# WATER RESOURCES DEVELOPMENT IN THE USUTU CATCHMENT SWAZILAND UNDER CLIMATE CHANGE


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**Abstract**

*The Usutu catchment which originates from South Africa traverses the four physiological regions before going into South Africa again and covers two thirds of the country. The population growth rate for Swaziland according to the 1996 census is 2.9% per year. The current population of about 1.0 million people was project to year 2075 using the continuous compound method and this, amounts to 8.802 million people. The domestic water demand for the country in year 2075 was estimated to be 17$m^3$/s which, translates to 12.75$m^3$/s, for Usutu catchment and this is equivalent to 0.092 mm/day. The irrigation water demand for the Usutu catchment in year 2075 has been estimated to be 0.058mm/day. Thus the total water demand in year 2075 is estimated to be 0.15 mm/day (1.8 million $m^3$ per day of 20.833$m^3$/s).*

*The impact of climate change on water resources in the Usutu catchment was evaluated using General Circulation Models and hydrologic models. The results of GCM models (precipitation, temperature and potential evapotranspiration) were used as input to WatBall model to forecast stream flow for the Usutu catchment for the wet, dry and average conditions for year 2075. A comparison between observed and simulated stream flow reveals that all GCM models are simulating low flows from June to September for the wet years and from May to September for the dry and average year conditions. Rainfall runoff simulation results have shown a water reduction of 134.0 million cubic meters per year. Implementation of water demand measures in the catchment will save about 42 million $m^3$ per year. This will leave a water deficit of 92 million $m^3$ per year. This water deficit will have to be provided for by the construction of a water storage dam. It has been established that, the water that will be available for storage under climate change during the summer months (October to January) is 0.07mm/day which is equivalent to 98 million $m^3$ per year. Therefore, there will be enough runoff to fill a reservoir with a capacity of 98 million $m^3$. Dam construction costs have been estimated to be 3500, 38,000 and 420,000 million Emalangeni for the construction periods of 2025, 2050 and 2075 years, respectively.*


## 1 INTRODUCTION

Human activities, however, are now raising the concentrations of these gases in the atmosphere and thus increasing their ability to trap energy. Carbon dioxide levels have risen from 280 ppm by volume since before the industrial Revolution to about 360 ppm by 1990. Fuller (1997) reports that, carbon dioxide emission will increase by 12% between 1990 and 1995. Man-made carbon dioxide which, is the most important contributor to the enhanced greenhouse gases effect, comes mainly from the use of coal, oil, and natural gas. It is also released by the destruction of forests and other natural sinks and reservoirs that absorb carbon dioxide from the air.

According to the IPCC (1990), if countries around the world do not reduce emissions of greenhouse gases by the end of the next century:

- Temperatures are expected to increase between 1 to 3.5 degree Celsius, depending on population and economic growth.

- Sea levels are expected to rise between 15 to 90 centimeters, with the best estimate being 50 centimeters and threatening 92 million people each year with floods by the year 2100.

- Mortality and illness will have risen as the intensity and duration of heat waves increased and as the tropical habitat of mosquitoes that carry malaria and fever crept northward.

- Rainfall will have decreased in some tropical and subtropical areas and increased in others, significantly reducing food crops in developing countries as a whole

The greenhouse gases effect is expected to cause global warming up which in turn will cause changes in average precipitation for any region in the order of plus or minus 20% (WMO/ICSU/UNEP, 1989). Generally it is expected that floods now considerd rare would occur more frequently in certain regions while drought related and competing water issues will intensify in other regions (Miller, 1989; Shaakee, 1989; 1PCC 1990b). Warmer temperatures may also affect snowmelt rates in spring and thus increase spring season runoff. It has been established that climate change will cause impacts through changes in rainfall distribution patterns, changes in magnitude and intensity of individual events, through changes in evaporation arising from temperature and radiation changes and thus changes in vegetation response. Globally, the greenhouse gases effect is expected to elevate average precipitation by 5 - 15 percent and evapotranspiration by 10 - 20 percent (WMO/ICSU/UNEP, 1989).

