Optimised Operation of ZRB Hydropower Reservoirs using a WAFLEX Model. Case Study of Kariba, Kafue and Cahora Bassa Dams.

INCEPTION REPORT

DATE: 29/12/2017

Andrea Vushe

avushe@nust.na

Contents

Abbreviations and Acronyms

CEO:	Centres of Excellence
HCB	Hidroeléctrica de Cahora Bassa is the company running the Cahora Bassa dam jointly owned by Mozambique (85%) and Portugal.
IWEGA	International Center for Water Economics and Governance in Africa at the University Eduardo Mondlane in Maputo in Mozambique
M1	Inception report
M2	Report and baseline database
M3	Report, multipurpose optimisation model for major dams and annexed database
NUST:	Namibia University of Science and Technology
SADC:	Southern African Development Community
SANWATCE:	Southern African Network of Water Centres of Excellence
UKZN	University of KwaZulu Natal
UZ:	University of Zimbabwe
WAFLEX:	Spreadsheet-based model that can be used for analysis of dam/reservoir management rules, including upstream-downstream interactions, water allocation policies and development options.
ZESCO	Zambia Electricity Supply Corporation; an electricity utility, which generates, transmits, distributes and supplies electricity in Zambia.
ZRA	Zambezi River Authority; a corporation jointly and equally owned by the governments of Zambia and Zimbabwe, which operates and maintains the Kariba Dam.
ZRB:	Zambezi River basin

Introduction

The Zambezi River basin (ZRB) is of paramount importance to the eight riparian SADC countries. The trans-boundary river is used for hydropower generation, provision of water for irrigation and ecosystem services to the region. The ZRB is characterized by extreme climatic events of floods and droughts resulting in challenges on balancing water allocation among the multiple and competing water uses. Population growth and industrial development in the region increased water demand especially for hydropower generation for the Southern African Power Pool (SAPP) and irrigation.

Kariba, Kafue and Cahora Bassa dams were constructed for hydropower generation and are managed by ZRA, ZESCO and HCB respectively using independent models and operating rules, mainly for optimising income from the individual dams. However, the reservoirs are now subjected to multiple competing uses of hydropower generation, recreation, flood management and fisheries. There are plans for construction of additional hydropower dams to meet increasing energy demands and irrigation development upstream and downstream of the existing reservoirs. These developments are expected to complicate water management challenges in the future, hence existing independent reservoir operational models and operational rules may not effectively manage the water for the increasing multiple demands, especially under extreme climatic conditions. Hence, this research project will develop a multi-reservoir simulation model as a decision support tool for optimising reservoir operation and assessing impact of management strategies for the changing water demands. Optimizing management of the three-hydropower reservoirs and the Zambezi River runoff may also optimise economic benefits for the riparian states, hence, the simulation model will assist in managing the ZRB sustainably, as well as enhance optimisation of multiple economic benefits for the riparian states and the SADC region.

Scope of Work

The research project work involves gathering and processing data, producing information and developing a simulation model which will be used for evaluating operation rules and impact of policies on water resources allocation, utilisation and management in the ZRB. The following will be done:

1. Gathering and processing historic data and information on. Assessments of data quality and hydrological balances of the existing hydropower reservoirs in the ZRB at appropriate time steps (weekly, monthly or annual).
2. Get a detailed understanding of the river system, its management. baseline conditions and hydropower patterns assessment.

3. Preliminary economic assessment (limited to a cost benefit analysis) of hydropower and the major competing water demands under different scenarios. Input data of primary cost and primary benefits will be obtained from IWEGA in Maputo in Mozambique.
4. A preliminary water footprint (environmental impact) assessment of past and current management practices and planned major related economic activities.
5. Develop a simulation model based on the WAFLEX platform and evaluate current operating rules and proposed optimisation strategies and operation rules of the Kariba, Kafue and Cahora Bassa Reservoirs, and ZRB runoff regimes.
6. Hydrological balances assessments of the existing three hydropower reservoirs and existing competing uses (fisheries, urban water supply and irrigation schemes) in the ZRB at appropriate time steps (weekly, monthly or annual) using the validated model.
7. Modify the validated simulation model to include future development scenarios (including proposed hydropower dams, urban water supply and irrigation schemes, and including impacts of climate change), formulate and evaluate future optimisation strategies and operating rules for all water demands in the future.

