Supporting low carbon development and climate resilient strategies

Capacity building regional project

[Uganda]

STUDY ON CURRENT AND FUTURE POTENTIAL WATER RESOURCES, UNDER DIFFERENT CLIMATE SCENARIOS, FOR THE MPANGA RIVER BASIN (UGANDA)

Final report

05/05/2015

www.expertisefrance.fr

TABLE OF CONTENTS

TABLE OF ILLUSTRATIONS

Figures

1. INTRODUCTION

The Mpanga River basin has a catchment area of around 5,130 km² at its outlet into Lake George. The two main rivers of the Catchment are the river Mpanga and the Rushango River (see Figure 1). Altitudes range from 3,000 m in the source areas down to 915 m at the outlet. The stream length of the Mpanga River is around 200 km.

One can distinguish different parts of the catchment, each one having its own particularities and issues.

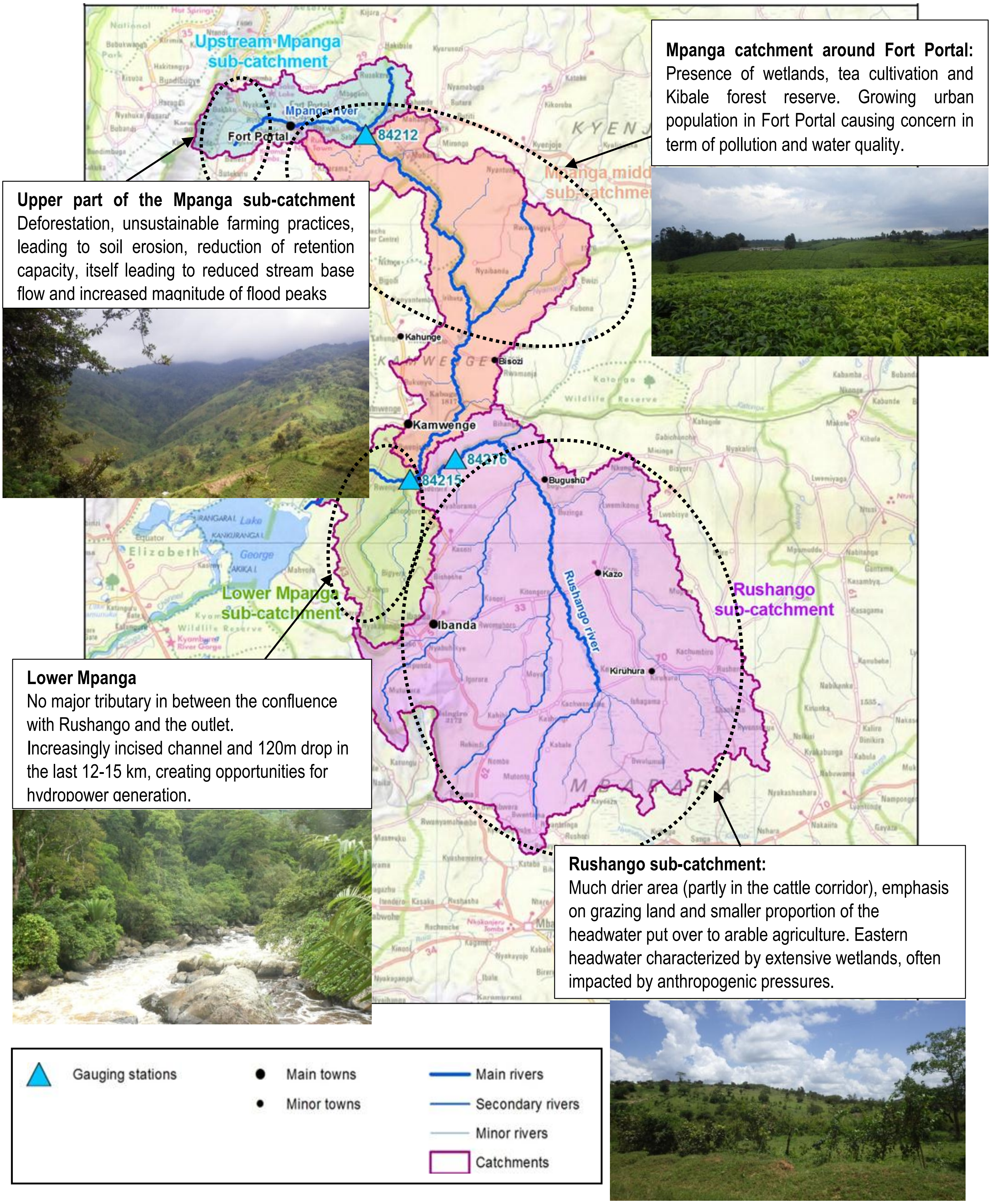


Figure 1 : Mpanga River basin – Location map

2. MAIN STEPS FOLLOWED TO COMPLETE THE ASSIGNMENT AND METHODOLOGY

2.1 OBJECTIVES AND STEPS OF THE STUDY

The AFD and FFEM entrusted ADETEF with the management of the Supporting low carbon and climate resilient development strategies Regional Project (Uganda, Kenya, Gabon, Benin). The project includes components in the 4 countries with the objectives of facilitating the institutional and technical process of climate change public policy development and/or its early implementation. The study on "Current and future potential water resources, under different climate scenarios for the Mpanga River Basin (Uganda)" is one of the three components that have been developed in Uganda under this project.

The objective of the study is to *assess the impact of different climate change scenarios on the water resources of the Mpanga River*. The results of this study will be used as a basis for future Integrated Water Resources Management (IWRM) processes within the Mpanga catchment area, hence supporting the sustainable management of the water resources. In particular, work will start soon on the re-drafting of the Catchment Management Plan for the Mpanga Basin[1]. A better understanding of the basin's water resources under both present and future climatic conditions will provide essential information for this plan.

This report is the **final document for the study, it describes the main steps followed, the outlines of the methodology and the main results and conclusions**.

The assignment was carried out through:

- A first field visit (September 2014), with the objectives of visiting the catchment, meeting the main stakeholders and collecting the data needed for the next steps. The detailed planning and outcomes of this first visit to the catchment is presented in the "First mission report" in annex 1.
- The water resource assessment under different climate change scenarios (including data analysis, choice of climate change scenario, rainfall-runoff modelling, assessment of the impact of climate change on the catchment's water resources). The detailed methodology and results for these analysis are presented in the Task 3 report (see Annex 2) which is the main technical document for the study.
- A second visit to Uganda (February 2015), essentially for a major stakeholder workshop for the presentation of the results and conclusions of the water resources assessment to the Mpanga-basin stakeholders. This workshop was organized in collaboration with the MoWE, the Albert Water Management Zone, PROTOS (NGO) and Baastel. It was the occasion to give all the stakeholders an overview of the different initiatives going on in the catchment (catchment management plan, work with catchment management organisations, water resources assessment and economic assessment of the impacts of climate change in the basin). More details on this workshop are provided in Annex 3 (second mission report).
- The finalization of the study, including a presentation to ADETEF in Paris and the writing of the final report for the study, followed this second field visit.

[1] The current (and perhaps the future) draft of the Mpanga Basin Catchment Management Plan does not include the Rushango sub-catchment

2.2 METHODOLOGY OF THE WATER RESOURCE ASSESSMENT

The detailed methodology and results for the water resource assessment are provided in the Task 3 report (see Annex 2). The schematic in Figure 2 summarizes the main steps of this methodology.

The main data used where:

- Flow data from MoWE database at the different gauging stations of the catchment
- Historical rainfall and evaporation data from MoWE and international databases (GPCC for rainfall and FAO database for evapotranspiration)
- Future rainfall and future temperature datasets from two distinct studies:
  - The "*Regional-scale Climate Change Projection of annual, seasonal and monthly near surface temperature and Rainfall in Uganda*" (University of Pretoria, Baastel, may 2014); and
  - "*Tools and guidelines for Climate Change Adaptation Mainstreaming in water infrastructure development*," NELSAP/NBI BRLi 2011
- Information on current and future water demands, including the ones presented in the "*Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin*" Ark Consult & Engineering Ltd 2014-2015.

Current and future water resources have been assessed at 4 different locations in Mpanga basin, corresponding to the outlet of each one of the sub-catchment identified in the Figure 1.

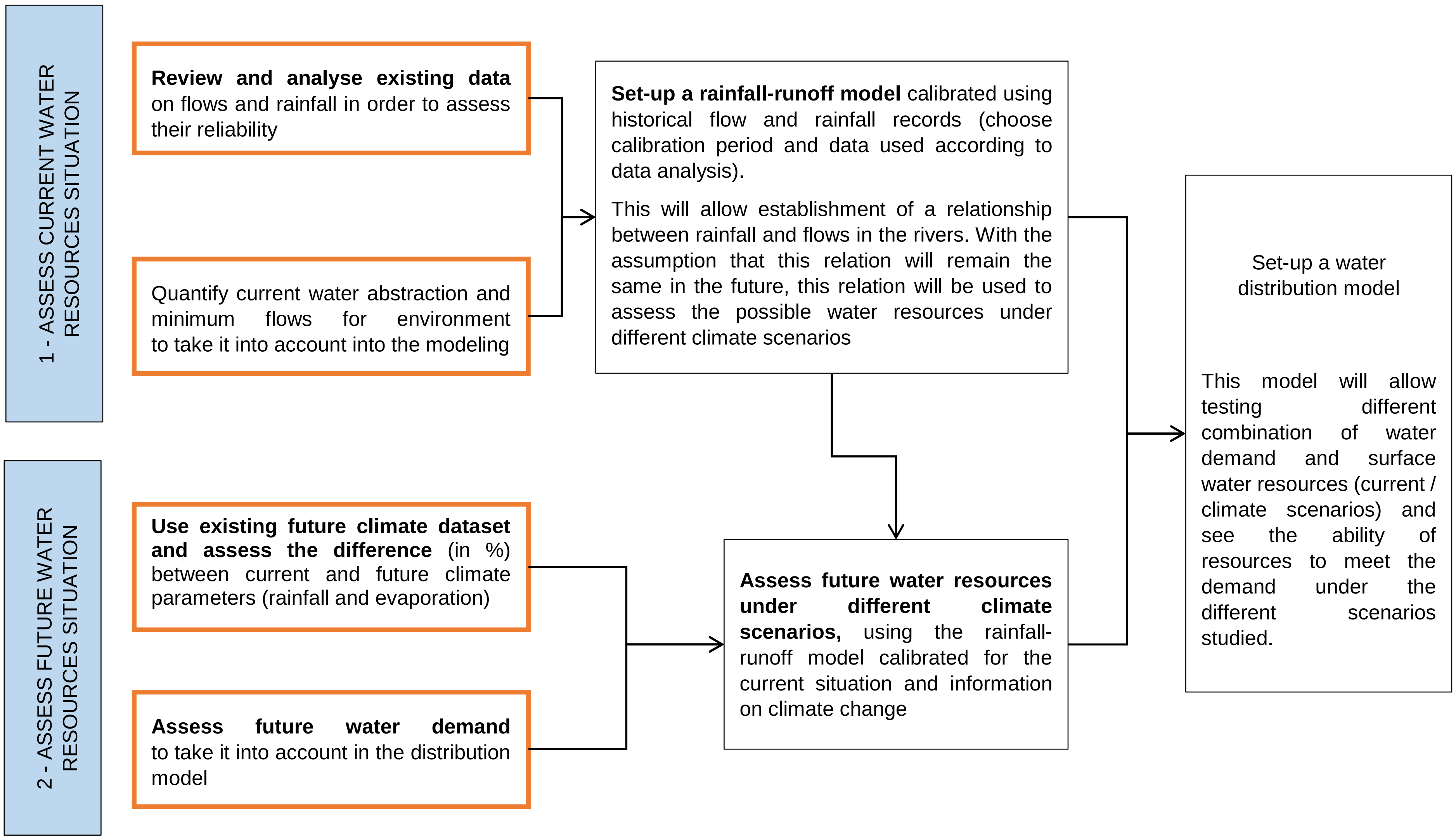


Figure 2 : Main steps of the methodology

3. CURRENT AND FUTURE WATER RESOURCES ASSESSMENT

3.1 CURRENT WATER RESOURCES

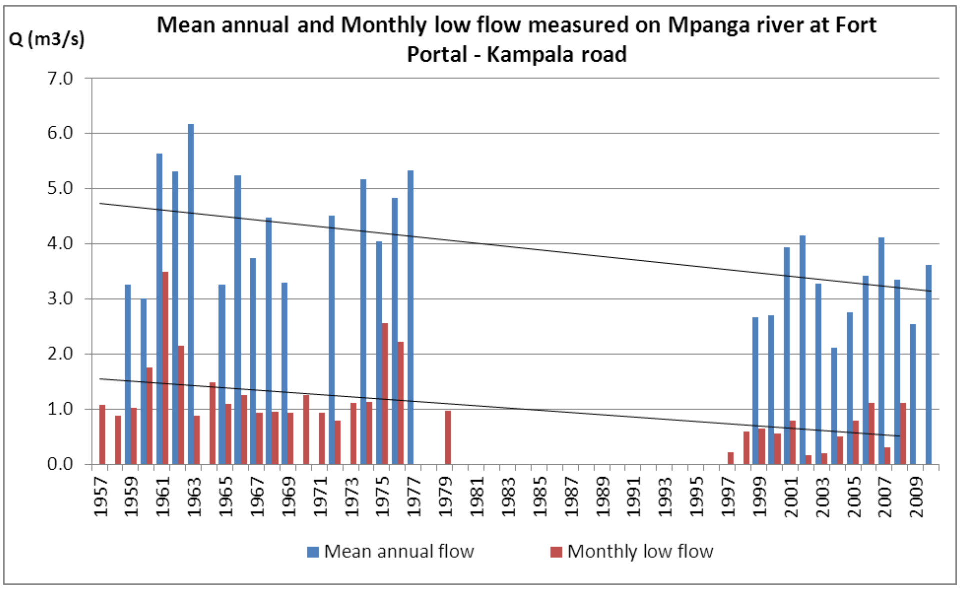
Availability of data

Three gauging stations provide flow records in Mpanga River catchment (see location on Figure 1). **At the time of this study, none of them functions correctly**. The two gauging stations on Mpanga River (n°84212 on Kampala-Fort Portal Road; and n°84215 on Fort Portal-Ibanda road) provide reasonably long data series. However the 84215 gauging station was destroyed by road works in 2012 and has been out of order since then, and data provided by gauging station n°84212 for 2011 onward seem to be unreliable (due to a change in cross-section caused by road works on the nearby bridge). The gauging station on Rushangwe River (n° 84276) has records for a few years only, and unfortunately it has no common period of functioning with any of the 2 other stations. **Estimations given for the Rushango sub-catchment are therefore subject to a high level of uncertainty**.

Observed trends

Flow records, especially at the upstream gauging station on Mpanga River (n°84214, on Fort Portal-Kampala road), show changes in the catchment hydrology (see Figure 3):

- Decrease in mean annual runoff. As detailed in Annex 2 (section 3.1), this apparent decrease in observed mean annual runoff is perhaps the result of the under estimation of high flows due to inaccuracies in the water stage/discharge rating curve for high flows at gauging station 84212.
- Decrease in monthly low flow,
- Decrease in daily minimum flow.
- Increase in daily maximum flow. As for the first bullet point above, there maximum flows may have increased to an ever larger extent than the data would seem to show.



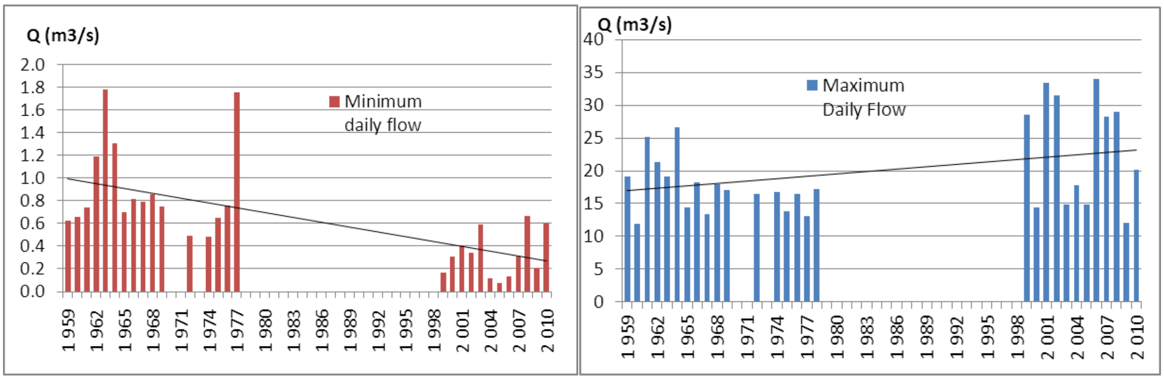


Figure 3 : Evolution of flows measured on Mpanga River at gauging station n°84212

Changes in land use, resulting in a change in the relation between rainfall and runoff is the most likely explanation of these observations as rainfall doesn't seem to have changed significantly at the same period. This period has seen a major increase in population pressure in the uppermost part of Mpanga catchment (deforestation, cultivation on steep slopes), as shown in the pictures below.

Current water resources in Mpanga basin

Surface Water

Figure 4 shows the mean flows and the drought flows (5 years return period low flows) at different locations in the Mpanga basin. The current water resources assessment showed that:

- The upstream part of Mpanga basin is the most productive part of the catchment, with a mean annual unit runoff of 8 l/s/km², whereas the unit runoff measured on Mpanga after the confluence with Rushango is only 3 l/s/km². Unit runoff in Rushango sub-catchment seems even smaller (1 l/s/km²).
- Inter-annual flow variability is relatively high. The minimum monthly flow (usually in July) during a dry year can be twice as small as the mean minimum monthly flow.

Groundwater

There is no groundwater monitoring stations in the Mpanga catchment, so it is difficult to provide an indication of trends. However, there is both anecdotal and scientific evidence to support the view that there has been a general decline in the groundwater table throughout the basin.

In the lower parts of the catchment, for example in the rural areas around Kamwenge where groundwater is the main source of water for most households, PROTOS reports that many of the hand pumps have dried up and new sites have had to be found. In the Rushango sub-catchment the same problem was reported. In some cases the groundwater sources dry up during periods of drought.

Groundwater and surface water are closely linked. The reduced low flows in the upper part of the Mpanga River have decreased, almost certainly as a result of a lowered groundwater table,

In general, it would appear that the availability of groundwater is being compromised by anthropogenic pressures across the basin. In the source areas this is due to the conversion of natural land cover into farmland and the ensuing poor farming practices. In the lower parts of the basin it is due to increased abstraction although the level and extent of this problem cannot be quantified because of a lack of monitoring data.

