ChemXpress
ISSN: 2320-1975
ChemXpress
Research | Vol 10 Iss 3

Optimising the Operating Rule Curve for Inanda Dam South Africa

Nkwonta OI[1*], Dzwairo B[2], Otieno FAO[3] and Adeyemo JA[4]

[1]Department of Civil Engineering, Mangosuthu University of Technology, Jacobs, Durban-12363, South Africa

[2]Research and Innovation, Durban University of Technology, Durban-1334, South Africa

[3]Masinde Muliro University of Science and Technology, Kakamega-190-50100, Kenya

[4]Civil Engineering Department, Durban University of Technology, Durban-1334, South Africa

[*]**Corresponding author:** Nkwonta OI, Department of Civil Engineering, Mangosuthu University of Technology, Durban, South Africa, Tel: + 27318199280; E-mail: onyinkwo2002@gmail.com

Received: Jun 15, 2017; **Accepted:** July 06, 2017; **Published:** July 10, 2017

Abstract

Effective water resources development and management is widely recognized as crucial for sustainable economic growth and poverty reduction in many developing countries such as South Africa. In this research the objective was to develop a decision support system for uMngeni Basin. The first step towards achieving this objective was to identify the requirements of different water users. The behaviour of uMngeni System was analyzed under the derived and current UWA operating rules using a WRYM for the planning period. The result shows that the model did not apply the optimization routine into utilizing surplus water in upper reaches of the Umgeni River system. It was concluded that the analysis was to ensure that the water from Inanda Dam was determined by the short-term yield versus demand balance, with the objective being to maintain the long-term assurance of supply and to therefore minimize spillage.

Keywords: ***Yield; Planning; Operating rules; Inanda dam; Demand balance; Spillage***

Introduction

Water has generally been thought of as a commodity, something that can be contained, transported and traded. The problem of allocating a resource such as water stored in a reservoir system is a complex task, especially due to the stochastic nature of inflows into the system. As water supply systems build up in complexity, from run-of-the river systems to single reservoirs then to multiple storages, the number of alternative ways of operating the system increases and the operation approach becomes less applicable [1].

The operation of most multiple reservoir systems reflect the fact that there are sometimes conflicting and sometimes complementary multiple purposes served by the water stored in and released from reservoirs [2]. For a complex system with

Citation: Nkwonta OI, Dzwairo B, Otieno FAO, et al. Optimising the Operating Rule Curve for Inanda Dam South Africa. ChemXpress. 2017;10(3):127

a large number of reservoirs and aqueducts, attempts to determine best operating policies by search i.e. trial and error, with a simulation model made to run on digital computers, have been found to require an inordinate amount of computing time. Therefore, the decision makers need tools to operate their reservoir systems in an optimal, or rather, in the best manner [3].

There is a need to introduce a water resources yield and planning model to ensure the supply of water resources to support changing water requirements at Umgeni basin (study area) and in a sustainable and cost-effective way. Essentially, the purpose of the water resources planning process is to balance the available water resources in a system with the water requirements and losses to which it is subjected in a sustainable way. ‘Sustainable ways’ includes economic, social and environmental. This can be achieved through assessment, intervention scheduling, system management and monitoring (FIG.1).