# 2 BACKGROUND INFORMATION

The water sources in Swaziland are mainly surface waters (rivers, reservoirs), ground water and atmospheric moisture. There are seven drainage basins in Swaziland and these are: Lomati, Komati, Mbuluzi, Usutu and Ngwavuma, Pongola and Lubombo. The latter two basins (Pongola and Lubombo) are smaller and under utilised and their water allocation has not yet been gazatted to be apportioned by the Water Apportionment Board, hence, there are no hydrometric stations in these two basins and their drainage areas are yet to be determined. The Komati, Lomati and Usutu basins originate in South Africa while the rest of the basins originate within Swaziland. It should also be noted that all the rivers in Swaziland are international rivers and therefore, the development of the surface water resources must be undertaken in collaboration with the other riparian states namely: South Africa and Mozambique.

The four major tributaries of the Great Usutu river basin which has an area of about 12,000 $km^2$ (Lusushwana, Upper Great Usutu, Ngwempisi, and Mkondo) originate in the Republic of South Africa, combine to form the Great Usutu river in Swaziland, and discharge into the RSA and eventually into Mozambique. Figure1 shows the map of Swaziland and the location of Usutu river basin. In Swaziland the Usutu river traverses the four physiological regions and covers two thirds of the country. About three quarters of the population of Swaziland live in the Usutu river basin. Therefore, this catchment was selected for modeling and thus would be representative of the country. The current water demand in the catchment is estimated to be 266400 $m^3$ per day which is equivalent to 0.0222 mm/day.

As mentioned earlier, the Usutu river basin covers two thirds of the country and three quarters of the population is found in this catchment. The population growth rate for Swaziland according to the 1996 census is 2.9% per year. The current population of 1.0 million people was projected to year 2075 using the continuous compound method and this, amounts to 8.802 million people. It has been assumed that all the population of Swaziland will be served with clean portable water by year 2020. It has been estimated that, the water demand per capita per day will be 167 litres for domestic and industrial activities. This mounts to $17m^3/s$ for the whole country, and translates to $12.75m^3/s$ for the Usutu catchment which is equivalent to 0.092 mm/day. It has been assumed that 15000 hectares will be under sugar cane irrigation in the catchment by year 2075. The water demand for sugar cane irrigation is estimated to be 1400 mm per year. Therefore, the water demand for irrigation will be 0.058mm/day. It has been assumed that there will be a decrease in livestock population by then, if land conservation measures will have been implemented. Thus the total water demand is estimated to be 0.150 mm/day (1.8 million $m^3$ per day or 20.833$m^3$/s).

# 3 WATER AVAILABILITY UNDER CLIMATE CHANGE

The methodology of evaluating the impact of climate on water resources in Swaziland is reported by Matondo and Msibi (2001) The water resources availability in the Usutu catchment under climate change was evaluated using the results of General Circulation Models and hydrologic models (Matondo and Msibi, 2001).

The GCM models which were used in the study are; the Geophysical Fluid Dynamics Laboratory (GFDL), the United Kingdom Transient Resalient (UKTR), and the Canadian Climate Change Equilibrium (CCC-EQ). The above models were used to simulate the temperatures and rainfall for Swaziland under baseline conditions. All the above models simulated very well the observed values. Therefore, they have been found ideal for Swaziland compared to the other models simulating future climate scenarios. Therefore, the results of the above GCM models (temperature, rainfall changes and potential evapotranspiration (for year 2075) were used as input to the calibrated WatBall model (Yates and Strrzepek, 1994) to forecast stream flow for Usutu for the wet years, dry years and the average year for year 2075 without taking into consideration of water abstractions (Matondo and Msibi, 2001). The results of the runoff simulations are shown in Figures 4, 5 and 6.

It can be seen from Figure 4 that the forecasted flows with inputs derived from the GCMs for the months of October to December are higher than the current observed flows. There after all the forecasted flows are lower than the current observed stream flows for the rest of the months except for the GFDL under Low Climate Change scenario for the months of April to September. The Models' average is also forecasting high flows for the months of October to December and predicting low flows for the rest of the months as compared to the current observed flows.

