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# **WATERQ2: UNDERSTANDING WATER** **QUALITY & QUANTITY IN THE LIMPOPO BASIN**

Quarterly Report, 01 July – 30 September 2019

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Milestone #7

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## WaterQ2: Understanding Water Quality and Quantity in the Limpopo Basin

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Cover photo: Cape buffalo standing in Shingwedzi River, Kruger National Park, photo credit: Mackenzie Martin.

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# Project Information

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## INTRODUCTION

The transboundary Limpopo River Basin crosses Botswana, Mozambique, South Africa, and Zimbabwe. At over 400,000 km<sup>2</sup>, the Limpopo River Basin is home to 18 million people living in both rural and urban areas. Industries in the Basin include businesses in the urban areas and water-intensive uses such as agriculture and mining; industrial water use is growing rapidly. In addition to the human residents, the Basin contains some of the most biodiverse natural areas on the planet.

The rainfall in the Basin is heterogeneous with some sub-basins receiving less than 400 mm on average and other downstream sub-basins in Mozambique receiving over 750 mm annually. Even meteorological stations located in close proximity demonstrate substantial spatial variation within sub-basins. The Basin has experienced severe droughts in the last decade. In addition to the variation in the amount of rainfall, the timing, especially the start of the growing season, has varied significantly. However, there remain many questions about the reliability of rainfall data and other water measurements due in part to the infrequent calibration and validation of field site measurements. **The limited confidence in these data, combined with the substantial variation through time and space necessitates an integrated approach to improve data collection, validation, and overall Basin water resource management in the Basin.**

The goal of this project is to build resilience through the support of Basin stakeholders, including The Limpopo Watercourse Commission (LIMCOM), to improve governance around water resources management and water security in the Basin. A systems approach, such as integrated water resources management (IWRM) is needed to address such complex, large, and interrelated components of water resources. IWRM is recommended by the United States Agency for International Development (USAID) Water and Development Strategy Implementation Guide (2014). This context will be combined with data collection and validation, data sharing, and continuous evaluation of the interrelations that affect water resources.

This project will support water resources monitoring, and the development of methods for water quality and quantity measurement based on *in situ* sensors and satellite measurements. These **measurements** will enable characterization of water resource dynamics at the whole Basin scale and form the foundation for hydrologic **modeling** that can help estimate hard-to-measure parameters and also provide holistic assessments of Basin scale stocks and flows. To support data sharing, the project will use cloud-based, automated data collection and web-based **data sharing**.

The Development of local capacity to maintain water resources and make proactive, scientifically justified management decisions requires a substantial human capital resource that is currently lacking in the Basin. The project will provide training, workshops, and conferences will focus on integrated water resources management (IWRM) and environmental flow analysis.

The results of the water resources and biodiversity studies conducted will be compiled into a report for the Basin stakeholders. Continued high-quality data collection, training, and general logistics depends on dependable physical infrastructure. To support data collection efforts as well as training and collaboration the Limpopo Resilience Lab at the University of Venda will be established. The sustainability of lab activity will continue with the implementation of a small user fee beyond the duration of the project. Annual training workshops and conferences will be located at or nearby the Resilience Lab.

In this report, the collaborators, Duquesne University (Duquesne), Rensselaer Polytechnic Institute (RPI), and University of Venda (Univen) report their activities and progress in the second quarter (Q2) of project year 2019-20 (PY 2019-20).

# PROJECT ADMINISTRATION

## STUDENT PROGRESS

Master of Science candidate, Mr. Hilton Thivhloni Shimbabu, has submitted his thesis proposal to Univen after consultation with his research supervisors and project PIs, Drs. Edokpayi and Kahler. The proposal has been approved by Univen.

## EQUIPMENT

Univen has obtained a current meter and multiparameter water quality meter consistent with the items in the proposed budget.