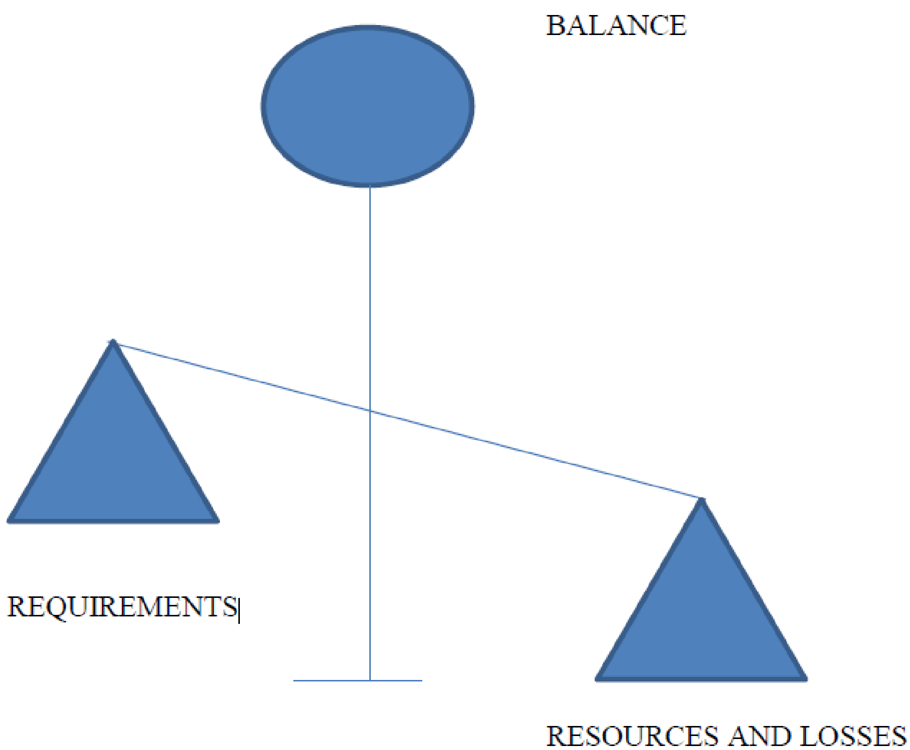

FIG. 1. **Shows the impact of requirements on resources.**

Overview of Water Resources System Analysis Model

The water resources system analysis model works as a system network simulation on a monthly time step. It also involves scenario analysis approach, where one develops levels, intervention options and operating rule operations. The purpose of the model is to determine the resource potential, allocation of resources, evaluation of intervention options, evaluation of operating rules and assessment of system behaviour with time [4]. The model strengths are flexibility, scenario management, result presentation, stochastic analysis with network model configuration. The model limitations are monthly time-step, no hydraulics, no water quality, extensive pre-processing (rainfall runoff modelling, GIS etc.). The model components are the database, user interface and user support.

Study Area

Umgeni Water is the largest water services provider in the KwaZulu-Natal region of South Africa, with an area of supply of some 24, 000 km^2 and annually producing just over 300, 000 000 m^3 of treated, or potable, water [5]. The monitoring programme, which has been running since 1988, collects approximately 22, 750 samples per year with an IS0 17025, 1999, accredited laboratory conducting approximately 375, 000 water quality analyses on these samples per year [6]. FIG. 2 shows the umgeni catchment and its dams.