It can be seen from Figure 5 that the forecasted flows with inputs derived from the GCMs for the months of October to January are also higher than the current observed flows. There after all the forecasted flows are lower than the current observed stream flows for the rest of the months except for the UKTR under high climate change scenario for the months of June to September. The Models' average is also forecasting high flows for the months of October to January and predicting low flows for the rest of the months as compared to the current observed flows.

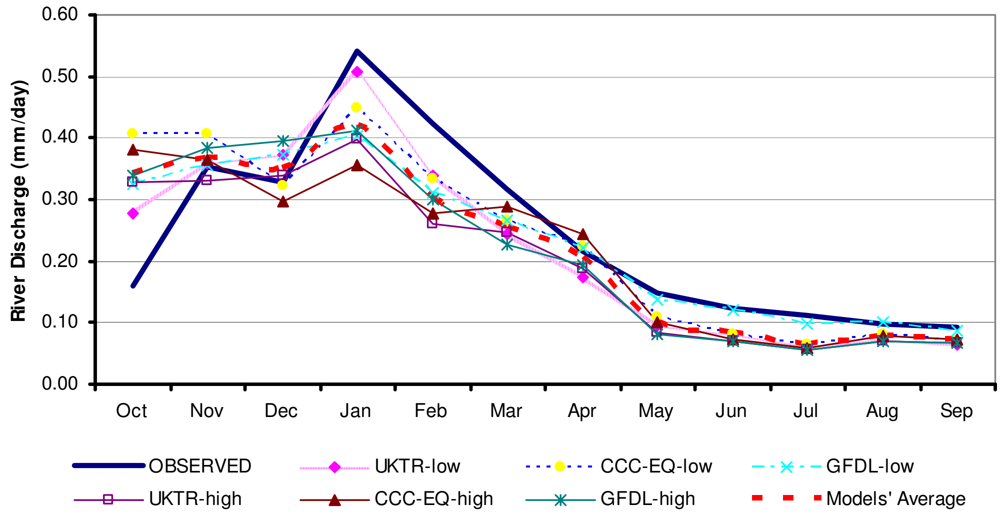


Figure 4: Simulated and observed stream flow for Usutu river (Dry Scenario)

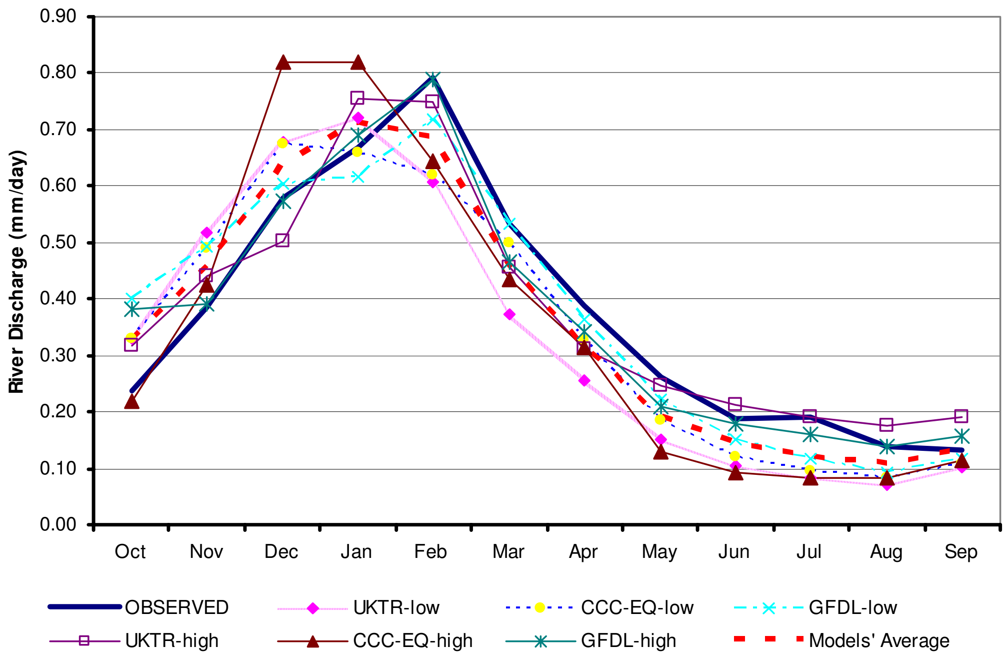


Figure 5: Simulated and observd stream flow for Usutu river (Normal Scenario)