# MODULES 1&3: WATER MONITORING

## HYDROMETEOROLOGICAL STATION NETWORK

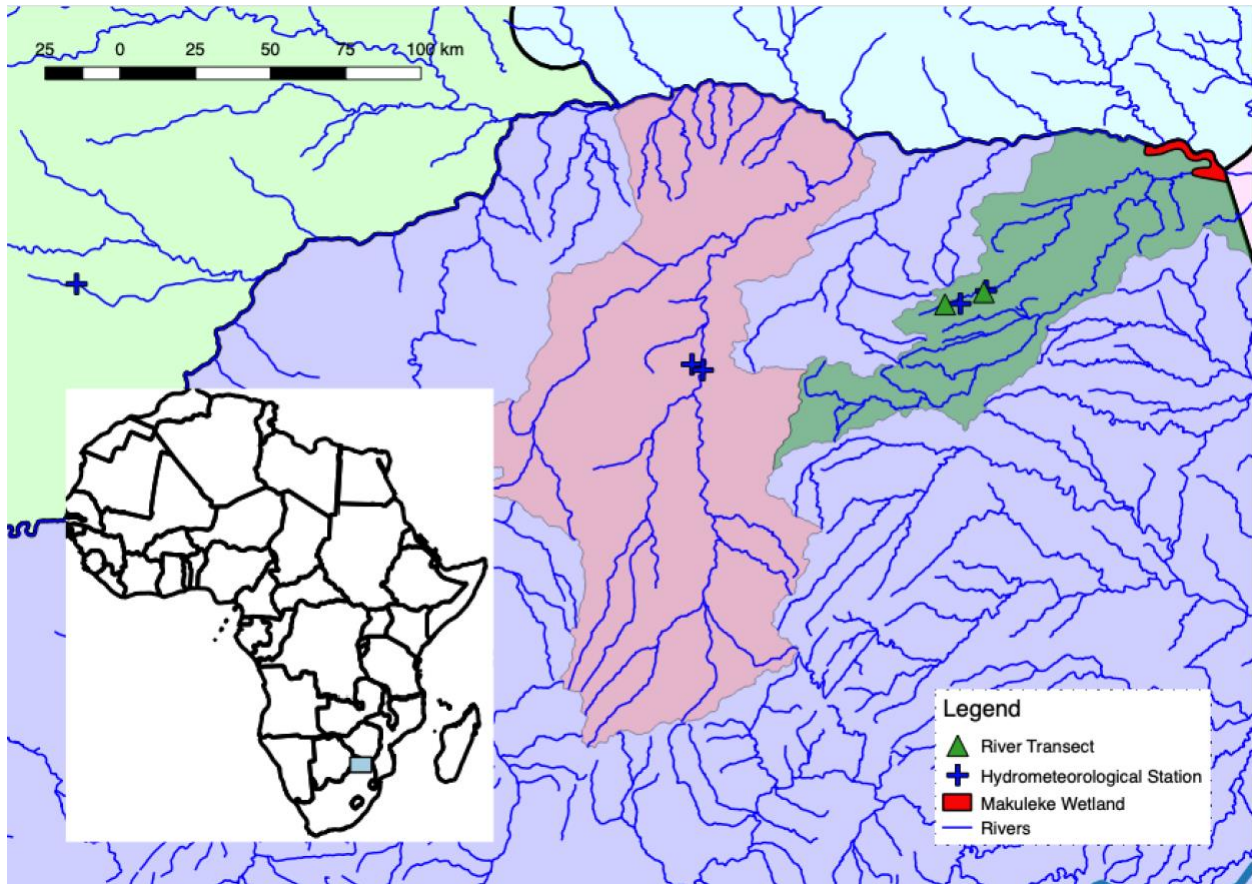


Figure 1: The Limpopo River Basin and Sand River catchment (pink) and Levuvhu/Mutare River catchment (dark green). The Basin spans Botswana (light green), Mozambique (light pink), South Africa (lavender), and Zimbabwe (light blue). Locations of installed and proposed stations, transect locations, and proposed groundwater investigation locations. The Leshiba Wetlands are located near the station in the Sand River.



Figure 2: photographs of the current stations: Mutale Weir (upper left), Mbehela School (upper right), Leshiba Wetland (lower left), and Medike Nature Reserve (lower right).

Stations were set up in key watersheds (Figure 1, 2) in the Limpopo Basin. Data are available through the Development Data Library, ([data.usaid.gov](https://data.usaid.gov)); however, users may find the map interface on the WaterQ2 project website to be more convenient to locate the data. The following stations have data available:

- Mutale Weir: <https://data.usaid.gov/Environment/Mutale-Weir/9ru6-b4nc>
- Medike Nature Reserve: <https://data.usaid.gov/Environment/Medike-Nature-Preserve/chfb-yzu5>



## **SATELLITE ALGORITHMS**

Work continues on the use of satellites to measure river discharge. Drs. Rose and Mlotha have begun work on measuring critical water quality parameters, specifically, turbidity and chlorophyll. For both projects, collaborators placed additional sensors at the Mutale River station during fieldwork in August. This expansion of the Mutale Weir and other stations is described in the Hydrometeorological Station Report available through the project website and introduced in this report above.

Satellite imagery for this research is from the Landsat mission (NASA, <https://landsat.gsfc.nasa.gov/>) and Planet Labs, Inc. (planet.com) *Education and Research Program*. Additional work has been discussed with scientists at Kruger National Park.

## **WATER POLICY**

To support the work on national water laws and policies, and the human right to water in the Limpopo Basin, Duquesne has begun to catalog as many documents as possible in an online library collection. The Gumberg Library at Duquesne has supplied space within the institutional repository. The online library is linked through the project website and available at [dsc.duq.edu/limpopo](http://dsc.duq.edu/limpopo).

## **CITIZEN SCIENCE**

In the WaterQ2 Stakeholder Engagement meeting in August 2019 in Pretoria, participants expressed the need for citizen participation in water resources management. This participation would be part of a larger effort by national governments to educate the general public on water scarcity. Citizen science was proposed to address two challenges: first, the participation of the general public in water resources surveillance, and second, data acquisition and quality control for water resources data.

As an example, the United States Geological Survey (USGS) and the State University of New York at Buffalo (SUNY) have developed software that uses Google Voice and a server-side python script to collect river height data sent via text message (Fienen and Lowry, 2012). The experiment showed that the river level reported by the citizen science program was consistent with traditional data loggers (Lowry and Fienen, 2013). Researchers also determined several limitations of the program; such river-monitoring programs needed feedback to the community to encourage continued participation (Lowry et al., 2019). Data collection also benefited from particular members of the community becoming involved and engaged in data collection; these citizen scientists were consistent data collectors (Lowry and Fienen, 2013).

WaterQ2 would like to develop a similar system in the Limpopo River Basin to collect citizen-science-reported river height data. These data can be used to measure river discharge (flow) as long as collected where a rating curve (Leopold and Maddock, 1953) exists or can be established, can be used to either provide a data quality check or populate the data itself.

### **Currently Planned Solution**

- I. Citizen sees the river gage plate. Nearby there is a sign that explains that citizens are needed to verify river height for the accurate monitoring and provisioning of water. The sign has a whatsapp number on it that requests that citizens submit information on river gage height.

2. Signs will be individualized; one per location. Use existing codes for each site. Be intentional on where to put the sign, requesting that people take the picture from that specific location toward the gage plate.
3. On the sign, citizens are asked to either
  - a. text in the site code and gage height as a single text string (e.g., RIVERCODE 136, where “RIVERCODE” is the unique identifier code for that location and “136” is the gage height recorded in pre-determined units such as cm).
  - b. take a picture of the gage plate along with a text of the unique identifier
4. Then they send this information to a phone number or WhatsApp address (that looks like a phone number). A single number will work as long as all received texts are accompanied by the unique site identifier code.
5. We then process it into data, and assign some sort of confidence score to it.
  - a. Data includes: location, date/time, river gage height, submitter
  - b. Derived characteristics can then be calculated, such as the difference between river gage height measured by the person and the river gage height recorded by the pressure sensor.
6. The Department of Water and Sanitation can then either set up a link to the citizen-science database (essentially using citizen data as another sensor) or query it for a particular river when you need to recalibrate the sensors. A query for a particular station would return a set of height and time readings (We can also add additional processing/data if that would be helpful).

