writing are ongoing. I aim to submit my final thesis in 2022.

An overview of the work at the Gatberg wetland are shown below.

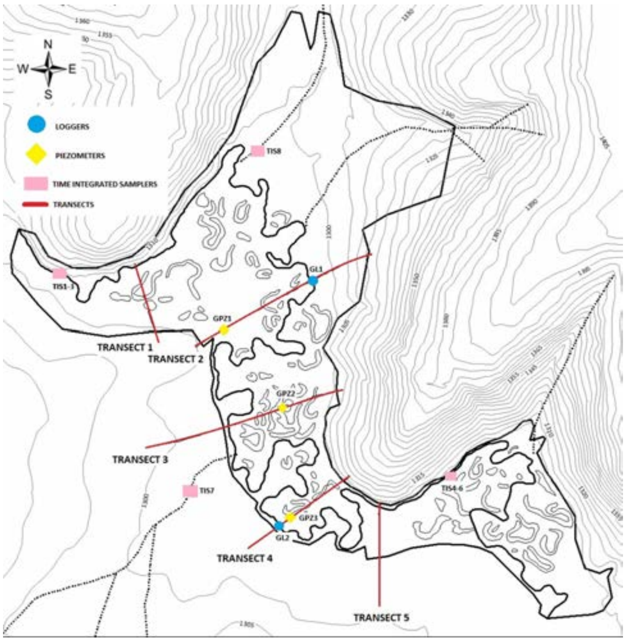


Figure 1: A topographical map of the Gatberg wetland showing transect and sampling sites

Figure 2: Aerial image of the Gatberg wetland

Figure 3: Topographical details of the five transects (locations shown in Figure 1) as well as their sampling sites from the Gatberg wetland

The development of Agent Based Modelling (ABM) as a stakeholder-driven process towards equitable water use and sustainable catchment management in the Koue Bokkeveld (KBV), Western Cape

Student: S Theron
Supervisors: SK Mantel, JL Tanner and B Paxton
Degree: MSc (Water Resource Science)

Background

The agriculture sector contributes significantly to the social economic welfare of the country, through the creation of employment curbing poverty and stimulating economic development. Water is crucial for the long-term sustainability in the region as a pillar which the agricultural sector relies on and for the ecological services water provides. Substantial research and development have gone into determining Ecological Reserves (or environmental flows) for South African rivers as defined under the National Water Act 36 of 1998, in terms of quantifying the volumes and flow regime (seasonal variability) to support ecosystem processes and downstream water users. But significantly less attention has been given in terms of implementing these flows through water management plans for catchments at a regional or catchment level.

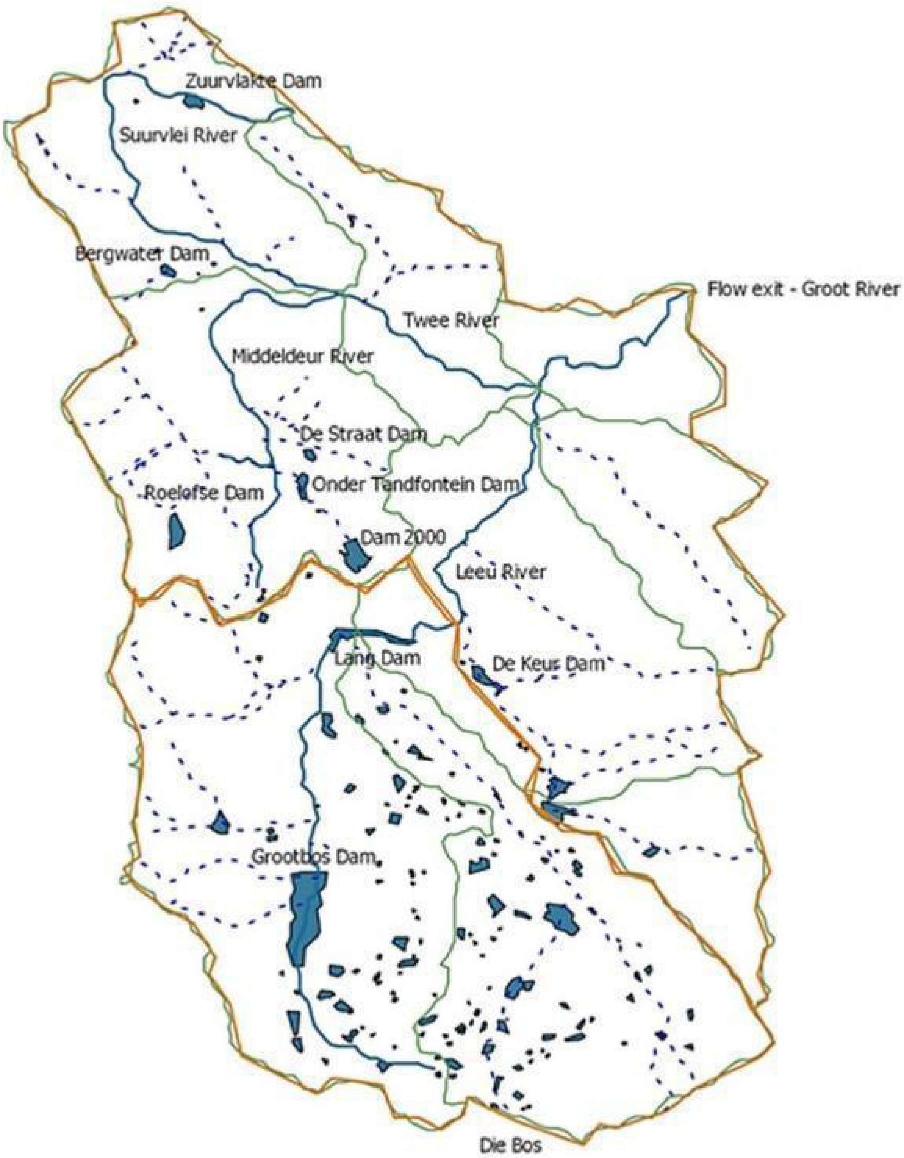


Figure 1: The study area - quaternary catchments E21H (top) and E21G (bottom)

Water resources in the Koue Bokkeveld (KBV) are well developed with numerous farm dams used for storage and irrigation. Larger, more numerous instream dams have both benefits and drawbacks from an ecological perspective. More or larger dams will cut the necessity of pumping and drawing down ecologically important summer flows on condition that environmental releases are made at this time of year. But holding back high flows comes with a trade-off that will have to be managed correctly to ensure that a prolonged dry season does not delay the onset of the wet season. This can interfere with the minimum water needed to maintain seasonal ecological function of the estuary. Obtaining scientific knowledge is essential, but it should be informed by the perceptions and institutional arrangements of key actors (government, farmers, and systemic interrelationships). By fostering cooperation, relationships, knowledge, and understanding, this process can be achieved. This approach, to encourage collaboration and co-learning among a project team that takes into account the values and needs of all project participants, is promoted by the social-ecological resilience framework. This study is part of a Water Research Commission funded project (started in April 2021) with the overarching aim to identify and recommend measures to mitigate impacts concerning the release of water from privately owned dams in the KBV to ensure environmental releases and access to water for downstream users in the network.

Study area

The Koue Bokkeveld lies within the Cape Floristic Region and the Cape Fold Ecoregion. The catchments of the Koue Bokkeveld cover 3,072 km^2. These fall within the Olifants-Doring River primary catchment (Olifants-Berg Water Management Area 9) (see Figure). Water resources management concerns will be explored specifically in the catchments E21H and E21G. As the KBV falls in the winter rainfall region that is characterised by long dry summers, during which irrigation is required, impacts on aquatic ecosystems can be exacerbated over the summer months (November to April). Consequently, it is over this time period it is critical that water use management measures be implemented on a landscape level to ensure that environmental flow targets are met in order to mitigate the anthropogenic impacts on the catchment and subsequent downstream users.

Aims, objectives and method

In view of the current over-abstraction of water in Koue Bokkeveld and the projected future climate change impacts, this study will focus on implementation of sustainable water management in Koue Bokkeveld through stakeholder engagement and institutional support through the use of Agent Based Modelling.

At stakeholder level, the projects aims to achieve the following:

- Through the feedback and involvement of the Koue Bokkeveld farmers, contribute data and information towards creating an Agent-Based Model for the Koue Bokkeveld.
- To provide baseline information towards structuring a water management plan for the Koue Bokkeveld catchment.
- Gathering stakeholder information (through interviews/meetings) to gain understanding of the stakeholder requirements.
- Communicate to stakeholders the need to reduce water demand and establish ecological reserves.
- The future security of water supplies: understanding the risks.

The ABM that will be developed by the team members will provide a tool to support decision makers towards a practical and holistic water use plan. The ABM will be merged with a catchment simulation hydrological Pitman model to evaluate the implementation of management scenarios in terms of water quantity demands.

Application of the Modified Pitman and Swat Models for groundwater recharge estimation of the Uitenhage Artesian Basin, South Africa

Student: P Wasswa
Supervisors: JL Tanner
Degree: MSc (Hydrology)

"It remains ironic that so many people face hardship daily because of lack of water, yet meters below their feet is an untapped source of water!" (Winter et al., 1999). Groundwater is the world's second-largest available store of freshwater after glaciers and it supplies nearly 36% of the world with drinking water and 42% of water for irrigation (Döll et al., 2012; Parsons, 2004; Parsons, 2001). In Africa, about 60% of the population depend on groundwater to meet their water demands, especially in rural communities where access to municipal water systems is limited (MacDonald et al., 2009). Besides, groundwater is used to supplement scarce surface water supplies during prolonged dry periods (Castle et al., 2014; Taylor et al., 2013). South Africa is largely a semi-arid region and is considered to be a water-scarce country. Notably, groundwater resources in this country play a fundamental role in its sustainable development and their management is an issue of national importance (Kelbe et al., 2010).

Groundwater recharge is defined as water that reaches the groundwater table and replenishes the groundwater stock (Boerner and Weaver, 2012; Nyagwambo, 2006). The role of groundwater, with recharge as a critical parameter for determining its sustainable use, is increasingly becoming important in the emerging integrated water resource management (IWRM). In arid and semi-arid areas, (i.e. South Africa), estimation of groundwater recharge is one of the key challenges since recharge rates are generally low in comparison with the average annual rainfall and this results in non-linear behaviour (Lorentz and Hughes, 2003). Groundwater recharge in these areas is usually very variable and heterogeneous over the catchment and different groundwater recharge estimation methods which are costly and time-consuming often give different recharge amounts. In South Africa, there exist tough arguments over the most appropriate type of integrated method one can use in water resource assessments and management (Tanner, 2013). It is recommended by scholars and scientists to use a variety of methods, and modelling is a key tool particularly for one to estimate groundwater recharge over a large area. To improve the utilisation of groundwater and surface water resources, there is a need to estimate groundwater recharge for sustainable water resource management.

Uitenhage Artesian Basin (UAB) (Figure 2), is South African biggest confined aquifer (Figure 1) supplying approximately 1400 ML/yr of water from springs for farming, domestic, commercial and industrial uses to Eastern Cape's largest industrial areas and South Africa's major car-manufacturing plants,(Nyawo, 2017, Maclear, 2001). It is experiencing a reduction in Piezometric level/artesian pressure levels due to over-extraction of groundwater. Though the basin has been quite well studied by different scholars (Nyawo, 2017; Chabangu *et al.,* 2014; Murray, 2012; Parson et al., 2001; Maclear, 2001, 1993), a comprehensive study of groundwater recharge estimation in the mountainous areas of the basin is still missing. The present study will provide a better understanding of groundwater recharge estimation in this basin.

The main objective of this research is to evaluate the applicability and suitability of the Modified Pitman model and Soil Water Assessment Tool (SWAT) model for groundwater recharge estimation in the Uitenhage Artesian Basin. This research will be governed by three specific objectives; i) to design a perceptual/conceptual model for groundwater recharge estimation of the Uitenhage Artesian Basin; ii) to estimate groundwater recharge using all available data together with two hydrological models in Uitenhage Artesian Basin and iii) to compare the application of the Modified Pitman model and SWAT model in groundwater recharge estimation of the Uitenhage Artesian Basin. Whereas the following research questions will be used; i) Using the Modified Pitman model, how much of the annual precipitation received in the Uitenhage Artesian Basin is recharged to groundwater? ii) to what extent can the use of the Modified Pitman model be relied upon as an appropriate practical method for estimating groundwater recharge considering its simplicity? and iii) how well does the use of the Modified Pitman model compare with the SWAT model in estimating groundwater recharge?

In this study, a conceptual model for groundwater recharge estimation in the Uitenhage Artesian

Basin will be developed and it will consist of six steps. The study will employ two hydrological models; the modified Pitman model and the SWAT model.

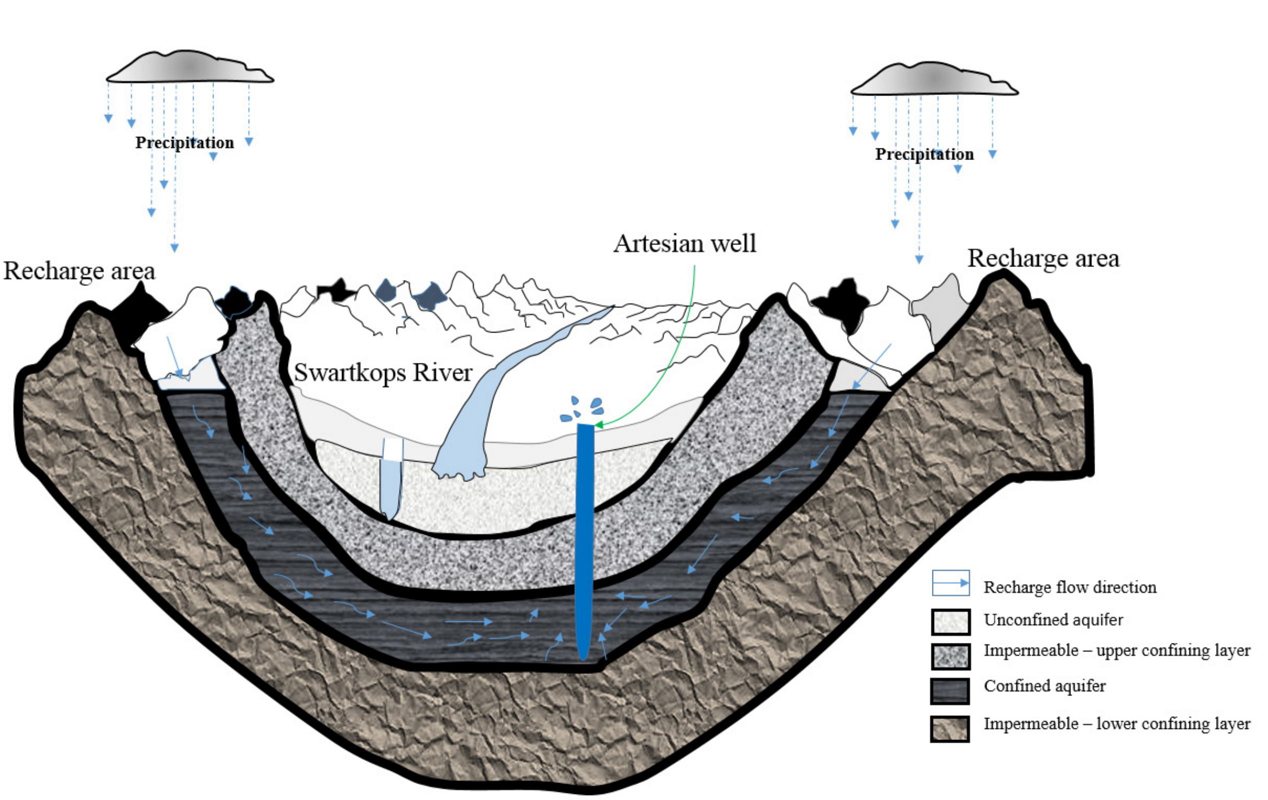


Figure 1: Illustration of the artesian basin

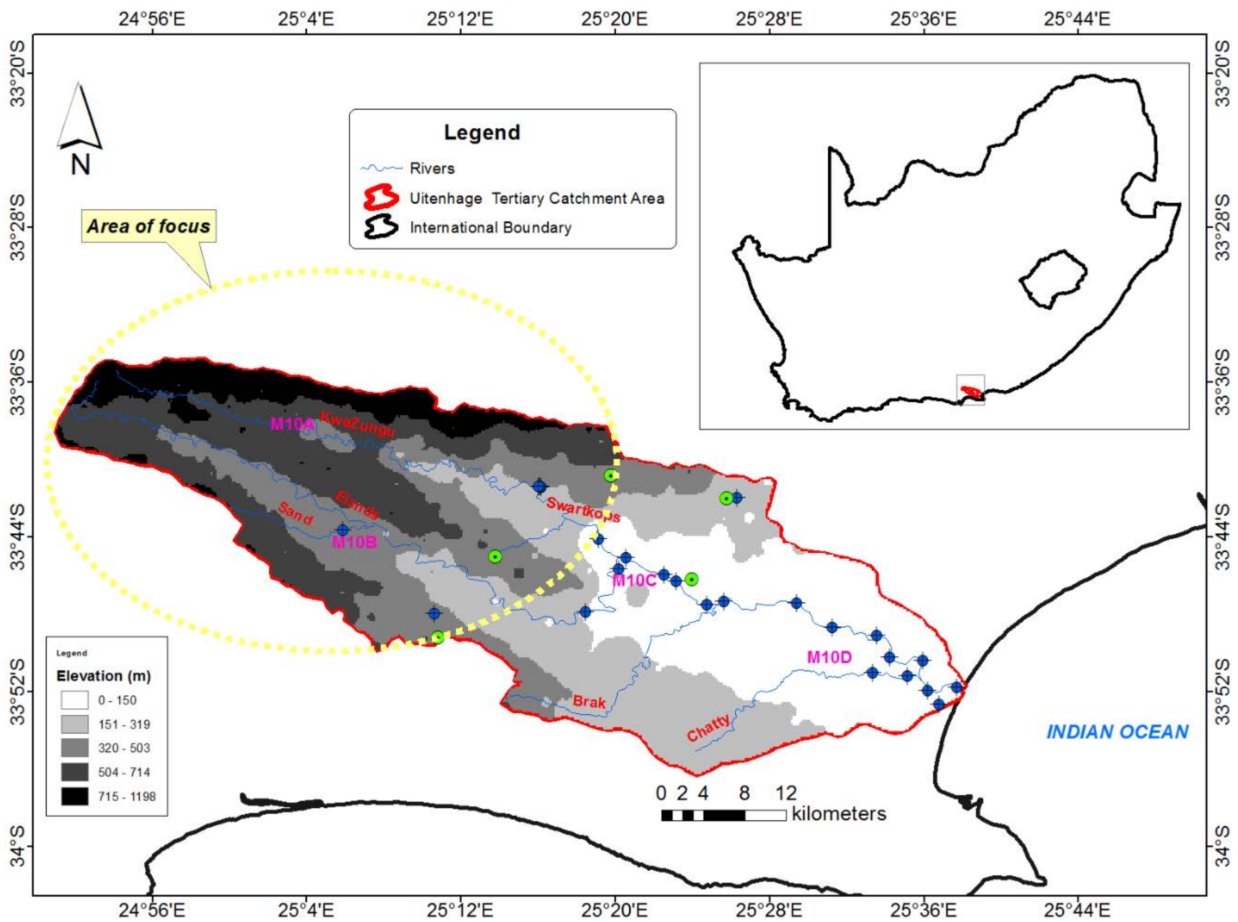


Figure 2: Location of the study area

Exploring the role of the Pitman decision-making model in reducing water risk uncertainty and improve decision-making

Student: BS Xoxo
Supervisor: JL Tanner and SK Mantel
Degree: PhD (Hydrology)

Improving equitable allocation and sustainability in water resource management is at the heart of the South African legislature (RSA, 1998), and the development agenda as noted in the recent water policy. Equity, sustainability and efficiency are the three pillars of water management in South Africa (RSA, 1998). While sustainability and efficiency have enjoyed adequate attention in debate and implementation, equity has trailed behind, hence equitable resource allocation has been included as a key development theme in the second National Water Resource Strategy. The principle of equity relates to fairness in water allocations with management considerations of social, ecological and environmental needs (RSA, 1998). In South Africa, management of water resources requires a medium-term (five to ten years) outlook. The National Water Act 36 of 1998 supported by the Water Services Act 108 of 1997 stipulate that all water uses are subject to a system of allocation licences and general authorization, suggesting a fixed water supply for a certain period. However, changing conditions (e.g. climate and economic motives) may lead to changes in water demand, forcing users to reconsider their decisions in line with their needs. Therefore, decision-support systems that estimate risks associated with actions around the consumption of scarce water resources are required to highlight variable water uses and probable impacts of decision options.

Contributing to the 2013-2023 Panta-Rhei initiative, the Institute for Water Research developed a simple system analysis and water allocation model that involves water users during model setup, and explicitly incorporates uncertainty (Pienaar & Hughes, 2017). Recognising uncertainty and the importance of hydrological models for decision-support, the Pitman Water Allocation model tries to facilitate equitable water sharing among users in the least harmful way possible to both users and the environment (Figure 1). The strength of the Pitman Water Allocation model over other system analysis tools is inclusion of uncertainty, stakeholder involvement in model setup and results interpretation, and communication of uncertainty to users using probabilistic distributions as opposed to actual water deficits. Models run in the absence of the three above features are often met with scepticism from users and decision makers, constraining their valuable contribution to decision support.