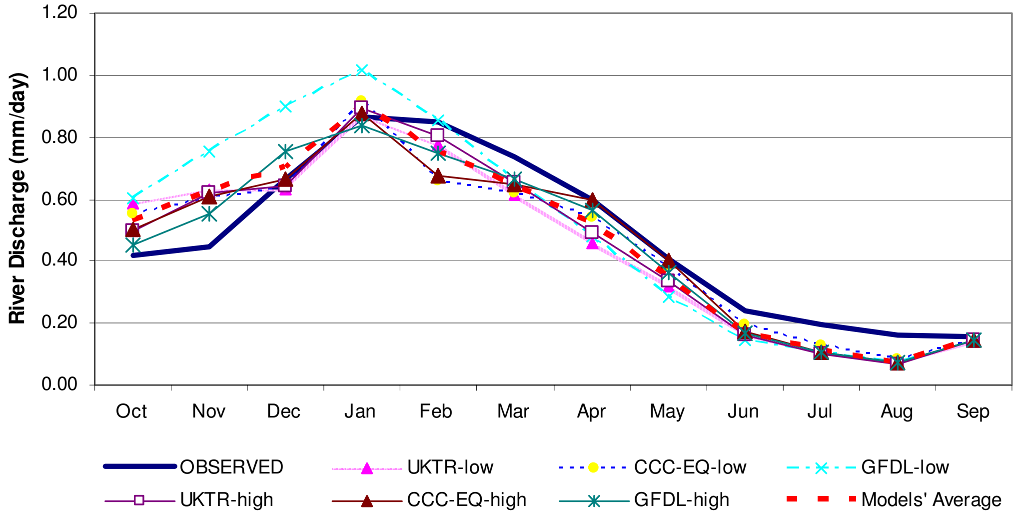


Figure 6: Simulated and observed stream flow for Usutu river (Wettest Scenario)

It can be seen from Figure 6 that the forecasted flows with inputs derived from the GCMs for the months of October to January are also higher than the current observed flows. There after all the forecasted flows are lower than the current observed stream flows for the rest of the months. The Models' average is also forecasting high flows for the months of October to January and predicting low flows for the rest of the months as compared to the current observed flows.

Looking at the above simulation results it can be concluded that the forecasted flows are higher during the early summer months (October to January) and lower during the late summer and winter months (February to September). Which implies that, the country could experience high flows during the early summer months and low flows thereafter. This is due to the fact that the expected climate change will bring high temperatures and therefore, high evapotranspiration and thus low flows during the late summer and winter months.

Figure 7 shows the % annual runoff change for all the GCMs under dry, normal and wet scenarios for all of the climate change scenarios (Low, Medium and High). It can be observed form Figure 7 that the high annual runoff change (Reduction) occurs during the dry scenario under almost all the climate change scenarios (Low, Medium and High) followed by the normal and the wet scenario.