## REFERENCES

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- Lowry, C. S., Fienen, M. N., Hall, D. M., & Stepenuck, K. F. (2019). Growing Pains of Crowdsourced Stream Stage Monitoring Using Mobile Phones: The Development of CrowdHydrology . *Frontiers in Earth Science* .

## MODULE 2: TRAINING, WORKSHOPS, AND CONFERENCES

### PROJECT-SPONSORED EVENTS

Central to the work of the WaterQ2 project is gaining information from a range of stakeholders who work in the Limpopo River Basin and building collaborative relationships with these stakeholders. This section reflects the meetings held with stakeholders in August 2019. A comprehensive report is available through the Development Experience Clearinghouse ([dec.usaid.gov](http://dec.usaid.gov)) and linked from the project website.

The project also conducted a training workshop with students from the University of Venda on surface water measurement. This short course focused on practical river measurement techniques and data quality assurance.

### UNIVERSITY OF VENDA MEETING

The collaborators met with Professor John Odiyo, Dean of the School of Environmental Sciences at the University of Venda (Univen). The collaborators discussed the current initiatives under the USAID-funded WaterQ2 project and specifically the training programs that have been planned. Many of these training programs will be offered at Univen. The Dean was very excited for Univen to be part of the USAID grant and he looked forward to the upcoming training sessions. The WaterQ2 project also supports two graduate students and their research, and attendance for the Univen collaborators to attend and share their research at international scientific meetings.

The collaboration between the collaborators and the University of Venda has made this work in the local communities possible. The Dean of Environmental Science gave us his full support and offered to set up future talks and learning opportunities at the university, and invited the collaborators to present public lectures at the Univen to help increase awareness of the project and its goals.

Duquesne and Univen are drafting a memorandum of understanding (MOU) to formalize the relationship between the universities. This MOU will facilitate future research collaboration, and student and faculty exchanges.

### KRUGER NATIONAL PARK MEETING

The collaborators were invited to meet with staff from the Conservation Services and Scientific Services of Kruger National Park. These groups work in concert to fulfil the park's role as stewards of the vast natural resources within this protected area. As part of the Greater Limpopo Conservation Area and responsible for monitoring rivers of two transboundary watersheds (the Limpopo and the Komati river basins), Kruger staff play an important role in transboundary natural resources management.

The collaborators met with scientists at Kruger National Park to find out more about their current projects and their data needs. In discussions with the scientists at Kruger National Park, the collaborators identified several potential projects to enhance the research collaborations with Univen.



Figure 3: WaterQ2 collaborators Joshua Edokpayi, David Kahler, and Kevin Rose discuss aquatic species conservation in a riverbed with Kruger National Park Scientist Robin Petersen (left to right).

### Understanding temperature and turbidity effects on fishes of Kruger National Park

The rivers of Kruger National Park contain nearly 50 fish species, yet little is known about how these fishes respond to environmental perturbations or climate change. For example, the thermal tolerances of fishes are unknown. Temperatures have been increasing with unknown consequences. Additionally, Kruger maintains minimal environmental flows in Park rivers by having upstream dams release water during the dry season when flows fall below a legally defined minimum. However, dam releases are usually pulsed water from the hypolimnion of the water column, and the temperature of released water is substantially colder than the what is in the rivers beforehand. The ecological consequences of these pulsed dam releases and the rapid changes in water temperature are unknown; while they may preserve the minimum environmental flows, the cold temperature may have other adverse ecological impacts. Finally, agricultural growth throughout the Limpopo River Basin is correlated with an increase in river turbidity levels. Anecdotal evidence collected by Kruger National Park scientists indicate that the deep river pools, which are essential for the largest fishes, have been filling in. Yet it is unknown what this loss of habitat has on the biodiversity of the rivers.

### The impact of agriculture and sand mining on river ecology

Local agricultural production is a keystone for food security and jobs provisioning in South Africa. However, South Africa's Department of Environmental Affairs estimated that 1.5 million hectares is degraded. Erosion, mineral and sand mining, and lack of land management have contributed to land degradation, which has diminished agricultural productivity and increased river turbidity levels. CSIR has proposed engaging with stakeholders and land managers to establish strategies to rehabilitate land. The Olifants River catchment (see Figure 1) is one area that has been identified as an area of substantial land degradation. However, best practices guidelines for agriculture have not been established. Additionally, there is a growing sand mining industry in the Basin, which is unregulated, occurs on riverbanks, and whose ecological and water resources impacts are unknown.

### The hydrology of the Makuleke wetland

The Makuleke Wetlands is located along the northern border of the Park and adjacent to the confluence of the Levuvhu and Limpopo Rivers. The Makuleke wetland is 7,757 hectare, Ramsar-recognized wetland within South Africa (<http://www.saramsar.com/2015/06/makuleke-wetlands.html>, <https://rsis.ramsar.org/ris/1687>). The wetland consists of 31 pans; however, the groundwater-surface water interactions have not been investigated. The wetlands are important to support the unique biodiversity of northern Kruger and provide regulation ecosystem services of river flow and water quality in the Levuvhu and Limpopo Rivers.

### Plans with Kruger National Park

The collaborators will apply to conduct research activities within Kruger National Park. This will allow the collaborators to conduct the identified projects in the Park and access the Park research infrastructure. These projects currently include:

- Hydrologic investigation of the Makuleke Wetland with ERT and
- Water quality and its relationship to upstream land use in the Ollifants River.

## PRETORIA STAKEHOLDER MEETING

The WaterQ2 project is pleased to welcome our partner in research, the Council for Scientific and Industrial Research (CSIR) in Pretoria. CSIR graciously hosted the *Pretoria Stakeholder Meeting*. CSIR was also instrumental in the identification of key stakeholders in the South African government, other riparian state governments, and other scientific organizations near Pretoria. A two-day meeting was held at CSIR, Pretoria campus. The goals of the meeting were to learn from the stakeholders about their needs around:

- Module 1: Water Resources Monitoring and Modeling,
- Module 2: Stakeholder meetings, technical training, and scientific conferences,
- Module 3: Reporting and sharing information, and
- Module 4: Limpopo Resilience Lab and technical resources in the basin.