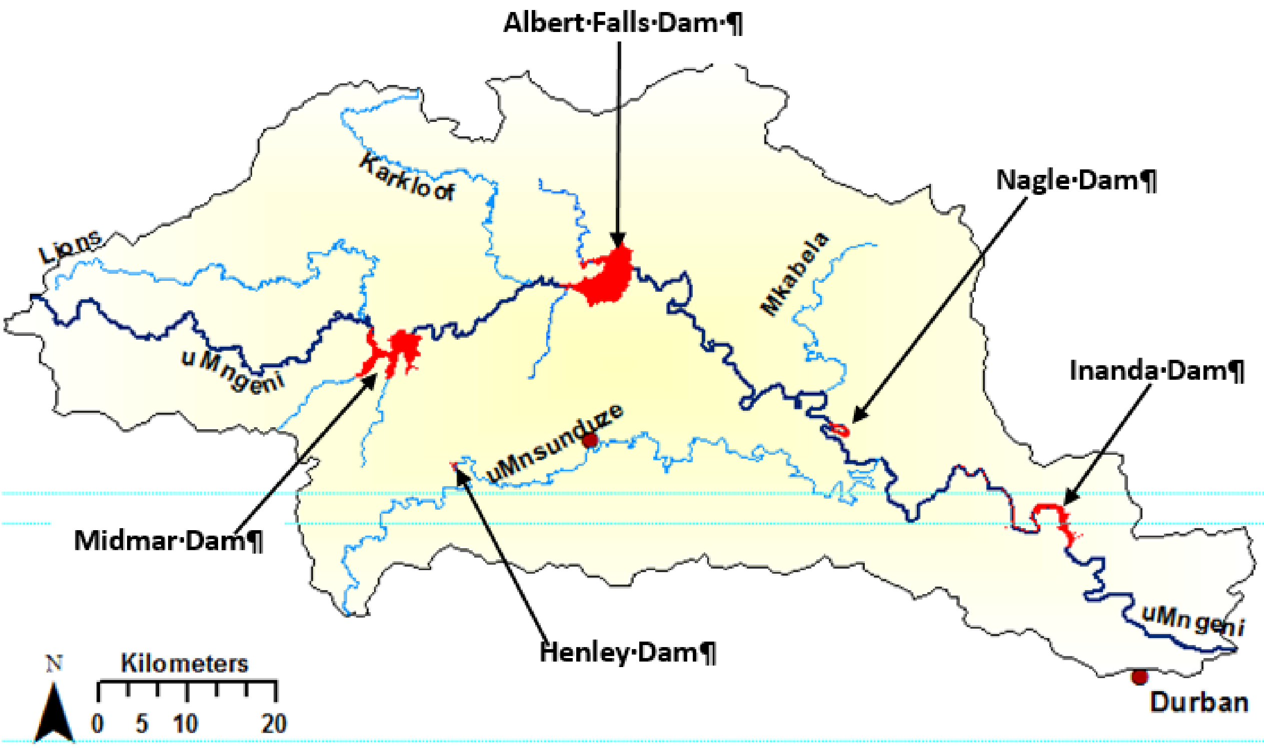

FIG. 2. **The position of Umgeni River, its major dams and tributaries.**

The anticipated growth in demand in the region has already exceeded the existing firm 1:100 year yield, and will soon exceed the yield derived from the short term solutions that are being put in place [6]. Clearly, a long term solution is required otherwise the risk of failure to meet the demand will increase to an unacceptable level and economic growth will become constrained. Steps are currently under way to increase this yield in the short term to about 1050 Ml/day through the raising of the existing Midmar Dam within the region, and by augmenting through the development of a relatively inexpensive transfer scheme from the adjacent Mooi river catchment [7]

Methodology

The research was conducted using the run description-facility, which allows for information to be provided on a WRSM model run and is essential as a means of managing the configuration, output and metadata related to undertaking water resource scenario analyses and ensures that the replication of results is possible. The run description that was used in this research includes three title lines which were written by the model as a header to the appropriate places in the WRSM data output files. The title line-facility also serves as a means of identification and reference between the input and output data sets and its integrity (relevance and reference between input and output data) was maintained.

A unique file name prefix was selected (of up to five digits), which enables the identification of the WRSM model data input and output files associated with a particular run. The prefix used by the WRSM in the naming of these files is written by the model onto the hard-drive of the computer. Analysis of the Umgeni River system was being undertaken, therefore a prefix “UMGENI” was selected, which means that the *F01.DAT-file was called UMGF01.DAT, the *F02.DAT-file UMGF02.DAT, the *SUM.OUT UMGSUM.OUT and so on Finally, it was noted that, in addition to the title line and file name prefix features shown above, the Water Resources Information Management System (WRIMS) provided robust information management and metadata capabilities for managing scenarios and related data sets. These were:

1. The study under which the run was being defined, as well as related information such as the study client, consultant, date and general description;

2. The sub-area within which the analyzed system lies, as well as a general description for the sub-area in question;

3. The scenario was analyzed, including a unique name, number and detailed description.

Finally, the WRIMS also allowed for a wide range of metadata particular to the scenario currently selected. This includes descriptions of the source of the hydrology time-series data, a study description, pertinent study results, proposed infrastructure changes, study reports, demand projections, the scenario strategy, development option sequences, study stakeholders, the operating rule strategy, etc.