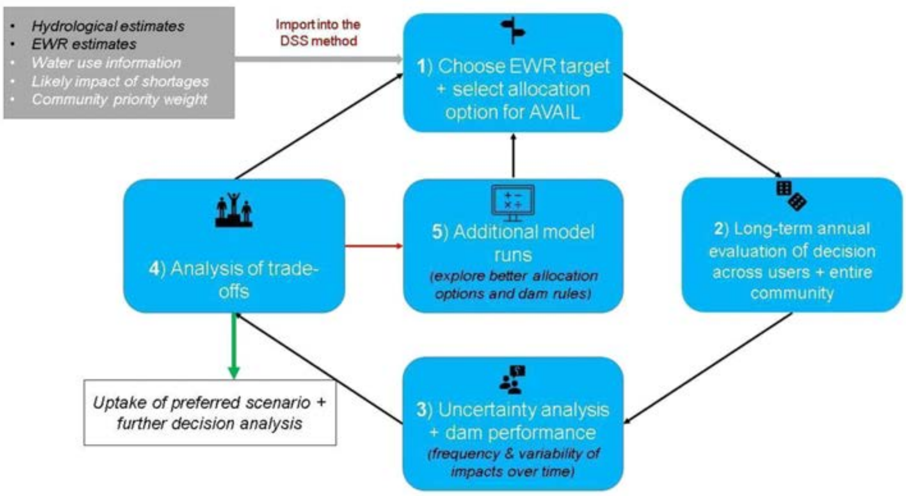


Figure 1: Conceptual diagram of the Pitman Water Allocation model.

While innovative and timely, the Pitman Water Allocation Model has never been tested in a real context, meaning the model still needs further updates to incorporate learning from real-world situations. This PhD research tests the model in a commercial agricultural context in the Western Cape, South Africa, where conflicts exist due to dynamic water use decisions. So far, in liaison with the model developer (Professor Emeritus Denis Hughes) a few updates have been made on the original model, and further updates are anticipated following the model run with stakeholders in the near future.

Environmental Water Quality projects

Contributions of an ethically-grounded and value-based approach to water governance – the case of two contrasting catchments

ON Odume

April 2019 – March 2022

Sponsor: Water Research Commission
Collaborators U Okeja (Department of Philosophy, Rhodes University)

In South Africa, there is a gradual move towards the governance of water resources in the context of social-ecological systems (SES), which recognises the coupling, interrelationships, and complex interactions between societal and ecological components of the SES. In this regard, there has been a growing body of knowledge that supports the governance and management of water resources in the context of SES. However, there is little parallel research effort aimed at developing an ethics and value-based approach for distilling ethical criteria and principles for navigating the array of complex issues such a systemic and holistic view of water governance raises.

The envisaged water governance outcomes are a move away from government oriented top-down, interventionist and command-and-control approach, to the development of systems and institutions that allow greater, enhanced and more effective participation of citizens in the decision-making processes affecting water resource management. However, systemic governance failures have been identified as top challenges in the water sector. The nature and characteristics of water, being a resource that affect all aspects of human endeavour, biological and ecosystem health, implies that the consequences of systemic governance failures would likely have ethical and value implications, and thus the need to consider the contributions of ethics and value-based approach to water governance in South Africa. This is critical because values underpin the way people interact with and lay claim to water, and it has been argued that much of the conflict around water is indeed value conflict. Therefore, an ethical approach to water governance is fundamental because it helps to clarify value claims, the implication of interaction of values in specific contexts, as well as enabling a deeper reflection and analysis of the implications of policy and governance decisions on water allocation, ecosystem protection and ways in which water is being governed.

Using the Lower Sundays River catchment and the lower section of the Upper Vaal River catchment as case studies, this project develops an ethical and value-based approach to water governance in South Africa. The intention is to bring ethics and value-based analysis to the domain of water governance, and to shed light on its contribution to realising the foundational values of equity, sustainability and efficiency enshrined in the National Water Act.

Project aims

The specific aims of the project are as follows:

1. Together with stakeholders, surface key values informing water governance in the selected catchments and undertake a value-based analysis of how the stakeholders go about reconciling/trading off conflicting values and the ethical implications.
2. Explore whether an appeal to ethics level context-sensitive principles can foster greater equity, sustainability, and efficiency in water governance in the selected catchments.
3. Explore instances of polycentricity in water governance in the catchments, paying attention to whether/or not, in such instances, it contributes to effective and cooperative water governance.
4. Synthesise lessons of the value of ethically grounded and value-based approach for policy, practice, and implementation, while providing comparative data from the selected catchments.

Project approach and methodology

The project uses a case study approach to generate insights and to synthesise knowledge on the contribution of ethically grounded and value-based approach to water governance. Both secondary and primary data were collected through document analysis, workshops, interviews, surveys and focus group discussion.

Project results and discussion

We developed perspectives on water governance challenges and their ethical dimensions as well as an analysis of key values underlying water claims and claimants in the catchments. Regarding water governance challenges in the two catchments, we identified six challenges. These are: challenge 1: effective participation, institutional legacies, and transformational challenge; challenge 2: accountability, cooperative governance, clear roles, and responsibilities; challenge 3: absence/near absence of effective leadership and management; challenge 4: systemic integration failure of the water-land-agriculture (food) nexus, including institutional integration; challenge 5: the regulatory system and failure of implementation; challenge 6: financing, infrastructure and technical capacity. We reflected on the ethical dimensions of these challenges. For example, regarding challenge 1, we reasoned that serious ethical concern exist about perpetuating power differentials on access to water resources within the Lower Sundays River catchment, thus raising issue of distributive justice. For instance, the National Water Act provides that members of irrigation board shall automatically become members of Water Users Association (WUA), inadvertently giving such members powers to set out the constitution, define the functions of the WUA within the ambit of the law. This raises a serious ethical challenge as historically powerful interests within irrigation boards retain enormous and disproportionate influence over the agenda and trajectory of the Lower Sundays River Water Users Association (LSRWUA).

Building on the perspectives on water governance challenges and their ethical dimensions, we identified efficiency, sustainability, equity, diversity, and inclusivity, transparency, accountability, and social and ecological justice as the key values underpinning water governance in the catchments. We draw on the theories of ethics to reflect on, and reason about, value claims. In this regard, we reason about value and morals from the perspectives of consequentialism, deontology, virtue ethics, Ubuntu moral theory and systemic-relational perspectives. By applying thinking from these field of ethical theories, we were able to clarify value claim about water in the catchment. For example, in both catchments the governance institutions seemed to emphasise efficiency and are thus consequentialist in moral outlook and in design. By drawing on the theories of ethics, we lay the foundation for clarifying value claims to water in the catchments, but the perspectives developed in this study can be applied elsewhere.

To address the question on how greater equity, sustainability and efficiency be achieved, we develop a framework for analysing value interaction in water governance, and factors that may impact on such interactions. We identified three dynamic zones of value interactions: i) the conflictual zone, ii) mutually enhancing zone and iii) the neutral zone. We reasoned that greater equity, sustainability and efficiency are better achieved in the mutually enhancing zone. Within this zone, the achievement of one of the values contributes to achieving the remaining two values. However, our empirical assessments suggest that in both catchments, the conflictual zone dynamic dominates. What this means is that the three values of equity, efficiency and sustainability are often in conflict in practical and policy sense, in such a way that practical and policy steps taken to achieve one value, constrain the achievement of the other values. We identified better understanding, appreciation and the role of i) context, ii) governance, iii) time-frame dependence iv) spatial-scale dependence v) agency and capability, and vi) resources and investment, as fundamental to shifting current realities away from the conflictual zone interaction to the desired mutually enhancing zone of value interaction. There are fundamental practical and policy implications in this regard. For example, a deeper appreciation of the true meaning of the values of equity, efficiency, and sustainability is needed. In practical and policy sense, equity needs to be better understood as a multidimensional concept involving procedural equity, distributive equity, contextual equity and recognitional equity. Short-sighted policy measures may focus on the distributive dimension, but this may not lead to a holistic achievement of the practical implication of equity. In the same sense, efficiency as we demonstrated is also multidimensional, so is sustainability, which has ecological justice implication.

We consider polycentricity as a governance approach whether it can contribute to effective cooperative governance in the two catchments. Drawing on the key characteristics of polycentricity, we develop an analytical assessment grid to determine the degree of polycentricity in the two catchments. Based on the assessment grid, the degree of polycentricity can be characterised as i) matured polycentricity, ii) x-emerging polycentricity, iii) y-emerging polycentricity and iv) budding polycentricity. We characterised matured polycentricity as instances where a multiplicity of autonomous or largely autonomous units exists governing a resource in a manner that show effective coordination, displaying interdependence, and varying intensity and frequency of interactions within define set of rules. We define the y-emerging polycentricity as a situation where few governance units are responsible for key governance processes and decision making but having high degree of coordination and interactions between these units, showing high levels of interrelations and interdependence. The x-emerging polycentricity exemplifies a situation whereby a diversity of largely autonomous units is responsible for and participate in the governance processes but show low coordination ability and thus low level of interrelation and interdependence. The fourth degree of polycentricity is what we have termed budding polycentricity typifying a situation where poor coordination and interrelations exist between the few governance units operating within a catchment.

The empirical evidence in the two catchments suggests that neither has matured polycentric governance approach. This then raises implication regarding the degree of adaptive capacity of the operating governance approaches in the two catchments. We reasoned that given the complexity of achieving equity, efficiency and sustainability, a high degree of adaptive capacity offered by a polycentric governance approach is desirable. The level of polycentricity in the two catchments then raises serious policy and implementation question regarding institutional design and operationalisation in the catchments and by extension in the country. The degree of polycentricity in the two catchments raises concern as to the alignment between institutional fit and social-ecological realities. An alignment is needed to achieve greater equity, efficiency and sustainability as factors impacting on these values operate across social-ecological scales.

Another governance implication that is raised in the catchment in terms of degree of polycentricity is whether there is enough room for learning and experimentation, and whether the current institutional and governance processes benefit from a diversity of knowledge sources and knowledge sharing across scales. For instance, diversity of knowledge sources and knowledge sharing imply participation by diverse stakeholders across jurisdictional scales in decision making. Such participation give effect to procedural equity, which may in turn accelerate distributive equity imperatives through representation and participation of diverse interest groups, particularly those who have been historically marginalised. We reasoned that the degree of polycentricity in the two catchments may have contributed to the observation that equity imperatives are often in conflict with those of efficiency. Part of the reason for this is that experimentation and knowledge sharing from diverse sources are critical to realise equity goals, yet current institutional design operating in the two catchments may not give sufficient room for such experimentation and knowledge sharing across scales and from diverse sources.

Recommendations

Policy and implementation

1. This study raises fundamental practical and policy issues. First there is a need for a deeper appreciation and understanding of the true meaning of the values of equity, efficiency, and sustainability. As we have demonstrated that these values are complex and multidimensional, relevant policies in the water sector need to appreciate these complexities and multidimensionality. For example, in policy matters, equity needs to be positioned in a multidimensional sense as including procedural equity, distributive equity, contextual equity and recognitional equity. This also applies to the multidimensionality of sustainability and efficiency. There is a need for a balance focus on all dimensions of these values as they are inter-linked, avoiding short-sighted policy measures that may focus on just one dimension e.g., distributive equity or technical efficiency.
2. Long-term policy instruments are needed to better appreciate how the three values may interact, the context in which such interaction come to play and the factors that may contribute to whether the interactions may be conflictual or mutually enhancing. Specifically, it needs to be made explicit in policy instruments that the pursuit of equity in the water sector is a long-term gaol. In this regard, indicators for monitoring equity progress in the short-, medium-, and long-terms also need to be developed and implemented in specific contexts. Policy guidance also needs to be given on how the pursuit of the values of equity, efficiency and sustainability may interact in the short-, medium- and long-term, and what needs to be done to shift these interactions away from conflictual to mutually enhancing. This would require a good understanding of time-frame dependence and spatial-scale dependence on the interactions between these values.
3. The concurrent achievement of equity, efficiency and sustainability in the water sector is a complex exercise impacted upon by several factors. In this regard, policy guidance is needed on how specific context in the water sector may influence the achievement of these value. Good governance also needs to be strengthened. A clear policy intent and implementation mechanisms need to be mapped on strengthening capabilities in the water sector and setting aside resources for investing into equity, sustainability, and efficiency imperatives over the short-, medium- and long-terms.
4. There is an urgent need for institutional reformation and re-design in the water sector as

exemplified in the two catchments to enhance their fit to local social-ecological realities and to enhance their adaptive capacity, promote participation and experimentation, learning, knowledge sharing from diverse sources and systems. For example, in the case of the Water Users Associations (WUAs) urgent reformation is needed to redesign these institutions so that historical institutional legacies that impede transformation, effective participation and power differentials are not perpetuated. At the time of writing, this task has been taken up by the Department of Water and Sanitation, urgent finalisation of this process is needed.

5. Training of policy makers, managers and water sector stakeholders is required across institutional and governance scales on how ethical thinking may contribute to clarifying value claims in the water sector, and its role in water diplomacy and dispute resolution. This is necessary because much of the conflict around water are indeed value conflict.

Further research

The following recommendations are made for future studies:

1. Examine and analyse the extent to which current institutional designs and governance processes in the water sector are contributing to the conflictual interactions between the value of equity, sustainability, and efficiency. Such an examination is important to distil important institutional elements necessary for shifting current realities away from conflictual value interaction zone dynamics to the mutually enhancing value interaction zone dynamics.
2. Undertake a case study-based approach to develop indicators that draw on the multidimensionality of equity, efficiency, and sustainability and to use the developed indicators to monitor the effectiveness of the implementation mechanisms for the values of equity, efficiency, and sustainability. Such study should also distil the role of agency and capability on the values of equity, efficiency, and sustainability in specific contexts.

Revision of the 1996 South African Water Quality Guidelines: development of risk-based approach using aquatic ecosystems responses

L Ncube, NJ Griffin, ON Odume, PK Mensah and E van Niekerk

15 April 2020 - 31 Jan 2023

Sponsor: Water Research Commission

This research project focuses on the revision of the 1996 SAWQG for freshwater ecosystems, with a view to developing a risk-based guidelines operationalised through a software-based decision support system. The final system will have spatially specific guidelines for a greater number of parameters than the 1996 guidelines. This approach follows the revision of water quality guidelines for other water users in South Africa.

The imperatives for the proposed research arise out of the realisation that current water quality guidelines have limitation in several important areas including i) non-alignment with approaches to water resource protection, ii) not being sufficiently risk-based, iii) lacking internal coherence between guidelines for different users, iv) not reflecting the full range of critical water quality variables such as POPs, pesticides and EDC, despite local and international research regarding these variables, as well as their non-coverage of estuarine systems. The proposed project is intended to address these short-comings through the development of a multi-tier decision support system allowing for risk identification, analysis and management. Therefore, the overarching aim of the current project is to review and develop an electronic-based decision support system (software) able to provide both site-specific and generic risk-based water quality guidelines for South African aquatic ecosystems.

Production of risk based guidelines will be data based, and data on responses of taxa (ideally South African taxa) to stressors, as well as data on ambient spatially specific water quality will be required to generate suitable guidelines. The project has gathered 219442 toxicological results from international databases, as well as 332084 water quality records from regularly monitored sampling points around the country, and data collection is

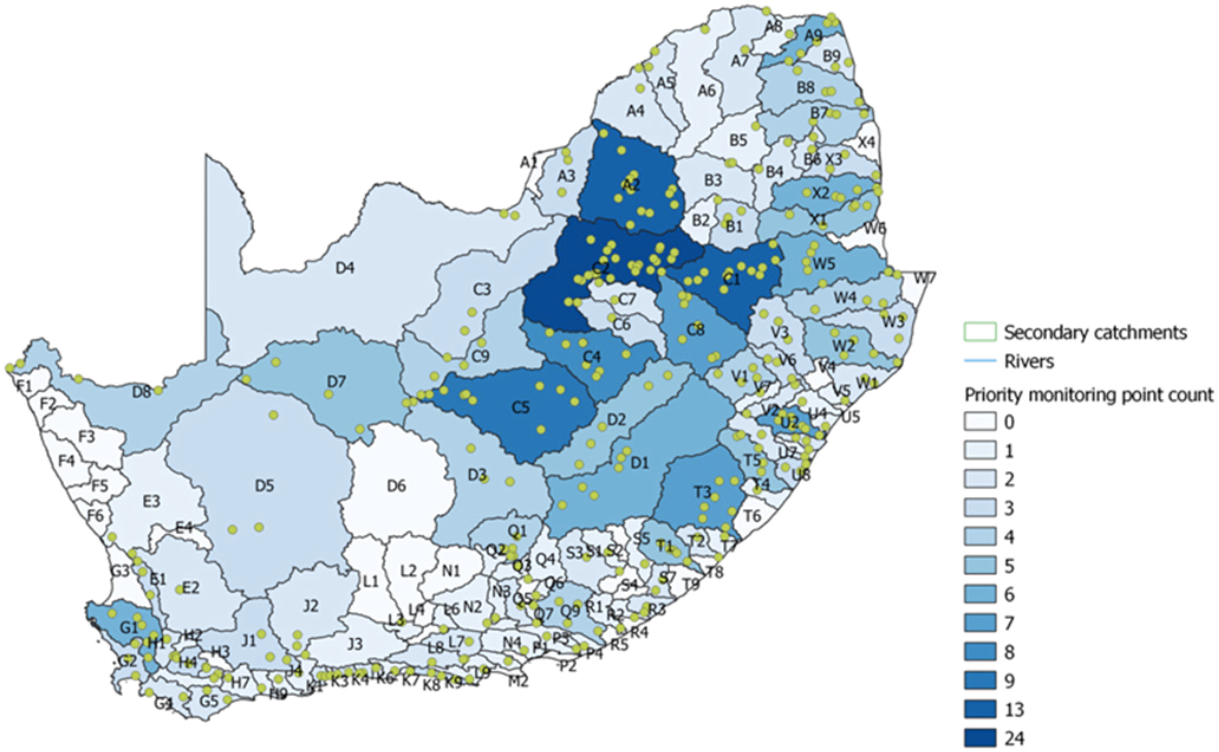


Figure 1: Secondary catchments and priority monitoring points for spatial reference data

continuing. A review of international approaches to risk-based guideline generation have led to a method selection that is similar to approaches adopted in the new Australian/New Zealand water quality guidelines.

Microplastics as emerging contaminants: methods development, ecotoxicity testing and risk assessment towards freshwater resource protection in South Africa

NS Mgaba, NJ Griffin, PK Mensah and ON Odume

1 April 2019 – 30 November 2021

Sponsor: Water Research Commission

Microplastics have been described as emerging pollutants, accumulating in aquatic environments worldwide. To gain a clearer understanding of the availability of microplastics and the threat they pose to aquatic life, and ecological processes, it is important to obtain accurate measures of their abundance in surface water, sediments and benthic organisms. Previous research shows that microplastics can be harmful to aquatic organisms such as fish and invertebrates. This is because they can constitute a threat as chemical and physical stressors. As chemical stressors, chemical makeup of microplastics can leach, potentially posing threat to aquatic life and the environment. As physical stressors, microplastics can cause abrasion to soft tissues, accumulate in and block such tissues, potentially posing a significant risk. A third dimension, which will not be investigated in this project is that microplastics can act as vectors transporting both chemical pollutants and pathogenic microorganisms. Thus, the aim of this WRC funded project is to evaluate the potential toxicity of microplastics as chemical and physical stressors and to develop/adapt methods for such studies.

In order to achieve the project aim, the project has the following specific objectives:

- Evaluate the potential toxicity of microplastics as chemical stressors (plasticisers) using novel endpoints based on selected test species: the snail *Melanoides tuberculata*, the shrimp *Caridina nilotica* and the fish *Danio rerio*. The tests used multiple life stages.

- Evaluate the potential toxicity of microplastics as physical stressors with a focus on size and shape using novel endpoints based on selected test species: the snail *Melanoides tuberculata*, the shrimp *Caridina nilotica* and the fish *Danio rerio*. The tests used multiple life stages.
- Adapt and/or develop methods for microplastics biomonitoring in freshwater systems and apply the adapted/developed methods in selected South African river systems (Swartkops and Buffalo Rivers).
- Undertake a comprehensive review of microplastics research in South African freshwater systems.

Testing and data analysis is largely complete. The overwhelming conclusion from the results is that, at environmentally realistic levels, the physical and chemical impact of microplastics on test taxa could not be statistically resolved. However, there were tests where a response to plasticisers was found, and these compounds, some of which are endocrine disruptors and/or known toxins, can induce a toxic response. In the tests that were undertaken even where statistical support for a result was lacking, higher levels of plasticisers seemed to have a minor impact that was masked by variation in results, and it is possible that a longer exposure, or greater replication, would produce a statistically supported impact. Microplastics levels in rivers that were sampled were high in comparison with South African and international data, and point to South Africa's failure to manage plastic waste that has been identified by other authors.