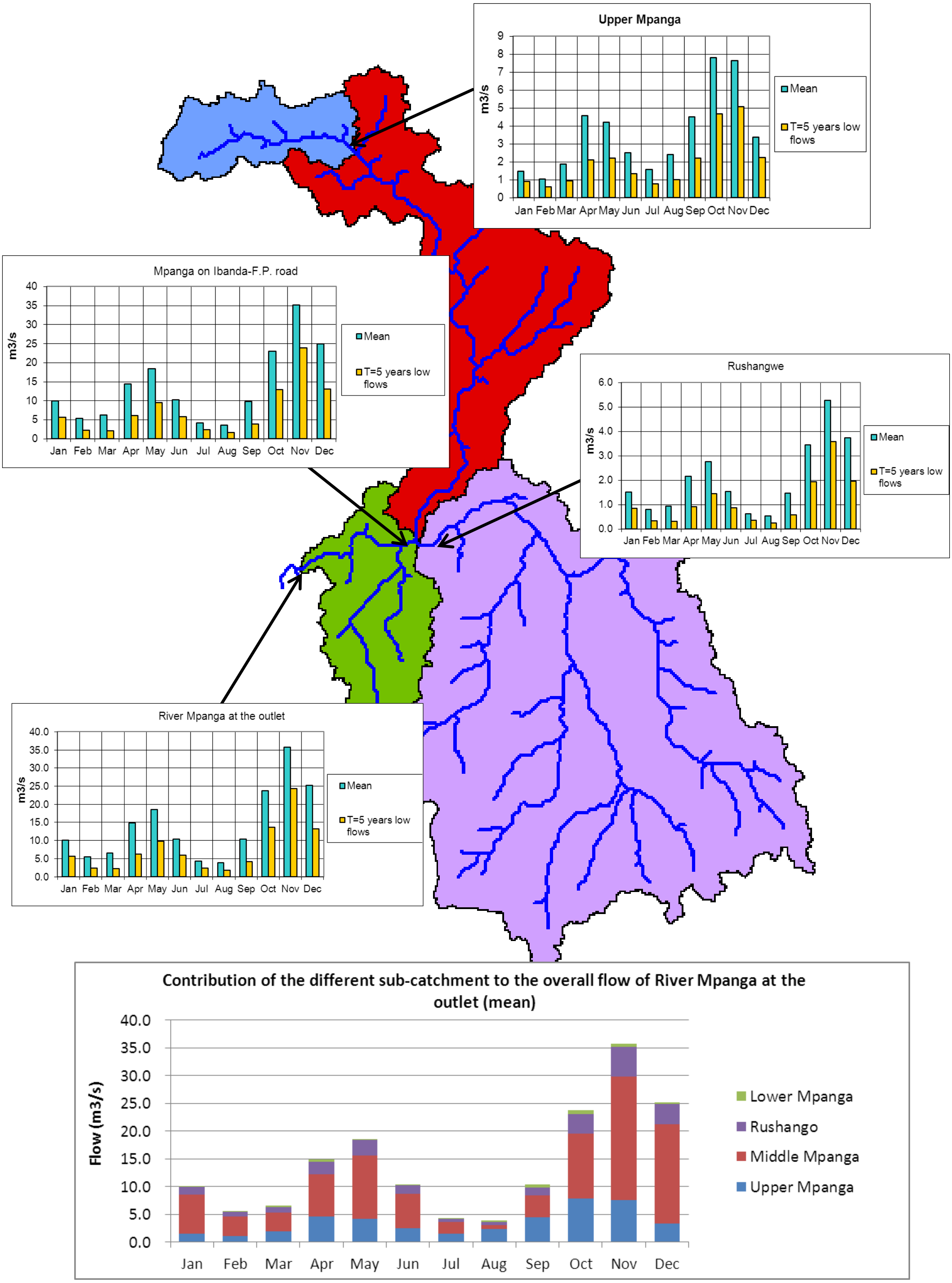


Figure 4 : Current water resources of Mpanga River basin

3.2 FUTURE WATER RESOURCES

Future climate scenario

All the climate modelling works undertaken in the Nile Equatorial Lake area indicate **a positive evolution (rise) of the temperatures,** the uncertainty remaining is about the intensity of this evolution. On the other hand, the **trend for precipitation is very difficult to ascertain**: the modelling outputs do not converge in the area.

Seven climate scenarios have been tested in this study. **The different scenarios indicate no or little change (decrease) in annual total, but rainfall distribution during the year is likely to change.** Although some scenarios lead to the opposite conclusion**, the period from April to September is likely to be dryer than what it used to be, whereas October to February tends to be wetter.**

Future water resources scenario

Future rainfall and evapotranspiration of the different climate change scenarios have been used as input for the rainfall-runoff models and allowed the generation of different future water resources scenarios.

The following graphs (see Figure 5) compare the current flows (average 1980-2010) (black line on the graphs) and the range of possible future flow (average 2021-2050).

The results are presented at 4 locations:

- River Mpanga on Kampala – Fort Portal road (current location of gauging station 84212)
- River Rushango just before the confluence with River Mpanga
- River Mpanga on Fort Portal-Ibanda road (gauging station 84215)
- River Mpanga at the outlet.

As a consequence of the high uncertainty regarding the trend of future rainfall, there is also a wide range of possible future water resource scenarios. **The combined effect of the evolution of rainfall and temperature leads to a decrease in flows from May to October. This decrease is particularly clear for the upstream part of Mpanga basin. The evolution of flows during the November to April period is not as clear, some scenario indicating a decrease in flows and some an increase.**

All the scenarios tested indicate **a decrease in mean annual runoff** ranging from a 9% to a 38% **decrease**.

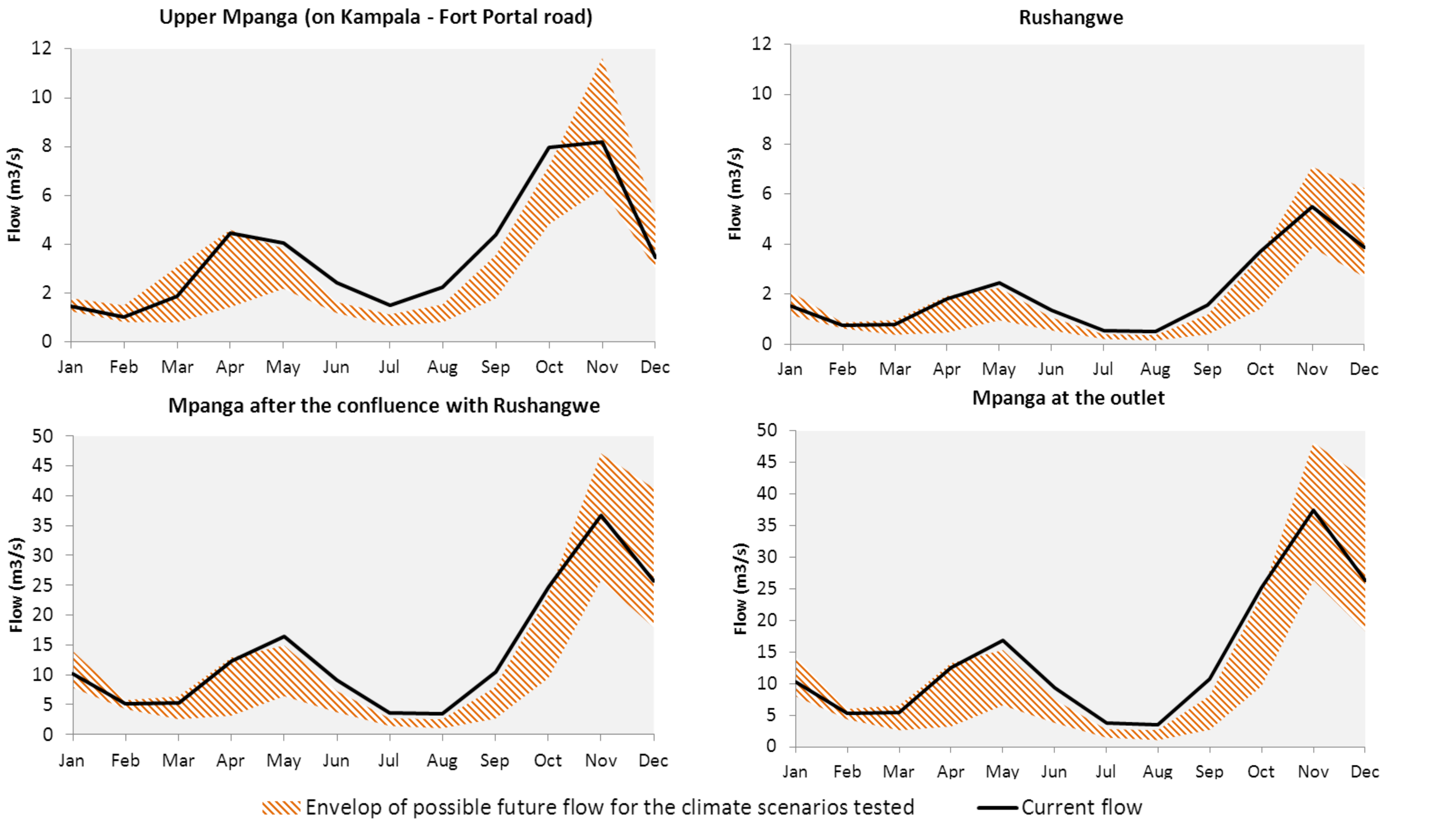


Figure 5 : Comparison of current average monthly flows and possible future average monthly flows at different locations in river Mpanga basin (future flows shown as a range)

3.3 WATER RESOURCES / WATER DEMAND BALANCE

Water resources and water demand have been compared for the different sub-catchments.

Under the reference scenario (current water demand, and current water resources), the overall quantity of water available in a year in the catchment is largely sufficient to meet the demand.

Under future climate scenarios, when considered on an annual basis, water is still largely sufficient to meet the demand (including future projected water demand) for the upper, middle and lower Mpanga sub-catchments. Of course, flow variability needs to be looked at more closely but this shows that the implementation of appropriate storage facilities and adequate water management at the catchment level should permit the satisfaction of demand. The situation is more difficult in Rushango sub-catchment where the water resource is less abundant and where water demand is expected to rise sharply.

A water resources/water demand balance analysis has been carried out on a monthly time step, using a water allocation model. The main results are presented in Figure 6 and Figure 7.

Figure 6 shows the percentage of months when water demand exceed water resources available, and the percentage of years when a deficit occurs in one month or more. For example, for the Rushango sub-catchment under the reference scenario (current climate and current water demand), deficits occur for 24 of the months tested (7% of the 360 months tested), distributed on 14 years (occurring for at least one month of 47% of the 30 years tested). Results are presented for current climate, and for the two extreme scenarios among the climate change scenarios tested.

For the upper and lower Mpanga, deficits never occur for current water demand, whatever climate scenario is considered. For future water demand deficits occur during less than 10% of the years tested, even for a dry year with a 10 year return period no deficit is encountered.

Deficits are a bit more frequent for the Middle Mpanga sub-catchment, however, deficit remains relatively low (less than 5% of the total demand for the most pessimistic climate change scenario).

It's for Rushango sub-catchment that the situation is the most critical. Even for the reference scenario (current climate and current hydrology) a deficit occurs almost 1 in every 2 years. The deficit that would have to be covered to satisfy the current water demand remains reasonably low (maximum of 15%, even for very dry years (10 year return period) and for the most pessimistic climate change scenario), but a deficit for the satisfaction of the future water demand is encountered every year whatever climate scenario is considered, and the proportion of unmet water demand can reach more than 45% under the worst configuration (10 years return period dry year and pessimistic climate change scenario).

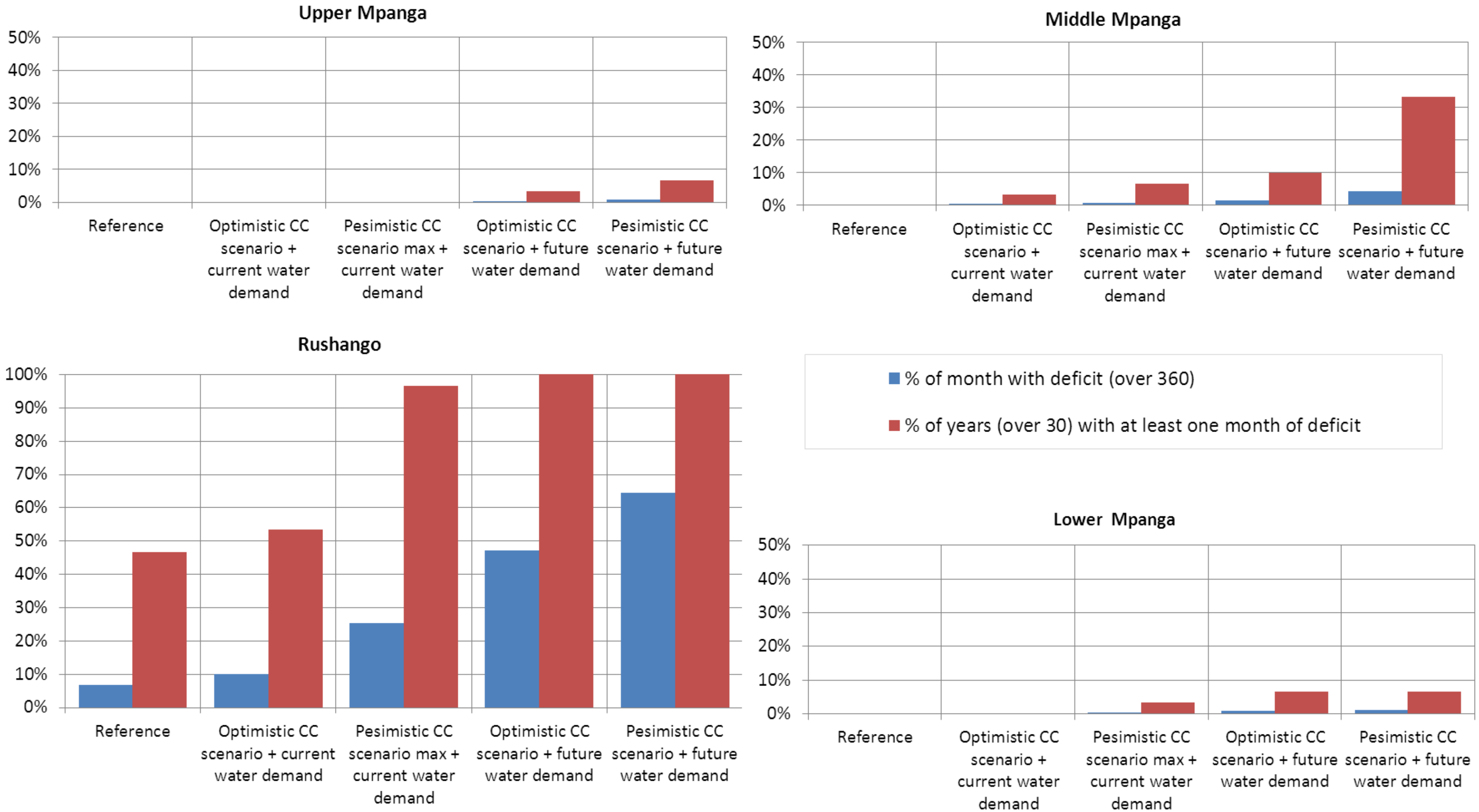


Figure 6 : Frequency of deficits (water demand>water resources) under different climate and water demand scenarios

Unmet demand for each one of the catchment has been calculated for a normal year (median) a dry year (5 years return period) and for a very dry year (10 years return period). Results are shown in Figure 7 for the middle Mpanga and Rushango sub-catchment (for upper and lower Mpanga sub-catchment, no deficit are encountered, even for 10 years return period dry years).

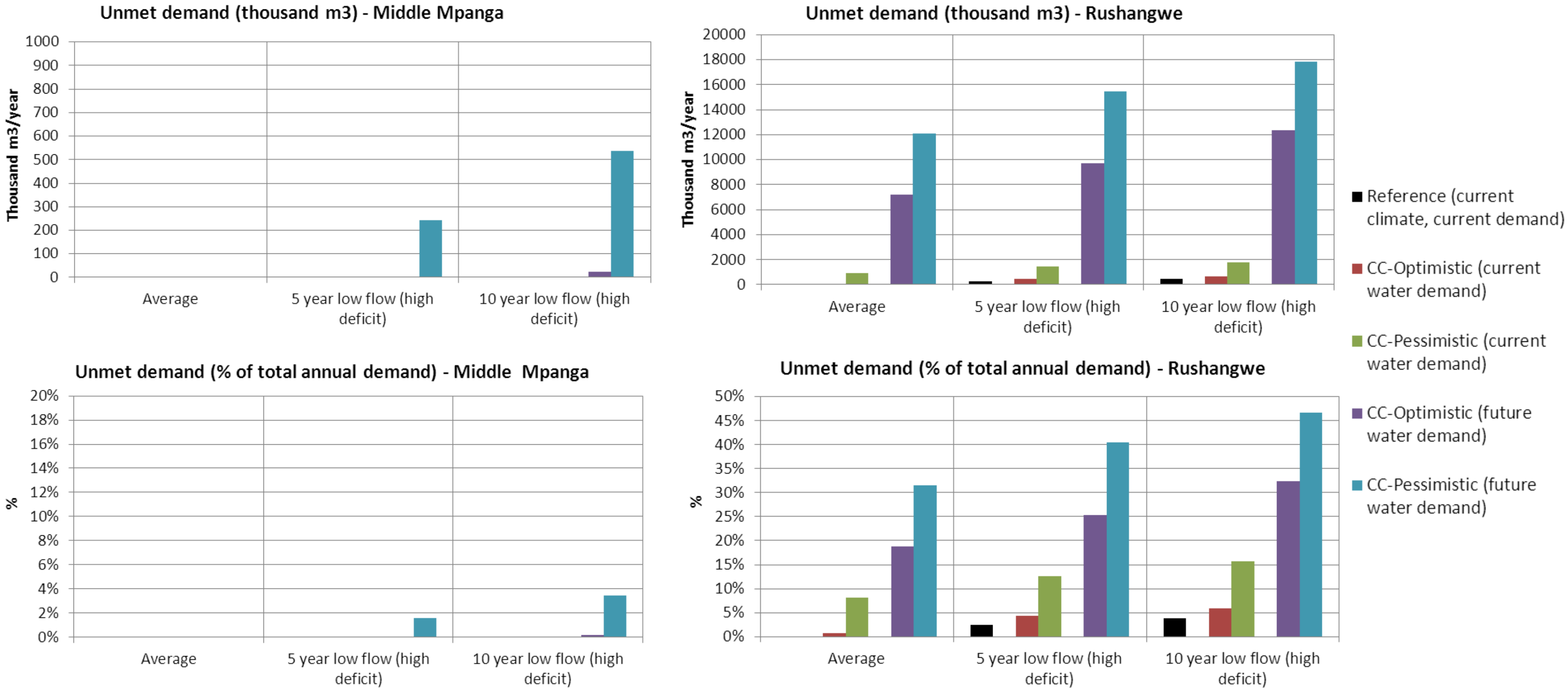


Figure 7 : Unmet demand for the different sub-catchment under different climate scenario (current water demand)

The annual water volume coming from river Mpanga and entering Lake George is on average around 430 Mm³/year. If water demands remain the same, the impact of climate change could go from a 5 to 10% decrease for the less penalizing scenario, to a more than 40% decrease for the most pessimistic scenario (see Figure 8). The impact of the evolution of water demand is of secondary importance compare to the impact of climate change or of inter-annual variability.

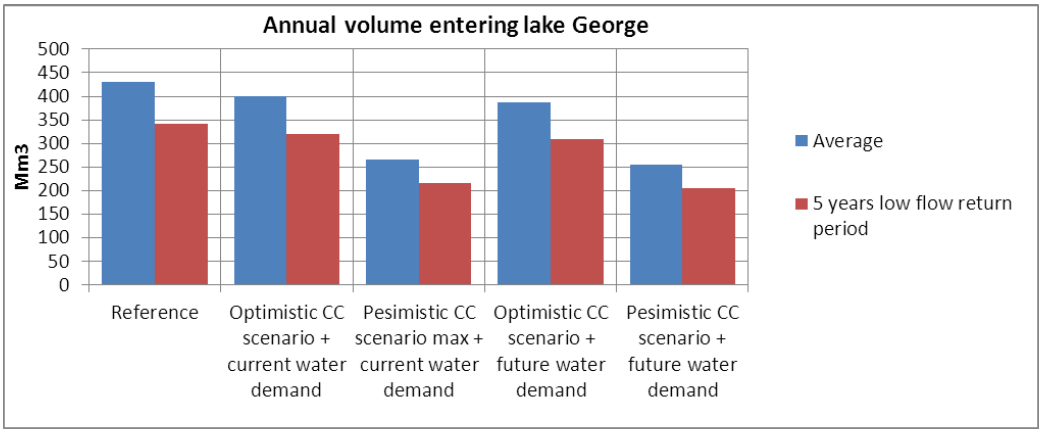


Figure 8 : Flow entering Lake George under different climate scenario (current water demand)

4. CONCLUSIONS AND WAY FORWARD

4.1 CONCLUSIONS AND RECOMMENDATIONS FOR THE MPANGA RIVER BASIN

While there is a high degree of uncertainty attached to the findings of the study, due to a paucity of reliable precipitation and flow data and considerable divergence between climate change models, a number of conclusions (some tentative) can be drawn;

- Over recent years (+/-30 years) it would appear that high flows have increased and low (base) flows have decreased in the upper part of the Mpanga basin. According to available data, the mean annual runoff has reduced. However, this conclusion should be treated with caution since the apparent reduction may be the result of an error in the upper part of the rating curve. During the same period, precipitation has not apparently reduced. The implication is that the problems encountered during the dry season are more likely due to catchment degradation (increased cultivation, poor farming practices and deforestation) than to climate change. Without either/both reversing this trend or building storage, shortages are likely to become increasingly frequent in the future as demand increases and the possible impacts of climate change are felt.