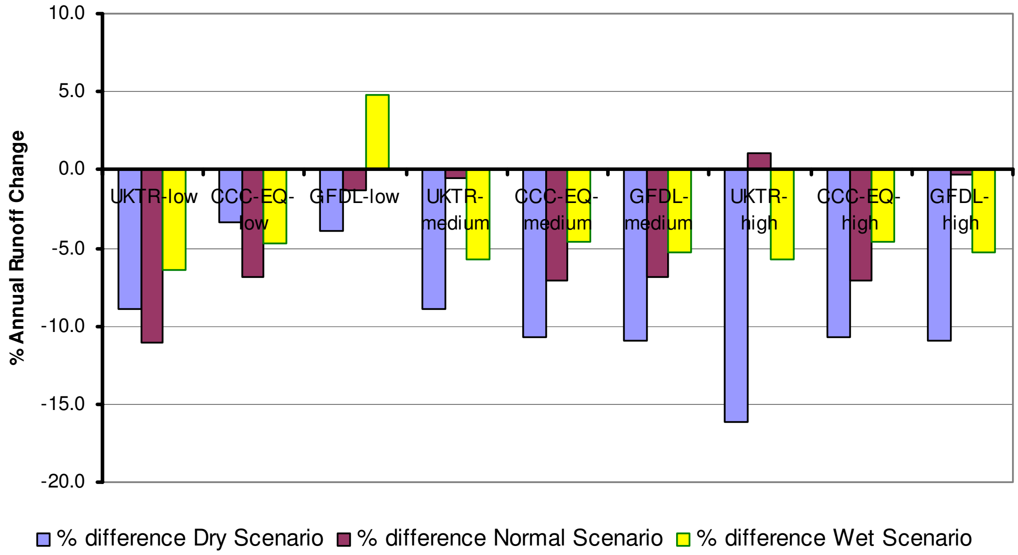


Figure 7: % Annual runoof change for Usutu river (for different scenarios)

Figure 8 shows the average of GCMs % annual runoff change for dry, normal and wet scenario for all the climate change scenarios (Low, Medium and High). It can be observed from Figure 8 that the highest % annual runoff change (12.6%) occurs under the dry scenario under high climate change followed by dry scenario under medium climate change and normal scenario under low climate change scenario and then by dry scenario under low climate change scenario. The % annual runoff change is the same under the wet scenario for all the climate change scenarios (Low, Medium and High). Therefore, there will be a maximum reduction in annual runoff of 12.6% in the Usutu river under climate change conditions which is equivalent to 133.6 million cubic meters (11.35 mm per year). When this maximum % annual runoff reduction is applied to all the catchments in the country, the predicted annual runoff reduction becomes 350 million cubic meters which is approximately the size of Maguga reservoir.

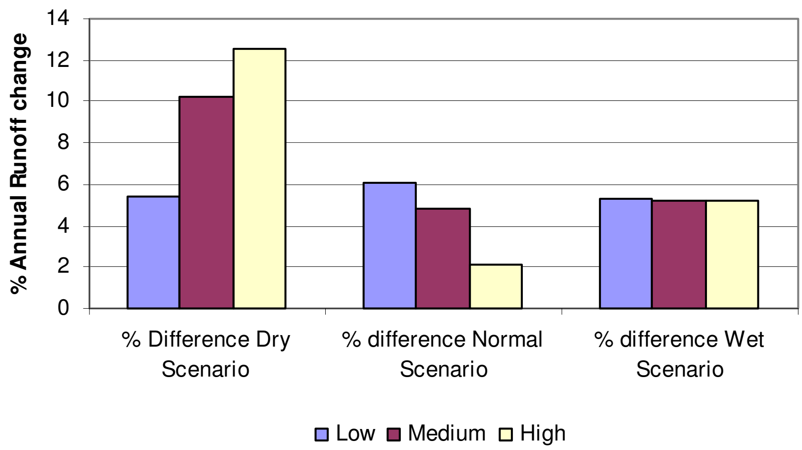


Figure 8: Average GCMs % Annual runoff change for Usutu river (for different Scenarios)

# 4 INTERPRETATION OF RESULTS

It has been found that stream flows will be high and low during the summer and winter months respectively under climate change conditions. Currently the country is experiencing flooding related problems during summer months of wettest years and drought related problems during years with low flows. Therefore, flooding and drought related problems will prevail during the summer and winter months respectively. The combined effect of high temperatures and low runoff especially during the winter months shall adversely affect groundwater recharge particularly in the Lowveld. Therefore, the present salinity of groundwater shall be worsened due to the reduced groundwater recharge and high evaporation rate. The low flows during the winter months will affect negatively the riverine ecological system.