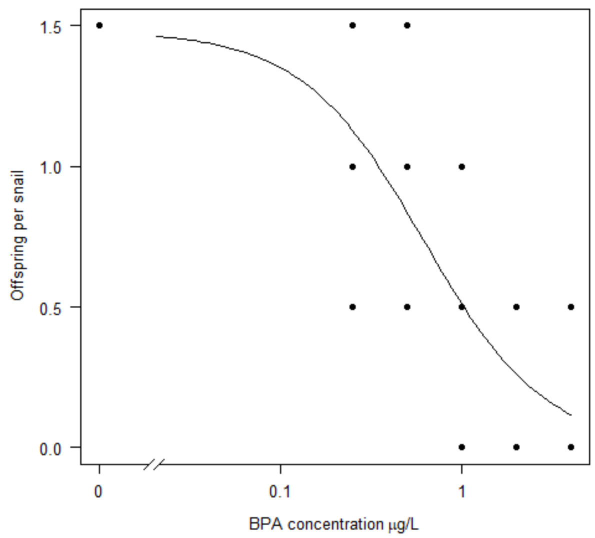


Figure 1: Offspring production in Melania tuberculata exposed to bisphenol A for 21 days.

Investigation of the occurrence and risk of infection of pathogenic and antibiotic resistant *Campylobacter* species in selected source waters within thE Kowie Catchment, Eastern Cape, South Africa

CF Nnadozie and ON Odume

1 April 2019 – 31 March 2023

Sponsor: Water Research Commission

In the last decade, the discovery of *Campylobacter* spp., an emerging pathogen, is now a serious public health concern. These infections are a main cause of gastrointestinal disease globally, and their occurrence rates are higher than those caused by *Salmonella* and *Shigella* in developed countries. Locally, diarrhoea is the third leading cause of death, and approximately R3.5 billion is spent annually on gastrointestinal diseases. To complicate issues, high prevalence of resistance in clinical isolates of *C. jejuni* and *C. coli* to first line antibiotics (fluoroquinolones, macrolides and tetracycline) that are used for treatment have been reported both developed and developing countries. The impact cannot be overlooked particularly in South Africa with a high population of vulnerable individuals due to several reasons, including the HIV pandemic. Campylobacter infections are amongst those that are caused through ingestion of contaminated food, but the primary reservoir of these pathogens are animals, faecal contaminated water or the environment. The Kowie River in Makhanda, Eastern Cape is used by the community for recreational, irrigational and spiritual (e.g. baptism) purposes. However, this river system is subject to various kinds of microbial contamination that poses a health risk to human. Makhanda and surrounding areas face a sewage treatment crisis and raw sewerage commonly flows into streams and rivers that eventually reach the Kowie River. Also, livestock farming is a common practice in the area, and much of the runoff containing manure from livestock from nearby farms flow into the river, thereby severely polluting it and affecting water quality. Besides, studies have reported the presence of sub therapeutic levels (in the range of ng/l) of antibiotics in surface waters locally, which can act as selective pressure for pathogens to develop antibiotic resistance in pathogens within the environment. While there is no documented waterborne outbreaks of *Campylobacter* gastroenteritis in South Africa, small scale local studies demonstrate that the rates of Campylobacter infections might be underestimated. Amongst those, 801/848 of isolates that were submitted by Group for Enteric, Respiratory and Meningeal Surveillance in South Africa (GERMS-SA) laboratories from different provinces in South Africa for a Campylobacter Surveillance Program, were positive for species of Campylobacter. These information and statistics are from clinical surveillance programs but no linkage with the environment. Yet, we know that the environment is a reservoir of resistant bacterial strains and antibiotics resistance genes, and antibiotic resistance genes that can potentially be incorporated into human as well as passing pathogens with time through horizontal gene transfer. It is against this background that this project is initiated, to investigate the incidence and risk of antimicrobial resistant *Campylobacter* infections from a One Health perspective. The One Health perspective recognises that human health, animal health, and the environment are interconnected. *Campylobacter* is a typical example of a One-Health challenge, which has emerged at human-animal-environment interface. Given the role of surface water in spreading antimicrobial resistance in humans, the goal is to develop a framework for human health risk assessment due to exposure of antibiotic resistant Campylobacter from river water.

Investigating the multiple risk dimensions associated with campylobacteriosis - a key poverty-related disease of South African urban source water environments

CF Nnadozie

July 2021 – July 2024

Sponsor: European Union and Foundation Botnar

South Africa remains one of the countries in the world with the widest disparities in wealth and access to resources. The majority of the population is overburdened with poverty-related diseases (PRD) such as HIV-AIDs, tuberculosis, and diarrhoea. Despite the incidences of diarrhoea being as high as 10 per 1000 of children admitted to a tertiary hospital in South Africa, the disease has not received much research attention compared to other PRD such as HIV/AIDs and tuberculosis. Campylobacteriosis, a disease caused by *Campylobacter* spp. is the main cause of diarrhoea globally and in South Africa. Another critical dimension of *Campylobacter* infection of urgent relevance in South Africa is Guillain-Barré syndrome (GBS), a neurological condition whereby the body's immune system incorrectly attacks part of its peripheral nervous system. Ingestion of faecal contaminated water is a principal risk factor for Campylobacteriosis. In South African urban centres, wastewater treatment works are overloaded, resulting in the discharges of poorly treated effluents into the receiving rivers. The urban poor, children and mothers as well as the adolescents who largely depend on rivers for recreational activities, spiritual activities such as baptism, harvesting of medicinal plants from the riverside, and fishing, are at the most risk of Campylobacteriosis. Given the link between diarrhoea, poverty, and environmental quality/sanitation, a more integrated, systemic approach that pays attention to the multiple risk dimension associated with Campylobacteriosis is crucial. Mapping the incidences of urban poverty, service delivery failure, as well as Campylobacteriosis, can provide policymakers much needed insights for comprehensive strategies for reducing the occurrence and potential risk associated with the disease in South Africa. Furthermore, microbial risk assessment is useful to estimate microbial risks associated with contaminated surface water. The difficulty of culturing of *Campylobacter* spp. for risk assessment studies can be circumvented by using next generation sequencing (NGS). By applying shotgun metagenomics, it is possible to sequence all the microorganisms within an environment to identify infectious etiologies and then by applying machine learning algorithms (MLA) to predict the risk from shotgun metagenomic sequences of an environmental sample. Therefore, this project will combine multiple approaches: NGS, MLA, microbial ecology, and risk mapping to attempt an integrated study of Campylobacteriosis-a key PRD in South African urban environments. The Swartkops River in the Nelson Mandela Bay Municipality (NMBM) and the Kowie River of Makana Local Municipality, Eastern Cape, South Africa, are to be investigated in this study.

Enhancing urban wetland and river ecosystem health – leading integrated research for Agenda (LIRA) 2030 in Africa

ON Odume and CF Nnadozie

June 2019 – May 2021

Sponsor: Network of African Science Academies (NASAC), International Science Council and SIDA
Collaborators BN Onyima (Nnamdi Azikiwe University, Awka, Nigeria), GO Omovoh (Federal Ministry of Environment, Nigeria), BO Omovoh (Federal Ministry of Environment, Nigeria), E Ogidiaka, Delta State School of Marine Technology, Uku Jude (Private).
Collaborating organisation: Nelson Mandela Bay Metropolitan Municipality; Port Elizabeth office of Department of Water and Sanitation

Short description of the project

Rivers and wetlands in African cities are heavily degraded, impacting on the ecosystem services they supply society and livelihoods. To change this trajectory, an integrated approach that draws on social ecological system thinking, and transdisciplinary research practice was applied to investigate the ecological, social, and institutional dimensions of urban rivers and wetland health. Our approach departs from the traditional assessment as it recognises that ecological and social-economic components together form an integrated and dynamic complex system of urban ecosystem health. The project results suggest that for rivers and wetlands in African cities to be on a sustainable path, the link between policy, practice and research needs to be strengthened. Integrated assessment metrics of urban river health are useful for providing detailed relational insights into the ecological, economic and governance implications of degraded urban rivers and wetlands health, and the interrelationship between rivers and people in catchments.

Project Objectives

The project has four objectives addressing ecological, institutional and social dimensions of river/wetland health as well as an integrative objective summarized as follows:

1. Develop context-sensitive, holistic multi-dimension (ecological, social, and economic) indicators of urban rivers and wetland health for tracking the trajectory of urban development.
2. Examine systemic institutional drivers of urban river and wetland health degradations and recommend ways to shift institutional practices for sustainable utilisation of urban river resources.
3. Analyse the inextricable interactions and linkages between urban rivers and wetland health, and urban dwellers' social-economic well-being (i.e. people-river relationality) to contribute to shifting social and institutional practices in ways that can enhance ecosystem health and their services.
4. Develop a framework for enhancing urban rivers and wetland health by taking account of the systemic-relational interactions, interdependence and potential trade-offs between ecological conditions, desired ecosystem services, institutional and social practices.

Expertise and partners involved

Disciplines involved: Ecology, Anthropology, Microbiology, Water Quality

The size of the research team: Eight researchers

Non-academic partners involved: Nelson Mandela Bay Metro, South Africa; Department of Water and Sanitation, South Africa, Ganisha, South Africa, Department of Environmental Assessment, Federal Ministry of Environment, Nigeria; Department of Forestry.

Methods applied to deliver research

The project uses transdisciplinary research practice and social-ecological system framing as overarching methodological framework. In this regard, workshops, community surveys, in-depth interviews and focus group discussions were the key social science methods applied. Water quality sampling, macroinvertebrate sampling, shotgun metagenomics, river habitat assessment and various multivariate and predictive statistics were the main methods applied in the natural sciences.

Recruitment catchment champions: Through partnership with the ward councillors in the Nelson Mandela Bay Metro, the project established catchment champions who are undertaking river clean ups and exploring ways of using eco-tourism to generate revenue.

River clean: In South Africa, the project embarked on three months clean-up of the Swartkops River. An NGO Ganisha is exploring ways to recycle waste collected during this period.

Deployment of artificial wetlands: Recognising the significance of pollution in the Swartkops River the project deployed artificial wetlands to absorb pollutants from the river system.

An educational video showcasing the value of urban river systems: An education video was produced on the importance of rivers and wetlands in cities.

Initiation of a multiparty process: In South Africa, the project initiated a multiparty process comprising of the local municipality, Rhodes University, Department of Water and Sanitation, and local communities for sustainable utilisation and protection of the Swartkops River resources.

Establishment of the Joint Forum for Regulators and Users of Rivers and Wetland Resources in the Federal Capital Territory (JOFRURF): This forum was established to bridge the gaps between the regulators and communities for sustainable management of rivers and wetlands within the FCT in Nigeria

Breaking silos institutional practices: The project in both Nigeria and South Africa brought together key governance and institutional actors that had always work in silos.

Figure 1: LIRA researchers and members of the Swartkops Catchment champions established with support of the LIRA project.

African Water Resources Mobility Network (AWaRMN): building transdiciplinary capacity for sustainable water resources management in Africa

ON Odume and CF Nnadozie

January 2020 – December 2024

Sponsor: Funded by the Intra-Africa Academic Mobility Scheme of the European Union

Collaborator organisations: Federal University of Technology, Minna, Nigeria; University of Kinshasa, Democratic Republic of the Congo; Makerere University, Uganda; National Higher School of Hydraulics, Algeria; TU Delft, Netherlands

Project website for additional details: https://www.ru.ac.za/intra-africa-awarmn/

This multi-partner EU-funded project aims to develop African capacity for sustainable water resource management through the training and exchange of MSc and PhD students as well as staff exchange among partner institutions across Africa. This objective is founded on the realisation that achieving sustainable development, and inclusive growth within Africa would largely be undermined if its water resources are not sustainably managed, utilised, protected and governed by competent and qualified professionals. The continent is facing multiple water-related challenges, including declining water quantity and quality, inadequate governance and institutional structures, declining monitoring networks, increasing resource use in the face of a growing human population, and increasing resource variability associated with future changing climates. As the region strives toward improving political, economic and social stability, the importance of secure water supplies will assume increasing significance. If this is neglected, a potential for conflict exists: 1) within and between communities -through a lack of water- and sanitation-related access and services, and 2) between countries- through a lack of agreement on transboundary sharing of water resources, and, most importantly, 3) between societal constituencies through perceived non-inclusive and equitable sharing of water resources (distributive justice).

The African Water Resource Mobility Network (AWARMN), which is a project of the Intra-Africa Academic Mobility Scheme, is a set up to address the water-related pressing needs on the African continent. The main objective of addressing these pressing needs are achieved through:

1. a transdisciplinary, socially-engaged training embedded in existing programmes within partner institutions, ensuring increases in the numbers of highly qualified and competent (MSc and PhD) graduates in the field of water resources in Africa;
2. develop and harmonise programmes and curricula, with a particular emphasis on disciplinary excellence and transdisciplinary capability;
3. build and sustain teaching and research capabilities among partner institutions;
4. design and implement research programmes based on collaboration and cooperation during, and beyond, the AWARMN funding;
5. facilitate student and staff mobility to promote multiculturalism and internationalisation among African institutions of higher learning;
6. contribute to innovation and water technologies that advance social-economic development of Africa and;
7. address the professional career development and employability of graduates by creating a direct interface between AWARMN and industry partners.

AWARMN is funded by the Intra-Africa Academic Mobility Scheme of the European Union (https://eacea.ec.europa.eu/intra-africa_en)

Pathways, contextual and cross-scale dynamics of science-policy-society interactions in transdisciplinary research in African cities.

ON Odume

April 2020 - March 2021

Sponsor: LIRA; Network of African Science Academies; International Science Council
Collaborators: Dr F Aziz (Water Research Institute, Ghana), Dr S Thiam(Institute for Health Research, Epidemiological Surveillance and Training, Senegal), Dr S Boatemaa (Stellenbosch University, South Africa), Dr ABK Amaka-Otchere 9Kwame Nkrumah University of Science and Technology, Ghana), Dr. BN Onyima (Nnamdi Azikiwe University, Nigeria).

The global Sustainable Development Agenda (SDGs) are inherently complex as are their interactions (Nilsson et al. 2016). Strengthening science-policy-society interaction has been conceptualised in the literature as one way of navigating the complexity of sustainability challenges, and of accelerating the achievements of the SDGs (Bernard et al. 2019). Conceptual models e.g. the Triple Helix model (Saviano et al. 2019), framework (Steg, 2008) and typologies (e.g. Sundquist et al. 2018) have been developed to analyse, reflect and integrate the triad of science, policy and society in projects, but the extent to which these are supported by empirical evidence, particularly in an African context remain largely unexplored.

Our LIRA integrative projects, which have been conceptualised to contribute to the achievement of the SDGs in Africa, and to accelerate specific project outcomes, provide a rare opportunity not only to interrogate and critique these models, frameworks and typologies, but to further develop them as a contribution from the global South. The proposed project thus explores ways in which the interactions between science-policy-society were foregrounded in small integrative projects concurrently addressing multiple SDGs in Africa. The project will address the following:

1. critique existing models, frameworks and typologies of science-policy-society interactions, drawing on empirical evidence from the African contexts;
2. draw on experiences of implementing integrative projects in Africa, and meta-analyses, to explore and showcase pathways and scales (space and time) of interactions, and associated principles;
3. analyse and reflect on systemic and contextual obstacles to, and opportunities for interactions, drawing on our specific project experiences and empirical evidence;
4. reflect on the specific contributions of fore-grounding science-policy-society interactions to the SDGs as manifested in the individual projects.

An ecosystem-based climate resilience approach to assure water security in the Amathole District Municipality, Eastern Cape, South Africa

ON Odume, CF Nnadozie, FC Akamagwuna and DJ Choruma

Nov 2021 – May 2022

Sponsor: GIZ

Assurance of water security is critical to socio-economic development and ecosystem functionality. South Africa, being a water scarce country, is particularly vulnerable to water-related shocks and crisis such as climate change and risk of pandemic occasioned by zoonotic diseases (Savelli et al 2021). In the Eastern Cape, including the Amathole District for example, climate-induced change has manifested in the form of prolonged drought and extreme rainfall variability. When the effects of climate change manifest, they impact on water resources, water services provisioning, food security as well as general socio-economic well-being of the people. As climate change continues to exert its influence on water resources and water-related services, the occurrences of zoonotic-induced pandemics are increasingly becoming a threat not only to ecosystems functionality but also to water-related service delivery. These diseases are transferred from animals to humans, through close human-animal interactions, and they have recently gained international prominence (Machalaba et al. 2015; UNEP 2020). Apart from the SARS-CoV-2 virus that have caused the global Covid-19 pandemic, there are other zoonotic pathogens, including viruses (e.g. H1N1 flu, avian influenza, Middle East respiratory syndrome (MERS), Ebola, Rift Valley fever, West Nile virus, Zika virus and sudden acute respiratory syndrome (SARS)); bacteria (*Escherichia coli* O157:H7, *Campylobacter jejuni, Campylobacter coli, and Campylobacter lari , Shigella sonnei, Shigella boydii, Shigella flexneri, Salmonella enteritidis*, and *Brucella* spp.) protozoans (*Ascaris, Cryptosporidium and Giardia*, etc.) (Cotruvo et al. 2004).

The combined effects of both climate change and zoonotic-induced pandemic can be devastating on the water sector as exemplified by the ongoing Covid-19 pandemic and the climate-induced water crisis in Cape Town (Shepherd 2019), Nelson Mandela Bay Metro and Amathole District Municipality. To develop an informed, systemic, and holistic strategy for the water sector to become more adaptive and resilient to such external shocks and crises, it is essential that such a strategy is informed by an in-depth, critical analysis of these two crises. Although climate change and zoonotic-induced pandemics can be both regarded as crisis, the way in which they progress and manifest often affect institutional and governance responses as well as risk perception (Lidskog et al. 2020). For example, climate change often progressed slowly, latently, but become imminent with time. This often results in i) a delay in categorisation/perception of climate-induced changes as crisis by those who are supposed to act across scales, and ii) large time lag between exercise of agency (individual, collective, institutional, and relational agencies) and the crisis. The large time lag between the exercise of agency and the perception of climate change as a crisis, often leads to devastating effects on both ecosystems and water security e.g. the 2017 Cape Town drought and water crisis (Shepherd 2019; Enqvist and Ziervogel 2019). On the other hand, zoonotic-induced pandemics, whenever they occurred, often develop rapidly but with huge uncertainties about their control because of their imminent and novel nature. The pace with which zoonotic-induced pandemics develop, often leads to small time lag between exercise of agency and the crisis yet can cause devastating effects on societies e.g. the Covid-19 pandemic. What this comparative analysis suggest is that for the water sector to be truly resilient to external shocks and crisis, a range of measures and mechanisms that can cope with sudden, abrupt, and novel crisis (e.g. zoonotic-induced crisis), and slowly developing crisis (e.g. climate change) are needed for both short and long resilience.

An ecosystem-based approach to strengthening the water sector resilience to stocks and crisis (zoonoses and climate change) is critical because it links water resources and freshwater ecosystems to water services and sanitation, as well as their associated institutions and governance processes. Viewed from a social-ecological system and One Health perspectives, the approach enables i) the identification of drivers and pressure on ecosystem structure, function, and processes, ii) impact of pressure on ecosystem services and disservices flows, iii) the benefits and costs to societal constituencies, and iv) internal and external leverage points for enhancing ecosystem resilience to assure water security, sanitation, and reduction of zoonosis. Therefore, the main aim of the proposed study is to develop and implement, a multi-pronged, ecosystem-based approach to strengthen the water sector resilience to climate change and risk of zoonoses (pandemic) in the Amathole District Municipality in the Eastern Cape, South Africa.

African urban complexities and the governance challenges of urban rivers – a systemic-relational inquiry

ON Odume, CF Nnadozie, FC Akamagwuna and DJ Choruma0

June 2021 - May 2023

Sponsor: University of Bayreuth – Africa Multiple Cluster of Excellence
Collaborators: Dr BN Onyima (Nnamdi Azikiwe University, Nigeria), Mr O Gift (Federal Ministry of Environment, Nigeria), Prof. U Okeja (Department of Philosophy, Rhodes University)

The trajectory of urbanisation in Africa is complex, presenting a potentially intractable governance challenges of natural resources such as urban rivers. In Africa, urban river systems are often seriously degraded and recent empirical evidence suggest the accumulation of novel pollutants such as macro- and microplastics in such river systems (Grimm et al 2000). However, healthy urban rivers can contribute to and support sustainable urban development through the supply of desired and valued ecosystem services (MEA 2005; Wangai et al. 2017). We argue that if African urban rivers are to be on an ecologically sustainable path, then a new approach that recognises the complexity of the interconnectedness and dynamic interactions between social and ecological systems within African urban landscapes, is required. Our on-going research in the Nelson Mandela Bay Metro in South Africa and the Federal Capital Territory in Nigeria, which comes to an end May 2021, focuses on three key components of the notion of urban complexity in relation to urban river ecology and governance challenges i) the imperative for developing multi-dimensional (ecological, social and economic) integrative indicators of urban river health ii) institutional integration failure (i.e. silo operation) as a key governance challenge and iii) the complex interactions and linkages between urban river health and people social-economic well-being on river catchment. Early results and engagement processes with stakeholders in the two catchments, have highlighted additional challenges and concerns, which deserved urgent scientific investigation, and by so doing extending and building on our current research projects. These additional challenges and concerns include:

1. The proliferation of macro- (plastic size range 25 – 1000 mm), meso (size range 5 – 25 mm)-and microplastics (size range ≤ 5mm) in urban rivers, which have to date received little or no attention in these catchments and more widely in African water resources. Here, important knowledge gaps exist, which include the influence of bio-habitat complexity on the dynamics of plastic pollutants, influence of plastics on the assemblage distribution of biota in river systems, and plastic as potential vectors of pathogenic microorganisms and emerging pathogens.
2. The governance of water-land-agricultural nexus as a critical challenge to realising urban river health. For example, in both urban centres, land-based activities such as solid waste disposals have been implicated as contributing negatively to urban river health, implying the need for a nexus governance approach.
3. The urgent need to examine urban river governance challenges such as the regulatory system, cooperative governance etc. in addition to institutional integration failure (which is already a subject of another project).
4. The imperative for investigating ethical implications of governance challenges in the context of social-ecological systems in urban landscapes.
5. And fundamentally the criticality for long-term research project interventions in order to be able to monitor, track and evaluate changes over time. The concept of river-people relationality, which we coined in our on-going project, which comes to an end in May 2021, has allowed us to begin investigation into peoples' values, perception, attitude and behaviour in relation to urban rivers. But research projects durations are usually short, often one to two years as in our case, which makes tracking, monitoring and evaluating changes over time almost impossible. Stakeholders within the two catchments have expressed desire for long-term intervention. Thus, there is a need to extend on-going research intervention in these area in order to track, monitor and evaluate shift in perception, values, attitudes and behaviour in the selected catchments.