  Putting a stop to the continued deforestation of the source areas, improving farming practices and providing alternative rural and urban-based livelihoods should be regarded as a priority and ongoing efforts in this respect should be encouraged and further supported.

  The monitoring of groundwater at selected sites in the source areas is advisable and would give better insight into the relationship between groundwater levels and river base flows

- The Mpanga catchment is situated in an area where the magnitude of the effect of climate change on precipitation is very unclear. Since this understanding is unlikely to improve in the near future there is a strong argument for improving the quality and density of the rain gauge network. In this way it should gradually become possible to identify climate change trends as they develop.
- As a consequence of the high uncertainty regarding the trend of future rainfall, there is also a wide range of possible future water resource scenarios. The combined effect of the evolution of rainfall and temperature leads to a decrease in flows from May to October. This decrease is particularly clear for the upstream part of Mpanga basin. The evolution of flows during the November to April period is not as clear, some scenario indicating a decrease in flows and some an increase. All the scenarios tested indicate a decrease in mean annual runoff ranging from a 9% to a 38% decrease.
- Without mitigation actions (building of storage and/or rehabilitation and protection of the wetlands in the source areas), the worst water shortages will occur in the Rushango catchment. This catchment is considerably less well-watered than the Mpanga catchment and the population is higher.
- The most critical area of the catchment, the Rushango sub-catchment, is also the area where there is least confidence in the river flow data. Given the potential costs that could be incurred to develop storage in the Rushango sub-catchment, the highest priority should be given to
  - improving the accuracy of stream flow records. The rehabilitation and operationalization of the closed river gauging station (as a minimum) on the Rushango should be carried out as a matter of urgency. Consideration should also be given to the erection of a new station measuring flows originating in the mountains in the west of the Rushango sub-catchment (see also next point)
  - Design and implementation of a groundwater monitoring network aimed at identifying and closely monitoring areas where groundwater is under pressure during the dry season.

- The monitoring of springs should be undertaken. For example the bulk water supply to the rapidly growing town of Ibanda is entirely supplied from springs in the mountains several kilometres away. While there has been no failure in supply this far, it is important to monitor the condition of these springs.

- There may be a need to consider the construction of some intra-seasonal storage in the upper parts of the Rushango (probably in the hilly part of the western side of the sub- catchment) and Mpanga sub-catchments. While this may not be required in the immediate future, it would be useful to investigate potential sites. The aim should be to have relatively small storages with flexible release systems so that shortages during dry years can be mitigated against. The alternatives are i) to increase the use of groundwater through the development of bulk water schemes for villages and individual water points (handpumps/solar etc.) and ii) the conjunctive use of groundwater and surface water storage
- Given that all the GCModels point to a decrease in the mean annual runoff of the Mpanga River entering Lake George, it would be useful to investigate the potential impact on the lake.
- Work is required to investigate and better define environmental flow requirements, especially in the upper part of the basin. Satisfaction of these requirements would be a priority (over upstream uses) and would therefore provide a better level of equity between upstream and downstream users (including the environmental flow requirements downstream.

4.2 LESSONS LEARNT AND CONCLUSION FOR FURTHER CLIMATE CHANGE ASSESSMENT STUDIES

Carrying out this assignment has also brought out conclusions about the relevance of such an approach, the conditions for its success and the ways in which the results could be used usefully.

Need for improvement of knowledge of the current status of water resources

Before attempting to estimate the impact of climate change on water resources, the mandatory first step is to assess and understand the water resources under current climatic conditions. This can only be achieved where sufficient hydrological (especially rainfall and river flow) data have been and are being collected. These assessments are based on the analysis of historical records. All other things being equal, the accuracy and reliability of the assessments are dependent on the length and quality of the historic records.

It's therefore essential to stress the importance of:

- Collecting data and therefore maintaining/renovating/implementing gauging stations
- Monitoring existing gauging stations in order to ensure the data collected are usable
- Analyzing the data provided. Data analysis should be done as data are collected, not later so that anomalies in the station functioning can be detected and corrected.

In some cases, (as for the upper part of Mpanga catchment), the analysis of past and current hydrology and flows can allow highlighting the impact of human pressure (land use, deforestation…) on the water resources, and stress the fact that, even without climate change, water resources are changing under the influence of inadequate management.

It goes without saying that such an assessment must be done for hydrological coherent units, (for example for the Mpanga River, any water management plan including the downstream part of the Mpanga River should include the Rushango sub-catchment).

While the importance of building long historical records is important, it should be stressed that the collection or river flow data for even a few years can contribute a great deal to the understanding of the water resources in a basin such as the Mpanga where there are so few data. If efforts start now to improve the coverage and quality of data collection, it will already be possible to greatly improve estimates of the water resources potential of the basin by 2020.

Concentration of initiatives in the catchment allowing a comprehensive overview

Mpanga River basin has enjoyed the advantage of the concentration of a number of different projects and initiatives that complement each other, associated with measures to raise awareness of the stakeholders and of the communities.

In addition to the water resources assessment carried out under this project:

- Mpanga basin was one of the detailed case study of the "Regional-scale Climate Change Projections of annual, seasonal and Monthly Near-surface Temperature and Rainfall in Uganda", so future precipitation and temperature data at local level where available.
- A draft catchment management plan has been produced, and the final catchment management plan is to be drawn up under a Consultancy that has just been awarded.
- Water uses and water remand have been assessed under a regional study on water demand in Lake George, Lake Edward and Kafu basin.
- Different projects have been implemented by NGO (PROTOS for example), the Mountain of the Moon University, and work with the communities and catchment management organisations has been done.
- Mpanga basin is one of the case-study or the "Economic Assessment of the Impacts of Climate Change in Uganda" (on going).

This surely allows a comprehensive understanding of the catchment issues and challenges for the future, each component complementing each other.

However, the lack of knowledge or data shouldn't be a brake for the development of water resources assessment in river basins. Although a minimum hydrological data is almost mandatory, the lack of climate data can often be supplemented by data from existing database (as long as the use of these databases can be validated for each specific catchment). Uganda has the advantage of having different climate change assessment, and has therefore almost ready-to-use datasets of future climate scenario for the whole country.

In any case, a water resources study of the nature that has been carried out, together with an analysis of existing and potential demands, should be one of the first studies to be carried out towards the development of a catchment management plan. The approach and methodology used in this study can certainly be applied in other catchments.

Information brought by water resources assessment studies and possible uses

A good water resources assessment is an essential element for catchment management planning.

- Knowledge of current hydrology will provide information to answer questions such as:
  - Where are the main source areas and where are the flows generated? These areas will then be the most relevant for the implementation of catchment protection measures.
  - What are the characteristics of the flows (variability, intensity…)? This information can be useful for the planning of water storage facilities.

- Water resources/Water demand balance analysis will provide information to answer questions such as:
  - In which part of the catchment is the risk of deficit to meet the water demand lower/higher?
  - How much room for manoeuvre is there in terms of the possibility for the resources to satisfy new/future water demands, (taking into account the need for minimum environmental flows)?
  - Is there enough water available during periods of high flows to be stored and supply water demand during low flows
  - …
- Climate change impact assessments will allow having an idea on how the issues will evolve, and anticipating new challenges.

Results of such studies are useful tools for decision making. However, the **uncertainties associated to these results must always be kept in mind**, and the results should rather **be seen as order of magnitude** than be taken as set in stone values.

Appropriation and relevance for the key stakeholders

Although climate change, hydrology and water resources modelling involves work of a highly technical nature, this type of study can lead to findings and conclusions that stakeholders can easily understand and appropriate if the rights efforts are made to present the information in a digestible form. This type of study adds value for the stakeholders because it provides hard evidence to support the need for change, something which is generally absent. For example, such studies can be used to quantify, explain or highlight phenomenon that local stakeholders experience on the ground (e.g. reduction of base flow) which will facilitates appropriation of the results and provide additional incentives to take action to mitigate against these phenomenon.

The factors seen as positive for appropriation of the results of such an approach by the stakeholders include:

- Interaction with the stakeholders (decision makers, representatives of organisations or communities…) at an early stage of the project facilitates their cooperation and allows them to be prepare for receiving the results at a later stage
- The concentration of various initiatives on the Mpanga catchment will without doubt be a positive factor that will ease appropriation by the stakeholders. The comprehensive overview of the situation allowed by the different initiatives make the stakeholders more aware of the issues and how they relate to each other.

In the case of Mpanga catchment, there is good hope that the results can be used by the stakeholders, especially regarding the main conclusions, including:

- Impact of land use and need for tackling the root causes of land degradation and deforestation (look for alternative livelihood) in the headwaters of Mpanga River.
- Importance of good quality data collection and analysis
- Need for inclusion of the Rushango sub-catchment in the Mpanga-catchment water management plan

What may be improved for other similar study is the appropriation of the technical aspects and methodology by staff from the MoWE and/or the Water Management Zone. This appropriation can only be achieved by involving MoWE staff in the technical realisation of the study (data analysis, water resources modelling, etc…), the consultant then intervening for capacity building and in the provision of technical assistance

Need for complementary action/information

To complete water resources assessment two components are needed and are often missing

- Assessment of minimum environmental flow requirement
- Study of hydrogeology and interaction between surface and groundwater

4.3 OPPORTUNITIES FOR FUTURE SUPPORT

Capacity building – hydrological and water resources modelling (WEAP)

It was agreed that the tools that had been developed for the study, in particular the WEAP water resources and simulation model, are both appropriate and useful. However, the need for ensuring that the capacity to update and continue using this and the associated hydrological models (rainfall/runoff modelling etc) was stressed. It is certainly true that the data within these models (essentially water resources data, demand data and management rules including allowance for environmental flows) should be updated on a regular basis and the WEAP model updated as well.

If used properly, the WEAP model can become a useful planning tool for the basin. Capacity-building is required for this to happen and support to ensure that this happens would be very useful.

Design and Implementation of Groundwater Monitoring Network

It has been highlighted in the report that there is currently no groundwater monitoring programme in the basin, this despite the fact that groundwater supplies around two thirds of demand in the basis. It is strongly recommended that support should be made available to design and implement an appropriate groundwater monitoring programme in the basin. This should include the **monitoring of springs** such as those currently being tapped to supply water to Ibanda.

Improved knowledge of environmental flow requirements.

It has been highlighted in the report that little is known of environmental flow requirements in the basin. This is a complicated area and requires a good understanding of a wide range water related environmental needs. It is strongly recommended that a study (including field assessments) is carried out to ascertain the flow requirements at different locations around the basin.

Livelihood-based watershed management – Pilot Project

It is clear that the land degradation issues in the upper part of the basin are caused i) by the uncontrolled expansion of farming into areas where agriculture is challenging and ii) the application of very poor farming practices. Expansion is driven by increased pressure on land further downstream and the need for people to find livelihoods.

A livelihood-based watershed management approach is increasingly being recognized as the ideal approach for integrated natural resources management in rainfed areas. The idea is to promote win-win activities through the promotion of good farming and land-use practices which result in improved livelihoods. These may be achieved through higher crop yields and/or value added activities or alternative livelihoods (such as bee keeping).

The success of watershed management largely depends on the community's participation. In a recent review (Joshi *et al*. 2000; Kerr *et al*. 2000) on the watershed projects in India, it was observed that most watershed projects did not address the equity issues of benefits, community participation, scaling-up approaches, monitoring and evaluation. Moreover, most of these projects relied heavily on government investments and were structure-driven (rainwater harvesting and soil conservation structures), and failed to address the issue of the efficient use of natural resources (soil and water).

Land degradation in parts (especially in the Upper Mpanga) is arguably the biggest challenge to the sustainable development and management of the Mpanga basin.

Improving water security in the Rushango sub-basin - Preliminary feasibility study into water supply options

The report has highlighted that there already chronic water shortage is the Rushango sub-catchment and that these will get worse. There is a need to start looking at options to improve the water supply. This could involve the construction of water storage reservoirs or the development of groundwater abstraction schemes or the conjunctive use of surface and groundwater resources. A preliminary feasibility study is required as a matter of urgency.

Catchment Management Plan for other catchments

It was agreed during the workshop that the approach adopted in this study should become one of the standard key building blocks for any catchment management plan. Work is currently already underway on the updating and upgrading of the catchment management plan for the Mpanga basin. It would be very useful to choose other critical basins and repeat the process right through to the development of a catchment management plan.

ANNEXES

ANNEX 1: FIRST MISSION REPORT

ANNEX 2: TECHNICAL REPORT ON HYDROLOGY AND CLIMATE CHANGE (TASK 3 REPORT)

ANNEX 3: SECOND MISSION REPORT

ANNEX 1: FIRST MISSION REPORT

MISSION REPORT

Supporting low carbon development and climate resilient strategies

Capacity building regional project

[Uganda]

STUDY ON CURRENT AND FUTURE POTENTIAL WATER RESOURCES, UNDER DIFFERENT CLIMATE SCENARIOS, FOR THE MPANGA RIVER BASIN (UGANDA)

adetef.
Assistance Technique France

November 2014

In association with

AGENCE FRANÇAISE DE DÉVELOPPEMENT

FFEM

BRL ingénierie

Study on current and future potential water resources, under different climate scenarios, for the Mpanga River Basin (Uganda)

1ST MISSION REPORT

November 2014

TABLE OF CONTENTS

1. Introduction

This first mission of the project team to Uganda and to the Mpanga River Basin in particular, took place within the context of the *Study on current and future potential water resources, under different climate scenarios, for the Mpanga River Basin.* Work on this study started with a Kickoff meeting in Paris on 10 July 2014.

The objective of the study is to assess the impact of different climate change scenarios on the water resources of the Mpanga River. The results of this study will be used as a basis for future Integrated Water Resources Management (IWRM) processes within Mpanga catchment area, hence supporting the sustainable management of the water resource. In particular, work will start soon on the re-drafting of the Catchment Management Plan for the Mpanga Basin[1]. A better understanding of the basin's water resources under both present and future climatic conditions will provide essential information for this plan.

This first mission had the overall objective of ensuring that all required available information and data would be available for the analytical work to proceed. Sub-objectives aimed at fulfilling the overall objective were:

- Completion of data and documentation collection, including an initial data quality assessment where possible
- Consultation with stakeholders, including information holders
- Reconnaissance and field measurements

The overall objective of the mission was achieved through a number of meetings and interviews in Entebbe, Kampala, Fort Portal and around the basin. This was in no small measure due to the excellent and enthusiastic cooperation of the Directorate of Water Resources within the MWE, as well as other governmental and non-governmental stakeholders.

The itinerary followed by the team around the basin is shown in Figure 1. Related to Figure 1 are a number of photographs taken at key locations during the mission (see Annex 1). In addition to the various meetings and interviews within Fort Portal the itinerary within the basin comprised the following key elements:

- Visit on foot to the source areas of the Mpanga River
- Visit to parts of the western side of the Mpanga catchment including several crossing points of the Mpanga River and its tributaries
- Visit to the Katonga tributary on the eastern side of the Rushango sub-catchment
- Visit to a large part of the Rushango sub-catchment including the central and upper areas and several crossing points of the Rushango River and its tributaries
- Visit to the lower part of the Mpanga and Rushango sub-catchments, their confluence and the lower Mpanga down to the Kamwenge power station
- The carrying out of discharge measurements at River Mpanga at Kampala – Fort Portal road, River Rushango upstream the confluence and River Mpanga after the confluence with Rushango (see Figure 1).

In view of the objective of the mission, rather than describing what was done in chronological order, this report has been organized along the lines of what information and data has been obtained

[1] The current (and perhaps the future) draft of the Mpanga Basin Catchment Managament Plan does not include the Rushango sub-catchment

under the key study thematic areas of i) the status of the catchment (under a number of thematic areas), ii) hydrology and water resources and iii) water demand Information. Gaps are then discussed and way forward presented.

Annex 1 provides a list of the meetings held with stakeholders during the mission and includes a brief overview of the discussions held and the key information/data provided.

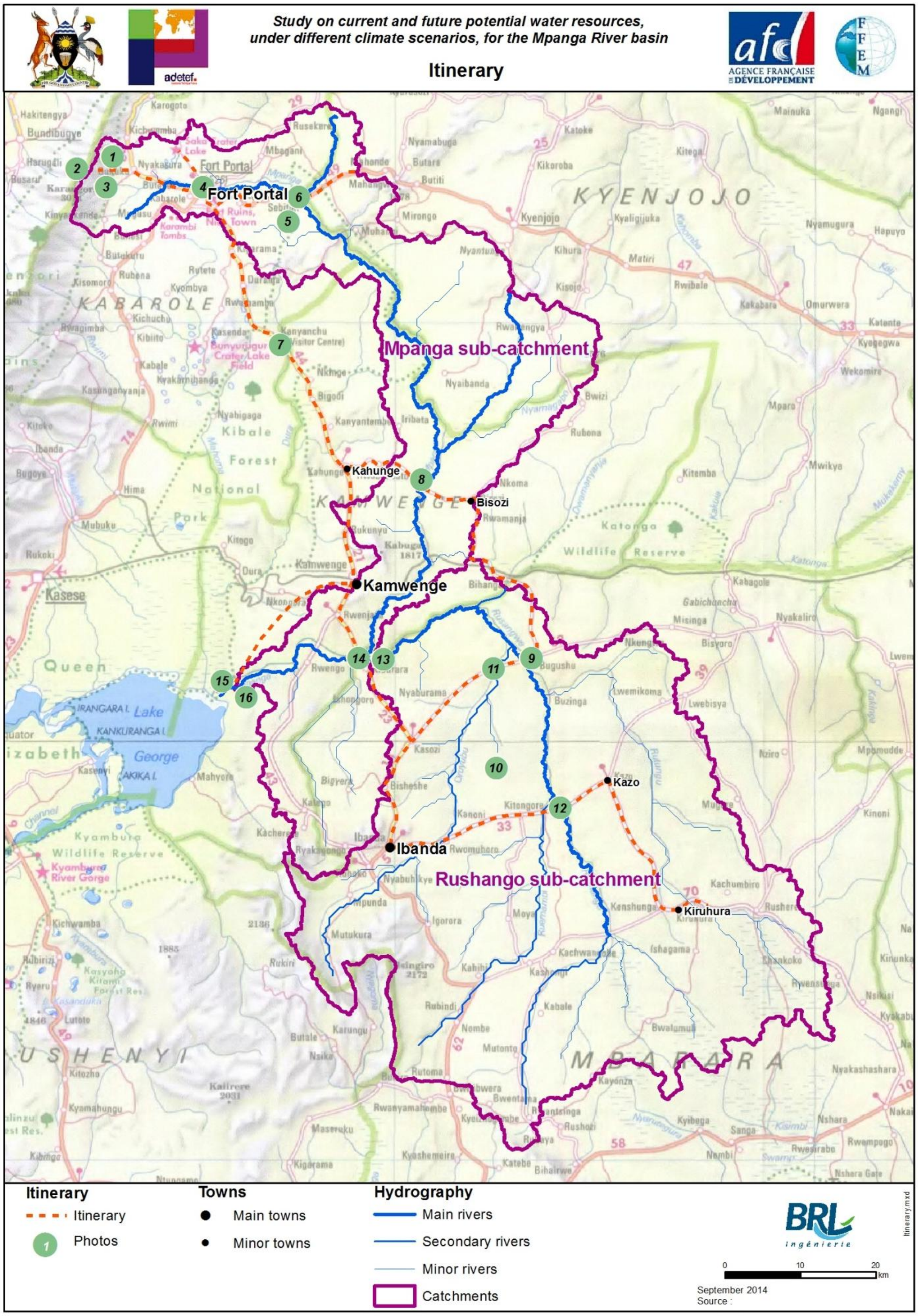


Figure 1 : Itinerary and places visited during the first mission

2. Information on catchment characteristics and status

2.1 Bibliography and data collected

A number of studies have been carried out in the Mpanga Basin and these help greatly in providing an overview of the catchment characteristics and state of the basin. However, it should be stressed that these essentially cover the Mpanga sub-catchment with very little work having been carried out on the Rushango sub-catchment which accounts more than 60% of the total basin's surface area. Some of the most useful sources of information are:

- Mpanga River basin area baseline assessment report, DWRM/MWE & Protos 2012, and other information from PROTOS including maps and detailed studies on specific aspects/parts of the Mpanga sub-catchment.
- Mpanga River Management Plan (draft). The draft report covers only the Mpanga sub-catchment of the Mpanga catchment. Although the report has to be re-drafted after a number of shortcomings were identified, it has still proved to be a useful resource, discussing some of the key issues including pollution, soil erosion, wetland protection and hydrological monitoring.