Objectives

To develop a model as a decision support tool for effective reservoir operation and optimisation of economic and environmental benefits as well as equitably satisfy the growing multiple water demands from the hydropower reservoirs in the Zambezi River Basin.

Scientific Activities

The tried and tested WAFLEX model will be modified to suit a conceptual model of the major reservoirs of the ZRB, namely Kariba, Kafue and Cahora Bassa and the model will be populated with the ZRB historic data. River runoff, and reservoir capacity curves, operation rules, seepage, overflow and water releases for the multiple demands (power generation, irrigation and for other ecosystem services) will be used as input data into the model. Scenarios will be developed in consultation with ZAMCOM and COEs in SANWATCE, but mainly based on historic, current and alternative operation rules, policies, climatic change variables, hydropower generation patterns and current and other planned major water uses. Reservoir operational rules and management strategies for water allocation will be developed for each scenario (low, average and high flow regimes) as input data into the model. Results obtained after running the model will be used to evaluate the effectiveness of the strategies and operational rules for the different scenarios. A calibrated and validated model will be made available to ZAMCOM, SANWATCE COEs and any other major interested stakeholders in the riparian states.

The specific scientific activities to be done in this study are:

1. Gather and process data for analysis and understanding of baseline conditions i.e. existing infrastructure, operations and management, benefits derived and challenges, and assessment of patterns of water demands. Assess the hydrological balance for the ZRB and the hydropower reservoirs. The required historic data and information is on river runoff, storage, evaporation, seepage, water demands, reservoir operation rules and challenges, hydropower generation and electric power demand patterns, existing plans on hydropower development and competing major water demands.

2. Gather and process the following sets of input data into the model;

- River runoff, reservoir water releases, seepage evaporation and storage.
- Reservoir capacity tables (preferably) and/ or capacity curves as per design and built stages, current and projected capacity tables and/or curves as storage is reduced by siltation.
- Past, current and planned medium to long term future water demands (official projections) for power generation, irrigation, environmental and recreation.

3. Develop a simulation model based on the WAFLEX platform for the Zambezi River runoff regime and major storage reservoirs (Kariba and Cahora Bassa) including the Kafue hydropower reservoirs on the Kafue tributary.
4. Input data for the scenarios into the model, test, validate, calibrate and run the model.
5. Evaluate current operational rules of ZRA, HCB and ZESCO under the low, average and high flow scenarios for the three major dams in the ZRB, based on historic water demands, existing operational rules and future development plans upstream and downstream of the reservoirs.
6. Develop optimisation strategies and respective operational rules and run the model, evaluate the results if the current strategies enhance:

- Optimized and sustainable hydropower generation through coordinated and systematic storage and releases of water under scenarios; low, average and high flow regimes.
- Optimised water storage and supply especially under low flow or drought conditions for downstream and upstream urban water supply, irrigated agricultures, fisheries and other eco-system services.
- Minimisation of flooding of upstream and downstream communities.

7. Interpret results and recommend optimization strategies and operation rules for sustainable water resources management for the multiple uses and optimized benefits under the low, average and high flow scenarios. also considering impact of climate change, and proposed hydropower dams and irrigation schemes.

8. Preliminary assessments of water footprints of existing operations and proposed strategies, limited to the primary environmental impact of consumptive uses and contamination of freshwater resources by power generation and the other major water demands.
9. Obtain data on primary production costs and primary benefits (annual revenue) and do preliminary economic assessments (cost/benefit analysis) of hydropower generation, fishery, tourism irrigation and water supply under existing and optimisation operational rules.
10. Research output dissemination, and teach interested fellow researchers and ZRB stakeholders on populating, running the model and results analysis.