All the above-mentioned challenges deserve urgent investigation, particularly through long-term projects/programmes. However, for the purpose of the proposed project, the focus of the research will be on i) addressing urban river governance challenges e.g. the regulatory system, and cooperative governance and their ethical implications in the context of social-ecological systems and ii) investigating the influence of bio-habitat complexity on the dynamics of macroplastics and the assemblage distribution of biota in river systems, as well as examining whether macroplastic support the establishment of pathogenic microorganisms and emerging pathogens, relative to the surrounding aquatic habitats.

We proposed to use the newly developed systemic-relational (SR) ethical approach by Odume and de Wet (2019) as an analytical lens for interrogating governance challenges and exploring their ethical dimensions. For example, a near absence of cooperative governance and failure of the regulatory systems have contributed to i) illegal discharges of waste into urban rivers ii) illegal abstraction of water from urban river resources and iii) the way in which people on catchment relate to and value urban rivers. These are matters of ethics in as much as they relate to the law. For instance, the illegal discharges in the Swartkops River have negatively impacted on other water users who have legitimate right to access these water resources, raising potential ethical concern. We take ethics as a systematic concern with the principles by which conducts, morals and values are clarified and justified, as we seek to distinguish between right and wrong in our behaviour towards other people and towards nature (Odume and De Wet 2016).Overall, by situating the study within social-ecological system framing, which recognises that both social and ecological components form a unifying social-ecological system (SES), we are able to concurrently explore both ecological and governance dimensions of urban river systems Using two African Metros, where we have been working, the Nelson Mandela Bay Metro in South Africa and the Federal Capital Territory, Abuja in Nigeria as case studies, this research examine i) the concept of African urban complexity by an investigation of urban river governance challenges e.g. the regulatory system, cooperative governance and exploring their ethical implication in social-ecological systems, and ii) investigating the influence of bio-habitat complexity on the dynamics of macroplastics and the assemblage distribution of biota in the selected rivers and iii) examine whether macroplastic support the establishment of pathogenic microorganisms and emerging pathogens, relative to the surrounding aquatic habitats. The two case studies have been selected because i) they both share similar features in that they are situated in large cities, ii) our on-going project suggest similar governance and ecological challenges as already argued and iii) Federal Capital Territory in Nigeria is strategic being the administrative seat of the Federal government and any successful intervention in the Federal Capital Territory would likely influence the governance and management of urban rivers in the rest of the country.

Our proposed research foregrounds mobility in as much as it relates to understanding the mobility of macroplastics, biota in urban rivers as well as reflection of governance challenges of urban rivers in cities in two different countries; relationality in as much as our project using the SR and SES perspective to interrogate the dynamic interaction between the ecological and social components of urban river catchments; transdisciplinarity in as much as it engages in the process of knowledge co-production with societal actors and bringing together multiple disciplines and morality, exploring the ethical implications of governance challenges of urban rivers in social-ecological systems.

POSTGRADUATE ACTIVITIES

Macroplastics in the environment: are they suitable microhabitats for macroinvertebrates in headwater streams?

Student: AA Ali
Supervisor: ON Odume and CF Nnadozie
Degree: MSc (Water Resource Science)

An estimated 360 million tons (Mt) of plastic were produced globally in 2019 compared to 1.5Mt in 1950. Furthermore, it has been projected that approximately 800 Mt of plastic will be manufactured by the year 2050. The increased production rate, low recycling rate, and lack of plastic degradation have created a sizeable problem, bringing about the accumulation of plastics in the environment at an alarming rate. Since the inception of plastic, humans have been disposing plastic in marine and freshwater ecosystems, causing consequential environmental problems. Alongside climate change, plastic pollution is an emerging issue that might affect human health and biological diversity.

The presence of plastic debris in freshwater environments is gaining recognition. While research data on plastic pollution monitoring from the freshwater environment is still in its infancy, evidence of its presence in rivers is well established. Freshwater plastic research worldwide has been more frequently centred on microplastic rather than macroplastic, which are similarly dangerous for the ecosystem. Once released into the environment, plastic items with a diameter ≥ 25mm are commonly considered macroplastics. Macroplastic is understudied despite being pervasive in river systems worldwide. They may concentrate on reaching a high density in the riverbed. As a result of their sizes and nature, macroplastics can displace natural microhabitats, potentially impacting habitat heterogeneity, quality, stability, and diversity. The creation of poor habitat heterogeneity affects riverine biota, including macroinvertebrates. Rivers play a significant role in transporting mismanaged plastics from land sources into the ocean. Therefore, the measurement of ecological impacts of river macroplastics is a necessity.

Macroinvertebrates have significant ecological relevance in the aquatic environment as an indicator of water quality and a critical part of the food web. Macroinvertebrates are an integral part of the structure and function of their habitats; the presence of unique assemblage can inform the intensity of anthropogenic disturbance in a particular area. In freshwater systems, most macroinvertebrate taxa are benthic and therefore related to the benthic zone, making them potential biological indicators of water-sediment interface quality. The traits of an organism mediate underlying interactions between an organism and its external environment, and thus, organisms can adapt to and survive in their environment because they possess the right combination of traits. Understanding the ecological preferences and features of distinct macroinvertebrates communities colonising the novel macroplastic established microhabitat can help direct river management strategies.

Macroplastics may be submerged in rivers, and when macroplastics interact with rivers by displacing natural habitat such as the sediment (muddy) area by creating hard surface, causing anoxic atmosphere, reducing the penetration of available sunlight for the photosynthetic organisms, they may alter the natural physical habitats, thereby influencing macroinvertebrates communities in such rivers. However, there is no data on macroplastic effects on the physical habitat, and therefore macroinvertebrate assemblages in freshwater ecosystems. This study aims to investigate the impact of macroplastics on microhabitat quality and macroinvertebrate assemblage structure in four selected headwater streams in Eastern Cape, South Africa. Headwater streams are the first expression of flowing freshwater ecosystems (between a spring and a stream), and they provide essential sources of water, sediments, and biota. Because of the near-pristine nature of headwater streams, this study intends to, through manipulative experiment in the field, gain an understanding of macroplastic-induced physical habitat alteration away from other anthropogenic stressors capable of influencing unique macroinvertebrates assemblage. The objectives of this study are as follows:

1. To determine whether macroplastics are suitable habitats for macroinvertebrates in selected

headwater streams.

2. To examine the effects of macroplastics on the quality of macroinvertebrates microhabitats.
3. To identify traits and ecological preferences that mediate the potential colonisation of macroinvertebrates assemblage on macroplastics.

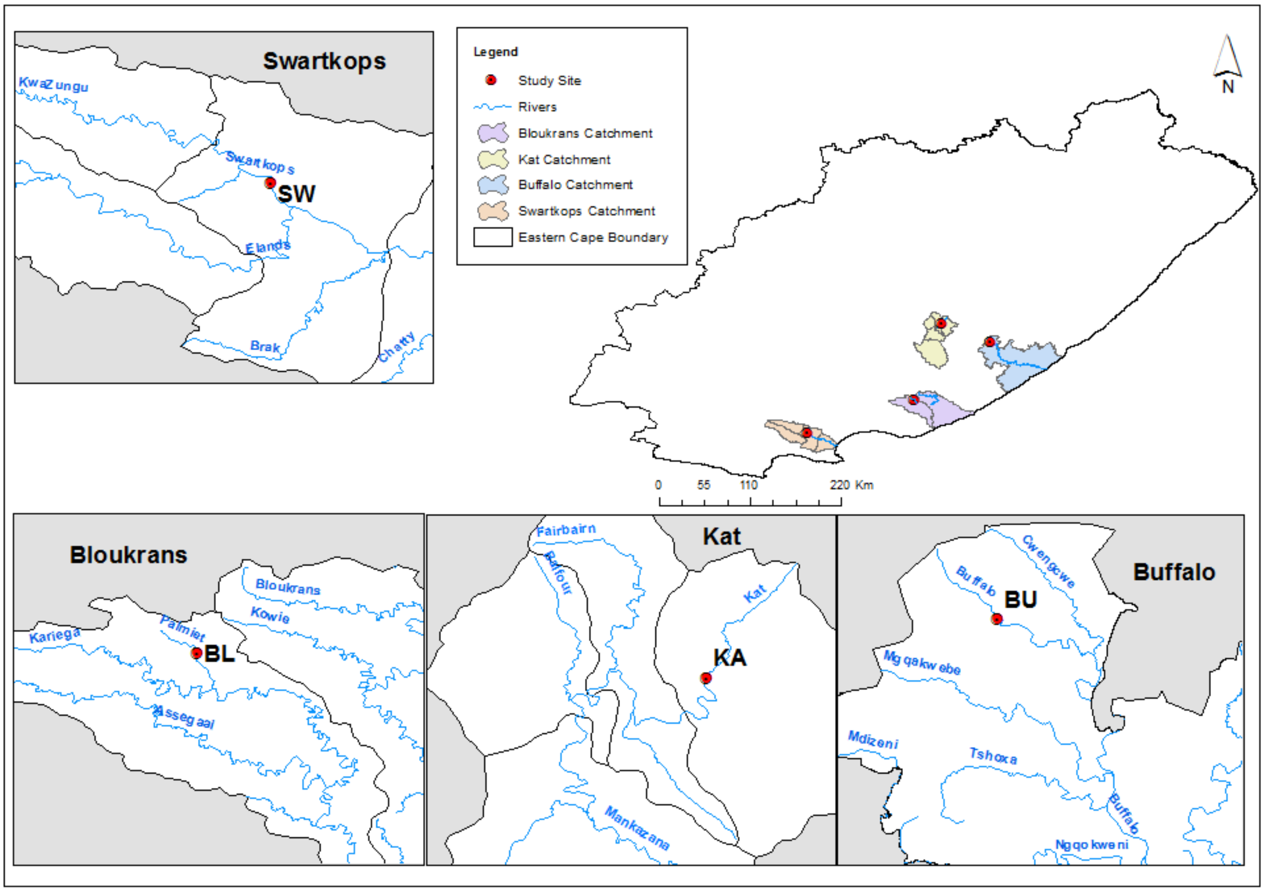


Figure 1: Study area map showing the different headwater points (Swartkops, Bloukrans, Kat and Buffalo Rivers) and Eastern Cape

Figure 2: Macroplastic before deployment (left) and submerged (right) in the river.

Source attribution and human health risk assessment of antibiotic resistant *Campylobacter* in Bloukrans And Swartkops Rivers in the Eastern Cape, South Africa

Student: M. Chibwe
Supervisor: CF Nnadozie and ON Odume
Degree: PhD (Water Resource Science)

Rivers serve as source water for drinking, irrigation, a place for recreation, and interaction for spiritual and cultural purposes. However, microbial pollution of rivers is a growing problem. Rivers are majorly polluted with human and animal pathogens of enteric origin. These pathogens originate mainly from faecal contaminated soil, animals, wastewater from nearby wastewater treatment plants, and effluent from livestock farms. Polluted rivers play a critical role as transmission route and reservoir for many pathogenic microorganisms including the antibiotic resistant ones. The occurrence of Antibiotic Resistant Bacteria (ARBs) and Antibiotic Resistance Genes (ARGs) in the environment is a global concern. Specifically, ARBs can be transmitted to humans upon exposure to contaminated water. Also ARGs can be acquired from the environment by clinically relevant pathogens passing by. Antibiotic resistance of bacterial pathogens leads to increased hospitalization and mortality rates of infected patients as infection caused by ARBs are becoming difficult to treat.

Campylobacter species cause gastroenteritis especially in children and immunocompromised individuals. In different parts of the world, isolates of *Campylobacter jejuni* and *Campylobacter coli* have shown resistance to erythromycin, azithromycin and clarithromycin), amoxicillin, fluoroquinolones (ciloxacin) and tetracycline which are the recommended antibiotics for treating campylobacteriosis. Transmission of pathogenic *Campylobacter* species is through faecal contaminated water and zoonotic sources (avian, bovine and ovine).

Figure 1: Cattle going to access drinking at sampling point near Vukani location on Bloukrans River.

Bloukrans and Swartkops rivers are faecally contaminated through various sources, including poorly treated wastewater discharge, agriculture effluent, faecal matter from animals from nearby farms, as well as surface run off bearing different pollutants. Therefore, these rivers are potential hotspots for transmission of ARBs. In order to prioritise management interventions and therefore effectively control the burden of human illnesses due to exposure to ARB from these rivers, there is a need to identify the leading source of ARBs. It is cardinal to conduct human health risk assessment for management of environmental water systems to assess ARB risks, safeguard people from exposure and promote public health. This project is assessing the human health risks posed by the presence of antibiotic resistant (AR) *Campylobacter* species in Bloukrans and Swartkops rivers, Eastern Cape, South Africa and attributing it to specific sources. Local cases of human antibiotic resistant *Campylobacter* species/genes will be linked to identified sources and consequently an indicator pathway for infection, will be developed. An important outcome of this study will be a holistic framework for Risk Assessment of ARB *Campylobacter* in source waters.

Exploring stakeholder contestation and applying a simple decision support system linking resource quality objectives to discharge standards in water use licences within the Vaal Barrage and its associated tributaries in the lower section of the Upper Vaal

Student: A Chili
Supervisor: ON Odume
Degree: MSc (Water Resource Science)

Deteriorating environmental water quality is one of the complex challenges in South Africa that threaten freshwater ecosystem health and functionality. An emerging concern is the contestation of water quality regulatory instruments such as standards in water use licences (WUL), and the resource quality objectives. In the Vaal Barrage catchment where this study was undertaken these contestations were evident, suggesting the need for both technical and social solutions to water quality changes in socio-ecological systems. The Vaal Barrage catchment within the lower section of the Upper Vaal is a highly developed, urbanised, and complex catchment supporting and contributing to the social-economic development of Gauteng Province and the entire country, as the Upper Vaal contributes 20% to the Gross Domestic Product of South Africa.

This study explored the motivations for stakeholders' contestations of water quality regulatory instruments in order to contribute to ways in which water resource users and regulators can collaboratively address water quality challenges in the Vaal Barrage catchment. The study also explores water quality scenarios and their ecological and management implications. Document analysis, participant observations and a semi-structured questionnaire were deployed to explore stakeholders' motivations, values and perceptions of the water quality regulatory instruments. The results were triangulated to gain better insights into research participants' responses. To explore water quality management scenarios, the study applied a water quality systems assessment model Decision Support System (DSS). The DSS was recently developed as part of a bigger project within the Vaal Barrage catchment. Regarding stakeholders' motivation for contesting water quality regulatory instruments in the catchment, the results revealed a perceived lack of scientific credibility and defensibility in the processes used for deriving standards in WUL, a lack of transparent linkage between the WUL and resource quality objectives, and the increased need for stakeholder engagement in the resource quality objective formulation process. Furthermore, the study revealed punitive measures, education and awareness, self-regulation as mechanisms to encourage compliance.

The applied DSS results showed that high nutrient loads, sulphate and total dissolved solids sourced from upstream catchments contribute to water quality deterioration in the Vaal Barrage catchment. The results also showed that the Vaal Barrage catchment could not host additional licence emitters because of total dissolved solids (TDS), phosphate and nitrate levels, which pose a serious risk to the ecology of the Vaal Barrage catchment, indicating that system had exceeded its assimilative capacity for critical water quality variables. Lastly, the results evidenced the need for collaborative action by the waste emitters within the Vaal Barrage catchment, particularly collaboration between upstream and downstream waste emitters. The study has far-reaching implications for water quality management in South Africa. These include i) the need for transparent and open processes and methods for deriving standards in water use licence, ii) the need for a water quality DSS that recognises catchment hydrological complexity in deriving standards in WUL, and for linking WUL and RQOs, iii) collaboration between resources users, and between the resources users and the regulators to bring pollution to acceptable levels and iv) both social and technical solutions are necessary for managing water quality challenge, particularly in a highly developed catchment such as the Vaal Barrage system.

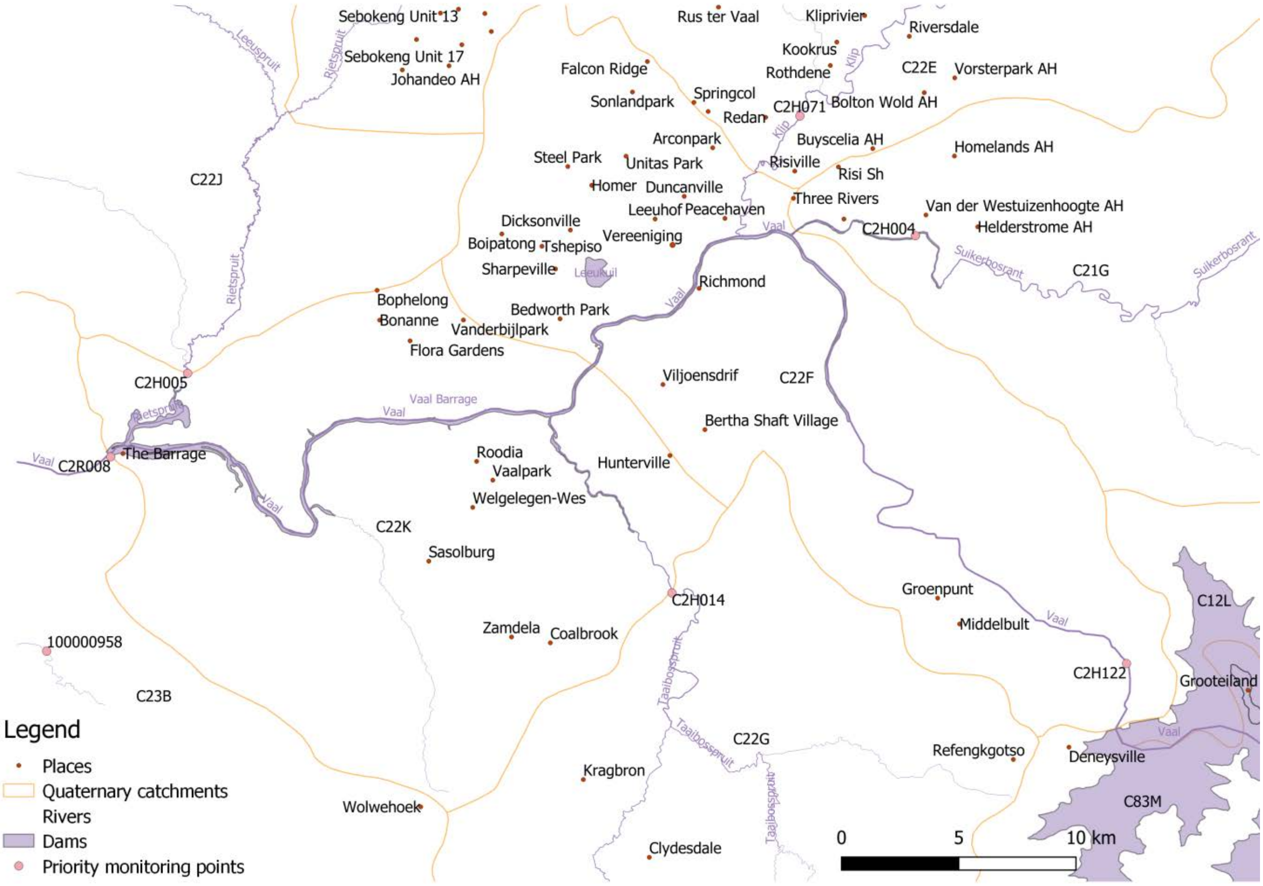


Figure 1 The Vaal Barrage and associated rivers (Source: Odume et al., 2021). The supporting tributaries of the Vaal Barrage include the Klip River, Blesbokspruit, Suikerbospruit, Taaibospruit and Leeuspruit.

Developing ecotoxicological methods for evaluating the potential effects of microplastics at environmentally realistic concentrations in South African freshwater systems

Student: Z Mtintsilana
Supervisor: N Griffin
Degree: MSc (Water Resource Science)

Plastic production has increased drastically worldwide over the last 50 years, increasing from 0.5 million tons per year in 1960 to roughly 300 million tons in 2013. Larger plastic particles break down over time as a result of different processes to form smaller plastic particles called microplastics. Microplastic pollution is found in a wide variety of habitats. Microplastics exposure is considered an environmental stressor and can be associated with several negative effects such as reduced food consumption, excessive weight loss, reduced growth rate, blockage of gills, decreased energy and negative impacts on successive generations. This research aims to contribute to the development of methods for assessing the potential ecotoxicity caused by microplastics in South African freshwater systems.