Various stakeholders also provided a considerable quantity of useful information including maps and/or GIS layers on land cover, land use, administrative boundaries etc).

The Feasibility Study and Environmental Impact Assessment reports for the Hydropower station on River Mpanga could also give provide useful information. These have not been obtained as yet, but efforts to procure them from the relevant stakeholders will be pursued.

2.2 Reconnaissance of the catchment

Six days were dedicated to a reconnaissance of the catchment and carrying out some discharge measurements at key locations. Figure 1 shows the itinerary and Annex 1 some selected photographs of places visited or issues noted.

A brief description of the different parts of the basin, with a focus on the hydrology and associated aspects is provided as follows:

- **Upper part of the of Mpanga sub-catchment:**

The River Mpanga takes is source on the slopes of Mount Karangora which rises to 3014m in the Rwenzori National Park.

While the uppermost part of the catchment lies within the Rwenzori Mountains National Park and remains forested, it is not free from wood-cutting, both for immediate use and especially for charcoal.

Figure 2 : View on the source area of River Mpanga

The areas of forest and woodland immediately below the Park boundary are being encroached upon and cleared for agriculture at an alarming rate. From a hydrological perspective, the loss of tree cover and the generalized poor farming practices which include the almost total absence of terracing and other soil conservation measures (see Photo 2 in A) inevitably means that:

- The volumes of top soil being washed into the river are dramatically increased
- The retention of precipitation and subsequent release into stream base flow is reduced
- The lack of retention of precipitation increases the magnitude of flood peaks

From a livelihoods perspective it is clear that the farming practices are unsustainable and this was supported by anecdotal evidence which indicated that virgin land remains productive for only a few years at most and that many farmers have made significant financial losses in the area. In some cases, seeds planted on steep slopes are washed away by heavy rain before properly germinating.

In addition to deforestation the riverine environment is also experiencing high levels of pressure with stone and sand mining (see Photo 3 in Annex 1) all along its length. This results in the destabilization of its banks, erosion and damage to ecosystems.

Many of the stakeholders are aware of the problems and there are efforts to promote alternative livelihoods such as beekeeping. The main challenges would appear to be inadequate coverage of agricultural extension service and lack of law enforcement.

- **Mpanga catchment around Fort Portal:** It was not possible to visit all of the areas around Fort Portal but the area is characterised by the presence of significant wetlands and the cultivation of tea (see Photo 5 in Annex 1). The extensive tea plantations generally provide good protection against erosion. How this measures up against natural ground cover is not clear.

  The presence of Fort Portal, a town which is growing quite rapidly is cause for concern in terms of pollution and water quality. Wetlands downstream of the town probably play a critical role in water purification.

  There are also a number of volcanic crater lakes to the north of Fort Portal. These represent significant localized water resources and concentrations of biodiversity.

  Most are essentially self-contained depending on rainfall and localized precipitation, while a number are connected to stream systems acting as sources and/or receiving some inflow.

Figure 3 : Crater Lake in Mpanga catchment (on the land of Mountain of the Moor University)

  The Mpanga River is gauged at Station 85212 just upstream of the Fort Portal-Kampala Road and downstream of Fort Portal.

- **Rushango sub-catchment**: As already indicated, most studies on the Mpanga catchment have been focused on the Mpanga sub-catchment. The visits to most parts of the Rushango basin were therefore highly informative.

  The source areas of the Rushango sub-catchment are quite different from those of the Mpaga sub-catchment. They lie in the much drier cattle corridor where there is an emphasis on grazing land (see photos 10 and 11 in Annex 1) with a much smaller proportion of the headwaters put over to arable agriculture.

The eastern half of the headwaters is characterized by extensive wetlands. According to the Environmental and Water Officers in the Kiruhura District these are largely seasonal and all except one of the upper Rushango tributaries fed by these wetlands dries up, during the main dry season (May-August). The ephemeral nature of these wetlands would seem to be the result of a combination of i) much lower rainfall (compared with the Mpanga sub-catchment), ii) a more distinct dry season, iii) anthropogenic pressures on the wetlands and the construction of valley dams on the streams feeding the wetland areas (although many of these are heavily silted - source: District Water Officer).

As a result of the nature of the wetland source areas, the Rushango River is much less turbid than the Mpanga River.

It should be noted that the upper half (especially the eastern part) of the Rushango sub-catchment was observed under particularly dry conditions since the rainy season had not yet started in this area. Flow in the Rushango upstream of its western tributaries has been reduced to a few litres per second (see Photo 12 in Annex 1).

The western feeder tributaries of the Rushango River rise in the hiller areas around Mount Isingiro (2172m). There are perennial springs in these hills and indeed five have been developed to supply the rapidly expanding town of Ibanda with potable water. During the visit the Oruyubu and Ruernamo tributaries (see Photo 11 in Annex 1) were observed to flowing relatively strongly and indeed accounted for almost all of the flow in the Rushango in its lower reaches.

There are no gauging stations on the Rushango River although the site of what believed to be a closed station (84276) was visited and a discharge measurement performed (see photo 13 in Annex 1).

On the eastern side the Rushango River is joined by the Katonga River. During the time of the visit there was a small flow in the Katonga River under the road towards the Rushango River. It is understood that the precise line of the watershed of the Katonga River can shift eastwards when levels in the Katonga headwaters are high, creating more flow for the Rushango River.

- **Lower Mpanga (below the confluence with Rushango):** The Mpanga and Rushango rivers make their confluence about 30 km upstream of Lake George. The river is gauged at Station 84215 just downstream of the confluence although it is temporally closed having been destroyed during the construction of a new road bridge close to the site.

  Between the confluence and Lake George there are no major tributaries joining the river which continues to flow through largely arable farmland.

  In the last 12 to 15 km of its length before reaching Lake George the Mpanga River drops 120m creating opportunities for hydropower generation. The channel also becomes increasingly incised.

  Hydropower has only been developed at one site on the lower Mpanga. The Kamwenge power station is situated 10km upstream of Lake George. A weir has been constructed across the river to divert water to a power plant with an installed capacity of 18MW. The scheme was visited during the trip. There is sufficient water in the Mpanga River for it to operate at full capacity for around 3 months a year.

  The flow of water through the hydropower turbines is measured as is also the discharge over the diversion weir. However, allowance has also been made for meeting environmental flow requirements through two pipes passing through the weir. This is not measured, but could be calculated based on the water level record at the weir.

3. Rainfall, hydrology and water resources

3.1 Data on rainfall

3.1.1 Historical data records

The map below shows the location of the existing rainfall station included in the national meteorological database (small squares). Stations for which data have been collected are indicated by bigger symbols.

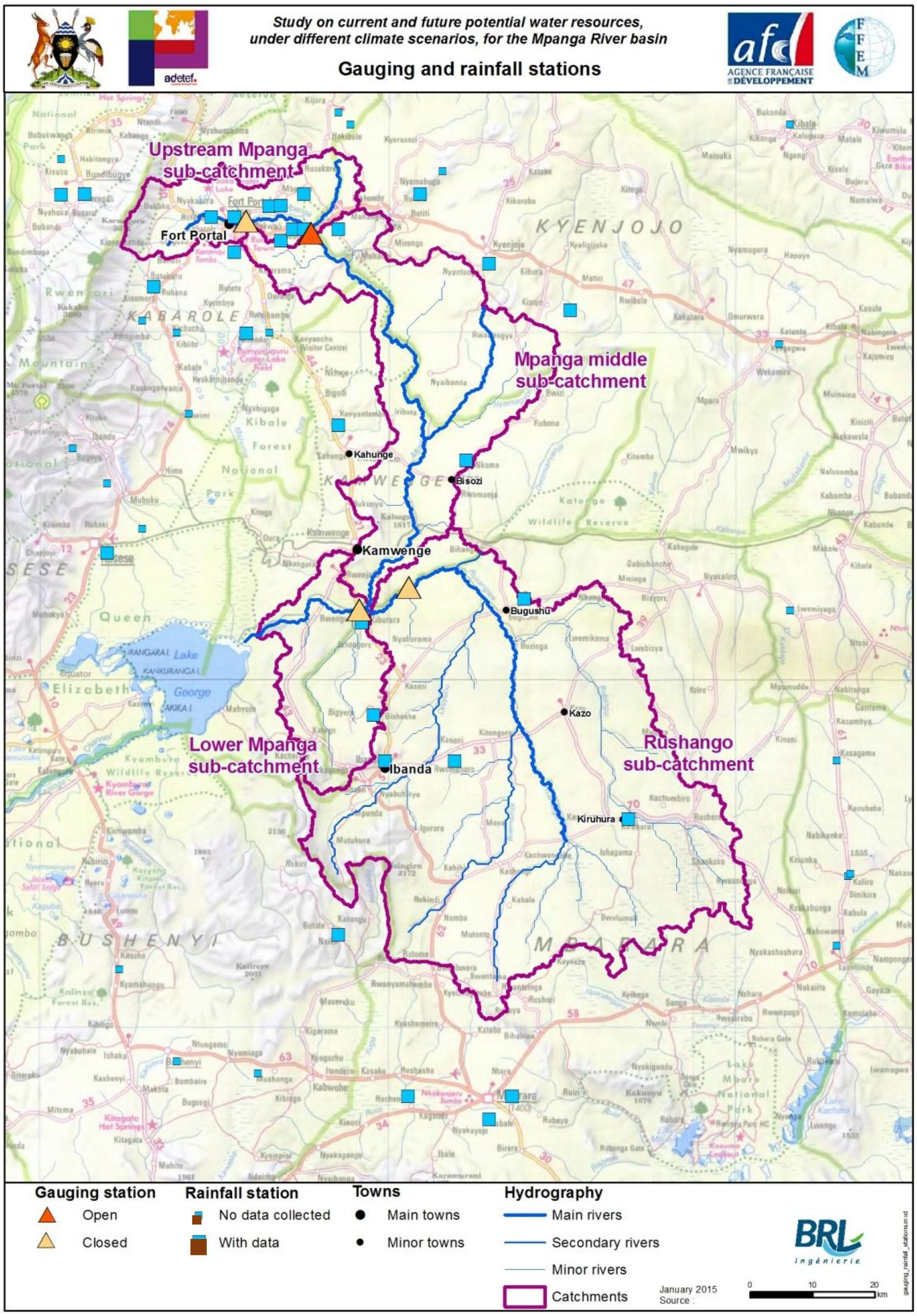


Figure 4 : Location map of rainfall stations and gauging stations

These data will be further analyzed during the next steps of the study. The graphic below (Figure 5) shows the data availability for each one of these rainfall stations.

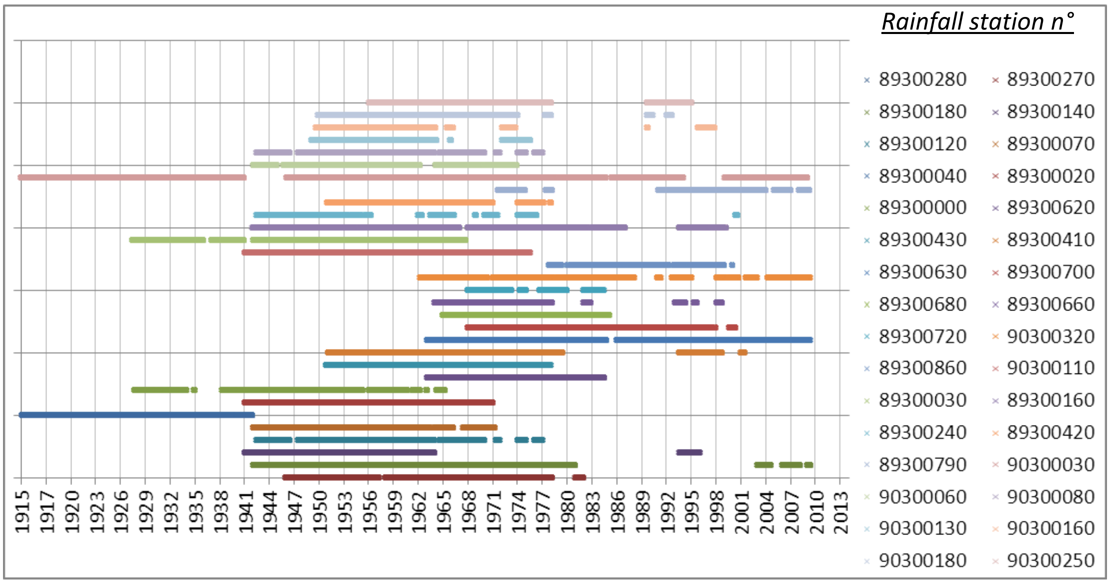


Figure 5 : Availability of rainfall data collected

As indicated in the figure above there are few data for the more recent past. It is likely that many of these stations are still functioning. Indeed, hard copies of rainfall records were collected by the team from the Rwebita Tea Research Centre for the years 2003 to 2014 (they correspond to the station referenced as n° 89300070) during the visit. MWE have undertaken to try and obtain the rainfall data that may still be outstanding for other stations and the team's locally-based expert will also try to obtain data directly from some of the stakeholders (schools, tea estates, prisons) during the weeks following this first mission.

3.1.2 Climate change data

A highly relevant and useful study, *Regional-scale Climate Change projections of Annual, Seasonal and Monthly Near-surface Temperatures and rainfall in Uganda,* was recently carried out by a group of consultants led by Baastel, Belgium, on the request of the Climate Change Unit within MWE. The report was only released in May 2014. During the course of the Inception Phase it was agreed that the team should try to obtain the relevant data from this study from the Baastel team and this task was facilitated by ADETEF.

As a follow up to this, a meeting was held in Pretoria (en route to Entebbe for this first mission) with Dr. Hannes Rautenbach who had led some of the climate changes downscaling work. He agreed to supply the following data for the RCP 4.5 and 8.5 emissions scenarios for each 50 x 50km grid square in and around the Mpanga catchment in text and "Netcdf" formats:

- Monthly temperature and precipitation data series for 1950 – 2005 (modeled historic)
- Monthly temperature and precipitation data series for 2005 – 2100 (modeled future)

These data have not been received as yet but it is anticipated that they will be forthcoming in the immediate future.

3.2 Data/Information on flows

3.2.1 Gauging stations in Mpanga catchment

The existing and closed gauging stations on Mpanga river basin are shown in Figure 4. All the existing data and information available for these gauging stations have been provided by the MWE. This included daily water level and flow records, details of all gaugings (discharge/flow measurements) carried out, and the water stage/discharge ratings that have been used. Table 1 below provides a summary of the information obtained for each one of them.

Two stations on River Mpanga have quite long flow data records (30 years or more), while one has only water level (no rating curve has been established). The station on River Mpanga at Kampala-Fort Portal road (84212) is the only one that is still operating. Even if only a few years of data are available at the closed gauging station on Rushango River (84276), they should help to give some indication of the contribution of Rushango River to overall Mpanga river flows. However, there is no period of concurrent records for the Rushango station and either of those on the Mpanga Rvers (see Figure 6).

Table 1 : Data available on the existing and closed gauging stations

N° and name	Water level	Rating curve	No. od Gaugings	Length of flow record	Comment
84212 – Mpanga at Kampala-Fort Portal road	Yes	Yes	220 gaugings	44 years	Operating but road works (new bridge) immediately downstream of the station (2012-2013) seemed to have had a (temporary?) impact on the station's cross-section and hence rating curve
84215 – Mpanga at Fort Portal – Ibanda road	Yes	Yes	98 gaugings	30 years	Closed after destruction due to road works (2010)
84216 – Mpanga at Highway bridge	Yes	No	No	No data	Only a few years of water level data are available (7 years in the 70's).
84276 – Rushango at Buteraniro	Yes	Yes	13 gaugings	5 years	

The graph below shows the period of availability of flow data at the different gauging stations in Mpanga river catchment.

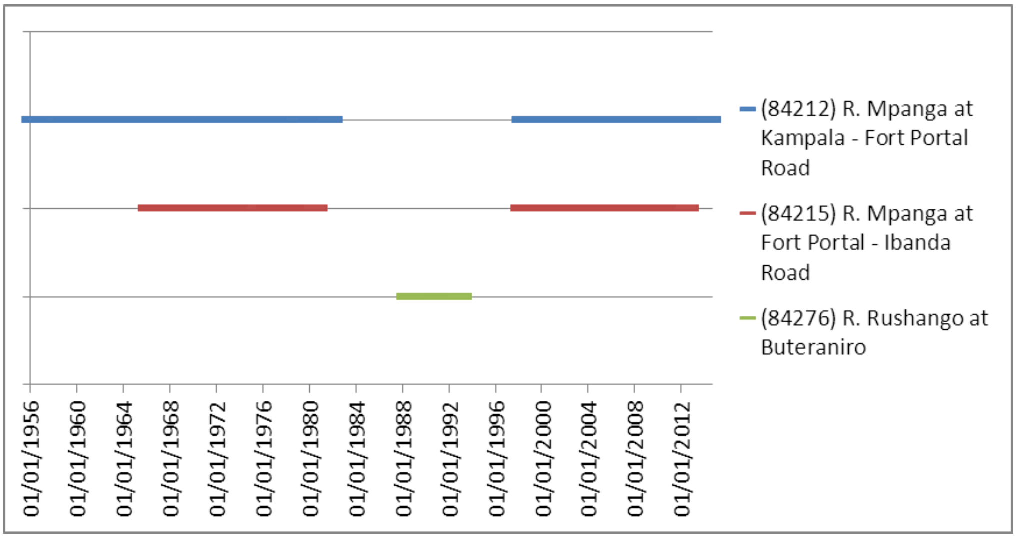


Figure 6 : Availability of flow data in Mpanga catchment

These data will be further analysed in the next step of the study.

3.2.2 Measurements at the hydropower plant (outlet of Mpanga River)

The hydropower plant at the downstream end of the catchment started operating in 2011. Water is taken out of River Mpanga at a diversion weir (a minimum flow of 1 m^3/s is left for the environment). The diversion weir was visited during the mission and the team was informed that data on flows and water levels can be made available on official request. These data could give a good idea of the total flows at the outlet of Mpanga River. The measurements taken are:

- Hourly readings of water level upstream of the weir, which can be converted into flow overflowing the weir using an appropriate weir formula
- 5 minutes recording of water level in the headrace, which can be converted into flow sent to the turbines.

Allowance is also made for meeting environmental flow requirements through two pipes passing through the weir. This is not measured, but could be calculated based on the water level records at the weir and knowing the characteristics of the pipes.