In the WaterQ2 project application, the collaborators planned to hold large stakeholder meetings at Univen and invite representatives from all of the riparian states (Botswana, Mozambique, South Africa, and Zimbabwe), relevant transboundary organizations (e.g. LIMCOM), and sub-national stakeholders. While gauging interest in the meeting, the collaborators were advised that representatives would likely not be permitted to travel for a week (the proposed duration and pragmatic for the longer journey) for a meeting with a new organization. The collaborators decided to change the stakeholder meeting format in favor of smaller meetings close to the centers of government. To start, the collaborators selected Pretoria to target representatives from stakeholders from the South African government. Representatives were invited (invitation Appendix A) from LIMCOM and the other riparian states and a representative from Botswana was able to attend. Future meetings are targeted for Maputo, Mozambique in January 2020 and Gaborone, Botswana in August 2021.

## RESILIENT WATERS MEETING

The United States Agency for International Development, Southern Africa Regional Mission has a large program on water security run by Chemonics, Inc. called Resilient Waters. This program is staffed in Johannesburg. In addition to staff from Resilient Waters attending the WaterQ2 stakeholder meeting, the collaborators were invited to meet with the Resilient Waters staff. The discussion included a discussion of the shared goals of these two programs and potential collaborations. Professor Willem presented his work on the Vhembe Biosphere Reserve.

Resilient Waters has issued an annual program statement with a grant program. Univen is interested in applying to this program to support continued activities within the Limpopo Resilience Lab.

## ENDANGERED WILDLIFE TRUST

Endangered Wildlife Trust (EWT) has a field station at Medike Nature Reserve and collaborative conservation agreements with Leshiba Wilderness Reserve, Sigurwana Lodge, and Lejuma Research Center. EWT received funds from World Wildlife Fund South Africa and the Coca-Cola Foundation to

remove invasive trees from the various farms and lodges near Medike Nature Research in the Sand River catchment in the Soutpansberg Mountains. The trees to be removed are the Black Wattle, or Acacia, *Acacia mearnsii* and *Eucalyptus Eucalyptus camaldulensis*. These trees are not adapted to water-stressed environments and have been shown to detrimental to groundwater resources (Le Maitre et al., 2002). The trees in this western Soutpansberg region are sparsely populated in contrast to the occurrence of timber farms with *Eucalyptus* trees and the spread of this invasive species in the eastern Soutpansberg. EWT's goal is complete eradication of these invasive species in the western Soutpansberg. The research component of this conservation measure is to monitor the water budget in these high-elevation catchments to determine if the removal of these trees increases the water resources that flow to the Sand River. The Sand River is dry through the Soutpansberg Mountains; these high-elevation catchments may be the most important water source for the agricultural region north of the mountain range.



Figure 4: WaterQ2 and EWT staff after a tour of the tree removal projects.

## TRAINING WORKSHOP: RIVER DISCHARGE MEASUREMENT AND MONITORING

**TRAINING OBJECTIVES:** participants should be able to:

- Apply empirical formula to the calculation of discharge
- Apply the mathematical relationships of hydraulic geometry to river gages
- Measure the discharge of a river with a current meter

Participants were provided the training outline with additional resources (Appendix E) and participate in hands-on training on river discharge measurement (Figure 10 and 11). Additionally, students will gain experience with an automatic level used in surveying (Figure 12) and other hydrology and water quality instruments as available.

## OTHER EVENTS

### GLOBAL LAKE ENVIRONMENTAL OBSERVATORY NETWORK (GLEON) CONFERENCE

Dr. Mlotha (as first author) has been accepted for a poster presentation to the GLEON 21 meeting in Ontario, Canada in November.

**TITLE:** Monitoring water quality in Limpopo River Basin, Southern Africa using remote sensing.

**AUTHORS:** Mlotha, J. M., Kahler, D. M., Edokpayi, J. E., and Rose, K. C.

**ABSTRACT:** Monitoring the quantity and quality of inland water bodies is essential for understanding ecological processes and providing water for human use. The ability to characterize water quality enables communities, governments, and the public to plan utilization of aquatic resources and manage pollution control programs for healthy aquatic ecosystems. While in situ monitoring is common in many regions, it is often not practical in many developing countries due to factors such as cost, potential equipment losses, and technical expertise. It is with this concern that geospatial technologies like satellite remote sensing imagery provide a useful tool to monitor water quantity and quality over large areas of land. In this current study, we report the use of satellite imagery to understand spatial and temporal variability of water resources in the region, focusing on remote sensing of turbidity and chlorophyll *a* as indicators of water quality. The Limpopo Basin is characterized by water scarcity compounded by a changing climate and ongoing drought. Both mining, wastewater discharge and agricultural activities are increasing in impact, and land use transformations appear to be reducing water quality. Our research indicates that publicly available imagery, such as Landsat, is adequate to characterize land use patterns and changes and assess water quality in large rivers during wetter times of the year. However, dry conditions, which are occurring more frequently, limit the applicability of publicly available imagery due to coarse pixel size. Complementing this, commercially available imagery enables characterization of water quality in smaller river and lake networks.

#### WATER INSTITUTE OF SOUTHERN AFRICA (WISA) 2020

The collaborators have been accepted for an oral presentation at WISA 2020. The abstract is an expanded abstract (Appendix D).

#### ASSOCIATION FOR THE SCIENCES OF LIMNOLOGY AND OCEANOGRAPHY MEETING, JANUARY 2020

Dr. Rose and others have proposed a session at the ASLO meeting.

