ENVIRONMENTAL MANAGMENT
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EFFECTS OF CLIMATE CHANGE ON DAM

Groundbreaking study in Lesotho

A first-of-its-kind study was commissioned by the Metolong Authority in Lesotho to research the potential impacts of climate change on the long-term yield of the proposed Metolong Dam. Experts from consulting firm Arcus GIBB, supported by consultants Jeffares & Green, who specialise in the fields of hydrology, water resources planning and the impacts of climate change on hydro-climatic hazards, looked at the possible effects of climate change on an infrastructure that will need to stand for at least the next 100 years.

Jeffares & Green's Ian Marriott looks upstream towards the proposed site of the Metolong Dam on the Phuthiatsana River.

Climate change and water resource planning

"The issue of climate change and its impacts on water resources is not new but planners are increasingly concerned about the possible negative impacts of climate change on the utilisable yields from dams and water resource systems," said Gerald de Jager, an associate of Jeffares & Green and a key member of the team which undertook the study.

"Emphasis is now being placed on the need to implement special adaptation measures to mitigate such impacts and to consider how such efforts can fit within the mainstream of developmental strategies. We are now taking into account the fact that the useful life of large water infrastructure is often measured in multiple decades, and investments that are made today will still be operating under the new climates of the twenty-second century," said De Jager.

Jeffares & Green and Arcus GIBB, both long-established firms of engineers and earth scientists, were appointed by the Metolong Authority to investigate the potential impacts of climate change on the long-term yield of the proposed Metolong Dam. The proposed dam, which will be located on the South Phuthiatsana River in the Lesotho Lowlands, some 35km outside Lesotho's capital Maseru, will form part of the *Metolong Dam and Water Supply Programme*, and is an initiative aimed at providing clean and safe drinking water to local inhabitants as well as support to a burgeoning industrial sector, particularly textile factories.

Funding for the design and construction of the dam is being provided by four Funders (Kuwait Fund, Arab Fund for Economic Development in Africa, Saudi Fund for Development and OPEC Fund for International Development). The estimated cost of the implementation of the Metolong Programme is US$ 370 million and it will consist of the dam, water treatment works, downstream conveyance system, advance infrastructure and a comprehensive Environmental and Social Management Programme. The Metolong Authority is the project implementing agency operating under the government of the Kingdom of Lesotho's Ministry of Natural Resources.

Predicting changes in global climate

In order to understand the impacts of climate change on water resources it is first necessary to be able to predict three things: (i) changes in the magnitude and variability of rainfall and stream flows (so as to determine water availability and storage requirements), (ii) changes in the magnitude and severity of extreme flood and storm events (to design infrastructure so as to withstand them), and (iii) related changes in vegetation and land use.

Predicting such changes generally involves the use of computer models, referred to as General Circulation Models (GCMs). GCMs are essentially sophisticated numerical representations of various parts of the Earth's climate system that attempt to model the global effects of incoming and outgoing radiation, the way the air moves, the way clouds form and precipitation falls, the way ice sheets grow or shrink, and so forth. Very importantly, they also attempt to model the impacts of global warming caused by the ever-increasing emission of greenhouse gases (GHGs).

Climatic modelling has been the subject of scientific research for some time and more than 20 internationally developed GCMs have been used by the Intergovernmental Panel on Climate Change (IPCC) in their latest climate change assessment report, providing scientists with a vast array of possible climate scenarios over the next 50 to 100 years.

In a recent collaborative study by the School of Bio-resources Engineering and Environmental Hydrology (SBEEH) at the University of KwaZulu-Natal and the Climate Systems Analysis Group (CSAG) at the University of Cape Town (WRC Report 1562/1/10), five of these GCMs were selected for the purpose of developing climate change scenarios for the southern African region. For this purpose, scenarios from the GCMs, which were derived at a large geographical scale, were downscaled by the CSAG using so-called empirical (or statistical) downscaling methods in order to obtain corresponding results that are representative of specific areas (i.e. at a smaller scale).

The downscaling undertaken by the CSAG was for more than 2 500 rainfall stations and 400 temperature stations in southern Africa and they were all based on the so-called "A2" GHG emissions scenario,

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which assumes that emissions continue relatively unabated into the next century.