3.2.3 Gaugings (flow measurements) undertaken during the first mission

One day of the mission was dedicated to carrying out gaugings. This was made possible by the Albert Water Management Zone which made both the equipment and technicians available to carry out the gaugings.

The original main objectives of the gaugings were:

- to get a recent check on the water stage / discharge relationships at each of the open (and closed) gauging stations where possible
- to get an indication of the relative contribution of the Rushongwe tributary

Unfortunately, the fact that gauging station *84215 – Mpanga at Fort Portal – Ibanda road*, including all benchmarks) had been destroyed during the construction of the new road and bridge, means that the first of these objectives could only be realized at Station 84212.

Gaugings performed at Station 84215 and the old station 84276 will only really be useful for the second of these objectives, to see how much flow is coming from the Rushongwe catchment and how much from the intervening Mpanga sub-catchment downstream of station 84212.

The gaugings were carried out using an OTT current meter suspended from bridges at the three sites. The methodology is straightforward and is illustrated in Figure 7.

The cross-sectional area of the river is measured stepwise across the river through depth soundings and horizontal chainages. At each depth sounding the velocity of the river is measured using a calibrated propeller. Depending on the depth, velocity measurements can be made at more than one point between the water surface and the stream bed. Conventionally, where just one point is chosen, this should be at 60% of the sounding depth (from the surface). Where three points are measured in a vertical, they should be at 20%, 60% and 80% of the depth. In principle, the more points taken the more accurate the gauging is likely to be.

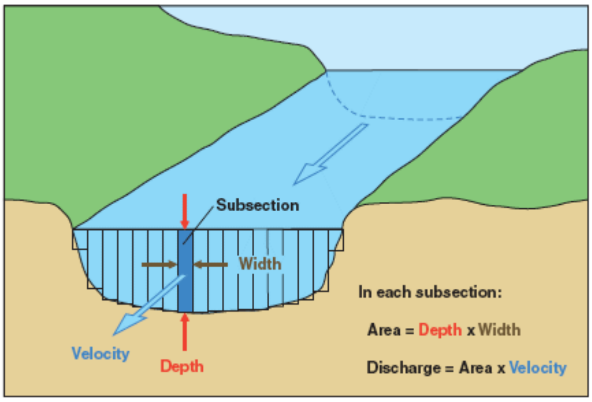


Figure 7 : Methodology for calculation of flow using velocity measurement (source: USG Survey)

The gaugings were carried out using the one point method with the point at 50% rather than 60%. This would appear to the method generally used by the Ministry's gauging teams and while it probably yields satisfactory results, it is not known why it is preferred to the conventional 60%. The possibility of using the three point method was also discussed with the Ministry's gauging team, who were familiar with it. Three points were indeed then measured at the deeper parts of the cross-section.

The results of the three gaugings will be available very soon. Their calculation will be carried out by the Ministry's gauging team using customized software.

Without the results of the gaugings it is difficult to draw conclusions. Analysis of the results will however be included when the rainfall-runoff modelling is carried out.

Figure 8 : Gaugings on River Mpanga at Kampala – Fort Portal road.

3.3 Other related information

During a meeting with researchers of the Mountains of the Moon University, SATNET and members of the Water Management Zone, other potentially useful sources of information were identified. These included a recent PhD thesis on the Katonga River.

4. Water demand

4.1 Data and information available

In addition to the main studies already mentioned in the Introduction and Section 1, information on water demand collected on the Mpanga basin came from the field visit and meetings with different stakeholders and water users (see Annex 1). Additional information should be availed in the near future, including information from:

- **Water Permits:** A list of water users holding abstraction permits in the Mpanga catchment will be provided by MWE. The team met with those responsible for the maintenance of the permit database and it was agreed that they would abstract the required information. The permit information will be very useful since it should provide a catchment-wide overview of the theoretical water demand. Since permits define the maximum amount of water that a user can abstract they often tend to overestimate what is actually being taken from the water source, so the information will have to be used with care and cross-checked on the ground, at least for the larger users.
- **Study on water demand:** The team was informed that there is an ongoing study on water demand in the Mpanga sub-catchment as part of a wider study. The results of this study will probably not be available until the end of November so the modelling work will have to proceed without them. However, it should be possible to improve the accuracy of demand estimates at a later stage using the results of this study.

- **Additional data collection:** The locally-based experts on the team will carry-on with the collection of information on water demand. In particular, this will include getting information on irrigation, urban water supply and hydropower from the Water for Production Department

4.2 Water Demand for Urban and Rural (potable) Water supply

Fort Portal, Kamwenge and Ibanda are the three main urban centers supplied in water with water coming from Mpanga catchment. The three piped schemes are managed by the NWSC services whom have been met during this first mission.

- **Water supply for Fort Portal**: 2500 m^3/day are pumped from the River Mpanga to supply 6000 connexions in and around Fort Portal. This demand is almost constant through the year. The plant is currently functioning at full capacity and NWSC plans to extend it in a near future. Data on the growth in annual water abstraction during the past 15 years is apparently available and should be received soon. High sediment loads in the river during high flows increase the use of chemicals for treatment and sometimes prevent the plant from functioning.
- **Water supply for Kamwenge**: 200 m^3/day, (6000 m^3/month), are pumped from the River Mpanga to supply the town of Kamwenge. The scheme was implemented in 2009 with operation contracted out to the private sector. Operation was apparently not satisfactory with production never exceeding 4000 m^3/month. The NWSC has been in charge of operating it for four months so there are no useful data on seasonal variations in demand and production. Production is reportedly growing steadily and the Area Manager anticipates that it will reach 10000 m^3/month in the very short term. The expansion of the network is planned and the area manager expects production to reach 1000 m^3/day on a medium term. The Area Manager considers the water quality in River Mpanga as good, compared to the one of the adjacent Rwizi River.
- **Water supply for Ibanda**: The Water Engineer of NWSC was not around the day when the team visited the NWSC offices in Ibanda and should be contacted to get more detailed quantified information on water abstraction and water demand. The NWSC is very new in Ibanda and has been operating the scheme for only 2 months. Previously it was privately operated. Five springs, located in Lukiri (western highlands of the Rushanwe sub-catchment) area are used to supply 2200 metered points. The population and demand in Ibanda is growing rapidly but so far, the springs are able to meet demand, even during the dry season.
- **Rural water supply**: Rural water supply is difficult to quantify accurately. Most of the smaller rural communities depend on groundwater. Small urban centres (eg Kuruhura town) are sometimes supplied with piped water derived from a borehole scheme. An estimate of rural and semi-urban demand could be made based on an estimate of the rural population and an estimate of average daily demand. The 2014 census took place in Uganda at the end of August beginning of September but the publication of its results is not expected before November or December 2014. As a result, the most recently available population figures date back to 2002 and are particularly difficult to use because of the high levels of displacement and migration that has taken place since then in the project area.

4.3 Water Demand for Industries, factories

There is little industry or factories abstracting water within the Mpanga river catchment. Abstraction is largely limited to a few tea factories. The extent will be better understood once the water permit information has been received.

A visit was made during the mission to the Mpanga Growers tea factory. Its manager explained that water is used in the process only for cleaning. The nurseries for the tea plants are not irrigated. He estimates that approximately 20% of the water abstracted in consumed and 80% return to the environment after some limited treatment (essentially oxidation ponds).

4.4 Water Demand for agriculture and cattle

Apart from the tea estates located between Fort Portal and Kibaale forest, agriculture in Mpanga sub-catchment is mainly rainfed subsistence farming. The main crops grown are bananas, annual vegetables, as well as cereals (maize, millet, sorghum). A few perennial cash crops such as coffee and fruit trees are also grown in some parts (upper part of Mpanga sub-catchment, between Kibaale forest and Kamwenge).

In Mpanga sub-catchment near the confluence with Rushango and Rushango sub-catchment, the main activity is agro-pastoralism (part of the Rushango sub-catchment is located in the cattle corridor).

Cultivation sometimes takes place in wetlands, in Mpanga sub-catchment around Fort Portal (source: baseline study, Protos), and in the upper part of Rushango sub-catchment, in Kiruhura district (source: discussion with local government).

From the observation made and discussion with the stakeholders, **there seem to be no irrigation going on in Mpanga catchment, apart from very limited and localised labour-intensive initiatives.** This will be confirmed once the water permit information has been received. However, the apparent need for some supplementary irrigation during the dry season was expressed by several stakeholders. Many valley dams are located in Kiruhura district, but most of them are heavily silted.

4.5 Hydropower production

The VSHydro Ltd Company has been operating a hydropower production plant located on River Mpanga downstream of the confluence with Rushango, around 8 km upstream of its outlet in Lake George since 2011.

The plant has a maximum capacity of 18 MW (that corresponds to a flow of 16 m^3/s). According to the person in charge the plant works at full capacity in average 3 months per year. The diversion weir installed on the River Mpanga does not allow for significant storage and power production is essentially run-off the river. The flow available for power production is the flow in river Mpanga after allowance for the environmental flow requirements. This is approximately 1 m^3/s that is left in the river between the head and tail races. The environmental flows pass through the weir via tow uncontrolled pipes in order to maintain this minimum flow requirement at all time.

4.6 Environmental minimum flow requirement

According to the Water management Zone Area Manager, in the absence of any specific study, the Q90[2] is usually used by default as environmental minimum flow requirement in Uganda.

As mentioned above, the environmental flow downstream the diversion weir of the hydropower plan is 1 m^3/s. The team will follow up with Hydropower plant management in order to find out the origins of the definition of environmental minimum flow that they are using.

---

[2] The Q90 corresponds to the daily flow that is statistically overpassed 90% of the time.

5. *Identified gaps and way forward*

5.1 Identified gaps

A number of gaps were identified, largely in line with what had been anticipated. In general these are gaps which cannot be filled (either at all or not realistically during the timespan of this study but which need to be recognised and worked around. They include the following:

- Rainfall data:
  - Rainfall data in the source areas is lacking. Given that much of the runoff in the Mpanga sub-catchment results from rainfall in the uppermost part of the sub-catchment (between 1500 and 3000m) it would be useful to have precipitation records from this zone. These are, not surprisingly, lacking.
  - Long reliable records. There are few long reliable rainfall records. From the data collected so far it seems that there is only one station with an almost unbroken record going back 80 or more years.
- Flow data:
  - Lack of concurrent flow record for Mpanga and Rushwange rivers. While there are two years of record for the closed gauging station on the Rushango River they are not concurrent with any of the stations on the Mpanga sub-catchment. This will make it challenging to get an accurate split of how much water comes from the Mpanga and Rushango rivers.
  - Missing data for recent years at the two Mpanga gauging stations. The construction of a new bridge at the Ibanda station has resulted in the station being closed for the last 2 – 3 years. The water level/flow data being collected at the Kamwenge Power station may prove to be a useful alternative. Construction of a new bridge at the Kam station has resulted in the water stage/discharge rating being rendered invalid for a period of at least 1 – 2 years. The gauging carried out during this mission may shed light on whether the existing rating curve is still valid or not.
- Land Use: Lack of information on changes to land use over the last 50 years. Recent land use studies, in particular that carried out by PROTOS, will be very useful but do not cover the Rushwange part of the catchment.
- Demand data
  - Lack of up-to-date demographic data: The most recent census data dates back to 2002. Given the high level of resettlement and migration in the study area over the last 15 years, it is acknowledge that this
  - Non-availability of the results of the ongoing water demand study. While the data gathered so far and what is anticipated in the next few weeks should be sufficient to adequately calibrate the water distribution model, it is hoped that the results of this study will be available for use but this may not be the case. This would be especially useful for increasing confidence in demand projections.
- Sediment load data:
  - While these data would are not essential for the proposed rainfall-runoff modelling, it is clear that erosion and the resultant high sediment loads are a part of a major water resources management issue and it is important to get better quantification of the problem. Done properly, obtaining good information on sediment loads is not easy and certainly beyond the scope of this study. Not only is specialized equipment required but samples have to be collected frequently so that the rising and falling limbs of hydrographs are sampled on several occasions through the year. Some useful data may

be available from the water treatment plant in Fort Portal and this possibility will be followed up.

5.2 Way forward

5.2.1 Completion of data sets

As mentioned earlier in this report there remains an immediate task to complete the data collection work before the modelling can get properly underway. Completion of the datasets mainly comprises:

Completion of the observed rainfall datasets. Although some rainfall data have been obtained, they are not complete and it will be necessary for some additional data to be collected on the ground and for the Directorate of Water resources to request the remaining data. If the rainfall data sets available are not sufficient, other sources of data could be used, such as the Climate Research unit database[3].

- Completion of datasets on current water demand around the basin. This will be based on a variety of data sources including the water permit database. Some details on abstraction have already been requested and are awaited.
- Precipitation and temperature datasets generating from the regional downscaling work have been requested and should be received shortly.

5.2.2 Using the data – next steps

In line with the methodology, the next steps will be as follows:

1. Rainfall-runoff modelling. The obtained rainfall datasets and observed runoff (flow) datasets at the river gauging stations will be used as inputs for the rainfall-runoff modelling aimed at generating as complete as possible historical runoff data series for the gauging sites (and possibly other locations in the catchment).
2. Building of a water distribution model (using WEAP) aimed at carrying out a water balance for the main sub-catchments under present conditions of demand.
3. Use of the water distribution model to investigate the impact of future levels of demand (2030 and 2050) on the water resources of the catchment assuming no climate change.
4. Running of the rainfall-runoff model using the precipitation and temperature data for the period of 2030 to 2050. This should generate a new set of runoff data for the same locations as done under step 3 above. This is effectively the runoff that would be anticipated in the future. This would be done for the RCP4.5 and RCP 8.5 emissions scenarios effectively providing two sets of runoff data.
5. Repeat Step 6 above but using the climate change affected runoff series. This would yield four sets of results:
   - 2030 levels of demand under emission scenario RCP4.5
   - 2030 levels of demand under emission scenario RCP8.5
   - 2050 levels of demand under emission scenario RCP4.5

[3] The CRU avails a dataset of historical precipitation gridded at 0.50° x 0.50° resolution, on a monthly time step. This grid has been constructed from a total of over 11,800 stations worldwide. This database has the advantage of presenting long period rainfall historical data based on observation. However on a relatively small catchment such as Mpanga catchment and where rainfall spatial variability is high, this source of data may not be accurate enough and its relevance will have to be checked.

- 2050 levels of demand under emission scenario RCP8.5

6. Draw conclusions and recommendations
7. Presentation to stakeholders in Fort Portal
8. Finalisation of report

Annexes

Annex 1: Selection of photographs taken during the reconnaissance of the catchment

N° 1: Upstream part of the Mpanga sub-catchment – forest remaining (in Rwenzori National Park)

N°2: Upstream part of the Mpanga sub-catchment; cultivation on steep slopes, lack of soil and water conservation measures

N°3: Upstream part of the catchment - gravel and sand mining on the river bank

N°4: River Mpanga at the intake of NWSC in Fort Portal

N°5: Tea estates in Mpanga River sub-catchment

N°6: Mpanga river at Kam gauging station (84212, Fort Portal – Kampala road)

N°7: Kibale forest

N°8: River Mpanga on Kahunge-Bisozi road

N°9: Rushango sub-cathment – Rushango River on Kasozi – Bugushu road

N°10: Rushango sub-catchment – dryer climate, few arable farming areas, majority of grazing land (cattle coridor)

N°11 : Rushango sub-catchment – River Nwaru (local name) / Oruyubu tributary (name on map) on Ibanda – Kazo road

N°12 : Rushango sub-catchment – River Rushango on Ibanda – Kazo road (at lowest base flow level)

N°13: River Rushango just upstream of its confluence with River Mpanga

N°14: River Mpanga downstream of the confluence with River Rushango, an Kamwege-Ibanda road

N° 15 : River Mpanga donwstream of the Kamwenge power station

N°16: Lake George

Annex 2: List of meetings

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
10/09/2014 (Entebbe)	David Cheptoek (MWE, DWRM)	Senior Water Officer at Department of Water Resources Regulation	Discussion of the regulation and enforcement system in Uganda and on information available in the water permit data base. He agreed to extract the required information (max water abstraction permitted, source of water abstracted, location of the abstraction point etc) by e-mail	Water permits granted in Mpanga Basin (Holder, location of abstraction point, volume permitted, type of use, date of permit, water source etc…)
10/09/2014 (Entebbe)	Simon Etimu (MWE)	Water quality Management department	Discussion on water quality data available. Data are in the Central office in Kampala but must be requested and will be provided through the Water Management Zone	Details to be discussed with Jackson at the WMZ
10/09/2014 (Entebbe)	Leo Mwebembezi (MWE, DWRM)	Principal Water Officer	Presentation of the project. Discussion on the required hydrological data on hydrology and GIS. Mr. Mwebembezi will organize preparation of data with the persons in charge of the GIS and of hydrology database.	
10/09/2014 (Entebbe)	Olivier Beucher	Baastel	Discussion on the ongoing (or soon to be started) projects within Mpanga basin and on possible synergies.	- Climate change vulnerability assessment, Adaptation strategy and Action Plan for water Resources sector in Uganda (2009) - Operationalization of catchment-based Water Resources Management (COWI, 2010) - Climate Change Adaptation Strategy for the water sector (2011) - National Irrigation Master Plan 2010
10/09/2014 (Entebbe)		Mapping and Survey department (1/2)	Enquired on the availability of maps of the basin at 1 :50,000 and 1 :250,000	Purchased available maps(in print) of the catchment

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
10/09/2014 (Entebbe)		NBI	The appropriate people were unavailable due to a training organized in NBI. We briefly spoke to Mr. Tafase who advised us to contact Dr Abdul Karim if required	
10/09/2014 (Bugolobi, Kampala)	Dr. Callist (MWE, DWRM)	Commissioner (Water Resources Planning and Regulation department)	Discussion on - General project background, - Stakeholders we should meet - Arrangement for collection of data (esp. rainfall data) - Practical details to organize the visit of Mpanga catchment	
11/09/2014 (Bugolobi, Kampala)	Johannes Rumhor (and Daniel Opwonya (dams study)	GIZ, Kampala	Discussion on the project and on the work GIZ is leading on hydropower production. GIZ produced an inventory of dams in Uganda. Daniel Opwonya to send the information on the dam existing in Mpanga basin	- Water risk and sustainability assessment (WRSA) for the River Rwizi Catchment in Uganda - Hydropower in Uganda factsheet
11/09/2014 (Entebbe)		Mapping and survey department (2/2)	Ordered outstanding 1:50,000 and 1:250,000 maps for printing (done in-house)	Outstanding maps purchase
11/09/2014 (Entebbe)	Albert Orijabo (MWE, Albert WMZ)	Team Leader of Lake Albert Water Management Zone	Discussed organization of field visits to the Mpanga river basin. A study on water uses and water demand is ongoing (report due at the end of the month) on several catchments in Uganda including Mpanga catchment river basin is one of them. This study also includes information on pollution load. This study and draft Mpanga management plan do not include Rushongo catchment	
11/09/2014 (Entebbe)	Charles Kywalabye (MWE, DWRM)	In charge of hydrological database at the Water Resources Monitoring and Assessment department	Collection of requested hydrological and rainfall data in electronic format	- Flows, Water level, rating curve, and gauging for running and old gauging station in Mpanga basin - Rainfall data of rainfall station within the basin