**TITLE:** Big data ecology: leveraging large scale data sets to understand aquatic ecosystem structure and dynamics at macrosystem scales

**ABSTRACT:** Aquatic ecosystems are experiencing substantial pressure in many regions from population growth, urbanization, changing land use, invasive species, and climate change, among other drivers. To address these challenges, researchers are increasingly using large volumes of compiled field, model, and remotely sensed data, including from programs such as the EPA National Aquatic Resource Surveys (NARS), the USGS National Water Quality Assessment (NAWQA), the National Ecological Observatory Network (NEON), the Lake multi-scaled geospatial and temporal database (LAGOS), and satellites such as Landsat and Sentinel series. Analysis of these large datasets enable characterization and attribution of environmental patterns, variability, and change at macrosystem scales. In this session, we invite contributions that improve understanding of spatial and temporal patterns and dynamics in aquatic ecosystems at regional to continental scales. We also encourage contributions that describe improvements in analytical techniques (e.g., algorithms or software packages) for generating insights into aquatic ecosystems at these broad scales. We seek to highlight novel applications and advancements in using these tools and data sets to understand aquatic ecosystems and to synthesize similarities and differences in lotic, lentic, wetland, and coastal ecosystem responses to climate, land use, hydrogeomorphic, and other key drivers.

Proposed (to be convened) by W. Beck (US EPA), **M. Glines (RPI, WaterQ2)**, K. Hondula (University of Maryland College Park), **M. J. Mlotha (RPI, WaterQ2)**, and **K. C. Rose (RPI, WaterQ2)**

## **MODULE 4: LIMPOPO RESILIENCE LAB**

The collaborators have identified space available at the University of Venda, School of Environmental Science for the Limpopo Resilience Lab. The space will undergo a large cleanup and signage consistent with the Marking and Branding Plan. Univen is currently renovating additional laboratory space and the school administration may wish to distribute the functions of the Lab across several units within the school. In this event, consistent branding will be placed in each location.

The Limpopo Resilience Lab has unveiled the website. The website, which is the same as the project website, is named the Limpopo Resilience Lab in order to have continuity from this project to the ongoing Lab presence. The website is available at [duq.edu/limpopo](http://duq.edu/limpopo), with the site map (Appendix A) and usage information (Appendix B) available.



## MONITORING AND EVALUATION

### MODULES 1 AND 3: WATER MONITORING

There are two primary research activities that have continued in this quarter that are supported through this project. They all fall into USAID category, *Production Systems Research*, as they are a component of natural resources management: they are both in the *field-testing* phase of research. The two areas of research are:

- Satellite methods to determine river flow
- Satellite methods to determine water quality (e.g., turbidity and chlorophyll)

The investigators have already begun to prepare a manuscript on the river flow method, which will be submitted to USAID when submitted for publication. For the first quarter, no other activities have reached monitoring values.

**TABLE 1: MODULES 1&3 INDICATORS**

INDICATOR	DISAGGREGATION	CURRENT VALUE	PROJECT TOTAL
Number of technologies, practices, and approaches under various phases of research, development, and uptake as a result of USG assistance	Phase: Under research	0	2
	Under field testing	2	2
	Made available	0	0
	Demonstrated uptake	0	0
Number of peer-reviewed scientific publications resulting from USG support to research and implementation programs	None	0	0
Number of hectares of land under improved technologies or management practices with USG assistance		0	0
Number of datasets shared, which were generated as a result of USG assistance	Basin country	0	0

## MODULE 2. IWRM TRAINING, WORKSHOPS, AND CONFERENCES

Module 2 contains two primary components: convene stakeholder workshops and trainings; and convene future collaborators at conferences. The first stakeholder workshop has been scheduled for August 2019 at CSIR in Pretoria.

The project-level goals for these are to identify environmental champions and cultivate partnerships for future collaborations, especially with the Limpopo Resilience Lab. Project staff has been in close contact with CSIR, Kruger National Park, and Endangered Wildlife Trust. These groups will strengthen the network of water resources and biodiversity professionals in the area.

**TABLE 2: MODULE 2 INDICATORS**

INDICATOR	DISAGGREGATION	CURRENT VALUE		PROJECT TOTAL	
		Male	Female	Male	Female
Number of people trained in sustainable natural resources management and/or biodiversity conservation as a result of USG assistance	Sex	5	5	5	5
Number of water and sanitation sector institutions strengthened to manage water resources of improve water supply and sanitation services as a result of USG assistance	Institutional scale	0		0	

## PROJECT PROGRESS

### WORK PLAN PROGRESS

Table 3 outlines progress on work plan activities (outlined in the Mobilization Plan) and the ongoing research activities. As specified in the Project Description, the following activities were planned.

TABLE 3: PROJECT ACTIVITIES														
#	ACTIVITY	2019			2020				2021				2021	
		2	3	4	1	2	3	4	1	2	3	4	1	
	Startup activities: Mobilization Plan, Staffing, EMMP	■												
1	Establish meteorological, river, and groundwater stations, <i>Water Monitoring and Algorithm Development Report</i>	■	*				■							
1	Groundwater measurements (ERT), to be included in <i>Water Monitoring Report</i>		■		■		■		■		■		■	
1	Develop satellite algorithms	■	■	■	■	■	■	■	■	■	■	■	■	■
1	Develop hydrologic and water quality models	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Convene stakeholders in workshops		■				■				■			
2	Scientific conferences					■				■				
2	Training workshops		■	*	*		■				■			
3	Publish and present basin report				■	■	■	■	■	■	■	■	■	■
4	Launch Limpopo Resilience Lab				■	■	■	■	■	■	■	■	■	■
		■	Completed					■	In-progress/planned					

The activities marked with a star (\*) have been adjusted for scheduling purposes. Hydrometeorological data collection was scheduled for July 2019; however, due to scheduling, has been moved to August 2019. This results in a one-month delay of the first report on the locations and data collection outlined in Milestone 4. Additionally, the staff has decided to add training opportunities in January 2020 following

recruitment in the first stakeholder meeting. Groundwater investigations have also been delayed due to an unforeseen shipping delay.