Results and Discussion

The main objective was to develop a decision support system for uMngeni Basin. The first step towards achieving this objective was to identify the requirements of different water users. The behaviour of uMngeni System was analyzed under the derived and current UWA operating rules using a WRYM for the planning period. The result shows that the model did not apply the optimization routine into utilizing surplus water in upper reaches of the Umgeni River system. It was concluded that the analysis was to ensure that the water from Inanda Dam was determined by the short-term yield versus demand balance, with the objective being to maintain the long-term assurance of supply and to therefore minimize spillage.

Reservoir Output

TABLES 1 to 4 show the result of the reservoirs. To achieve this we set a target draft and dead storage zone in the reservoirs, then the supply will be from the yield channel above DSL and also for spillage will be above FSL. From the results below, Umgeni water should utilize more water from Inanda dam, to avoid spillage and also make use of Durban height and Wiggins waste water treatment facilities to supply water to Durban Township.

TABLE 1. **Midmar dam water balance.**

Rainfall (m^3/s)	0.488
Evaporation (m^3/s)	-0.653
Change of storage (m^3/s)	0.001
Net	-0.165

TABLE 2. **Albert fall (711) water balance.**

Rainfall (m^3/s)	0.627
Evaporation (m^3/s)	-0.817
Change of storage (m^3/s)	0.000
Net	-0.190

TABLE 3. **Nagel dam (717) water balance.**

Rainfall (m^3/s)	0.037
Evaporation (m^3/s)	-0.047
Change of storage (m^3/s)	0.000
Net	-0.011

TABLE 4. **Inanda dam water balance.**

Rainfall (m^3/s)	0.256
Evaporation (m^3/s)	0.334
Change of storage (m^3/s)	0.003
Net	-0.075

Long Term Analysis

Historic firm yield and long-term stochastic analyses were carried out for all the dams using Water Resource Yield Model (WRYM). The yield results were shown below in TABLE 5.

TABLE 5. **Long term analysis**.

Umgeni Dams	**Long term yield**			
	1:20 year	1:50 year	1:100 year	1:200 year
	Yield results			
Midmar dam	3.21	3.01	2.26	2.20
Albert falls	1.74	1.62	1.31	1.02
Nagel dam	2.60	2.17	2.06	1.83
Inanda	7.20	7.01	6.42	6.12

We noted that yield analysis results showed that all the systems are totally over allocated. Results showed that accepted supply to Durban is achieved when 70% of water is supplied from Inanda dam.

Planning Analysis Results

The WRPM modelling approach was based on the assumption that a water resource system can be represented by a flow network. A water resource system was configured using nodes and links to represent the various elements of the system being modelled. The WRPM was capable of simulating a wide range of operating policies governing the allocation of water in multi-purpose multi-reservoir systems. The specific strength of the model lies in its flexibility in allowing the user to define operating policies governing the allocation of water. It was noted that the WRPM did not apply the optimization routine into utilizing surplus water in upper reaches of the Umgeni River system. The purpose of the analysis was to ensure that the water from Inanda Dam was determined by the short-term yield versus demand balance, with the objective being to maintain the long-term assurance of supply and to therefore minimize spillage. The alternative proposed user priority is shown in TABLE 6.