The microplastics chosen for the study were polyvinyl chloride (PVC), polyethylene (PE) and polypropylene (PP). In a series of experiments, microplastic concentrations and different endpoints such as survival, growth, and reproduction were tested using juvenile and adult *Melanoides tuberculata* (a snail), *Caridina nilotica* (a shrimp) and *Tilapia sparrmanii* (a fish). In general, clear responses of test taxa to microplastics were difficult to confirm statistically, as variation in outcomes outweighed any clear response to environmentally realistic microplastic concentrations. At the moment all of the data analysis for the research project has been completed and analysed, and currently the discussion is being written.

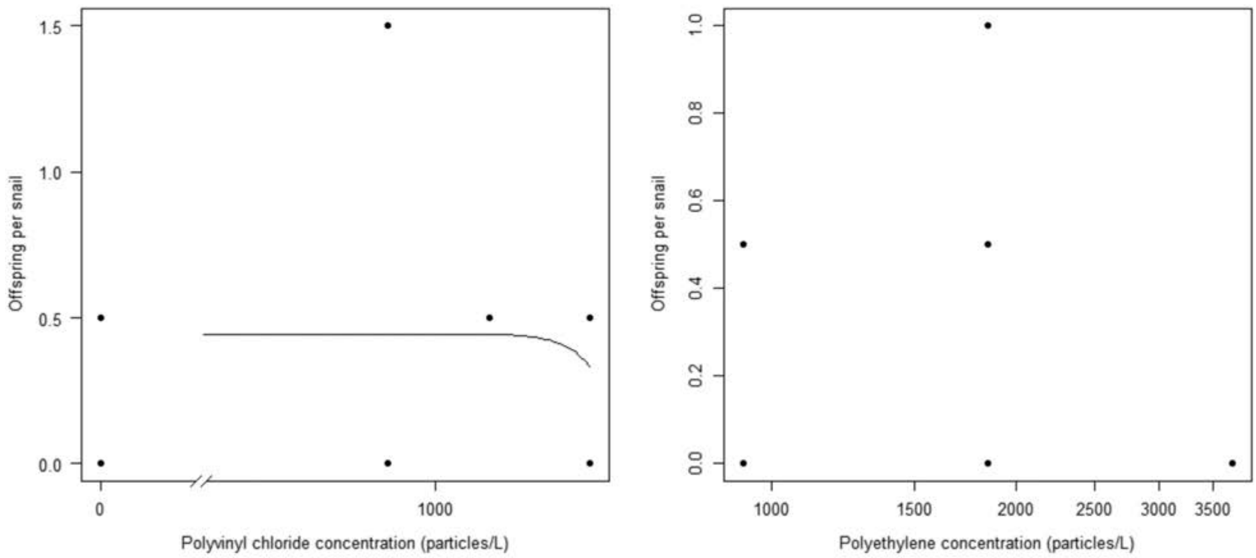


Figure 1: Dose-response curve showing offspring production per adult snail in varying concentrations of PVC and PE suspension. No detectable response to any concentration of tested microplastic suspensions was found.

Investigation of methods of detection of *Campylobacter* spp. from river water samples in Bloukrans River, Eastern Cape

Student: N Ngoni
Supervisors: CF Nnadozie and C Knox
Degree: MSc (Water Resource Science)

Campylobacter species are slender Gram-negative rod-shaped, spiral-shaped, and curved-shaped with single or pair of flagella. They are the leading cause of diarrheal disease globally and the country›s third leading cause of death. River water contaminated by faeces is a major risk factor for transmission to humans. Their detection in a water sample is critical to ascertain potential risks to humans. However, methods to isolate and detect *Campylobacter* in river water samples is lacking. Therefore, this study examined different approaches to concentrate and isolate *Campylobacter* spp, from river water samples. The Bloukrans River was chosen for this study because it is suspected to be contaminated by faecal inputs from the nearby informal settlement without adequate sanitation, untreated/insufficiently treated effluents from nearby wastewater treatment plants. Firstly, faecal contamination of water samples was confirmed by culturing on Membrane Faecal Coliform agar. After that, different approaches were examined to isolate *Campylobacter* from river water samples, namely,(i) direct plating of water samples on Modified charcoal cefoperazone deoxycholate agar (mCCDA), (ii) concentrating *Campylobacter* in water samples by centrifugation followed by membrane filtration of supernatant, and after that enriching the membrane-filter-attached residues with the pellets on in Preston broth, before playing on mCCDA agar, (iii) Moore Swab technique whereby flowing surface water is filtered by gauze deployed in the river for 48 hours, followed by enrichment of the gauze in Preston broth, before plating on mCCDA agar. Colony counts were compared against the three different methods. Suspected Campylobacter colonies were subjected to morphological identification, gram staining and colony polymerase chain reaction (PCR) analyses. Obtained PCR amplicons were sequenced using the Sanger method, and the identity was confirmed by NCBI BLAST. Gram›s staining indicated the presence of expected cell shapes of *Campylobacter* spp. Also, PCR results indicated the expected band size of *Campylobacter* spp., and Sanger sequencing confirmed the organisms to be *Campylobacter jejuni*. For this study, the combination of centrifugation and membrane filtration indicated the highest colony count and can be concluded to be the most suitable recovery method for the water samples.

Taxonomic and trait-based macroinvertebrate responses in sediment impacted rivers, Eastern Cape, South Africa.

Student: P Ntloko
Supervisor: ON Odume and CG Palmer
Degree: PhD (Water Resource Science)

Degradation of freshwater ecosystems and loss of biodiversity is a major concern worldwide (Strayer and Dudgeon 2010). Human-induced factors including urbanisation, industrialisation, and a growing human population are the main drivers of the degradation of freshwater ecosystems (Vörösmarty et al., 2010; Kopf *et al.,* 2017). There is an expected growth of the human population up to 8.6 billion by 2030, 9.8 billion by 2050, and 11.2 billion by 2100 (NEP, 2011; UN, 2017). The projected population growth implies increased demand for food and consequent increased pressure on water resources, which may manifest in the form of increased abstraction and pollution, impacting both water quantity and quality (Strayer and Dudgeon, 2010; Steffen et al., 2015; Zhang *et al.,* 2017). A critical water quality stressor is excessive input of fine sediments into freshwater ecosystems from anthropogenic activities in the catchments (Larsen *et al.,* 2011; Tiecher *et al.,* 2017). Freshwater quality is deteriorating due to fine sediment inputs (Van der Merwe-Botha, 2009), reducing ecosystem services that benefit humankind, for socio-economic development and prosperity. Fine sediment is composed of both suspended and settled fine sediment grain sizes and are defined as materials <2 mm in size and encompassing sand (<2000 to >62 µm), silt (<62 to >4 µm), and clay (<4 µm) (Wood and Armitage, 1997; Owens *et al.*, 2005; Jones *et al.*, 2012; Vercruysse *et al.,* 2017).

Although fine sediments are natural components of river systems levels beyond the natural backgrounds are a major stressor of riverine ecosystems (Walling and Fang, 2003; Conroy *et al.,* 2016; Doretto *et al.,* 2017; Vercruysse *et al.,* 2017). For example, elevated fine sediments in freshwater ecosystems changes channel morphology, reduces water flow, and increases turbidity in freshwater ecosystems (Mathers *et al.,* 2017), thereby affecting biodiversity and ecosystem functioning (Jones *et al.,* 2012). Elevated levels of fine sediments can potentially lead to several biological and ecological effects including gill clogging, smothering of eggs, filling up of interstitial spaces, disruption of fine feeding organs, the burial of less motile species, and depletion of dissolved oxygen, while leading to an increase in turbidity causing visual impairment and reducing light penetration (Dallas and Day 2004; Extence *et al.,* 2011; Gordon *et al.,* 2013; Turley *et al.,* 2016). These effects impact aquatic biodiversity by affecting respiration, food and feeding behaviour, mobility, habitat stability, and reproduction of aquatic organisms. The effects may manifest at the species, population, community, and even ecosystem levels (Bona et al. 2016). Fine sediments clog the habitats, increases macroinvertebrates drift, and reduces available habitat for organisms (Schalchi, 1992; Jones *et al.,* 2012). Fine sediments have been reported to differentially affect macroinvertebrates. For example, species of the orders Ephemeroptera, Plecoptera, and Trichoptera have been reported to be vulnerable to sedimentation, and their species richness is reduced in fine sediment impacted habitat (Jones *et al.,* 2012; Beermann et al., 2018). However, the abundance and richness of some species of Chironomidae have been observed to increase about fine sediments increases because they have adaptive traits that allow them to withstand sediment stress (Kreutzweiser *et al.,* 2005).

The input of excessive fine sediment can have important hydrological, geomorphological and ecological implications, changing the physical and biological environment and causing lotic ecosystem degradation (Owens *et al*., 2016; Laceby *et al*., 2017; Mathers *et al*., 2017; Stopps, 2018). For example, elevated sediments in freshwater ecosystems affect channel morphology, water flow and turbidity (Mathers *et al.,* 2017). The transport of fine sediment in the water column increases turbidity and reduces light penetration, thereby reducing primary production and the availability of high-quality habitat for macroinvertebrates (Wilbur and Clarke, 2001; Collins *et al*., 2010b; Stopps, 2018). Many changes occasioned by fine sediment inputs are detrimental to instream biota through effects on respiration, micro-habitat, Physico-chemical characteristics, food web and food quality, and availability (Bryce *et al*., 2010; Kemp *et al*., 2011).

A growing number of studies have investigated the impact of important water quality stressors such as fine sediments, eutrophication, flow reduction, pesticides and climate change and their effects on aquatic biotic communities and ecosystem functionality (Matthaei et al., 2010; Piggott *et al.,* 2015b; Bruder *et al.,* 2016; Piggott et al., 2015a). Also, in recent years, there has been great concern regarding the levels of fine sediment being delivered to and transported by rivers and streams. River bank erosion is known to contribute greatly to fine sediment delivery in freshwater ecosystems (Herlihy *et al.,* 2005; Stott, 2005) and adversely affects habitat compositions (Dunbar *et al.,* 2010a). Poor land management practices such as agricultural practices (Jones and Schilling, 2011; Zhang *et al.*, 2014; Collins *et al*., 2016; Naden *et al.,* 2016), forestry operations (Negishi *et al*., 2008; Futter *et al*., 2016), construction (Angermeier *et al*., 2004; Lachance *et al*., 2008) and mining (Brown *et al*., 1998) contribute greatly to sedimentation processes. Landscape degradation can accelerate the input and delivery of fine sediments into the stream and riverine ecosystems (Zhang *et al.,* 2017). For example, landscape degradation resulting from agricultural activities accounts for 48% of stream pollution from excessive fine sediment loads in the United States of America (USA) (Sutherland *et al.,* 2012). In South Africa for example, landscape degradation is considered to be the major source of fine sediment delivery (Le Roux & Sumner, 2013). South African rivers deliver sediment in the excessive amount to the ocean, with the Orange River delivery the most (Gordon *et al.,* 2012). Sedimentation of South African rivers is one of the leading causes of water quality degradation (Le Roux & Sumner, 2013), exacerbated by other interacting factors, which include soil erosivity, slope steepness, flow, and rainfall variabilities (Msadala *et al*., 2010). The major sources of fine sediment load in South African rivers can be classified into in-channel and non-channel sources, where channel sources are those derived from the beds and banks of rivers and streams as a result of widespread erosion (Basson *et al.,* 2010). Non-channel sources originate from the wider landscape and may include activities such as logging, agricultural activities, and urban development (Le Roux *et al.,* 2008; Lorentz *et al.,* 2012; Gordon *et al*., 2013). Over 70% of South Africa's surface area has been affected by various degrees of soil erosion (Le Roux *et al.,* 2007; Le Roux *et al.,* 2008; Collins *et al.,* 2016), making most riverine systems in South Africa, and in particular in the northern part of the Eastern Cape province, vulnerable to fine sediments loads as soils in these areas are considered duplex and dispersive.

The Eastern Cape province of South Africa is currently classified among the most severely impacted by soil erosion in the country (Le Roux *et al.,* 2007; Foster *et al.,* 2017). The Mzimvubu catchment, which includes the Tsitsa River and its tributaries in the Eastern Cape where this study was undertaken consists of highly erodible duplex soils, placing it among the highest sediment yielding regions in South Africa (Msadala *et al*., 2010). The Tsitsa River is subject to excessive fine sediments input through the effects of gully erosion (Le Roux, 2013). Sediment loads derived from gully erosion and other forms such as rill and sheet erosion could possibly affect the overall integrity and ecosystem health of the Tsitsa River system. The trait-based approach (TBA) is rooted in theoretical ecological concepts such as the habitat template concept (HTC), habitat filtering concept (HFC), functional diversity, redundancy and uniqueness (Schemera *et al*., 2017, Odume *et al.,* 2018). The trait-based approach expands biomonitoring beyond the traditional taxonomy-based assessments by providing mechanistic linkages between the composition of the macroinvertebrate community and the environmental conditions. The presence of specific traits has the potential to indicate how different stressors influence the macroinvertebrate communities (Culp *et al.,* 2011; Van den Brink *et al.,* 2011, Beeckman, 2017). The trait-based approaches could provide simple tools that could be particularly useful in less well-studied areas, including developing countries because in some instances one may not need to identify macroinvertebrates specimens to recognise their traits e.g. body shape, body size, and possession of certain structures such as gills (Van den Brink *et al.,* 2011). South Africa, is among the developing countries where the approach has not gained popularity in terms of applying it to biomonitoring (Odume, 2014; Odume *et al.,* 2018), and therefore the present study is among the first to explicitly apply the approach to a specific freshwater stressor. The trait-based approach is an adaptation of the standard biomonitoring approach, the sampling strategy remains the same, but the taxonomic composition of macroinvertebrates is translated into a trait composition through a trait database, observation, measurements and the literature (Culp *et al.,* 2011).

Therefore, the study of the interactions between traits and elevated fine sediments can lead to the potential identification of trait-based indicators of fine sediments in rivers, which can provide a basis for mechanistic insights into how fine sediments drive macroinvertebrate communities to change. Further, given that traits mediate organism-environmental interactions, it is also possible to develop a trait-based approach for identifying potentially vulnerable and resilient macroinvertebrates taxa to elevated fine sediments. In this study trait-based indicators are developed, and an approach for predicting the potential vulnerability and resilience of macroinvertebrates communities to effects of fine sediments is also developed. This is the first study in South Africa to develop explicit trait-based indicators of elevated fine sediments as well as an approach for predicting macroinvertebrate's vulnerability and resilience to sediment effects, thus

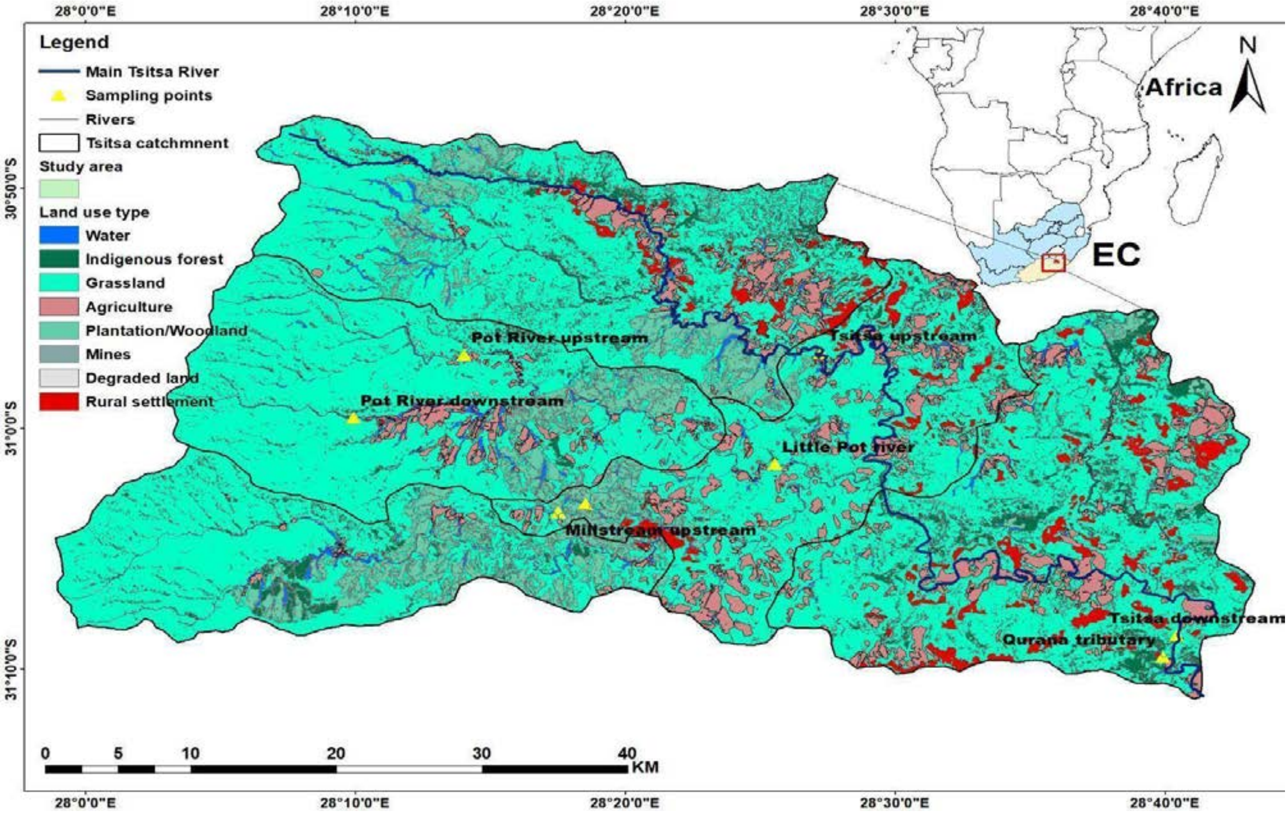


Figure 1: Land use map of sampling sites on the Tsitsa River and its tributaries showing the land cover around each site.

advancing the science and practice of freshwater biomonitoring.

Aim of the study

The overall aim of this study was to develop novel taxonomic and trait-based approaches for assessing macroinvertebrate responses to elevated fine sediments in Tsitsa River and its tributaries, Eastern Cape, South Africa.

Project objectives

- To characterise suspended and settled fine sediments grain sizes and their distribution in the Tsitsa River and its tributaries
- To develop and validate a macroinvertebrate-based sediment specific multimetric index suitable for monitoring effects of elevated fine sediments in the Tsitsa River and its tributaries.
- To explore macroinvertebrate ecological preferences and traits with a viewing to identifying possible trait-based indicators of fine sediment stress in the Tsitsa River and its tributaries
- To develop a novel trait-based approach for assessing and predicting the potential vulnerability and resilience of South African macroinvertebrate families to fine sediment stress in the Tsitsa River and its tributaries.

Limitations of the study

The concept of traits is relevant to all taxonomic groups and at family level only and not species level. Life-history research is not within the scope of the present study; however, in compiling the database, literature on life-history research and experts in the relevant disciplines were consulted and the research findings on life history information mainly based at family level. The main limitation of the work is that the compiled trait database is inadequate owing to the limited availability of trait information on South African aquatic macroinvertebrates in the literature. Further testing of the SMMI across different riverine ecosystems in the country is recommended. This would allow for identifications of areas requiring refinement and improvement. Existing SASS5 data collected from systems known to be stressed by sediments can serve this purpose.

Recommendations for future research

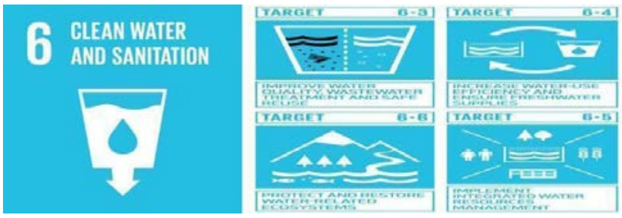
Testing the SMMI across different riverine ecosystems in the country is fundamental and would allow for identification of areas that need improvement.

Development of modelling tools linking trait-mediated biotic response to specific water quality stressors, habitat characteristics, as well as stream hydrology.

An understanding of the vulnerability and resilience of freshwater ecosystems to sediment stress, from a biological perspective, could help in planning and decision making.

Comparative application of eDNA, taxonomic and trait-based approaches for assessing macroinvertebrate assemblage response to pollution in selected urban river systems, Eastern Cape, South Africa

Student: MO Osoh
Supervisors: ON Odume and CF Nnadozie
Degree: PhD (Water Resource Science)



Rapid urbanisation remains one of the greatest threats to freshwater ecosystems globally (Edegbene et al., 2020). This threat is exacerbated by the rapidly growing human population, rural-urban migration in search of decent work, increasing food demand, and critical knowledge gaps in urban pollution management. Some of the threats that urban rivers face include sediment input from storm water runoff, untreated sewage, water abstraction and pesticide application for agriculture, which modify the ecological integrity, biodiversity and ultimately, the functioning of freshwater systems (Ternus et al., 2011; Wiederkehr et al., 2020; Akamagwuna, 2021). These problems hamper freshwater ecosystems in urban centres from providing essential, desired and valued ecosystems services, especially in Africa, where urban rivers and streams contribute critically to human well-being and livelihood (Odume, 2020).