## MILESTONE PLAN

TABLE 4: MILESTONE PLAN													
#	MILESTONE	2019			2020				2021				2021
Quarter:		2	3	4	1	2	3	4	1	2	3	4	1
1	Mobilization Plan	Apr											
2	Environmental Mitigation and Monitoring Plan	Jun											
3	Quarterly Report	Jul											
4	Water Monitoring and Algorithm Development Report		Dec*										
5	Stakeholder Workshop Report		Nov										
6	Annual Work Plan		Aug										
7	Quarterly Report		Dec*										
8	Quarterly Report				Jan								
9	Quarterly Report <sup>^</sup>					Apr							
10	LRL Website and Planning					Apr							
11	Scientific Conference						Jul						
12	Basin Report						Jul						
13	Quarterly Report						Jul						
14	Stakeholder Workshop Report							Sep					
15	Annual Work Plan							Aug					
16	Quarterly Report							Oct					
17	Quarterly Report								Jan				
18	Quarterly Report <sup>^</sup>									Apr			
19	Scientific Conference										Jul		
20	Quarterly Report											Jul	

21	Stakeholder Workshop Report	Sep
22	Water Monitoring: Two manuscripts	Aug
23	Annual Work Plan	Aug
24	Quarterly Report	Sep
25	Quarterly Report	Jan
26	Basin Report	Mar
27	LRL Continuity Report	Mar
28	Quarterly Report	Apr

Shaded items are completed or pending approval. It is recommended that the Milestone Plan be revised so that the annual cost share report, which was originally marked to occur for the reporting quarters #5, 9, and 12, will be included in quarterly reports, marked with a carrot (^), for reporting quarters #4, 8, and 12. The water monitoring report (Milestone #4) is also marked (\*).

# FINANCIAL

## PRIME RECIPIENT

Duquesne University has used project funds for the expenditures in Table 5. Duquesne University has used other funds for the expenditures in Table 6; these represent cost share.

**TABLE 5: PROJECT EXPENDITURES**

ITEM	Q2 EXPENDITURE	PROJECT TOTAL
Financial details have been withheld from the published report.		
<b>Total</b>	\$106,623.89	\$106,623.89

Notes: Student support is billed to accounts at the start of the University's fiscal year in June for the upcoming academic year.

Subaward payments are accounted in the budget justification letters provided (Appendix C).

**TABLE 6: COST SHARE**

ITEM	Q2 EXPENDITURE	PROJECT TOTAL
Financial details have been withheld from the published report.		
<b>Total</b>	\$0	\$52,049.46

Subawardee cost share will be accounted annually.

## APPROVAL

This Quarterly Report has been received and approved by USAID. This satisfies the requirements set forth in the Milestone Plan, item #7: Completion of Quarterly Report (Q2).

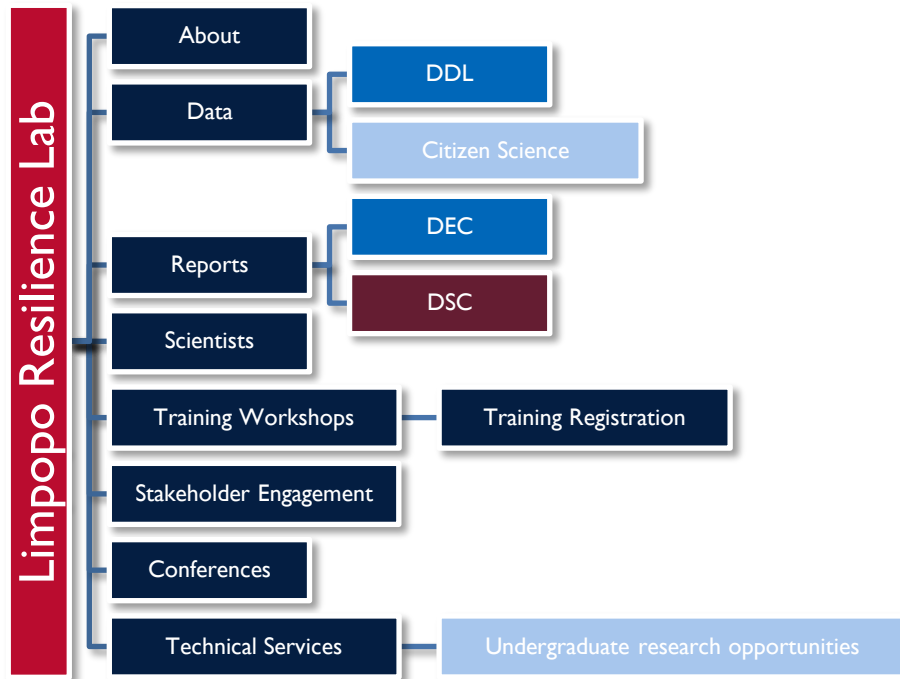
Signature: \_\_\_\_\_

Name: \_\_\_\_\_  
Agreement Officer's Representative

Date: \_\_\_\_\_

## APPENDIX A: PROJECT WEBSITE MAP

The project website is easily accessible by the link, [duq.edu/limpopo](http://duq.edu/limpopo), which points to the full universal resource locator at <https://www.duq.edu/academics/schools/natural-and-environmental-sciences/academics/departments-and-programs/environmental-science-and-management/limpopo-resilience-lab>. It is the intention of the collaborators to forge a long-standing relationship; this website has been named for the Limpopo Resilience Lab, which is the project’s sustainable entity, which will remain functional after the end of the current grant.



- Limpopo Resilience Lab (Duquesne University)
- Gumberg Library at Duquesne University
- USAID
- In-progress or proposed component

- Data are housed at USAID’s Development Data Library, [data.usaid.gov](http://data.usaid.gov). The collaborators are considering other databases better designed for scientific data.
- Reports will be housed at USAID’s Development Experience Clearinghouse, [dec.usaid.gov](http://dec.usaid.gov).
- Some materials that are not generated by the project will be stored on Duquesne University’s institutional repository, the Duquesne Scholarship Collection (DSC), [dsc.duq.edu/limpopo](http://dsc.duq.edu/limpopo).
- In preliminary discussions with the South Africa Department of Water and Sanitation (DWS), DWS has indicated willingness to ultimately host the database on their server. Currently, the testing software is hosted on a development server at RPI.