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
11/09/2014 (Entebbe)	Caroline Nakalyango DWRM	In charge of GIS at the Water Resources Monitoring and Assessment department	Discussion on the list of GIS layer needed: - Location of gaugins station and rainfall station within and around Mpanga catchment - Location of water quality monitoring network in Mpanga catchment - Administrative limits (2012) (although have changed recently). An up-to-date version is to be delivered to the Ministry by UBOS by the end of November and will include information on the last census. - Land cover (1999 and maybe one available of 2005) - Streamlines including wetlands for the basin area - Water infrastructure (but more up-to-date information at MIS (Ministry of Information Systems) - Location of abstraction points (from water permit database)	
12/09/2014 (Kampala)	Virginie Leroy Saudubray	AFD	General discussion on the Mpanga River Basin and on the project. There is a Bulk Water Supply in Kiruhura district (planning stage) that may have an impact on Mpanga river (Rushango sude). Dr Callist or J. Twinomujuni may have more information on that project.	
12/09/2014	Sophie Makame	French Embassy	Brief presentation of the project to the Ambassador	
12/09/2014 (Kampala)	Paul Isabirye (MWE, Meteorological Authority)	UNFCCC national focal point for Uganda and ag. Director (Traiining and research) at Meteorological Authority)	General discussion on the climate change policy and adaptation strategy at a national level	
13/09/2014	Drive to Fort Portal, passing by Kam gauging station (River Mpanga at Fort-Portal - Kampala Road)			

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
14/09/2014	Leader of the Bee keeper association / Community members		Reconnaissance on foot of the upstream-most part of the Mpanga basin (Steve Crerar, Clovis Kabaseke, Marion Mahé).	
15/09/2014 (Fort Portal)	- Albert Orijabo; - Brian Guma (MWE, Albert WMZ)	Team leader of AWMZ Focal point for Mpanga catchment at AWMZ	Discussion on : - work undertaken at the WMZ level in general and in Mpanga catchment in particular. A draft catchment management plan has been produced for Mpanga river catchment (excludes Rushango sub-catchment). The WMZ has asked consultancy to update this plan and make it fit with the World Bank catchment development guidelines. In this catchment plan, Mpanga river catchment has been divided into 8 areas where have been identified different issues and challenges. Some actions have already been taken to address these issues (restock fish in lakes, river bank protection etc) - the objectives and approach used for the study (study on current and future potential water resources, under different climate scenarios for the Mpanga river basin) - the local stakeholders who should be met in the basin.	- A PhD has been done on Katonga catchment (Abraham Bradley, 2012) and may give information on how the water divides between the Katonga and Mpanga catchment. - Currently use on E-flows =Q90 for planning purposes (in irrigation Master plan, etc…)
15/09/2014 (Fort Portal)	- John Tibenda - Enoch W. Makoko - Brenda Kabugabi (NWSC)	Area Manager of Fort Portal; Quality control Officer;	- Discussion on the water demand for Fort Portal and on information available from NWSC. - Abstraction is currently 2500 m^3/day, almost constant through the year. There are plans to extend the treatment plan as it already works at 80% of capacity. There is no gauge in place at the intake to measure the river flows before the abstraction point.	- Historical annual abstraction volumes - Return flow data (going out of sanitation treatment plant) - Water quality data (on river Mpanga water)

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
15/09/2014 (Fort Portal area)	- Adolf Sabiiti (General Manager) - James Okello - George Kaihura	Mpanga Growers tea factory	Discussion on the rainfall data available from the factory. Discussion of the water demand of the factory: the water is used for cleaning, around 80% of it is not consumed and returns to the river (after some processes). The factory is supplied by NWSC and doesn't have its own abstraction point and supply system at the moment. No irrigation at the plantation, including for the seedlings.	
15/09/2014 (Fort Portal area)	Venancio Tumwine	Rwebita tea research center	This centre runs a weather station. (n°89300700). Recent data don't appear in the records available at MWE/Meteorological office but are available in hard copy at the research centre.	Hard copy of recent rainfall record (daily basis)
15/09/2014 (Fort Portal)	Mr. Thaddeo Tibasiima Kahiigwa	SATNET	Presentation of the project and discussion on information that the organization has	SATNET has essentially been working with the Community on ecological farming practices. They haven't got much information on irrigation.
15/09/2014 (Fort Portal)	- Violet Kisakye (PhD student in hydrology) - Dr Moses Muhumuza (Director of post graduate study and research)	Mountain of the Moon University	Two projects (VLIR project and Flemish partnership for water project) have joined their efforts to do a hydrological assessment of a small sub-catchment near to Fort Portal. 5 rain gauges have been installed (since Oct 2013) and a hydrological model will be used to study the hydrology. However, there is no data available on flows or actual measurement on this catchment. (project has been going on for 2 to 3 years). Afromaison project worked on Integrated water resources management for the Rwenzori region. They produced a tool-box for IWRM and have different scenario (on climate or development). More information can be found on internet.	
16/09/2014 (Ruchangwe sub-catchment)	Reconnaissance of Rushango sub-catchment (participant: Brian Guma (Mpanga catchment focal point at AWMZ), Steve Crerar, Clovis Kabaseke, Marion Mahé)			

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
16/09/2014 (Ibanda)	NWSC Ibanda	Agatha (accountant) George	Discussion on the water demand for Ibanda and on information available from NWSC.	NWSC has only been operating for 2 months in Ibanda. The water used to supply the town (2200 metered points) comes from 5 springs located around Lukiri. Those springs are rainfed and are therefore subject to climate change. So far, water is meeting the demand, but population is growing.
16/09/2014 (Kiruhura)	Local government – Kiruhura district	Deborah Namora (environment officer) Vincent Sesenga (water officer)	Discussion on water demand in the district, on the hydrology of the neighbouring streams and the state of wetlands during dry season.	There is a bulk water project taking place in Kiruhura district, but the water resource foreseen to supply it is Lake Mburo and the counties it will supply are not including in Mpanga catchment. During dry season the wetlands on the upstream part of Rushango river are usually dry and are encroached for cultivation. There are many valley dams and tanks in the district, but many of them are heavily silted.
17/09/2014 (Fort Portal)	Local government	Godfrey Ruyonga environment officer	Presentation of the study. Discussion on the state of the upstream catchment.	Issues are well known at local government level and ideas are there to tackle them. However the low budget allocated to catchment management gives little possibility to implement catchment management measures and work with the communities.
17/09/2014 (Fort Portal)	Lieven Peeters PROTOS	Regional Representative (Uganda, DRC)	Presentation of the study. Discussion on the work undertaken by Protos in general and particularly in Mpanga catchment. Mr Peeters stresse the need for the study to provide feedback and the need for two-way sharing of data and information	A number of useful maps, previous studies and some data are to be made available

Date	Name	Organization / Position or field of expertise	Discussion during the meeting	Information data collected
18/09/2014 (Mpanga basin)	Gaugings (participants: Gauging team from MWE, Brian Guma (WMZ) Steve Crerar, Clovis Kabaseke, Marion Mahé, Violet Kisakye (MMU)			
18/09/2014 (Kamwege)	Inocent Kabsiime NWSC - Kamwenge	Area Manager	Discussion on the water demand for Kamwenge and on information available from NWSC.	Kamwenge is supplied by water from the Mpanag River via a treatment plant currently producing 6000m^3/month. NWSC have only been in charge of the facility for 4 months and expect production to rise rapidly. They still have significant treatment capacity..
18/09/2014 (Outlet of River Mpanga)	William Mugisha	Technician Hydropower plant	Discussion on the functioning of the system, on the availability of water and on water level / flow measurement done at the intake. Visit of the intake and of the power plant.	Data on water level in the weir and flow diverted to the turbines can be available on official request only. The plant is designed for 16 m^3/s and a production of 18 MW. Production was 13 MW the day of the visit (but was at full capacity the previous day). In average, the plant can function at full capacity 3 months per year. (see main report for more detail)
19/09/2014 (Entebbe)	Charles Kywalabye (MWE - DWRD)	In charge of hydrological database at the Water Resources Monitoring and Assessment department	Collection of additional rainfall data	Additional rainfall data (mainly in Rushango sub-catchment)

ANNEX 2: TECHNICAL REPORT ON HYDROLOGY AND CLIMATE CHANGE (TASK 3 REPORT)

REPORT ON TASK 3

Supporting low carbon development and climate resilient strategies

Capacity building regional project

[Uganda]

STUDY ON CURRENT AND FUTURE POTENTIAL WATER RESOURCES, UNDER DIFFERENT CLIMATE SCENARIOS, FOR THE MPANGA RIVER BASIN (UGANDA)

adetef

Assistance Technique France

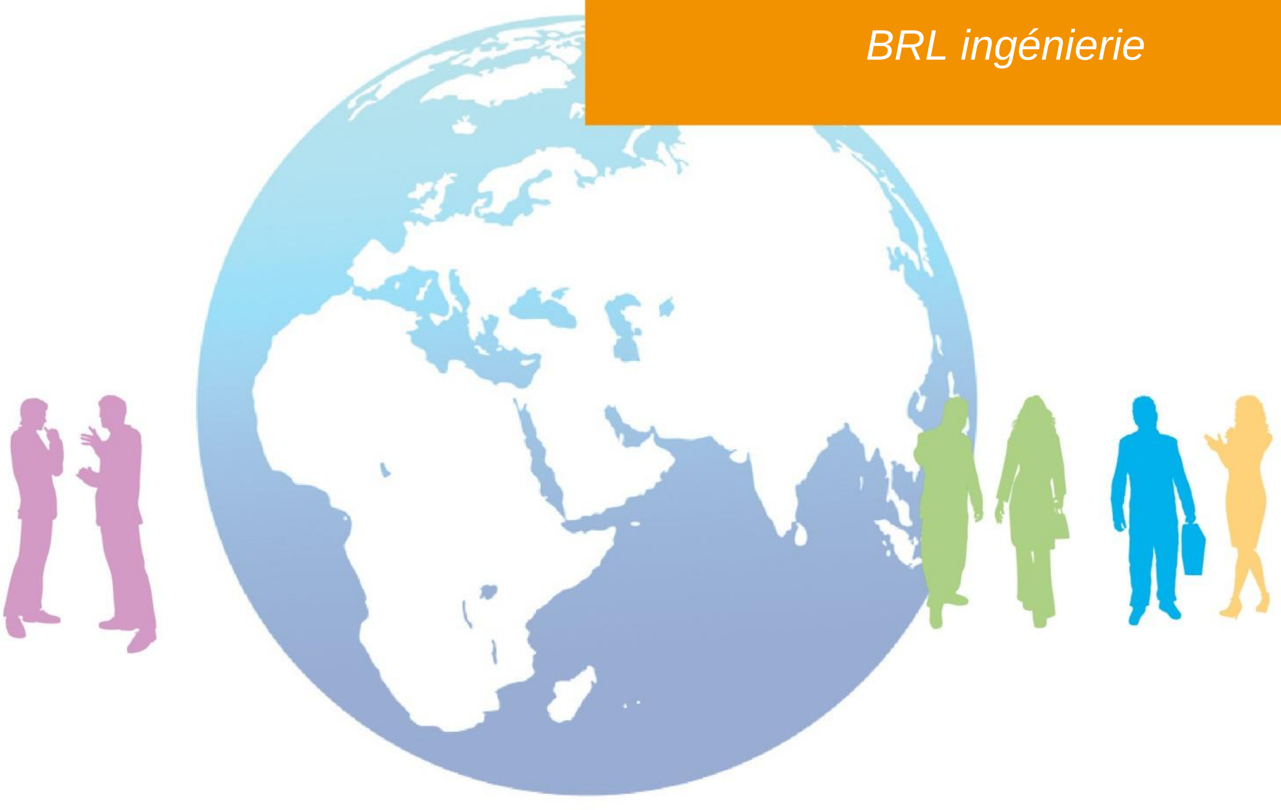
January 2015

In association with

AGENCE FRANÇAISE DE DÉVELOPPEMENT

FFEM

BRL ingénierie



Study on current and future potential water resources, under different climate scenarios, for the Mpanga River Basin (Uganda)

REPORT ON TASK 3: WATER RESOURCES MODELLING UNDER DIFFERENT CLIMATE SCENARIOS

January 2015

TABLE OF CONTENTS

TABLE OF ILLUSTRATIONS

Figures

Tables

1. Introduction

This report is the main technical document describing the methodology, data used and results obtained in *the assessment of the impact of different climate change scenarios on the water resources of the Mpanga River basin*. The outputs of this water resources modelling exercise will be used as a basis for future Integrated Water Resources Management processes within the Mpanga catchment area, hence supporting the sustainable management of the water resources. In particular, work will start soon on the re-drafting of the Catchment Management Plan for the Mpanga Basin. A better understanding of the basin's water resources under both present and future climatic conditions will provide essential information for this plan.

After a brief description of the study area and methodology, this report presents the different steps followed to assess the current and future potential water resources of the basin. The body of this report includes a description of the analysis done and places emphasis on the key results and main conclusions. Additional technical details are provided in the annexes.

1.1 Study area

There are a number of recent and ongoing studies and initiatives that concern the Mpanga River. A programme on Integrated Catchment Management and Climate Change adaptation at community level is led by the PROTOS NGO, in collaboration with the Ministry of Water and Environment (DWRM). Under this programme, a catchment baseline has been drawn up by researchers of the Mountains of the Moon University affiliated to the Afromaison project ("Mpanga Catchment area baseline assessment report", 2012). A catchment Management plan has also been drafted. These studies provide a good understanding of the state of the catchment, especially regarding issues such as erosion, pollution and agricultural practices. They don't include a quantitative assessment of water uses and water resources. They will therefore be usefully complemented by an ongoing study on current and future water demand (led by DWRM) that is aimed at quantifying current and future water needs, as well as by the outputs of this study, which will quantify the availability of current and possible future surface water resources.

Most of the work undertaken so far (including the catchment management plan and the on-going study on water demand) concentrate on the catchment of the River Mpanga itself and do not include the Rushango tributary (see Map in Figure 1). When looking at the hydrology and catchment water balance, the inclusion of the Rushango sub-catchment is essential, as it contributes to the flow available in the downstream part of the Mpanga catchment (including for the existing hydropower plant which is situated downstream of the Mpanga/Rushango confluence) and for flows into Lake George. It has therefore been included in the area covered by this study. Figure 1 shows the study area and the denomination used in the rest of this report. When reference is made to the "Mpanga catchment" in this study, unless stated otherwise, this means the whole catchment contributing to the flows reaching Lake George from River Mpanga (including Rushango sub-catchment). The different sub-catchments have been delineated and are described in Table 1.

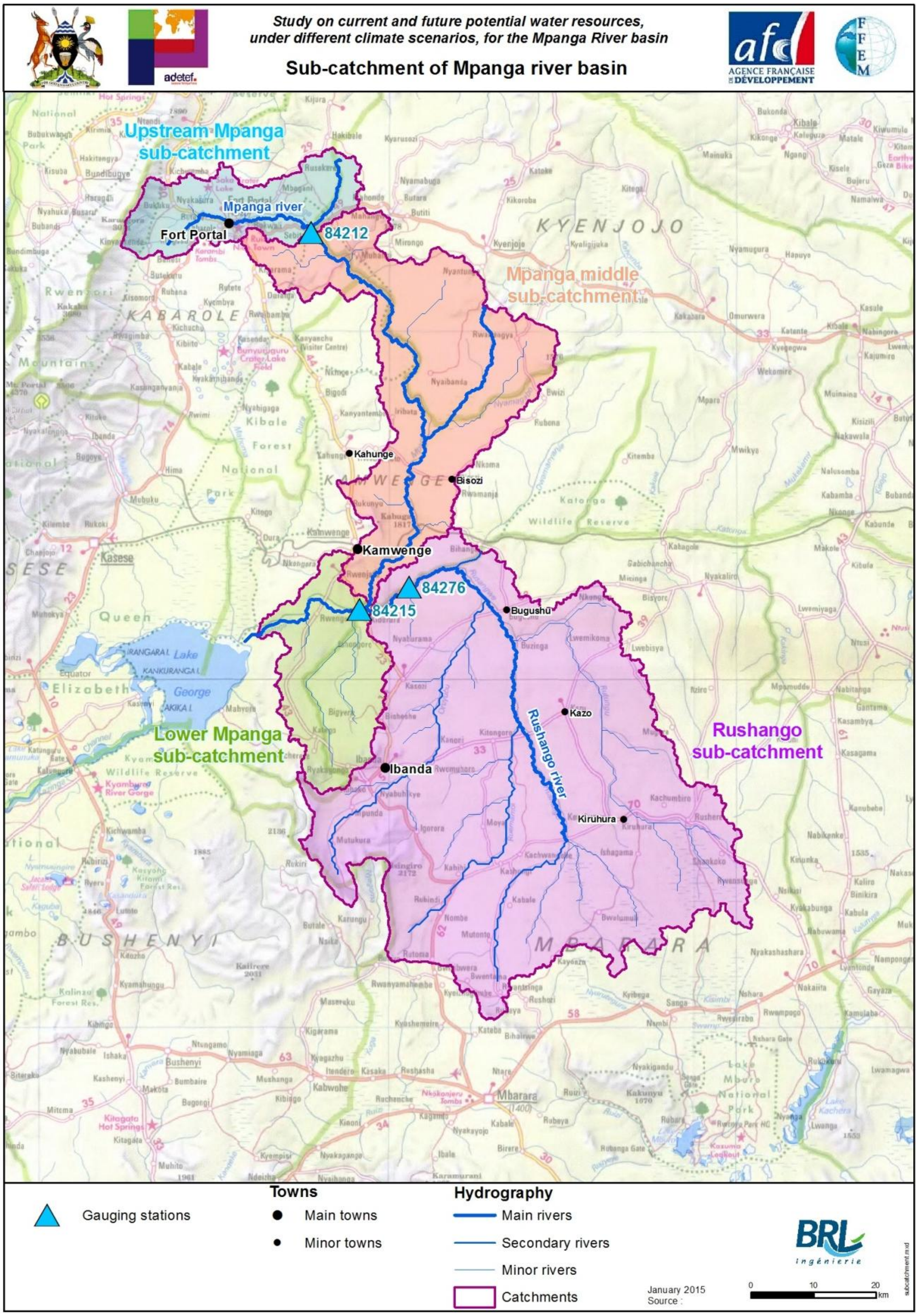


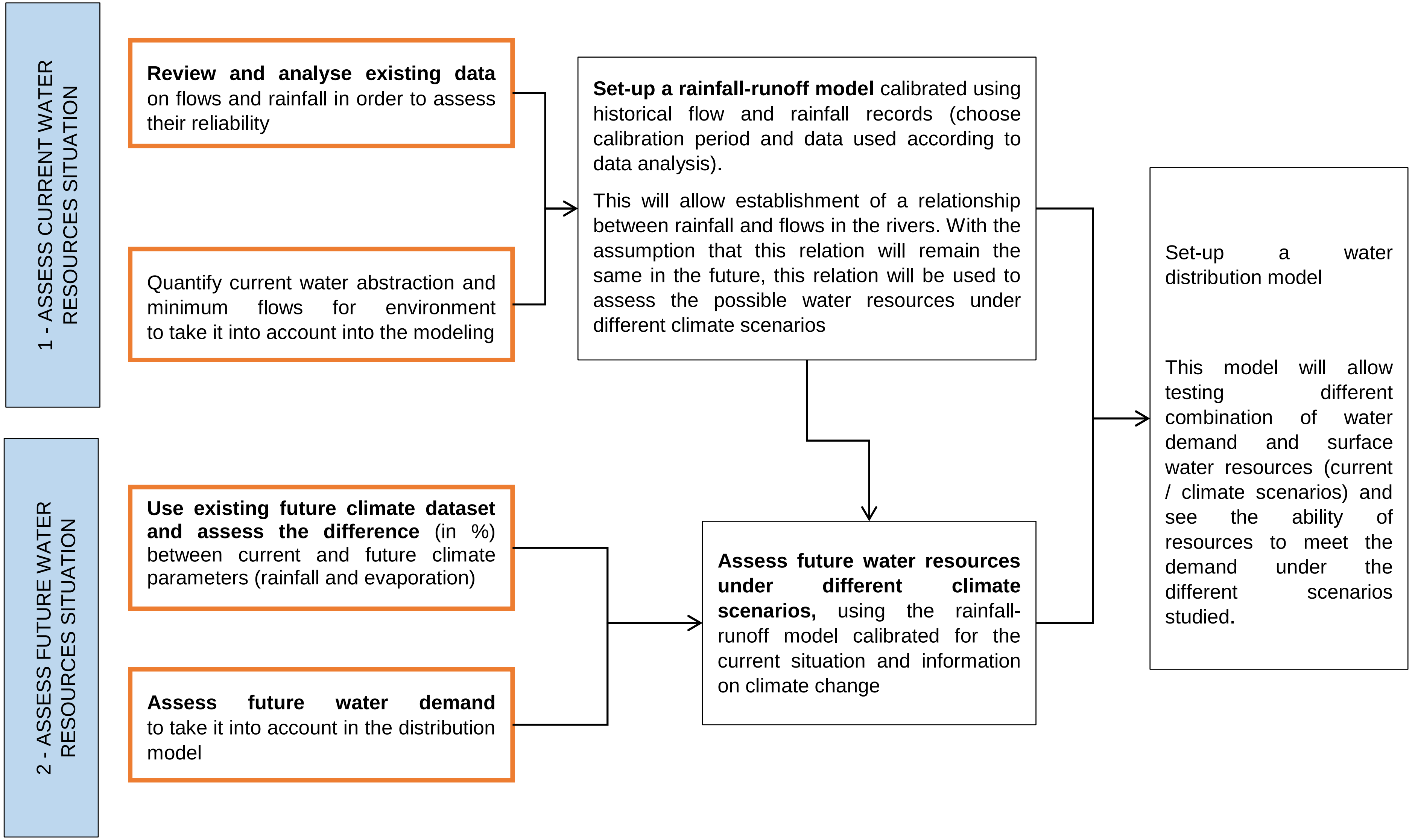
Figure 1 : Map of Mpanga river sub-catchments

Table 1 : Name and area of the catchment and sub-catchment of Mpanga River basin

Name of catchment or sub-catchment	Code	Description	Area (km²)
Upstream Mpanga catchment	C-I (= SubC-1)	Mpanga catchment from the sources to the gauging station n° 84212 (on Kampala – Fort Portal road)	401
Middle Mpanga sub-catchment	SubC-2	Mpanga catchment from gauging station n°84212 to gauging station 84215	1083
Rushango sub-catchment	SubC-3	Rushango catchment from source to its confluence with River Mpanga	3186
Lower Mpanga sub-catchment	SubC-4	River Mpanga catchment from gauging station 84215 to Lake George	464
Mpanga catchment upstream of the confluence with Rushango	C-II	All the catchment area corresponding to Mpanga catchment river upstream the confluence with Rushango (= SubC-1 + SubC-2)	1484
Mpanga catchment after the confluence with Rushango	C-III	All the Mpanga river catchment from the sources to the gauging station n°84214 (SubC-1 + SubC-2 + SubC-3)	4670
Mpanga catchment at Lake George	C-IV	Whole catchment area of Mpanga river, from the sources to Lake George, including Rushango (SubC1 + SubC2 + SucC3 + SubC4)	5134

1.2 Methodology

The schematic below summarizes the different steps followed to carry out the assignment.