We have a critical knowledge gap regarding the development of practical monitoring approaches to assess the effect of urban pollution. For example, water quality managers and policymakers use conventional (e.g., environmental water quality and taxonomic approach to biomonitoring) assessment methods to evaluate the level of impact of pollutants on a waterbody (Wang et al., 2019). Moreover, specific metrics obtained from aquatic communities such as morphometric measurements, community structure and family-specific attributes of plankton, macroinvertebrate and fish are used to assess the consequences of urban pollutants at the population or community level. These methods have drawbacks that limit their use in the comprehensive description of urban rivers' water quality status, contributing to the continued deterioration of freshwater ecosystems. Some of the impediments of the conventional methods include limited taxonomic resolution, the requirement of morphology-based taxonomic expertise, and the slow turnaround time of data acquisition for largescale biomonitoring of river systems. Thus, if urban rivers are to be set on an ecologically sustainable path, a paradigm shift from the existing monitoring approach to an approach that integrates multiple tools for water quality monitoring is needed. For example, a critical challenge for water quality managers and policymakers is the development of new tools and techniques to aid effective and rapid bioassessment of waterbodies.

Recently, the next-generation sequencing of environmentally extracted DNA of target organisms is increasingly used to monitor anthropogenic pollution of freshwater ecosystems (Baird & Hajibabaei, 2012). However, this approach has been mainly applied to studies involving biodiversity conservation and invasive species monitoring (Baird & Hajibabaei, 2012). My project seeks to test the efficiency of this new approach to biomonitoring river systems and compare it to the taxonomy and trait-based approaches using macroinvertebrate communities in selected urban rivers in Eastern Cape, South Africa. The objectives of this project are:

i) to develop an eDNA-based macroinvertebrates index for assessing pollution in urban river impacted systems;
ii) to explore the pattern and distribution of macroinvertebrates traits and ecological preferences using data derived from eDNA and conventional biomonitoring methods;
iii) to develop a trait-based approach for predicting the resilience and vulnerability of macroinvertebrates to urban pollution; and,
iv) to develop a multi-criteria approach for the use of eDNA and conventional approaches in freshwater biomonitoring.

Figure 1: Mr Osoh during sample collection at a site in Buffalo River

A mechanistic and trait-based approach to investigating the distribution and effects of microplastics on riverine macroinvertebrates.

Student: EK Owowenu
Supervisors: ON Odume and CF Nnadozie
Degree: PhD (Water Resource Science)

Microplastics pollution in global aquatic systems is increasingly becoming a concern as it may impact biota such as macroinvertebrates (Windsor et al., 2019). Microplastics, particles <5mm in diameter (Akindele et al., 2019; Dahms et al., 2020; Frias & Nash, 2019) have a widespread distribution (Dahms et al., 2020), with many studies demonstrating several ecological effects (de Sá et al., 2018a). Laboratory and field-based occurrence studies show that the ingestion of microplastics particles can affect aquatic organisms (de Sá et al., 2018a; Issac & Kandasubramanian, 2021; 2019; Scherer et al., 2017), including zooplanktons (Frias et al., 2014), invertebrates (Akindele et al., 2019; Scherer et al., 2017; Welden & Cowie, 2016), fish (Kühn et al., 2020; McNeish et al., 2018; Sequeira et al., 2020) and birds (Lavers et al., 2019). However, these studies were not designed to consider hydraulic habitat distribution/patchiness, yet hydraulic habitat patchiness influences the distribution of aquatic organisms such as macroinvertebrates (Thomson et al., 2001) and their potential exposure to microplastics. Previous studies have focused more on occurrence, polymer identification, as well as polymer shape and colour categorisation (Ockenden et al., 2021; Shen et al., 2021), yet there is no complete scientific understanding of how and what might predispose aquatic organisms to microplastics in their respective habitats.

Although lentic and marine habitats are the most probable ultimate sinks receiving microplastics from rivers with potential adverse effects for benthic invertebrates (Berlino et al., 2021; Hoellein et al., 2019; Tang et al., 2021), rivers can act as both conduits and accumulators of microplastics (Hoellein et al., 2019). In fact, there are a series of “flushes and sinks” within the riverine ecosystem created by differential flow conditions in different hydraulic biotopes, which are likely to hold comparatively different concentrations of microplastics. Hydraulic biotopes may be composed of very fast – slow-flowing patches, creating a picture of flush and sink zones. Fast-flowing – microplastics flush zones; slow flowing – microplastics sink zones. Since trait mediate organism-environment interaction i.e. a set of traits determines where a species can live (Schmera et al., 2017), it could then mean that trait may provide a rational, mechanistic understanding of species-environment relationships (Verberk et al., 2013). This suggests that macroinvertebrates that prefer a microplastics flush or sink zone may have a combination of traits that adapt them to such zones and might create differential exposure to microplastics. In this regard, traits that mediate between an organism and its environment are seen as key to achieving the goal of predicting an organism's response to environmental change, as well as diagnosing and discriminating between environmental stressors through mechanistically linked traits. Thus, hydraulic biotopes distribution/patchiness, traits, and ecological preferences are important biophysical factors critical to the understanding of the risk posed by microplastics on macroinvertebrates. This study therefore aims to investigate the distribution and effects of microplastics on riverine macroinvertebrates using a mechanistic and trait-based approach. The study is in its first year and will be carried out in three urban rivers: Swartkops, Buffalo and Bloukrans river catchments in the Eastern Cape of South Africa. The specific objectives are:

1. To determine the distribution of microplastics in relation to land use and hydraulic habitat types.
2. To use ecological preferences and a trait-based approach to explore macroinvertebrates' exposure to microplastics in the selected rivers.
3. To examine the effects of microplastics on selected macroinvertebrates based on their traits and ecological preferences.
4. To develop a mechanistic framework for predicting riverine macroinvertebrates exposure to microplastics.

Microplastics as potential vectors for selected organic chemical pollutants in freshwater ecosystems

Student: E Tumwesigye
Supervisor: ON Odume, GW Nyakairu and CF Nnadozie
Degree: PhD (Water resource science)

Research Project Proposal Synopsis

The increasing concentration of organic chemical pollutants of emerging concern, such as antibiotics and endocrine-disrupting compounds in freshwater ecosystems, is becoming a threat to aquatic organisms and humans via bioaccumulation in the food chain (Wang et al., 2020; Palmer & Herat, 2021).

However, numerous research findings indicate that these organic chemical pollutants in river water systems are associated and coupled with various plastics items and not freely dissolved in the surrounding water ecosystems (Müller et al., 2020; Puckowski et al., 2021). Based on the tuned physical properties of microplastics, size range 1-5000microns, i.e., large surface area to volume ratio, trim sizes, and hydrophobic surfaces, microplastics tend to interact strongly with the organic chemical pollutants in the environment through several mechanisms, electrostatic attraction/repulsion, partition effect, Vander Waals forces, π-π interactions (Wang et al., 2020).

The large surface area of microplastics also enables higher biofilm growth rates, including those containing antibiotic–resistance genes. The direct consequence is the contribution towards antimicrobial resistance development in pathogenic bacteria in the environment (Campanale et al., 2020; Pereao et al., 2020). This consequently endangers human health through the direct consumption of contaminated drinking water, which will jeopardise the availability of life-saving antibiotics in the future (Campanale et al., 2020; Pereao et al., 2020).

Based on these properties, a hypothesis is generated that microplastics can act as vectors for microplastics in freshwater environments (Barboza et al., 2020; Panti et al., 2020). Furthermore, it is hypothesised that the concentration accumulation of such contaminants on the microplastics particles could be higher than the concentration of the same contaminants in the surrounding water ecosystems (Liu et al., 2019, Puckowski et al., 2021). With research findings indicating aquatic organisms ingesting microplastics with similar physical features (sizes) to their natural prey (Boerger et al., 2010; Wang et al., 2020; Thiele et al., 2021), the microplastics can be desorbed from the microplastics following ingestion, and the combined toxicological effects might pose mixture – specific effects that deviate from additivity- synergy effect an additional threat to the freshwater organism.

Much of microplastic pollution within freshwater ecosystems of South African waterways remains largely understudied (Nel & Froneman, 2015; Dahms et al., 2020). Yet freshwater habitat conditions influence the distribution of microplastics and associated contaminants (Pereao et al., 2020); therefore, the risk posed by different microplastics sizes and associated microplastics concerning ecological exposure to the effect ofmicroplastics need to be investigated as is currently largely underreported (Dahms et al., 2020).

Therefore, this study proposed field-based studies coupled with well-designed laboratory experiments that give novel endpoints to quantify better the interaction mechanism between microplastics sizes and microplastics, which is essential in understanding the potential fate and ecological relevant carrier effects of microplastics in freshwater ecosystems (de Sá et al., 2018; Palmer & Herat, 2021).

The study investigates the vector transfer and potential sorption mechanisms of selected targeted antibiotics and endocrine-disrupting compounds associated with microplastics in two river systems in the Eastern Cape, South Africa, Swartkops and buffalo rivers. These two river systems have been selected based on their great deal of contamination with antibiotics and endocrine-disrupting compounds (Farounbi & Ngqwala, 2020, Vumazonke et al., 2020). The objectives are:

i) determine the concentration of selected antibiotics and endocrine-disrupting compounds on microplastics relative to the surrounding environments using Swartkops and buffalo river systems;
ii) investigate the sorption mechanism of selected antibiotics and endocrine-disrupting compounds on microplastics chosen types;
iii) To assess the fate, accumulation, and transfer effects of microplastics associated microplastics on the early developmental stages of zebrafish – Danio; and
iv) develop a conceptual framework that accounts for microplastics vector effect risk in freshwater ecosystems.

Adaptive Water Resource Management projects

Unlocking resilient benefits from African water resources (UKRI Research Excellence Grant)

Prof. CG (Tally) Palmer (Director), Dr Jane Tanner (Co-Director)

April 2020 – December 2023

Sponsor: UKRI-GCRF
Collaborators: Prof. Zerihun Woldu (Addis Ababa University, Ethiopia, Co-Director), Prof. Noble Banadda / Assoc. Prof. Isa Kabenge (Makerere University, Uganda), Prof. Frances Cleaver (Lancaster University, UK), Prof. Serigne Faye (Cheikh Anta Diop University, Senegal), Prof. Ezechiel Longe (University of Lagos, Nigeria), Prof. Joel Nobert (University of Dar es Salaam, Tanzania), Prof. Vanessa Speight (Sheffield University, UK), Dr Nsengimana Venuste (University of Rwanda, Rwanda), Prof. Kevin Winter (University of Cape Town, South Africa), Prof. Seifu Gurmessa (University of KwaZulu-Natal, South Africa)

The African Research Universities Alliance (ARUA) Water CoE is one of four multidisciplinary and multinational projects addressing the UN's Sustainable Development Goals (SDGs) that are supported by UKRI-GCRF Research Excellence Grant. The ARUA Water CoE Research Excellence project (also referred to as RESBEN) is titled *Unlocking Resilient Benefits from African Water Resources*. The aim of the project is to apply transformative, transdisciplinary, community-engaged research, to shift water development outcomes towards achieving the SDGs, with focus on continental water development priorities: water supply and pollution.

The project consists of six proposed project Case Studies that exemplify water-related challenges across Africa, and support progress towards SDG6, the core water-related Sustainable Development Goal. In addition to the six Case Studies, there are three South African learning sites (led by the University of KwaZulu-Natal [UKZN], the University of Cape Town [UCT], and Rhodes University) that will provide insights and learning opportunities related to Case Studies. The project team's vision is to change the approach to water development, for Africa, by Africans.

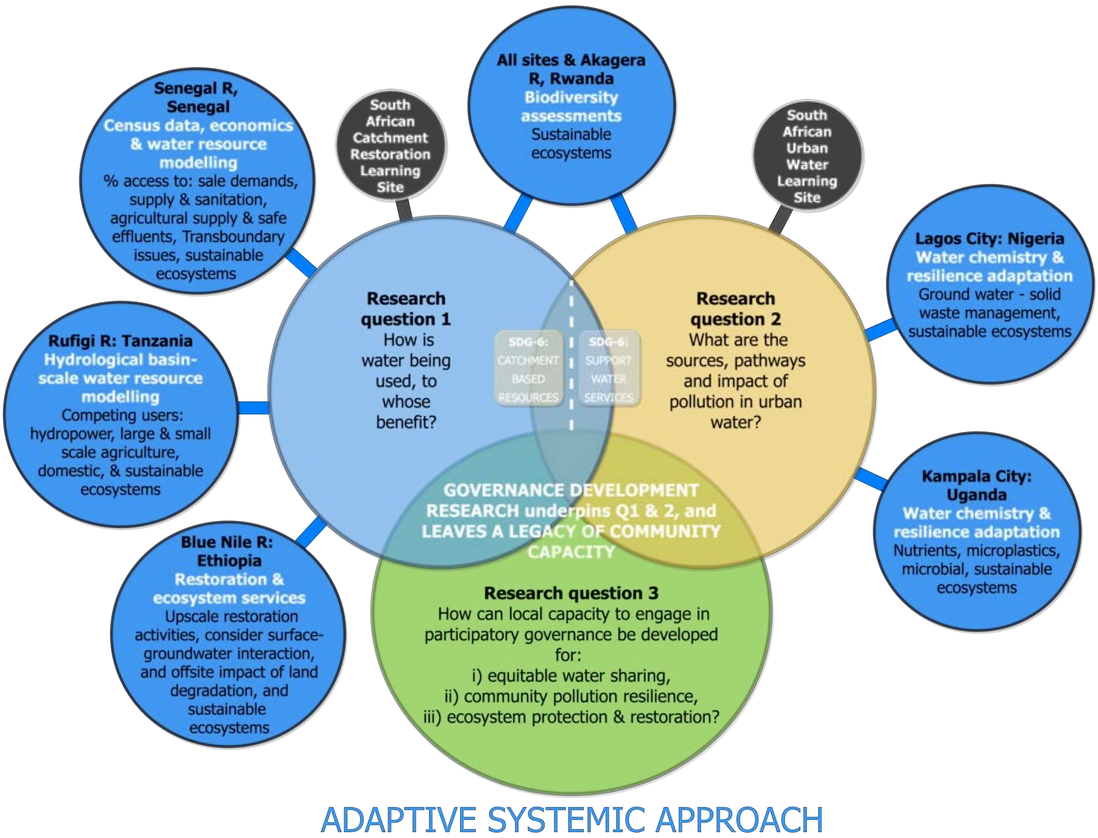


Figure 1: Main research questions being targeted under the RESBEN Project using the Adaptive Systemic Approach for transformative developmental research

The project objectives are:

1. To apply a novel Adaptive Systemic Approach to six country-based Case Studies that shifts developmental research outcomes towards greater equity and sustainability.
2. To address equitable sharing of water supply benefits arising from contested water use, in three catchment-based Case Studies.
3. To establish the sources, pathways and impact of selected pollutants and to develop community pollution resilience in two city-based Case Studies.
4. To develop participatory governance to support resilient water supply, water quality, and ecosystem protection in all Case Studies.
5. To build an effective, excellent, partnered African water research network.

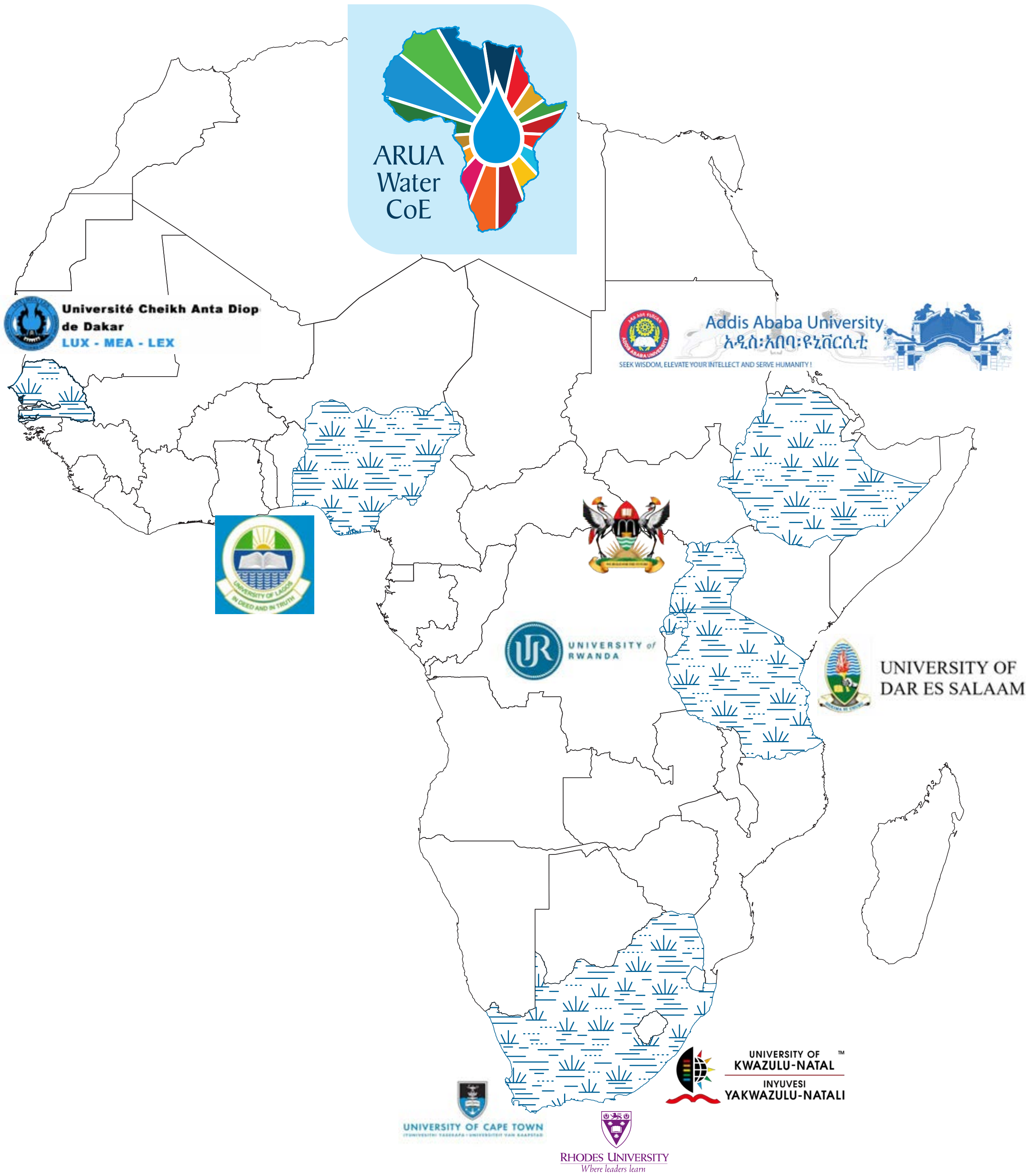


Figure 2: Collaborating Universities of the ARUA Water CoE in Africa and their strengths

Project progress

In March 2020, we received the unexpected and disheartening news from UKRI about the 50% cuts to project funding for the 2021/22 financial year. Due to the limited travel possibilities under COVID, we had some unspent funds in the UKRI-funded Capacity Building project (detailed below). UKRI also allowed for a portion of the funding to be shared between the two grants. This provided us with the flexibility to combine the funds from the two grants and to continue supporting the Nodes (particularly the Research Assistants) and the vulnerable at the Hub (project aligned postdoctoral fellows and staff whose salary is dependent on the UKRI funding). The second shock to our project team was the loss of the co-Investigator (CoI) for the Uganda Node (Prof. Noble Ephraim Banadda). Please see the tribute to his contributions and life on our ARUA Water CoE News page (www.ru.ac.za/iwr/aruacoe/news/). Associate. Prof. Isa Kabenge, Deputy CoI for Uganda Node, has stepped into the role of CoI and he spent 6 weeks at the Hub University in September/ October. The objective of the visit was to strengthen the working relationships and to develop ideas for future collaboration.

Several staff and postdoctoral fellows were appointed to allow successful delivery of this large grant, including Dr Sukhmani Mantel (Academic Manager), Mr David Forsyth (IT Manager), Dr Matthew Weaver and Dr Notiswa Libala (postdoctoral fellows at Rhodes University), Dr Ana Porroche-Escudero (Lancaster University postdoc) and Dr Bukho Gusha (NRF funded postdoc at Rhodes). Dr Sally Weston at Sheffield University left the network to work in Canada in March 2021. Dr Rebecca Powell was appointed as a Large Grants Manager, but with the cuts in funding and the need to focus our capacity and efforts on delivery of this grant, we reallocated her duties along with those of other postdoctoral fellows to work with specific Nodes and their Research Assistants.

We are also pleased to host Dr Bezaye Gorfu Tessema from the Water and Land Resource Centre, University of Addis Ababa, Ethiopia, who has been awarded the ARUA-Carnegie Early Career Research Fellowship for one year starting in October 2021. She is being hosted by the Water CoE Hub under the supervision of Prof. Tally Palmer and Dr Jane Tanner. Dr Tessema will function as an integral member of research teams, participating in technical workshops with fellow researchers and other stakeholders. She will also assist in creating and bolstering partnerships between the ARUA Water CoE and the African and European research and innovation units.

The original project vision for the RESBEN Project was that the Case Studies would be conducted as four Adaptive Systemic Approach (ASA) steps. The ASA foundation course in Addis Ababa in February 2020 under the Capacity Building grant provided the Nodes with the understanding and adoption of the ASA. However, due to travel restrictions under Covid-19, a majority of the interactions since the workshop have been online using Zoom. In September 2021, we took the brave decision to hold a Training of Trainers workshop for the Nodes who intend to run an Adaptive Planning Process (APP, a step under the ASA) workshop in their own countries.