## APPENDIX B: WEBSITE TRAFFIC REPORT

The project website has experienced some traffic since going live; however, we expect the website traffic to increase as more materials are made available. Site visits have come from around the world (Figure B1) with a concentration from the United States of America and South Africa (Table B1).

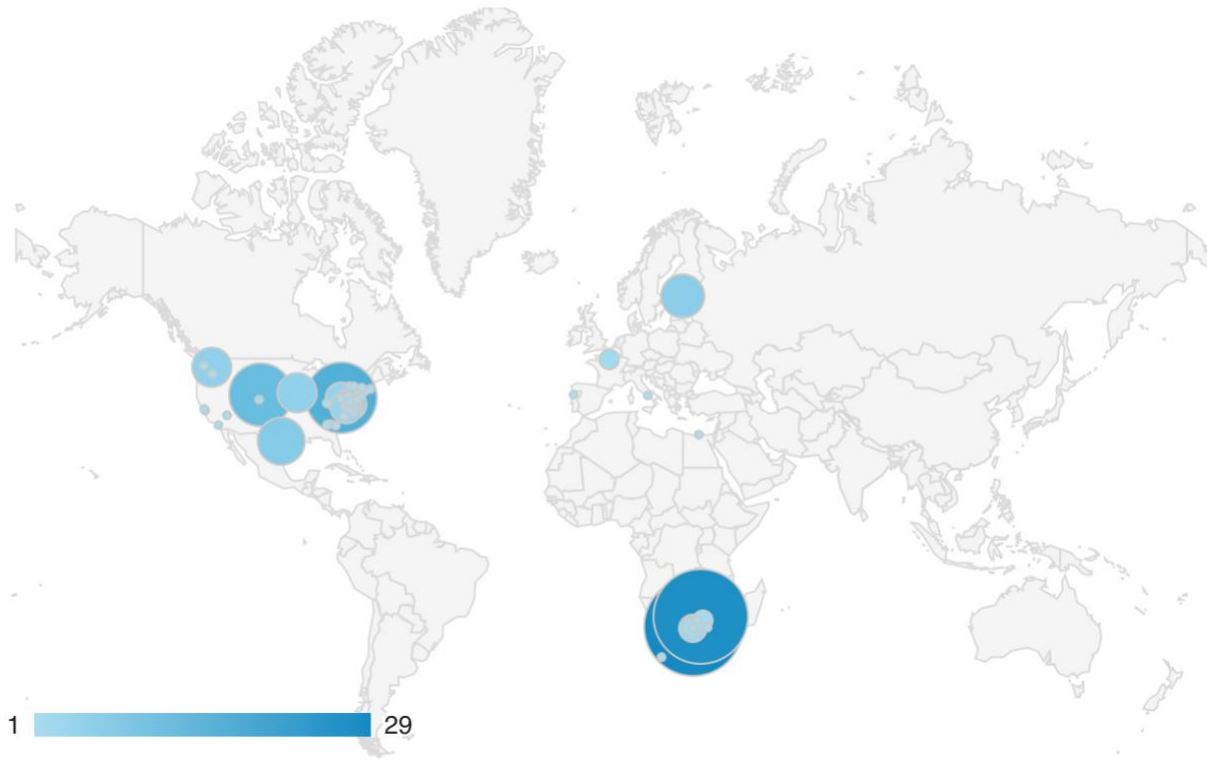


Figure B1: Map of audience for 01 June to 10 December 2019. Plotted are unique users for the period according to access of any page within the Limpopo Resilience Lab website (as indicated in Appendix A, excludes the DSC). Graphic from Google Analytics.

TABLE B1: GEOGRAPHICAL WEBSITE TRAFFIC REPORT FROM 01 JUNE TO 10 DECEMBER 2019				
COUNTRY	UNIQUE USERS	SESSIONS	PAGES PER SESSION	AVERAGE SESSION DURATION (H:MM:SS)
United States of America	116	161	1.94	0:02:24
South Africa	65	86	2.57	0:03:45
Italy	2	2	6	0:01:54
Egypt	1	1	3	0:18:03
Lebanon	1	2	1.5	0:04:18
Mozambique	1	1	5	0:17:17
Finland	6	6	1	0:00:00

France	2	2	1	0:00:00
United Kingdom	1	1	1	0:00:00
Portugal	1	4	1	0:00:00

Unique user access of the website (Figure B2) shows light use of the website except for the period of application for the upcoming GIS and Image Processing training offered at Univen in January. Data show the most frequently accessed page, other than the landing page, is the training workshops page.