1 - ASSESS CURRENT WATER RESOURCES SITUATION
Review and analyse existing data on flows and rainfall in order to assess their reliability
Quantify current water abstraction and minimum flows for environment to take it into account into the modeling
Set-up a rainfall-runoff model calibrated using historical flow and rainfall records (choose calibration period and data used according to data analysis).
This will allow establishment of a relationship between rainfall and flows in the rivers. With the assumption that this relation will remain the same in the future, this relation will be used to assess the possible water resources under different climate scenarios
2 - ASSESS FUTURE WATER RESOURCES SITUATION
Use existing future climate dataset and assess the difference (in %) between current and future climate parameters (rainfall and evaporation)
Assess future water demand to take it into account in the distribution model
Assess future water resources under different climate scenarios, using the rainfall-runoff model calibrated for the current situation and information on climate change
Set-up a water distribution model
This model will allow testing different combination of water demand and surface water resources (current / climate scenarios) and see the ability of resources to meet the demand under the different scenarios studied.

2. Review and comment on available data

2.1 Data on climate (historical)

2.1.1 Evapotranspiration

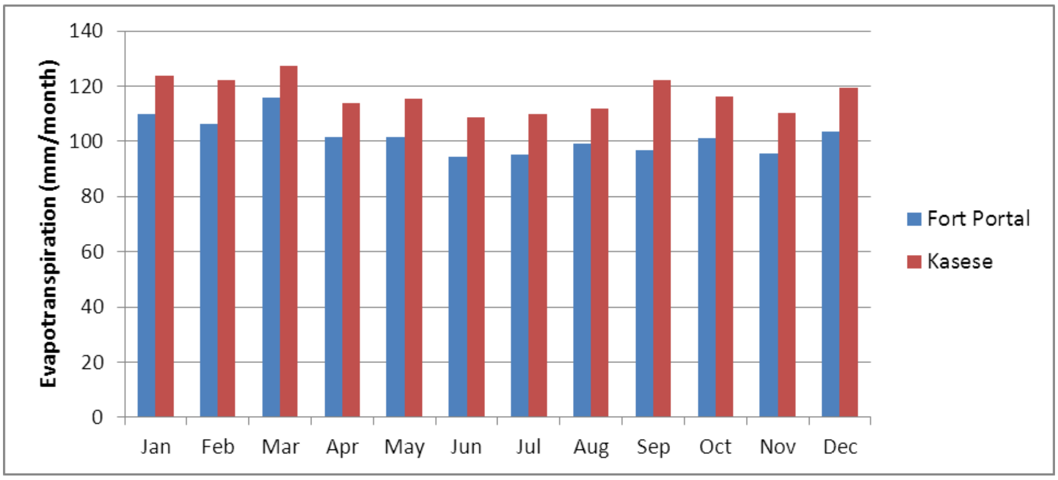
Evapotranspiration data will be used in this study as input for the rainfall-runoff models.

For the purpose of this study, the Consultant has used the mean monthly evaporation data available in the FAO CLIMWAT database (21 stations for Uganda). The two key stations used in this study are:

- Fort Portal (Longitude 30.28, Latitude 0.66, Altitude 1539), mean evaporation 1221 mm/year
- Kasese (Longitude 30.1, Latitude 0.18, Altitude 961), mean evaporation 1401 mm/year

Their locations are shown in Figure 3.

The graph below shows the mean monthly evapotranspiration at these two locations.



Source: Agrometeorological Group of FAO/FDRN, 2006. CLIMWAT2.0 for CROPWAT

Figure 2 : Mean monthly evapotranspiration at Fort portal and Kasese station

Being higher in altitude, Fort Portal experiences lower evapotranspiration than Kasese. Both locations have a similar monthly distribution, with lower evapotranspiration between June and August, and highest from December to March.

Figure 3 : Map of evapotranspiration and rainfall stations

2.1.2 Rainfall

Three main sources of rainfall data have been examined and are described in the following paragraphs.

Records of observed rainfall

The available daily rainfall data have been collected (see mission report). However, there are very few data available for recent years. Only 5 rainfall stations have significant records from year 2000 onwards, and unfortunately this is the period when river flow measurements are most reliable and therefore the period that should be used for calibration of the rainfall-runoff model (see §2.2). These 5 stations are identified on Figure 3 with bigger symbols, they are:

- Kasese Meteorological station (n°89300630) : this station has data for the period 1964-2012 including 38 years without major gaps;
- Mbarara (n°90300030): this station has one of the longest record periods. The records are spread over 90 years (starting in 1915), including 66 years without major gaps (only 6 after 2000).
- Bushenyi (n°90300320): this station has data for the periods 1963-1989 and 1999-2011 including 24 years without major gaps (only 2 after 2000);
- Kyenjojo first order station (n°89300790), this station has data for the periods 1972-1979 and 1992-2011, including 13 years without major gaps (5 after 2000);
- Kyembogo farm (n°89300180): this station has data for the periods 1943-1981 and 1992-2012, including 56 years without major gaps (records are available for all years from 2000 to 2012, however data taken during years 2001, 2002 and 2003 are highly dubious as rainfall amounts are twice to three times higher than usual amounts whereas none of the neighbouring rainfall station recorded similar anomalies).

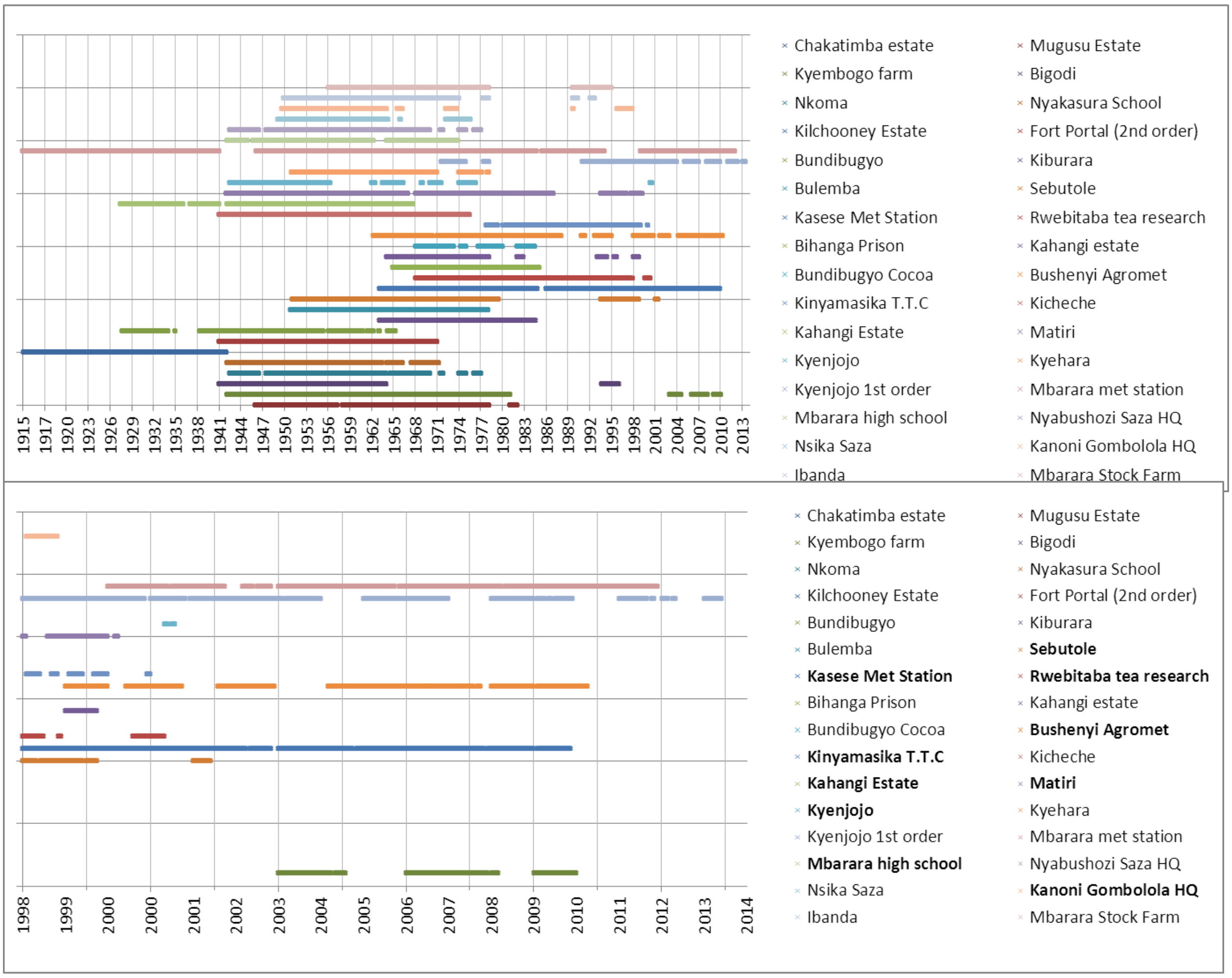


Figure 4 : Availability of rainfall data from station in and around the basin (whole period and zoom on recent years)

Data from the Climate research Unit (CRU) database.

The Climate Research Unit of East Anglia University avails a dataset of historical precipitation gridded at 0.50° x 0.50° resolution, on a monthly time step. This grid has been constructed from a total of over 11,800 stations worldwide. This database has the advantage of including long periods of rainfall historical data based on observations (data are available from 1901 to 2012). However on a relatively small catchment such as Mpanga catchment and where rainfall spatial variability is high, this source of data may not be precise enough.

Data from Global Precipitation Climatology Centre (GPCC).

The Global Precipitation Climatology Centre, operated by DWD (Germany's National Meteorological Service) under the auspices of the World Meteorological Organization (WMO) avails a full data re-analysis for the period 1901-2010, based on quality controlled data from all stations in GPCC's data base available at the time, with a varying coverage over time. Data set are available at different special resolution, including 0.5°*0.5°[1]. As for the CRU database, GPCC has the advantage of presenting long period of data without gaps. The difference between GPCC and CRU is mainly the stations used to produce the reanalyzed dataset.

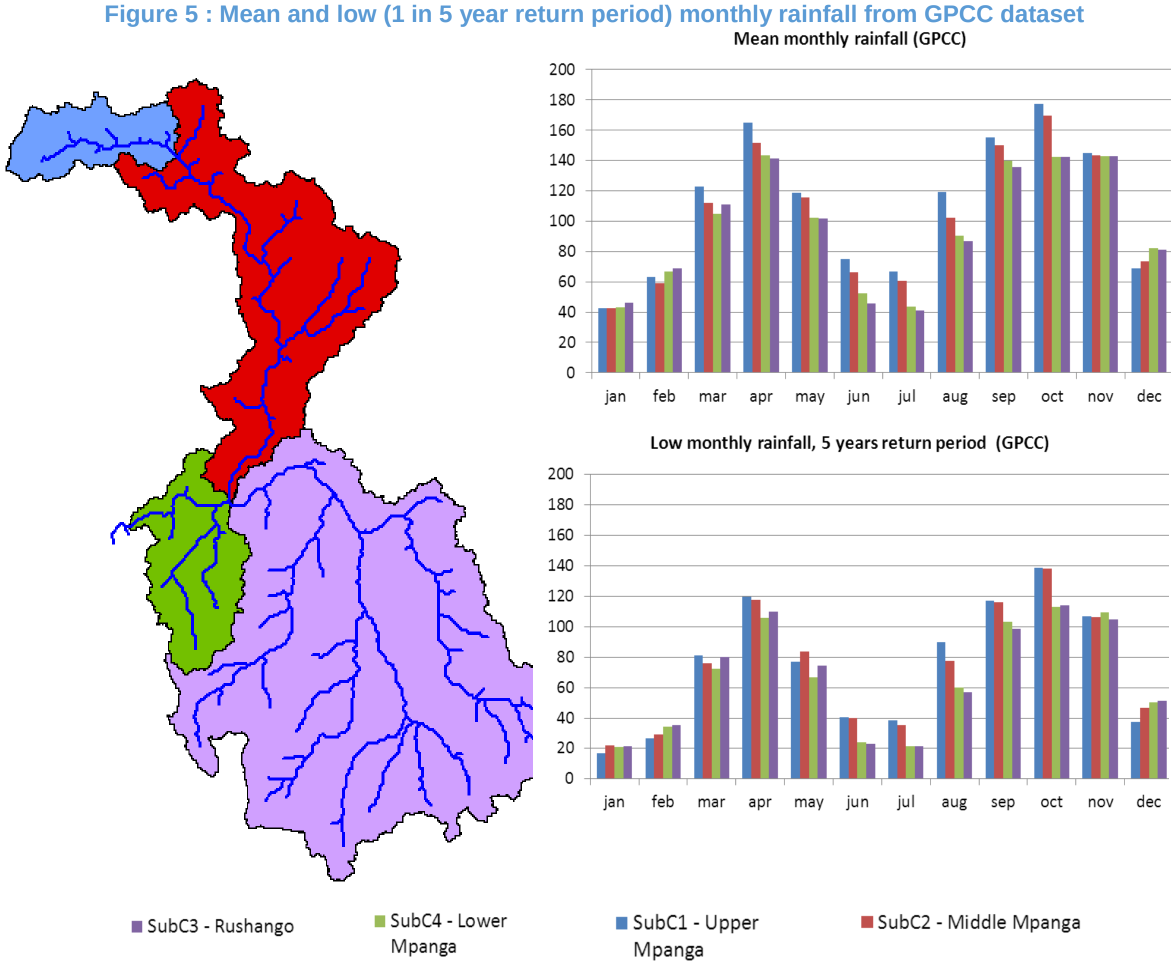
Data used for this study

The use of an existing database such as CRU and GPCC has the following advantages:

- It provides monthly data on a long record period, (including over recent years) without gaps (gap filling has already been carried out by way of a spatialized analysis).
- The data is spatialized

Checks and analysis have been performed to verify the coherence of data measured within the basin and reanalyzed data from CRU and GPCC (see annex 1). The conclusion of these analyses were (1) that rainfall data from CRU and GPCC seems fairly consistent with rainfall measured at stations in and around the basin and (2) between the two data sets, GPCC is the one that is best related with measured rainfall. **Data used in the rainfall-runoff modelling in this study are therefore data extracted from the GPCC database.**

Figure 5 : Mean and low (1 in 5 year return period) monthly rainfall from GPCC dataset



[1] Schneider, Udo; Becker, Andreas; Finger, Peter; Meyer-Christoffer, Anja; Rudolf, Bruno; Ziese, Markus (2011): "GPCC Full Data Reanalysis Version 6.0 at 0.5°: Monthly Land-Surface Precipitation from Rain-Gauges built on GTS-based and Historic Data"

2.2 Flow data

Three gauging stations provide flow records in Mpanga River catchment (see Figure 1)

The data of these three stations have been reviewed and their quality was assessed based on:

- Visualisation of data series to check if there is any obvious data anomalies
- Double mass curve analysis when possible
- Examination of the monitoring records for the gauging stations (period and regularity of gaugings, to ensure the station is still functioning and the rating curve still up-to-date).

Details on these aspects are provided in Annex 2, the main conclusions are outlined in the following paragraphs.

2.2.1 Station 84212, River Mpanga on Kampala – Fort Portal Road

This gauging station has data from 1957 to 1980 and from 1998 to present, with 30 complete years of data. The review of data (see Annex 2) led to the following observations:

- Data for 2011 onwards have been considered unreliable and unusable, they have been excluded from all the calculation and analysis performed in the rest of this report.
  - Flows recorded seem abnormally high (more than twice as high as in the rest of the record period, whereas an increase in rainfall is not observed).
  - The discharge measurements undertaken in the most recent years have shown that the relationship between flow and water level (“rating”) has changed.
  - Discussion with the gauging team of DWRM during the field visit also confirmed that repair and upgrading works on the nearby bridge downstream had perturbed the functioning of the station.
  - Double mass analysis show a clear change in relation between flows measured at this station and flows measured on gauging station 84215 (River Mpanga downstream).
- **1998-2010 is the period when data look the most reliable.** Ideally (if availability of rainfall data allows), **calibration period for the rainfall-runoff model should be chosen within this period**. Regular discharge measurements were undertaken at the gauging station, they validate the use of the rating curve and show that the station had been monitored during this period. Data from the two gauging stations on the River Mpanga seem well correlated (see double-mass analysis and correlation tests in Annex 2). The use of this period is preferable to the use of a former record period for calibration of a rainfall-runoff model, as it should better represent the current state of the catchment (although major changes have taken place between 1998 and 2014).
- **Data recorded between 1957 and 1968 are considered reliable.** The gauging station seems to have been very well monitored (1 gauging per month during the whole period). Correlation with measurement at the gauging station downstream on Mpanga river (n°84215) is not as good as for the 1998-2010 period. This is likely to be due to issues with the quality of the data at the gauging station n°84215.
- **Data recorded between 1969-1980 are to be treated with caution.** No discharge measurements were performed during this time period. Between 1975 and 1980 there was a change in the relationship between this station and station n°84215 (River Mpanga on Fort Portal – Ibanda road). This is probably due to issues with the records of the 84215 station.
- **Discharge measurements have been carried out up to a water level of only 1.2 m, or 22 m^3/s.** the vast majority of discharge measurements have been carried out during relatively low flow conditions. This is not surprising given i) that high flows are often short-lived making it difficult to get a gauging team on site and ii) the gauging of high flows is challenging in any

case, requiring the appropriate specialised equipment. The effect of this is that the accuracy of the water level (stage)/discharge rating curve, which is used to convert recorded water levels into flows, is questionable for the higher flows. This is not necessarily critical when looking at allocation issues during critical periods of the year. However, it can have a major impact on the accuracy of mean annual runoff and other hydrological statistics, important when looking at aspects such as intra and inter-annual storage requirements for potential reservoirs.