Simulation results have shown a water reduction of 12.6% which is equivalent to 134 million cubic meters. Therefore, if nothing is going to be planned for the development and management of the water resource, water shortage related problems could prevail by year 2075. The economy of the country is based on agricultural activities (agro-based economy). Therefore, the country will suffer economic loss in rain fed and irrigated agriculture, hydropower generation, livestock and other social economic water uses. The water shortage for domestic use will cause poor sanitation conditions and thus the outbreak of diseases. Therefore, the country will be forced to import food and medicine. The drought conditions will also impact negatively on the bio-diversity of the country.

# 5 WATER RESOURCES DEVELOPMENT IN THE USUTU CATCHMENT

It has been established that there will be a reduction in runoff under climate change conditions. Therefore, water use sectors will have to adapt to the meager resource that will be available. It has been assumed here that there will be no significant water savings from industrial and domestic water use which is currently at 4% of the total water demand. The major consumer of water in the country is irrigation and is at 96% (Matondo and Msibi, 2001). Therefore, it is expected that large savings in water will come from efficient use of irrigation water.

Currently the land that is under irrigation in the Usutu catchment is estimated at 15000 hectares. The acreage that is under furrow, centre pivot and drip system presently has been assumed as if it was under sprinkler system. The water demand for sugar cane under sprinkler irrigation system is 1400mm per year per hectare. With technological advancement there might be more efficient irrigation systems in the future. Currently when considering the drip system there is 20% water saving by switching from sprinkler to drip irrigation system. This water saving translates to 280mm per hectare per year. Therefore, the water that will be conserved in the Usutu catchment by the use of drip irrigation system amounts to 42 million $m^3$ per year. This will leave a water deficit of 92 million $m^3$ per year. This water deficit will have to be provided for by the construction of a water storage dam.

It has been established in this study that, the water that will be available for storage during the summer months (October to January) is 0.07mm/day which is equivalent to 98million $m^3$ per year. Therefore, there will be enough water to fill a reservoir with a capacity of 98 million $m^3$.

# 6 DAM CONSTRUCTION COST ESTIMATES

The cost estimates for construction of a dam in Usutu catchment in order to meet water demand due to anticipated climatic changes has been derived from the cost estimates for the construction of Maguga dam. The cost for the construction of the Maguga dam is currently at 1.2 billion Emalangeni. The Maguga dam will impound 330 million $m^3$ of water. Therefore, the cost of a

Dam in the Usutu catchment that will impound 92million $m^3$ will cost 330 million Emalangeni today.

The inflation rate has been fluctuating between 7% and 14%. Therefore, an inflation rate of 10% has been used in this study to discount the cash flows of dam construction into the future. Table 1 shows the cost of dam construction for the different time periods in the future.

Table 1: Cost estimated of dam construction for different time periods

| | Year 2001 | Year 2025 | Year 2050 | Year 2075 |
|---|---|---|---|---|
| Dam Const. (million E.) | 330 | 3500 | 38,000 | 420,000 |

# 7 SUMMARY AND CONCLUSIONS

The results of three GCM models were used in simulating the stream flow of the Usutu catchment in year 2075 for the wet, dry and average year for the natural conditions. All the GCM models are simulating high and low stream flows during summer and winter months respectively. Simulation results in this study are in agreement with the results of other studies that have been conducted in the Southern African region [Schulze and Perks, 2000].

Therefore, the country is expected to experience high and low flows during summer and winter months respectively under climate change conditions. The overall water deficit under climate change conditions has been estimated to be 134milliom $m^3$ per year. Water saving through efficient irrigation water application systems has been estimated to be 42milliom $m^3$ per year. A water storage facility is therefore, needed to provide 92million $m^3$. The cost estimate of this water storage facility has also been estimated. Miller [1989] contends that "adaptation strategies should be directed at developing robust water resource systems as well as techniques to incorporate climate change uncertainties into the long-term planning."

**Acknowledgement**

The authors would like to thank the staff of the department of meteorology and the water resources branch for their cooperation in the preparation of the climatological and hydrological information

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