Adaptive Planning Process (APP) Training of Trainers Workshop - 21-23 September 2021

The APP training workshop was designed for participants to build their understanding of the methodology and practical facilitation process of running an APP. The workshop was designed for participants to learn how to plan and facilitate an APP process by developing a Node-specific stakeholder engagement workshop plan that is informed by the APP process, in addition to practicing to run the planned stakeholder engagement process through a role-playing exercise.

The workshop was a big step towards Covid-19 sensitive, in-person workshop facilitation at Rhodes University. A total of 27 participants (including Node researchers from Ethiopia, Senegal, Uganda, Rwanda, Tanzania and South African participants from the University of Cape Town and the University of KwaZulu-Natal) engaged with facilitators in person, with an additional 12 participants and facilitators connected online (including researchers from Nigeria). The workshops was facilitated in a blended (face-to-face and online) format. Each session was designed to maximise inclusivity and fair participation of all participants (both online and in-person). Achieving this inclusivity, particularly with the intention not to alienate the online participants, was a challenge. With the help of smart audio and video technology and a dedicated technical team led by Mr David Forsyth, we ensured that no one was left behind.

The training sessions comprised of theoretical introductory lectures for each of the APP steps, followed by practice sessions. The introductory lecture was conducted with all participants in a plenary format and focussed on the purpose and a practical example of how one would facilitate that particular step. Participants then broke away into Node pair groups, each with dedicated trainers to practice the facilitation of that step while drawing on their home contexts using role-playing. Groups then discussed and reflected on their experience of facilitating the step and how it could be applied to their context.

The training workshop culminated in each Node drafting and presenting their context-specific stakeholder meeting plan that was informed by the APP. Value creation reflection data collection were conducted after each day of the workshop (see below on what the value creation process entails). These data inform the ongoing development of the Node stakeholder meeting plan and its implementation, the adaptation of the APP training process as well as the evaluation of the RESBEN Project as a whole. After returning to their countries, the Nodes developed their stakeholder engagement meeting plans based on the APP training, with support from the Water CoE hub team. Three of the Nodes have successfully conducted their stakeholder engagement (see next section), and the other three will be holding their workshops in 2022.

Figure 3: Participants at the ARUA Water CoE Adaptive Planning Process Training of Trainers workshop held at Rhodes University in South Africa

Figure 4: Participants of the APP workshop with online participants on Zoom (reflected on the wall)

Ms Mti was a part of the Rhodes University logistical organising team for this workshop. Ms Mti was responsible for ensuring that the African partners had their PCR testing upon arrival and before departure in South Africa. Thanks goes to the organising team for making this workshop a success!

APP workshops hosted by Water CoE Nodes with their stakeholders

Three of the Water CoE Nodes hosted their Case Study workshops with stakeholders, in-person, less than two months after their training in Makhanda in September 2021. Two South African team members joined the workshops held in Nigeria and Tanzania, but unfortunately the travel to Senegal was cancelled at the last minute due to the Omicron restrictions put in place. Dr Notiswa Libala (Hub postdoctoral fellow) and Ms Naledi Chere (Research Assistant, UCT) joined the Nigerian workshop. Dr Libala then travelled to Tanzania and was joined by Dr Bezaye Tessema (ARUA-Carnegie Early Career Research Fellow). The Nodes are currently writing their workshop reports, which will be shared with the Hub team in January 2022. The pictures of the three workshops held so far are included in this IWR Annual report and the 2022 report will provide more details of what relationships and outputs have emerged from the workshops.

Figure 5: Participants of the Senegal APP Workshop held on 30 November and 1 December 2021

Figure 6: Participants of the Lagos APP Workshop held on 30 November that was joined by Dr Libala and Ms Chere

Figure 7: Participants of the Tanzania APP Workshop held on 2 December that was joined by Drs Libala and Tessema

Exploring the impact of learning catalysed from the RESBEN Project: A value creation approach

The project is exploring the value catalysed for coordinators, facilitators, participants and stakeholders from their involvement and participation in the RESBEN Project. The Adaptive Systemic Approach is being affected through a series of social learning engagements, which cumulatively seek to support engaged social-ecological research processes across six African Case studies. The impact of the Project can be evaluated by exploring the different forms of value catalysed for participants as they engage in the collective social learning engagements facilitated through the course of the Project. Value creation-related data is being collected through observation within group engagements, reflection survey results after engagements, analysis of project outputs and key informant interviews. This research process is being led by Dr Matthew Weaver (Hub postdoctoral fellow) in collaboration with Dr Rebecka Henriksson (UKZN Early Career Researcher), Ms Ntombiyenkosi Nxumalo (UKZN Research Assistant) and Prof. Tally Palmer. To date, a total of approximately 200 value creation survey reflections have been collected from project engagements. Currently, the research team is in the process of conducting key informant interviews and concurrent data analysis.

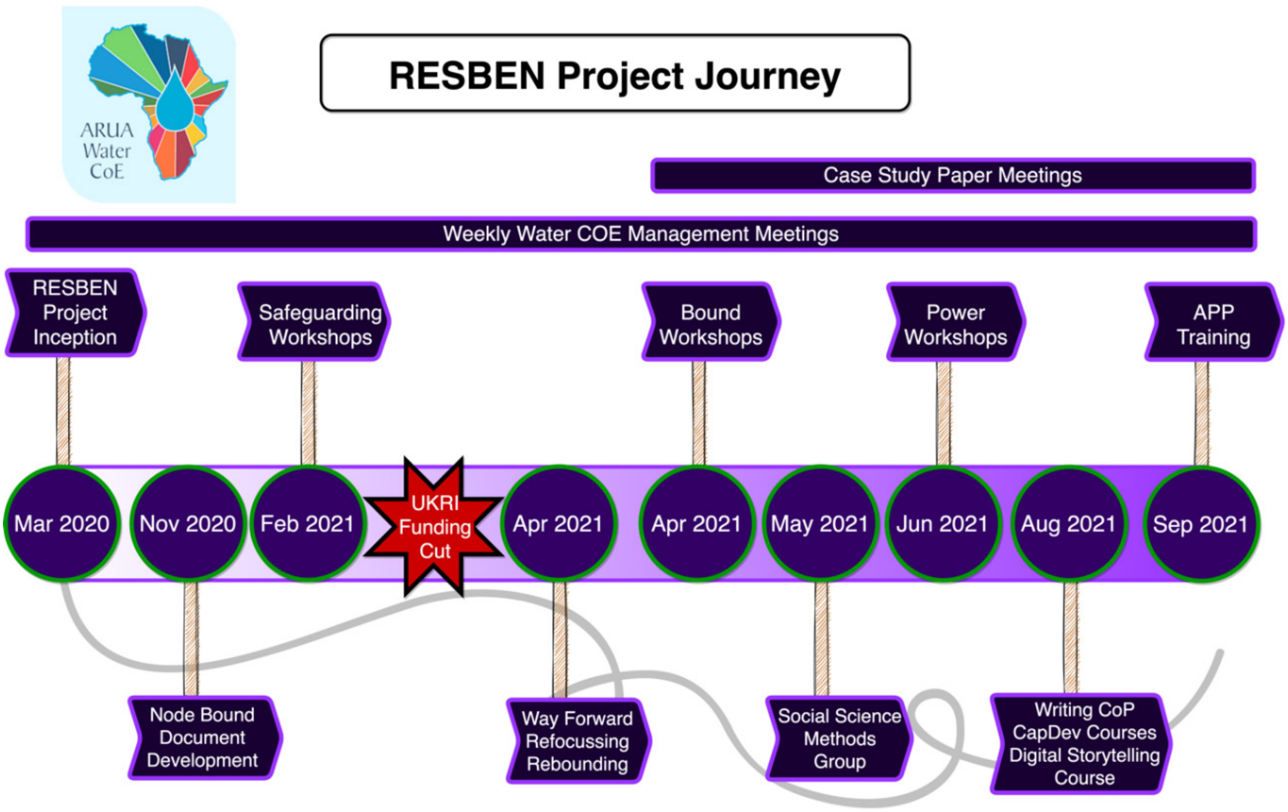


Figure 8: The cumulative RESBEN Project engagements that are included in the Value Creation research process

Safeguarding Training

A requirement of the UKRI funding is safeguarding practices that need to be in place at each University of the Water CoE. Lucy O'Keeffe, a South African-based organisational development consultant and a qualified coach with experience of organisational leadership, programme design, implementation, and management, primarily in the NGO sector, was appointed in 2020 to research the safeguarding policies in place and to make the staff and research assistants of the CoE aware of the practices required by the funder. Lucy works with Ms Arusha Sturgeon who is a UK-based psychiatric nurse and specialist safeguarding practitioner. Due to the Covid-19 pandemic regulations, it was decided to provide online safeguarding training for all Nodes via the same service provider. Lucy conducted safeguarding workshop with all the Nodes, including their Human Resources representatives, during late 2020 and early 2021; two follow-up workshops were offered in November 2021 for those Research Assistants and Early Career Researchers who were not able to attend the first set of training workshops. A comprehensive report of the interactions and policies is being prepared by Lucy for submission to UKRI as part of the Monitoring, Evaluation and Learning (MEL) Report.

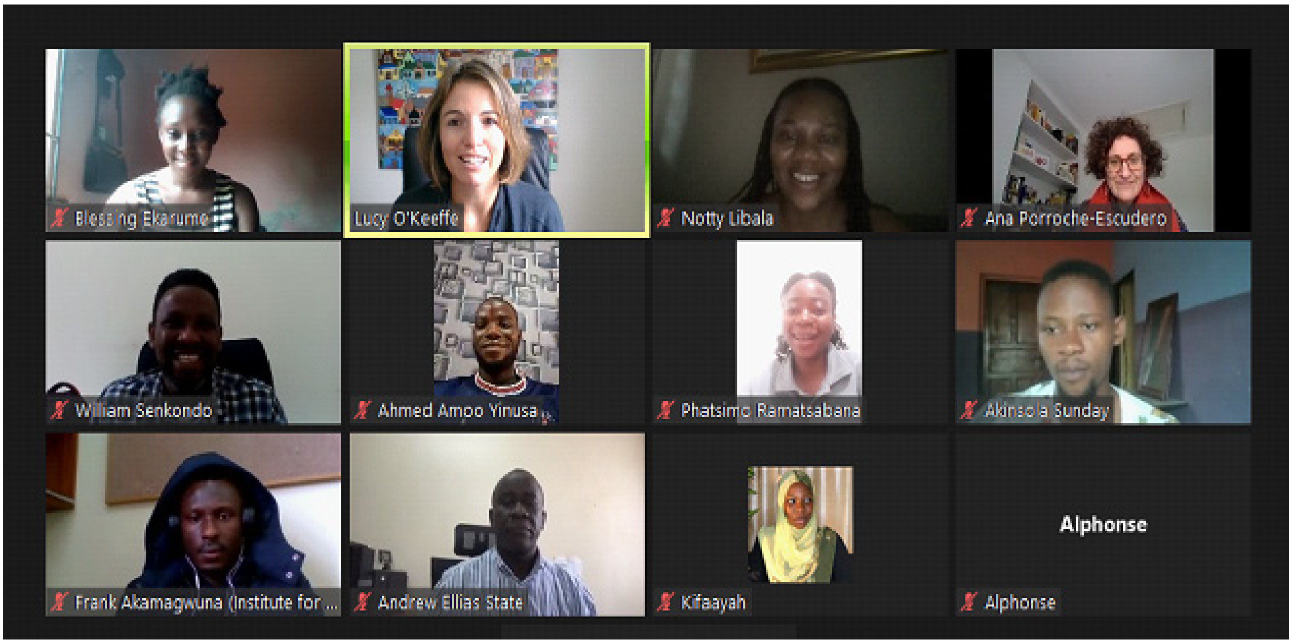


Figure 9: Safeguarding workshop on 8th November 2021

Water for African SDGs (UKRI Capacity Building Grant)

Prof. CG Palmer (Director), Dr JL Tanner (Co-Director)

September 2019 – August 2022

Sponsor: UKRI-GCRF
Collaborators: Prof. Zerihun Woldu (Addis Ababa University, Ethiopia, Co-Director), Prof. Noble Banadda / Assoc. Prof. Isa Kabenge (Makerere University, Uganda), Prof. Serigne Faye (Cheikh Anta Diop University, Senegal), Prof. Ezechiel Longe (University of Lagos, Nigeria), Prof. Joel Nobert (Dar es Salaam University, Tanzania), Dr Nsengimana Venuste (University of Rwanda, Rwanda), Prof. Kevin Winter (University of Cape Town, South Africa), Prof. Seifu Gurmessa (University of KwaZulu-Natal, South Africa)
Project website: https://www.ru.ac.za/iwr/aruacoe/

The ARUA-UKRI research programme Capacity Building Grant supports 13 ARUA Centres of Excellence, with the Water CoE project, *Water for African SDGs*, being one of them. The aim of the project is to establish and develop the ARUA Water CoE as an effective, high-performance, hub and network of nine African Universities' researchers and postgraduate students. The CoE plans to use research to catalyse change towards social and ecological justice and sustainability, paying attention to the African community water and sanitation needs. The project team brings together diverse strengths in the area of water, so the Nodes can flexibly link and innovatively respond to research funding calls, and effectively apply research.

The project objectives are:

1. Create a Community of Practice (CoP) of African scholars particularly Early Career Researchers (ECRs) conversant with water resources management in relation to the SDGs, with a complex social-ecological systems lens.
2. Provide African scholars, particularly ECRs with exposure to international facilities and scholars.
3. Provide support for scholarly performance e.g., through publications and project proposals which are closely linked with the Research Excellence grant and through postdoc support of writing.

The Capacity Building Grant proposal was envisioned to include capacity-building, exchanges, and training, and it plays a supporting role to the larger RESBEN project (detailed above). As noted in last year's report, we were not able to proceed with the originally planned in-person courses and therefore we had conceptualised a shift in the delivery of the project through transferring of in-person courses to online open courseware courses. This plan was shifted once again following the news about the 50% cuts to project funding by UKRI for the 2021/22 financial year. We also had to reorganise our capacity, time and efforts and focus attention on the delivery of the larger Research Excellence grant since at the beginning of 2021 there was no guarantee of funding past March 2022. We, however, delivered on several capacity building training and support events.

Mindfulness Based Living Course for IWR staff, students and the ARUA Hub team

To deal with the high levels of stress and worry experienced by the CoE staff, we reached out to Mrs Alexandra Johnson, a long-time facilitator of mindfulness practices based in Makhanda. The purpose of the Mindfulness Based Living Course was to offer mindfulness practices to staff and students which could help them to manage stress, and to increase connections between the course participants outside of academia. The course was run online on Zoom during working hours to encourage participation without having to commit extra personal time. The course was offered to all IWR colleagues who were interested and nine individuals (two staff, two postdoctoral fellows and five students) took up the opportunity. Holding the course online had the advantage of including members of the Institute who were overseas or living outside of Makhanda.

Overall feedback from the course was positive. Those who had previous experience with Mindfulness training benefitted from re-engaging with the practices and having the support of connection and regular meeting with a group. For participants who were new to mindfulness practices, they were pleasantly surprised at how much it helped them to learn new ways to manage their stress and engage with difficult emotions. Some expressed a noticeable reduction in their anxiety levels. One student suggested that the course be made compulsory, because even those who would be resistant to the idea would find benefits if they participated. Another participant expressed that "*the course opened my mind and paved me to always stick to the concept, 'I am the custodian of my mind and health'*". Feedback from one staff member on buddying up with students was that to "*hear their voices and how they felt that they benefitted was fantastic in helping me realise how beneficial this practice is*". In future, the Institute will consider holding similar courses for more people to benefit.

Training and support for the CoE Early Career Researchers and Research Assistants

Since the ASA approach used for the RESBEN project is novel, each African Node was offered a place for an Early Career Researcher or a Research Assistant in a short course held by the Environmental Learning Research Centre (ELRC at Rhodes University) titled *Facilitating Social Learning and Stakeholder*

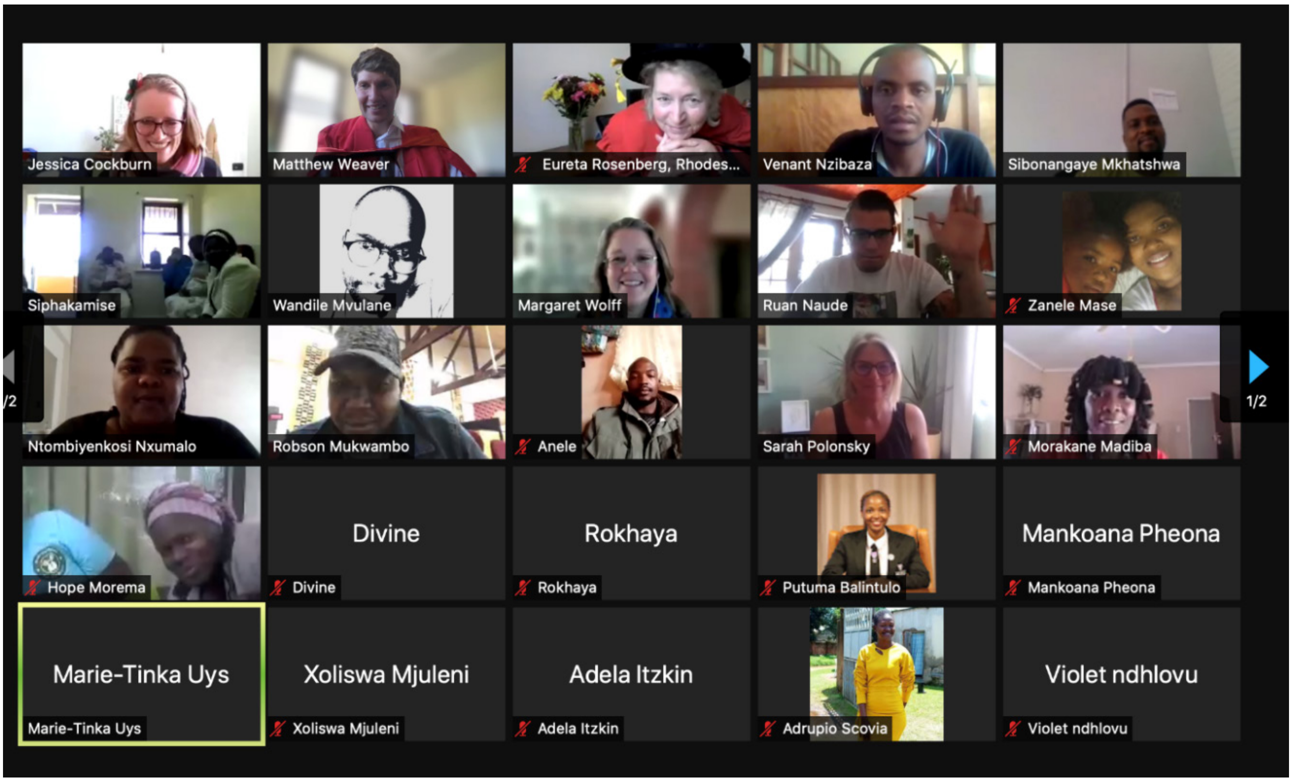


Figure 1: Training of Trainers graduation ceremony on 6th October 2021

Engagement in Natural Resource Management Contexts, or a 'Social Learning Training of Trainers' course. The course was led by Dr Matthew Weaver (Hub postdoctoral fellow) and Prof. Eureta Rosenberg from the ELRC. The attendance of the Water CoE Early Career Researchers and Research Assistants was funded by Prof. Palmer's National Research Foundation (NRF) Community Engagement Research account (Challenge and Mitigation Measure). The course comprised four modules to inform and strengthen the existing and future learning and stakeholder engagement facilitation practice of educators, trainers, and facilitators in Natural Resource Management contexts with up-to-date theory and methodology. The course had a strong practical element to it and much of the learning took place as participants engaged with their tutors to develop their assignments. Each of the modules and their corresponding assignment built upon one another culminating in the design, implementation, and evaluation of the learning and/or stakeholder engagement process. The course content and assignments linked to and strengthened existing and future learning and stakeholder engagement practice of researchers involved. The graduation ceremony of the course was held on 6th October 2021. Participant assignments underwent rigorous moderation to determine competency. Passing the course earned the participant a Certificate of Competence recognised under the National Qualifications Framework (NQF Level 5), thereby significantly contributing to their personal career development.

Another support mechanism for the Water CoE Research Assistants is an on-going paper writing community of practice (CoP) course, which is coordinated by Dr Matthew Weaver and Dr Notiswa Libala from August 2021 to January 2022. As part of this CoP, the team is participating in a Rhodes University facilitated Publication Course to develop a journal article from their individual research. Each CoE Case Study Node has agreed to submit a paper based on the Node's research by early 2022. The purpose of the CoP is to provide support to help make this commitment a reality. The paper writing process is facilitated by Dr Sherran Clarence and a complementary course on *Data Management and Analysis* that was led by Dr Kathleen Smart (postdoctoral fellow at the IWR). The Writing CoP covers topics from plotting and focussing the paper to developing paper structure, journal submission and peer review. The participants meet every two weeks to receive guidance and discuss their progress.