Interlinkages with other members of SANWATCE

The following members of SANWATCE will be expected to gather, process and share with the project team the respective data and information by the 9th month into the project i.e. in the middle of M2 period.

Stellenbosch University

I. Current and projected reservoir capacity tables (preferably) and/or capacity curves as well as historic and projected storage capacities as they decrease due to sedimentation.
II. Low, average and high flow runoff regimes of ungauged rivers flowing directly into the hydropower reservoirs and downstream of the hydropower dams after a hydrological assessment based on SWAT model or any other suitable model.

University of Botswana

Climate change impact factors on low, average and high flow runoff regimes of ZRB and evaporation rates.

IWEGA

Primary costs and benefits input data for a preliminary economic assessment of all major economic activities (hydropower generation, tourism, fisheries, irrigated agriculture and urban water supply).

UKZN and University of Malawi

Irrigation water demands upstream and downstream of the hydropower dams and water allocations under low, average and high flow runoff regimes as per riparian policies or ZAMCOM allocation strategies

Overall Workplan of Activities to be Implemented

No.	Activity	Months 1-4	Months 5-8	Months 9-12	Months 12-18	Name of Researchers
1	Gather data on baseline conditions					Mr Vushe, Mr Moyo & Dr. Makurira
2	Data analysis and understanding baseline conditions					Mr Vushe, Mr Moyo & Dr. Makurira
3	Develop the ZRB & reservoirs simulation model based on the WAFLEX platform					Dr. Makurira, Mr Vushe & Mr Moyo
4	Develop scenarios and operational rules for the ZRB and the three major dams					Dr. Makurira, Mr Vushe & Mr Moyo
5	Gather and process input data for the model for each scenario					Dr. Makurira, Mr Vushe & Mr Moyo
6	Input data for the scenarios into the model, test, validate, calibrate and run the model					Dr. Makurira, Mr Vushe & Mr Moyo
7	Interpret results, assess for hydrological balance and find optimization strategies					Dr. Makurira, Mr Vushe & Mr Moyo
8	Preliminary assessment of water footprint (environmental impact) of existing operations and proposed strategies					Mr Vushe, Mr Moyo & Dr. Makurira
9	Cost benefit analysis as a preliminary economic assessment of identified water uses under existing and future management strategies, and compare with proposed optimisation strategies					Mr Vushe, Mr Moyo & Dr. Makurira
10	Write and submit reports	M1		M2	M3	Mr Vushe, Mr Moyo & Dr. Makurira
11	Research output dissemination and teach interested fellow researchers, ZRB and other stakeholders on populating, running the model and results analysis.					Mr Vushe, Mr Moyo & Dr. Makurira

Possible Challenges and Possible Solutions

The following were identified research challenges and the respective proposed solutions.

No.	Challenges	Solutions
1	Historic data availability on request and on time, and data quality and quantity should be adequate for model calibration and validation	It is believed that all requested and available data will be availed if full cooperation exist between the researchers and ZAMCOM and its

		affiliate stakeholders like ZRA, HCB, ZESCO
2	Availability of data on plans in riparian states for major water uses e.g. hydropower generation and future developments upstream and downstream of the existing three dams	ZAMCOM and government departments and other stakeholders may provide the data if they are engaged on time using the right procedures
3	Harmonization of available time and related resources, logistical support from the major stakeholders in this research work; universities (UZ and NUST) and the ZAMCOM	Cooperation between admiration departments of the research institutions will be important
4	After developing an acceptable model, the current budget may not be adequate for covering dissemination and training costs. Also, trainees with minimum educational qualifications and interested in the simulation model should be available for the training workshops	A promise was given that adequate additional funding for dissemination and training will be available.