Impacts of climate change on yield

'Estimates of dam yields are traditionally based primarily on historical climatic behaviour and the observed occurrence of precipitation and stream flows in upstream catchment areas. However, scientists and engineers are now developing new ways of assessing yield and, in particular, the possible impacts of precipitation and stream flow changes caused by climate change,' said Darryn Knoesen, another member of Jeffares & Green's Earth Science division, who is also pursuing a PhD degree looking at *Integrating Hydro-Climatic Hazards and Climate Change as a Tool for Adaptive Water Resources Management in the Orange River Catchment*.

In order to provide the Metolong Authority with information on the possible impacts of climate change on the yield of the Metolong Dam, they modelled the behaviour of the dam for a range of different future situations. Each of these assumes an alternative set of inflows to the dam based on the climate change scenarios developed by the CSAG in Cape Town. The result of the analysis is a range of possible changes in yield which can be used by planners as an indication of future trends.

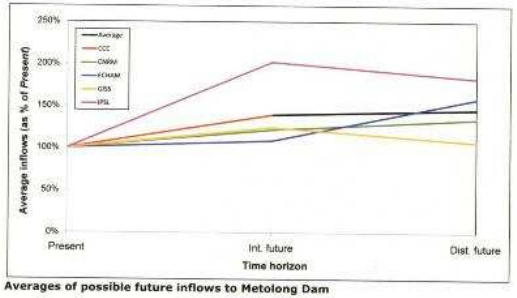
Inflows used for the analyses were developed by the SBEEH, based on the CSAG scenarios and using the daily time-step ACRU hydrological model. Inputs into the ACRU model by the SBEEH included, amongst others:

- daily rainfall for each climate change scenario;
- daily minimum and maximum temperatures for each scenario;
- soils information; and
- land cover information, which was assumed to be under natural conditions.

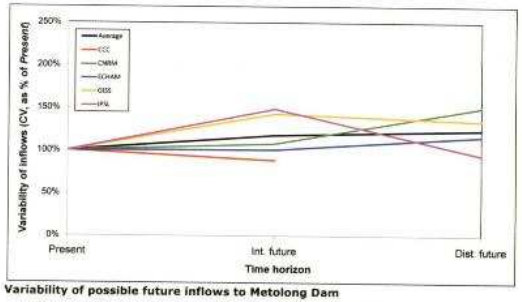
Resulting future inflow scenarios for Metolong Dam are shown and represent three distinct time horizons, each 20 years in length, namely, *present climate* (from 1971 to 1990), *intermediate future climate* (from 2046 to 2065), and *distant future climate* (from 2081 to 2100). They suggest that, in the intermediate future (i.e. 30 to 50 years from now) the average inflows to Metolong Dam are likely to increase moderately to significantly, together with some increase in variability.

Study team

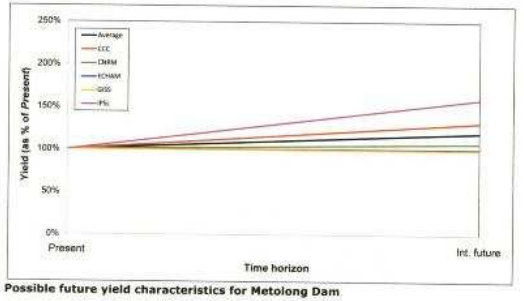
Beyers Havenga (Arcus GIBB), Gerald de Jager (Jeffares & Green), Darryn Knoesen (Jeffares & Green), Ryan Gray (Jeffares & Green), Ans Gerber (Eta Consulting) and Owen Wilson (Arcus GIBB) – with special acknowledgment to Professor Roland Schulze and the SBEEH of the University of KwaZulu-Natal for making their simulated climate change stream flow scenarios available for this study.



Averages of possible future inflows to Metolong Dam



Variability of possible future inflows to Metolong Dam



Possible future yield characteristics for Metolong Dam

Main findings

The main findings of the study are summarised above and suggest that, based on the GCMs selected and the A2 GHG emissions scenario, it is highly unlikely that the available long-term yield of Metolong Dam will decrease in the intermediate future (i.e. 30 to 50 years from now). In this case, therefore, no special adaptation measures will be required to account for the impacts of climate change on the yield of the dam over a 50-year planning horizon. However, since projected inflows to the dam, as well as their variability are expected to increase, design engineers should account for the possibility of associated increases in the magnitude and the severity of extreme flood events in the future.

Article, photograph and graphs by Jeffares & Green