The design of the *Data Management and Analysis* course by Dr Kathleen Smart was based on a poll of the CoE Research Assistants regarding their availability and needs for their research and planned paper. The responses indicated that most of the interest was in qualitative and quantitative analyses. The course covered some open-source datasets where limited data are available in the catchment, in addition to building skills in R software for running statistics. A second follow-up online course is planned for early 2022 and its content will be based on training needs identified by the participants.

Digital Storytelling Workshop for the Third ARUA Biennial Conference

The Water CoE hosted an online symposium at the Third ARUA Biennial Conference which ran from 17-19 November 2021. The focus of the conference was on *Global Public Health Challenges: Facing them in Africa*. This theme is significant given the health challenges Africa is facing at present from the Covid-19 pandemic. The conference had six parallel sessions of African speakers over the three days with several international keynote addresses relating to research on epidemiology, immunology, and infectious diseases.

The theme of the CoE workshop was titled *Digital Storytelling of African Water Challenges: Links to Human Health and Well-being*. The goal of the workshop was not only to feature the CoE's work, but also to highlight the use of digital storytelling as a tool for enhancing knowledge co-creation and awareness raising for water challenges in Africa. Digital storytelling is an ancient and modern tool for sharing knowledge, experiences, and innovations around a topic of interest. In the research arena, it is a useful tool for educational purposes, disseminating research findings and ideas, and for providing a platform for a range of stakeholders to have their voices equally heard.

During the Symposium there were two storytelling sessions led by Node ECRs on a) Water pollution and development challenges faced in African cities, and b) Water allocation and access challenges in rural African landscapes. The ECRs presented and discussed the videos they had created in a week-long Digital Storytelling course run by the Rhodes University Community Engagement group with co-facilitation provided by Mr David Forsyth (CoE IT Manager) and Dr Sukhmani Mantel (CoE Academic Manager). The recording of the workshop is available on the ARUA Water CoE YouTube channel www.youtube.com/watch?v=-K0FdopqxM8

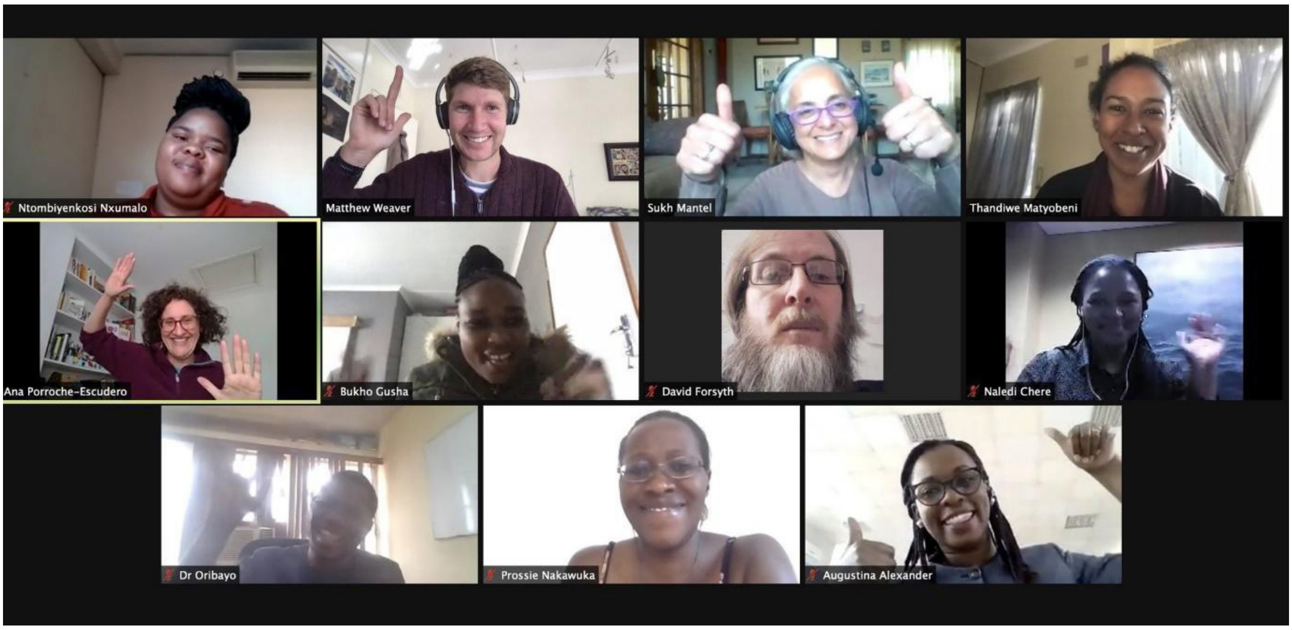


Figure 2: Participants of the Digital Storytelling course attended by Early Career Researchers from ARUA Nodes

The workshop was attended by 34 people including representatives from our Water CoE African Nodes and other international guests. The main successes and outcomes of the workshop included:

1. Showcasing the work of the Water CoE on an international front to generate awareness and foster potential future collaborations.
2. Showcasing how the CoE work links to the SDGs, contributing particularly to SDG6 on clean water and sanitation for all.
3. Demonstrating the use of digital storytelling as an innovative and accessible tool to generate awareness around local water challenges and to communicate scientific research findings to civil society and local water managers.
4. Discussing how digital storytelling could be used in future work of the Water CoE to forefront the voices of local communities who are usually marginalised in local water management decision making. The ECRs were given advice on how they could improve the use of digital storytelling in this area from other more experienced practitioners in the water sector.

The Water CoE workshop generated excitement and presented an opportunity for our partners to further explore the use of this tool in their water related work. We believe digital storytelling is a relatively new and valuable way to reach stakeholders in Africa, considering the wide reach of such a tool (including people who cannot read) under challenging situations of water availability, sharing and usability, and the projected impacts of climate change.

Tsitsa Project: governance community of practice

A Fry, N Libala, M Ralekhetla, N Mti, A Ntshangase and CG Palmer

April 2018 - March 2021 (extended to September 2021)

Sponsor: **Department of Forestry, Fisheries and the Environment: Natural Resource Management**
Collaborators: **Department of Environmental Science, Environmental Learning Research Centre (ELRC), Geography Department, Rhodes University**

The Tsitsa Project (TP) is an initiative by the South African government's Department of Forestry, Fisheries, and the Environment: Natural Resource Management (DFFE: NRM). The Tsitsa Project was envisioned as a 10-year (2015-2025) landscape restoration project in the Tsitsa River catchment which forms part of the greater Mzimvubu River - a key water source for the future development of the Eastern Cape. The Tsitsa Project has acknowledged the interconnectedness between humans and nature and has adopted a Complex Social Ecological Systems approach, in which participatory governance is seen as having the potential to increase the long-term impact of the project, contributing towards a healthy landscape which supports livelihood and human well-being.

Participatory governance research was initiated as a core process undertaken by the TP's Governance Community of Practice (GOVCoP) which is housed within the IWR's adaptive water resource management research group. The purpose of the GOVCoP is to leave a catchment where local people listen and speak knowledgeably and contribute to decisions that influence their lives. This work is guided by a five-step governance capability pathway: co-knowing, co-listening and co-speaking, co-planning, co-influencing, and co-deciding. On a national scale, the GOVCoP aims to contribute to the realisation of more participatory forms of natural resource management in South Africa by contributing to the advancement of engaged, transdisciplinary research and by engaging with policy.

In 2020, the GOVCoP focused on developing listening and speaking capabilities within the group of catchment-based monitors hired by the TP; this work built off the common terminology and understandings co-created as part of the co-knowing phase in 2019. In 2021, the GOVCoP and the TP monitors were involved (as tutors and participants) in the *Facilitating Social Learning and Stakeholder Engagement in Natural Resource Management Contexts* short course which introduced participants to stakeholder engagement in natural resource management contexts which involved steeping learning curves for everyone involved as we began learning online. This course was coordinated by Dr Matthew Weaver with support from a team from the ELRC. Improving our ability to interact online has been necessary as many governance engagements have moved online and shifted the landscape of participatory governance.

Furthermore, the GOVCoP contributed to the compiling the 'Tsitsa Approach', which synthesised the approach taken by the Tsitsa Project with specific recommendations as to how it may be taken into the mainstream of the DFFE:NRM's work. Part of this process included the GOVCoP contributing two 'practice and policy briefs' which will be released as part of a series by the Tsitsa Project.

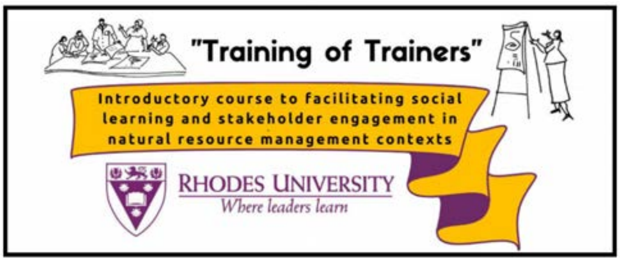


Figure 1: 'Training of Trainers' course in which various GOVCoP members were involved

Social learning and sustainable development community of practice: adaptive systemic approach to natural resource governance

AS Fry, N Libala, MJT Weaver and CG Palmer

March 2021 – December 2022

Sponsor: National Research Foundation
Collaborators: Led by the Environmental Learning Research Centre (Rhodes University) with collaborators such as the African Climate & Development Initiative (University of Cape Town), the Global Change Institute (University of Witwatersrand) and the Institute of Social & Economic Research, University of Fort Hare.

The Social Learning and Sustainable Development Community of Practice (CoP) aims to act as an interface between social learning processes and sustainability science knowledge production. By bringing together a diverse set of researchers and practitioners, the CoP aims to strengthen and support transdisciplinary research initiatives and practical sustainable development work. The CoP focuses on creating knowledge that can be presented in a way that has real policy and practice outcomes, addressing the science-policy-practice interface.

The longer-term vision of the CoP is to systemically influence formal and informal education, training, and skills development in South Africa. By bringing together sustainability scientists from a variety of backgrounds together with education, skills and social learning practitioners and academics, the CoP crosses the current boundaries which inhibit sustainability science from influencing the national education system, training, and social learning processes.

The IWR's involvement in the CoP thus far has been a series of knowledge sharing events. Most importantly being the National Environmental Skills Summit hosted by the Environmental Learning Research Centre in which the IWR supported the organising and presented a set of policy briefs which layout different parts of the adaptive systemic approach to natural resource governance adopted by the IWR.

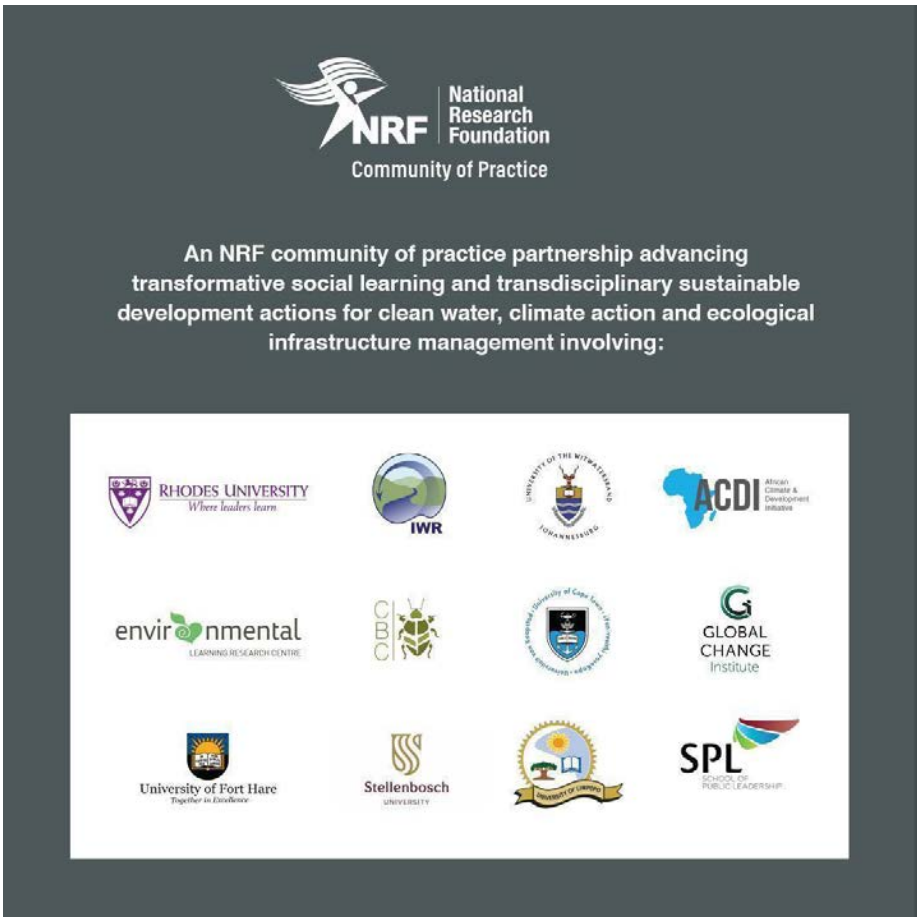


Figure 1: The various partners associated with the social learning and sustainable development community of practice

POSTGRADUATE ACTIVITIES

Participatory land and water governance in the Tsitsa River Catchment, South Africa: uncovering leverage points in a complex system

Student: AS Fry
Supervisors: CG Palmer and JK Clifford-Holmes
Degree: PhD (Water Resource Science)

Globally, we face unprecedented environmental crises that are increasingly being attributed to human impact on the environment. As conventional and intuitive solutions fail, the negative impacts of these crises will continue to disproportionally impact vulnerable communities. It is necessary to improve our ability to systemically understand the interaction between social and ecological systems to enable the emergence of more fundamental transformations at multiple levels and scales. Given the complex nature of natural resource governance, participation and collaboration are regarded as an important mechanism for enabling a more just transition. The legislation promoting participatory processes is well supported; however, there is considerable disagreement about what is meant by participation and how it can be achieved meaningfully.

Embedded in an innovative sustainable land management project, the primary aim of this thesis was to unearth high leverage points for enabling participation within the system of land and water governance in the Tsitsa River catchment in the Eastern Cape of South Africa (SA). The Tsitsa River catchment falls on the edge of the former Transkei homeland within one of the worst socio-economically performing municipalities in South Africa. The formal and informal governance institutions working within the Tsitsa River catchment face the challenge of maintaining the ecosystems on which people rely, while securing adequate service provision to communities not yet provided for. This system is aptly considered a complex social-ecological system (CSES).

Figure 1: Institute for Water Research researchers, Tsitsa Project catchment-based monitors and residents from Village 5 (in the Hlankomo traditional area, between Nqanqarhu and Mount Fletcher) discuss the landscape.

Transdisciplinary research has been proposed to engage with CSESs in order to identify ways to enable just and sustainable transformations. As transdisciplinary research requires working across disciplines and outside of academia, this shift to more engaged research requires new ways of working. Firstly, I analyse governance structures through a series of actor mapping processes that revealed three nested, but disconnected stories of governance. These stories are based on different assumptions, have different vocabularies, and operate on different temporal and spatial scales. Secondly, an engaged and systemic analysis of participation makes use of qualitative system diagrams to explore the interconnectivity of important variables influencing participation in this system of land and water governance. This systemic analysis highlighted the influence of the social and economic challenges on participation and the lack of local governance capacity to implement policy and guidelines conceptualised at the national level. The findings reaffirm the well-acknowledged lack of meaningful participation and collaboration in South Africa's current land and water governance system.

Finally, the results are synthesised into a set of potentially high leverage points which revealed a necessary reorientation towards multi-dimensional trust and creating shared understandings while acknowledging the need to build governance capabilities across formal and informal governance spaces if improved lives and livelihoods are to be realised. This thesis contributes to the growing efforts to bridge the gap between science and the practical realities of everyday life and I have explored what it means to work between groups and sectors in society as an engaged citizen/researcher working to solve the daunting challenges we face as a society.

The value of ecological infrastructure related to participatory governance processes in the Tsitsa River Catchment, Eastern Cape, South Africa

Student: AK Ntshangase
Supervisors: MJT Weaver and CG Palmer
Degree: MSc (Water Resource Science)

South Africa is facing high levels of environmental degradation which has resulted to some of its population living in ecologically degraded areas. The environmental degradation in the country is prevalent as a result of both human and climatic factors. An example of human-induced factors contributing towards environmental degradation is poor land use and management practises. These poor practices are causing ecological infrastructure in catchments to deteriorate. The degraded ecological infrastructure is having significant consequences on people's livelihoods and the economy of the country at large. In South Africa, ecological infrastructure supports the country's development objectives related to poverty alleviation, rural development and job creation.

It is acknowledged that most key ecological infrastructure elements are located in rural areas. In rural areas, ecological infrastructure normally mediates built infrastructure to support local livelihoods. However, despite the importance of ecological infrastructure to rural communities, the most deteriorated ecological infrastructure is located within these areas. The main factors driving the deteriorating ecological infrastructure are human-induced activities. These activities include but are not limited to, inappropriate land use, poor land management practises, proliferation of invasive alien plants and overpopulation. Therefore, it is important that rural communities become aware of the interrelationship between them and the functioning of ecosystems in their landscapes.

This study will be using the Tsitsa River catchment to explore how the interrelationship between people and ecological infrastructure can be used to develop participatory land and water governance in the catchment. Firstly, the study will provide a desk-top-based integrated analysis of biophysical and social elements and their relationships from the Tsitsa Project's research output repositories, in order to develop the current understanding of local people in relationship with ecological infrastructure. FThen the integrated analysis will be used to reflect the findings to the communities in the catchments and enrich the understanding of the social-ecological relationships. Lastly, this study will investigate the value of ecological infrastructure as a basis from which to enhance participatory landscape governance.

Figure 1: Degrading rangelands in Tsitsa River Catchment

Exploring the nature and meaning of participation in engaged land restoration project: a question of epistemic injustice

Student: M Ralekhetla
Supervisor: CG Palmer and S-A Paphitis
Degree: PhD (Water Resource Science)

While the concept of participation was initially positively received by many in the field of natural resource management, some concerns have been raised, particularly relating to the practicality of the promises made in the theory of stakeholder participation. The status of participation as a 'hurrah' word, which brings warm glow to its users and hearers, blocks its detailed examination, conceals the competing frames of meaning, masks the fact that participation can take on multiple forms and serve many different interests. The question remains, what constitutes real, meaningful participation that benefits all who engage? This is an important question because unmet expectations could lead to tokenism and failure to experience benefit. The Tsitsa Project offers an interesting context within which to explore critical questions of participation because some researchers engage with stakeholders in the catchment, at different scales, with a 'participatory intention'.

Social forms of injustice, such as epistemic injustice, are usually a result of power dynamics that become the primary challenge to sustainable participation. However, in these participatory settings, stakeholders see those higher up on the pyramid as having less credibility because of issues of citizens having lost faith in the administration or participatory projects do not hit matters of urgency for the stakeholders. I suggest the collection of narratives of participation because they reveal the reality of participatory processes in a more encompassing, complex and nuanced way. They are constructed through lived experiences and the meanings created, and can therefore give meanings that the different people who engage in the Tsitsa Project attach to the concept of participation based on their lived experiences. Addressing experience issues across the competing frames could mean avoiding tokenism, and lead to meaningful and ethical ways to understand participation.

Methods

Narrative approach or narrative inquiry was used for this research. It relies on the basis that stories can reveal the identity of the narrator, and give a context of how they view the world or how they construct meaning of the world. Narrative inquiry also highlights the factors that produce change and motivate the actions of the informants.

Narrative interviews were conducted with catchment residents, members of the Rhodes University research team, community engagement facilitators, and funders. The majority of the interviews were conducted via Zoom platform, due to the restriction of movement during the Covid-19 crisis. Advantages of using Zoom to collect qualitative data include: rapport, convenience, and user-friendliness.

Poetic analysis was considered the best method for data analysis. Poetry is an arts based approach, which holds potential to appeal to a wider range of audiences, especially the subjective experiences of the humans in a Complex social ecological system. Appealing to a wider audience is also helpful in the transdisciplinary kind of work that the Tsitsa Project engages in, in order for the different stakeholder groups to easily understand each other's subjective experiences of participation, so as to understand each other's meaning of true and beneficial participation.

Findings

Since analysis is currently still ongoing, below are examples of how the research poems are coming along, with each stanza from a different narrative. With just a glimpse at both, one can tell the context of how meaning was given, and some factors that motivated actions in the narrators' actions.

It's like they force me to participate,
When they call my name,
Asking for my thoughts;
I like it when I do have the answer,
But sometimes I don't.
It reminds me of my high school days,
I did not raise my hand,
But I would get it right when selected.
I misjudge myself.
I'm not sure;
I doubt if it's really correct.
It stings when someone saying what you were thinking,
But you missed out
Because you did not raise your hand.
So, being picked,
I feel more confident because
You can see me, you can read me.
It's not a fully bad thing, but it's not good either.

When I started working for the Tsitsa project,
The language barrier frustrated me.
It was my first time
Working with people who speak English,
Speaking English made meuncomfortable;
They tried translation,
But communication was not effective.
I thought to myself, should I giving up;
But my stipend came, and
Suddenly I could achieve certain things;
I decided to give it a chance.

Figure 1: The landscape of one of the villages in the Tsitsa catchment as modelled by its residents during one of the workshops. The idea was to tell us about their area, and they could use anything around them to create models. This is one of the participatory activities referred in some of the narratives.

Research Outputs

Peer review journals and conference proceedings

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