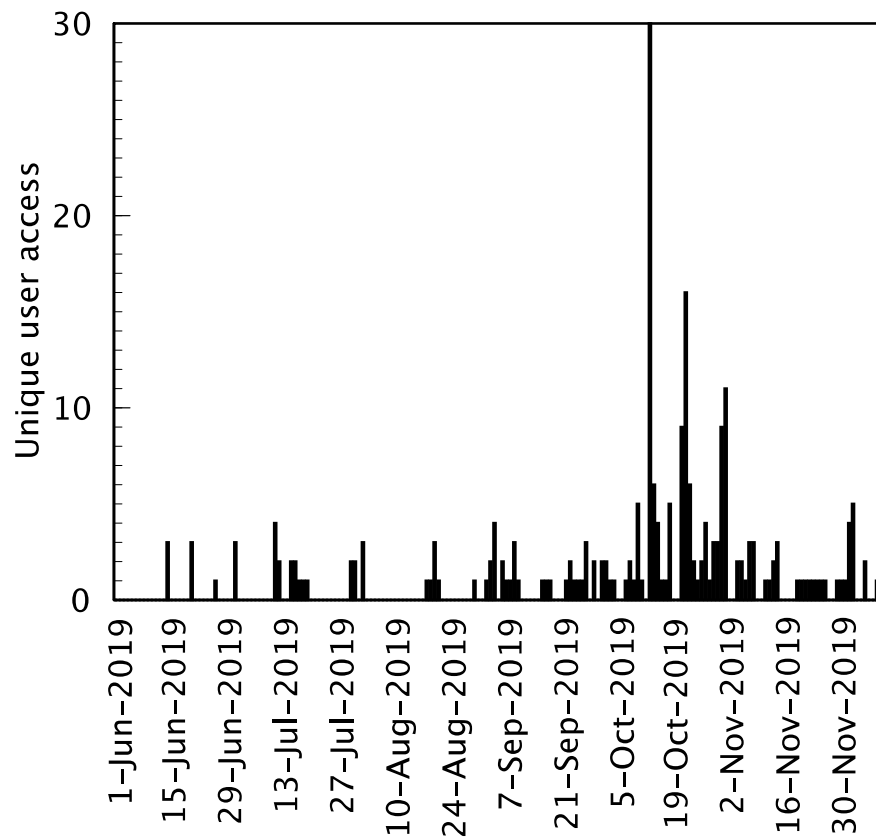


Figure B2: Daily unique users of all pages within the Limpopo Resilience Lab.

Website analytics will continue to be reported to USAID in quarterly reports.

## **APPENDIX C: SUBAWARD JUSTIFICATION LETTERS**

The following attached letters provide the budget itemization and justification for the subaward invoices. The letters are provided without the enclosures; however, all enclosures are on file for inspection at the request of the AOR or AO.

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## APPENDIX D: WISA PRESENTATION ABSTRACT

### TITLE: A SWOT ANALYSIS OF WATER RESOURCE MANAGEMENT OF THE LIMPOPO RIVER BASIN

#### BACKGROUND

The Limpopo River Basin (LRB), located in sub-Saharan Africa, is a transboundary river basin shared by the countries South Africa, Botswana, Zimbabwe, and Mozambique. The Limpopo river basin covers an area of 416, 296 km<sup>2</sup>, and is home to approximately 18 million people as of 2012, expecting to surpass 20 million by 2040. According to the United Nations Environment Programme assessment on water scarcity, the LRB will be in a state of physical water scarcity. Physical water scarcity is defined as physical access to water is limited, the demand for water is higher than the availability. The development of local capacity to maintain water resources and make proactive, scientifically justified management decisions requires a substantial human capital resource that is currently lacking in the basin.

#### METHOD

A stakeholder meeting was convened with major players in the water industry in Southern Africa region. Major participants were from the Department of Water Affairs and Sanitation of South Africa and Botswana. Research scholars from CSIR and Agricultural council of South Africa were also present with water experts from both national and international Universities. SWOT Analysis is a tool used for strategic planning and strategic management was used in this study to identify various areas of strength, weakness (needing improvement), opportunities and threat in the management of the Limpopo River Basin (Nazarko et al., 2017; Gürel and Emet, 2017).

#### RESULT

##### Strengths

- Organizational relationships intra- and inter-basin.
- Availability of policies at national-level and transboundary level
- Effective collaboration between riparian states
- Availability of local expertise
- Donor-funded projects and data
- Resilient Waters identified hotspots already
- Strong stakeholder participation
- Existence of and functionality of the River Basin Organisation (such as the Limpopo Watercourse Commission (LIMCOM), Southern African Development Community (SADC), Joint Permanent Technical Committee, JPTC).
- Groundwater aquifer research
- Networks of quality and quantity monitoring.

##### Areas for improvement

- Drought extent, prediction
- When will rainfall starts – for farmers for mitigation

- Real-time information on a number of parameters. Floods. Early-warning systems (drought, flood)
- Indicators suggest that water quality and quantity are declining, need prioritization of monitoring networks, alternative products (e.g., satellites).
- Knowledge management, lots of work done, hard to find what was done, hard to access data.
- Enhanced capacity building, joint cooperation, focused courses
- Best practices for data management, QA/QC, infrastructure, monitoring, and management
- Consistency/sustainability from basin organizations for M&E for water data
- Sharing of data, one center for your data/common repository
- Collection and management of water data – harmonization (QA/QC, metadata)
- Effective, integrated planning for wasted water
- Planning for results, long-term
- Surface water, lots of data, need to take data from just numbers to actionable, derived products (e.g., floods in Limpopo)

### Opportunities

- EFTEON (call for landscapes - 6, 20 years, provides infrastructure)
- Digital Earth Africa (Australian)
- External donors (EFTEON, NRF, ODAs, UNESCO, SIDA, GIZ)
- Other support, data management (IGRAC, ORASCOM)
- New organizations: SADC GMI (groundwater)
- Other organizations: Waternet (capacity building), mining organizations (Chamber of Mines, NBI), agriculture (farmers' union), local municipalities.
- WSSLG – water and sanitation sector leader group ("360 group", high-level)
- Gender and water

### Threats

- Demographic changes
- Data access and availability from external organizations: cost, availability
- Open-access as a key principle
- Lack of information infrastructure: external data sources, formatting, data infrastructure (NIWIS as an opportunity to address this)
- Highest-level prioritizations sometimes don't consider long-term
- Lack of polluter pays principles
- Limited institutional knowledge management
- ODAs
- Gender disparity in the water sector

## CONCLUSION

Results from the SWOT analysis can be used to mitigate the threat identified associated with the current management of Water Resources in the LRB. The strengths and opportunities identified can be harnessed such that their effects can work simultaneously to improve water resource management in the LRB. Also, strategy on minimizing the weakness and threats while exploiting the available opportunities will also lead to improved Water resource management in the river basin

## REFERENCES

Gürel and Emet. "Swot Analysis: A Theoretical Review." *Journal of International Social Research*, vol. 10, no. 51, 2017, pp. 994–1006., doi:10.17719/jisr.2017.1832.

J Nazarko, J Ejdys, K Halicka, A Magruk, Ł Nazarko, A Skorek. Application of Enhanced SWOT Analysis in the Future-oriented Public Management of Technology *Procedia Engineering* 182 (2017) 482 – 490: doi:10.1016/j.proeng.2017.03.140



WaterQ2: Understanding Water Quality and Quantity in the Limpopo Basin