TABLE 6. **User category and priority classifications proposed to be used in Umgeni River basin.**

User Category	**Priority Classification**			
	Low assurance) (1:10 year)	Medium low assurance) (1:50 year)	Medium high assurance) (1:100 year)	High assurance) (1:200 Year)
	Portion of water requirement supplied (%)			
Mining and Industrial	20%	20%	20%	20%
Domestic	5%	5%	20%	70%
International	10%	10%	20%	60%
Irrigation	100%	0%	0%	0%
Curtailment level	0	1	2	3 4

Optimisation Period and Reservoir Operation

However, for Umgeni system, which has a significant growth in annual demand, it was suggested that the average demand corresponding to the 'sustainable yield' be used in the derivation of restriction rules. With the 'sustainable yield' scenario it was assumed that further augmentations were not possible to the water supply system due to reasons such as non-availability of suitable hydrologic sites. Generally, the systems, with growth in annual demand are fairly large with significant carryover storage. Certainly this was the case with Umgeni system. The initial storage conditions affect the computation of yield of these systems.

However, it is suggested that the most likely storage volume (such as mean/median value of storage volume over the planning period, or half-full storage) be used as the initial storage volume for the demand analysis. Results of each optimization run were analyzed to determine the performance indices (monthly time reliability, worst restriction level and maximum duration of any form of restrictions) of the security criteria adopted by Umgeni water. To obtain the maximum duration of continuous restrictions, the restriction levels output file was analyzed for each replicate but for the whole planning period, and the number of months that had continuous restrictions for each replicate computed [8]. The maximum duration of continuous restrictions considering all replicates was noted. The worst restriction level (such as maximum restriction level) is extracted from the file considering all years and replicates, and noted.

Conclusion and Recommendation

The effective management of water resources is of great importance to ensure the supply of water resources to support changing water requirements over a selected planning horizon and in a sustainable and cost-effective way. Essentially, the purpose of the water resources planning process is to balance the available water resources in a system with the water requirements and losses to which the system is subjected [9]. It also considers the way in which a system is operated since this directly influences its resource capability and includes aspects such as detailed operating rules for reservoirs and inter-basin transfer schemes, the prioritization of water sources and supplies, special operating rules associated with the blending of water for the purpose of meeting special water quality criteria, operational cost savings and system maintenance schedules [10].

Several recommendations emanate from this study, the most significant of which are as follows:

1. Initiate further studies, using the same methodology, to determine potential impacts on all existing and proposed supply dams.

2. Compare predictions from climate change impact assessments with measured data. So, although results remain inconclusive and further investigation and research is required, in the interim Umgeni Water will continue exploring traditional and new methodologies to improve the management and supply of water.

Acknowledgement

The authors would like to thank Durban University of Technology for offering the funds that enabled this project to be undertaken.

REFERENCES

1. Adeyemo JA, Otieno FAO. Optimising reservoir operation for maximum benefit. Proceedings of the Australia natural water conference and exhibition. Melbourne, Australia 2009, Australian Water Association (AWA).
2. Harman C, Stewardson M. Optimizing dam release rules to meet environmental flow targets. River Research and Applications. 2005;21(2-3):113-29.
3. Perera BJ, Codner GP. Reservoir targets for urban water supply systems. Journal of Water Resources Planning and Management. 1996;122(4):270-9.
4. Rangeti I. Determinants of key drivers for potable water treatment cost in uMngeni basin. Durban University of Technology. 2014.
5. South Africa. Department of Water Affairs and Forestry (DWAF). Hydrological records for river gauging station U2H054; 2009.
6. South Africa. Department of Water Affairs and Forestry (DWAF). Resource management plan for Inanda Dam; 2008.
7. Stalnaker C B, Arnette JL. Methodologies for the Determination of Stream Resource Flow Requirements. 1976.
8. Dickens CH. State of Rivers Report – uMngeni River and neighbouring rivers and streams. Water Research Commission South Africa, 2008.
9. Dickens CH. State of Rivers Report – uMngeni River and neighbouring rivers and streams. Water Research Commission South Africa, 2002.
10. Wurbs RA. Reservoir-system simulation and optimization models. Journal of water resources planning and management. 1993;119(4):455-72.