2.2.2 Station 84215, River Mpanga on Fort Porta - Ibanda Road

This gauging station has data from 1966 to 1980 and from 1998 to 2012, with 21 full years of data. Review of data lead to the following observations:

- **1998-2012 is the period when data look the most reliable**. Regular gaugings have been done at the gauging station during this period, and the relationship between this station and the gauging station upstream on river Mpanga seems consistent (see correlation and double mass).
- **Data recorded between 1966 and 1980 are to be used with caution, especially during the last 5 years.** Regular discharge measurements were carried out during the first years but then stopped from 1970 to 1980. Cross checks with data from the gauging station 84212 show a change in the relation between the two stations in the 1975-1980 period, probably due to a shift in the cross-section of Station n°84215 (flows measured seems slightly higher than what is usually measured whereas such phenomena is not observed at the upstream gauging station nor in the rainfall records).

2.2.3 Station 84276, River Rushango at Buteraniro

This gauging station has data from 1988 to 1992 with only 2 full years of data. Unfortunately, it has no common period of functioning with any of the two other stations. During its short period of functioning, it seems the station has been well monitored, and 13 discharge measurements were performed, all for flows lower than 3 m^3/s. **High flow data will therefore be used with caution.** The unit runoff for the catchment draining to this station seems much smaller than the one measured on the Mpanga River (see section 3.2).

2.3 Groundwater

There are no groundwater monitoring stations in the Mpanga catchment, so it is difficult to provide an indication of trends. However, there is both anecdotal and scientific evidence to support the view that there has been a general decline in the groundwater table throughout the basin.

In the lower parts of the catchment, for example in the rural areas around Kamwenge where groundwater is the main source of water for most households, PROTOS reports that many of the hand pumps have dried up and new sites have had to be found. In the Rushango sub-catchment the same problem was reported. In some cases the groundwater sources dry up during periods of drought.

Groundwater and surface water are closely linked. This is especially true in the wetter source areas where the strengths of springs and the base flows of perennial streams are closely related to the condition of the water table. As already discussed under Section 2.2.1 earlier, the low flows in the upper part of the Mpanga River have decreased. During the dry season, low flows are maintained by an effluent groundwater table, ensuring the perenniality of the streams that it feeds. Because of reduced infiltration and recharge during the rainy season, it would appear that the groundwater table in the source areas has decreased.

In conclusion, it would appear that the availability of groundwater is being compromised by anthropogenic pressures across the basin. In the source areas this is due to the conversion of natural land cover into farmland and the ensuing poor farming practices. In the lower parts of the basin it is due to increased abstraction although the level and extent of this problem cannot be quantified because of a lack of monitoring data. It is likely that there are some areas where the level of abstraction cannot be sustainably supported, while in others there is no problem at present.

Given the importance of the resource, with around two thirds of all water supplied (excluding hydropower) coming from groundwater, the lack of consistent monitoring is serious cause for concern.

2.4 Information on current and future water demand

Information on water demand used in this report comes from three main sources:

- Information gathered in the basin (during the first mission and completed by the team's locally based expert)
- List of water abstraction permits provided by DWRM
- A study done under DWRM, "Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin" (Ark Consult & Engineering Ltd, draft report, December 2014) (referred to as "water demand study" in the paragraphs below).

  This study estimated current and future water demand for different sub-basins, including Mpanga basin; differentiating the Rushango part, and the Mpanga part (from the sources to Lake George, which corresponds to the sub-catchment 1, 2 and 4 of the present study).

2.4.1 Water abstraction for agriculture and cattle

Description of agricultural system

Apart from the tea estates located between Fort Portal and Kibaale forest, agriculture in Mpanga sub-catchment is mainly rainfed subsistence farming. The main crops grown are bananas, annual vegetables, as well as cereals (maize, millet, sorghum). A few perennial cash crops such as coffee and fruit trees are also grown in some parts (upper part of Mpanga sub-catchment, between Kibaale forest and Kamwenge).

In the Mpanga sub-catchment near the confluence with Rushango and Rushango sub-catchment, the main activity is agro-pastoralism (part of the Rushango sub-catchment is located in the "Cattle Corridor").

Cultivation sometimes takes place in wetlands, in the Mpanga sub-catchment around Fort Portal (source: baseline study, Protos), and in the upper part of Rushango sub-catchment, in Kiruhura district (source: discussion with local government).

From the observation made and discussion with the stakeholders, **there seem to be no irrigation going on in Mpanga catchment, apart from very limited and localised labour-intensive initiatives for which abstraction is minimal.** The list of water permit obtained from DWRM also doesn't mention any abstraction related to irrigation.

However, the apparent need for some supplementary irrigation during the dry season was expressed by several stakeholders. Many valley dams are located in Kiruhura district, but most of them are heavily silted.

Remark: A project in Kiruhura district is planned with AFD (French Development Agency) support,, but it does not involve water from the basin and has no impact on the present study.

Quantification of water demand for agriculture and livestock

Water demand for livestock has been estimated in the water demand study, using the UBOS Livestock Report (2009) and the Tropical Livestock Unit from which equivalent water consumption figures per specie were derived.

Table 2 : Water demand for Livestock (2015-2035 projections)

m3/day	**2015**	**2020**	**2025**	**2030**	**2035**
Mpanga	9,870	10,849	11,857	12,446	13,064
Rushango	13,191	14,479	15,875	16,653	17,470

Source: "Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin" draft report, December 2014

The water demand study underlines the difficulty of assessing water demand for irrigation and to proceed to water demand projections. Projections were made in that study, at the district scale, taking into account the areas of potential irrigation defined in the National Irrigation Master Plan (MWE, 2011) and assuming that 10% of seasonal wetland could be irrigated in the future, at the rate of 10,000 m^3/year/ha (see Table 3).

The distribution during the year of water demand for irrigation will depend on many factors such as the type of infrastructure available in the future, the number of cropping seasons (itself conditioned by the available irrigation technologies), the type of crops cultivated etc.

Table 3 : Area of potential irrigation in the Edward-George catchments

District	Seasonal wetlands (ha)	Potentially irrigable area (10% of seasonal wetlands) (ha)	Amount of water needed for irrigation (m3/day)
Kyenjojo	8,477	848	23,225
Ibanda	315	32	863
Kamwenge	947	95	2,595
Kiruhura	8,044	804	22,038
Mbarara	1,117	112	3,060

Source: "Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin" draft report, December 2014

To estimate the water demand at the scale of the sub-catchment considered in this study, the water demand for irrigation has been distributed between the 4 sub-catchments considered (see Table 1) according to the overlapping of each districts with the sub-catchment boundaries[2]. The result is shown in Table 4

[2] This implies that the distribution of wetlands in the districts is supposed homogenous, which is not necessarily exact.

Table 4 : Potential irrigation water demand per sub-catchment

	Potentially irrigable area (ha)	Amount of water needed for irrigation (m3/day)
Upper Mpanga	56	1,543
Middle Mpanga	824	22,562
Lower Mpanga	23	629
Rushango	944	25,861

2.4.2 Water supply

Fort Portal, Kamwenge and Ibanda are the three main urban centres supplied in water with water coming from Mpanga catchment. The three piped schemes are managed by the NWSC services who weremet with during this first mission.

- **Water supply for Fort Portal**: 2500 m^3/day are pumped from the River Mpanga to supply 6000 connexions in and around Fort Portal. This demand is almost constant through the year. The plant is currently functioning at full capacity and NWSC plans to extend it in a near future. Data on the growth in annual water abstraction during the past 15 years is apparently available and should be received soon. High sediment loads in the river during high flows increase the use of chemicals for treatment and sometimes prevent the plant from functioning.
- **Water supply for Kamwenge**: 200 m^3/day, (6000 m^3/month), are pumped from the River Mpanga to supply the town of Kamwenge. The scheme was implemented in 2009 with operation contracted out to the private sector. Operation was apparently not satisfactory with production never exceeding 4000 m^3/month. The NWSC has been in charge of operating it for four months so there are no useful data on seasonal variations in demand and production. Production is reportedly growing steadily and the Area Manager anticipates that it will reach 10000 m^3/month in the very short term. Expansion of the network is planned and the area manager expects production to reach 1000 m^3/day in the medium term. The Area Manager considers the water quality in River Mpanga as good, compared to the one of the adjacent Rwizi River.
- **Water supply for Ibanda**: NWSC is very new in Ibanda and has been operating the scheme for only a few months. Previously it was privately operated. Five springs, located in Lukiri (western highlands of the Rushanwe sub-catchment) area are used to supply 2200 metered points. The population and demand in Ibanda is growing rapidly but so far, the springs are able to meet demand, even during the dry season.
- **Rural water supply**: Rural water supply is difficult to quantify accurately. Most of the smaller rural communities depend on groundwater. Small urban centres (eg Kiruhura town) are sometimes supplied with piped water derived from a borehole scheme.

Estimates of current and future water demand for potable water supply are given in the water demand study, based on (1) census data, (2) hypothesis on future growth rates, (3) hypothesis on future consumption unit rates (l/head/day). Population at the basin's scale was been estimating assuming that the district population is homogeneously distributed within the district (see Table 5).

Table 5 : Estimated population of the sub-catchments

	2015	2020 (growth rate r=3.2%)	2025 (r=3.1%)	2030 (r=3.0%)	2035 (r=2.9%)
Mpanga	212,968	246,295	290,406	336,660	388,391
Rushango	542,886	635,489	740,287	858,196	990,065

Source: "Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin" draft report, December 2014

Table 6 : Water supply demand projection

	in m3/day	2015	2020	2025	2030	2035
Mpanga	Domestic water demand	4,685	5,734	6,970	8,417	10,098
	Water demand for institution	982	1,014	1,045	1,076	1,108
	Total	5,667	6,748	8,015	9,493	11,206
Rushango	Domestic water demand	11,943	14,616	17,767	21,455	25,742
	Water demand for institution	976	1,007	1,036	1,067	976
	Total	12,919	15,623	18,803	22,522	26,718

Source: "Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin" draft report, December 2014

2.4.3 Water abstraction for industry

There is little industry or factories abstracting surface water within the Mpanga River catchment. Abstraction is largely limited to a few tea factories, where water is used for cleaning purposes. It is estimated (see 1st mission report) that approximately 20% of the water abstracted by tea factories is consumed and 80% return to the environment.

The water demand study provides an estimate of water demand for industry and mining (see Table 7), considering that industrial demand is proportional to water supply demand (e.g. industrial demand for a sub-catchment = 30% of water supply demand for the same sub-catchment).

Table 7 : Demands estimates for industry and mining

	in m^3/day	2015	2020	2025	2030	2035
Mpanga	Industrial water demand	1,406	2,294	4,182	6,733	10,098
	Mining and minerals extraction	703	1,147	1,742	2,525	3,534
	Total	2,109	3,441	5,924	9,258	13,632
Rushango	Industrial water demand	3,583	5,846	10,660	17,164	25,742
	Mining and minerals extraction	1,792	2,923	4,442	6,436	9,010
	Total	5,375	8,769	15,102	23,600	34,752

Source: "Consultancy services to determine and map water use and demands in Lake George, Lake Edward and Kafu basin" draft report, December 2014

2.4.4 Hydropower production

The VSHydro Ltd Company has been operating a hydropower production plant located on River Mpanga downstream of the confluence with Rushango, around 8 km upstream of its outlet in Lake George since 2011.

The plant has a maximum capacity of 18 MW (that corresponds to a flow of 16 m^3/s). According to the person in charge, the plant works at full capacity for on average 3 months per year. The diversion weir installed on the River Mpanga does not allow for significant storage and power production is essentially run-off the river. The flow available for power production is the flow in river Mpanga after allowance for the environmental flow requirements. This is approximately 1 m^3/s that is left in the river between the head and tail races. The environmental flows pass through the weir via two uncontrolled pipes in order to maintain this minimum flow requirement at all time.

2.4.5 Water demand considered in the water demand – water resource balance analysis

For the present study, quantified water demand estimates are needed at the sub-catchment scale to do a water balance analysis and to compare water available in the rivers of Mpanga catchment, with the water demand using these rivers as water resources. For that purpose, water demand estimates must:

- Be at the sub-catchment scale and not only differentiating Rushango and the rest of Mpanga catchment;
- only include water demand relying or having an impact on surface water
- take into account not only the overall abstraction for the different uses, but also the return flows.

Distribution of water demand by sub-catchment

The distribution of water demand between the upstream, middle and lower part of Mpanga basin has been done based on the overall estimate for Mpanga River available in the water demand study, the observation from the first field visit, and taking into account the following parameters:

- For irrigation: information on irrigation potential at the district scale (available from the water demand study), and the share of each district in the different sub-catchments (see Table 4).
- For water supply: information on population at the district scale (available from the water demand study) and the share of each district in the different sub-catchments. This implies that population distribution in the districts is supposed homogenous, which is not necessarily exact. A cross check has also been carried out using the information obtained in the field visits regarding the daily water demand for supplying Fort Portal municipality. The distribution finally applied is: upper Mpanga: 45%; middle Mpanga: 40%, lower Mpanga: 15%.
- For industry: information on population at the district scale (available from the water demand study) and the share of each district in the different sub-catchments. This implies that population distribution in the districts is supposed homogenous, which is not necessarily exact.
- For livestock: the area of the sub-basin, and taking into account the importance of pastoralism in the lower Mpanga sub-catchment and southern part of middle Mpanga sub-catchment.

Water demand for Rushango sub-catchment was already available in the water demand study.

Impact on surface water resources

Only part of the water demand estimated in the overall water demand study impacts on surface water. Water demand fed by deep wells, boreholes, doesn't have a direct impact on the flows in the rivers. The bigger towns of the catchment like Fort portal, Kamwenge and Ibanda, are supplied by surface water, (from sources of rivers), but rural areas or other town such as Kiruhura rely on groundwater.

There is a high uncertainty on how much of the water demand relies on surface water, especially for water supply. The assumptions made are presented in the Table 9 and are based on the following observations:

- Water demand for hydropower: the hydropower plant in the catchment abstracts surface water from the river (as would do any hydropower scheme, if any are planned in the future)
- Water demand for irrigation: energy cost (for pumping), the quantity of water needed and the investment capacity of farmers make it difficult to use groundwater for irrigation,
- Water demand for water supply:
  - in the upper Mpanga it was assumed that the large majority of the population is supplied with surface water, as surface water resource is relatively accessible and clean, and that the main town (Fort Portal) is supplied by surface water. Moreover, a large part of this sub-catchment falls in Kabarole district which has a poor potential of ground water (*source: "Kabarole district information", Water supply Atlas, 2010*)
  - In the middle Mpanga sub-catchment, Kamwenge town is supplied with surface water coming from river Mpanga. In Kamwenge and Kyenjojo district (where most of the middle Mpanga sub-catchment falls in), the share of population served by deep boreholes is only 4.8% (Kamwenge district) and 16% (Kyenjojo district) (see Table 8).
- In Rushango, Kiruhura town is supplied by a piped scheme relying on groundwater. In Kiruhura district, more that 57% of the people are served by deep boreholes (see Table 8)

Table 8 : People served by technology

	Kyenjojo	Kamwenge	Kiruhura	Ibanda	Kabarole	Mbarara
Protected spring	29.2%	27.5%	3.3%	26.9%	26.9%	32.2%
Shallow well	49.6%	45.5%	34.3%	25.8%	52.9%	8.3%
Deep Borehole	16.0%	4.8%	57.3%	4.6%	5.1%	15.2%
Rain water Harvesting tank	0.2%	0.2%	4.9%	0.1%	0.2%	3.1%
Public tap	5.0%	22.0%	3.3%	42.5%	14.9%	41.1%

Source: Water supply Atlas; MWE, DWD (2010)

Table 9 : Assumptions made regarding the impact of water demand on surface water resources

Use	Share of water demand having an impact surface water resources
Irrigation	100%
Industry	100%
Hydropower	100%
Water supply, upper and middle Mpanga sub-catchment	90%
Water supply, lower Mpanga subcatchment	70%
Water supply, Rushango sub-catchment	50%

Return flows

Not all the water abstracted is consumed: a part of it is released back into the environment and eventually goes back to the river. This needs to be taken into account in the water balance analysis. The share of water consumed and returning to the environment is different depending on the type of use: for hydropower production, the totality of the water abstracted returns to the river after going through the turbines, whereas for irrigation, a part of the water can return to the environment (infiltration, outlet of irrigation canals etc.) but another part is consumed by the crops. The Table 10 sums-up the assumptions made about the share of water returning to the environment.

Table 10 : Return rate for the different water uses

Use	Return rate
Hydropower	100 %
Water supply	70 %
Industry and mining	80 %
Irrigation	40 %

Water demand taken into account in the water demand – water resource balance analysis

The table below sums-up the water demand considered as having an impact on the rivers of Mpanga catchment, at present, and in 2035, based on the estimates provided in the water demand study, and on the assumptions presented in the previous paragraphs.

Table 11 : water demands used in the water balance analysis

In m3/day		Current Water demand			Future (2035)		
		Total	*With an impact on surface water*	*Return flow*	*Total*	*With an impact on surface water*	*Return flow*
Upper Mpanga	Water Supply	2,550	2,295	1,607	5,043	4,538	3,177
	Agriculture (irrigation and livestock)	1,481	1,481	592	3,502	3,502	1,401
	Industry and mining	427	427	342	2,762	2,762	2,210
Middle Mpanga	Water Supply	2,267	2,040	1,428	4,482	4,034	2,824
	Agriculture (irrigation and livestock)	5,922	5,922	2,369	30,400	30,400	12,160
	Industry and mining	1,211	1,211	969	7,827	7,827	6,261
Lower Mpanga	Water Supply	850	595	417	1,681	1,177	824
	Agriculture (irrigation and livestock)	2,468	2468	987	3,895	3,895	1,558
	Industry and mining	471	471	377	3,043	3,043	2,434
Rushango	Water Supply	12,919	6,460	4,522	26,718	13,359	9351
	Agriculture (irrigation and livestock)	13,191	13,191	5,276	43,331	43,331	17,332
	Industry and mining	5,375	5,375	4,300	34,752	34,752	27,802
Total	Water Supply	18,586	11,390	7,973	37,924	23,108	16,176
	Agriculture (irrigation and livestock)	23,061	23,061	9,224	81,128	81,128	32,451
	Industry and mining	7,484	7,484	5,987	48,384	48,384	38,707
Total (equivalent in m3/s)	Water Supply	0.22	0.13	0.09	0.44	0.27	0.19
	Agriculture (irrigation and livestock)	0.27	0.27	0.11	0.94	0.94	0.38
	Industry and mining	0.09	0.09	0.07	0.56	0.56	0.45

These estimates will be used in the water demand – water resources balance analysis (see section 4.3).

It should be noted that the majority of water is supplied from groundwater, hence the need to ensure that the monitoring of groundwater becomes a priority.

2.4.6 Environmental minimum flow requirement

According to the Water management Zone Area Manager, in the absence of any specific study, the Q90[3] is usually used by default as environmental minimum flow requirement in Uganda.

As mentioned above, the environmental flow downstream the diversion weir of the hydropower plant is 1 m^3/s.

[3] The Q90 corresponds to the daily flow that is statistically overpassed 90% of the time.

3. Assessment of current surface water resources

3.1 Observed flows

Measurements taken at gauging station n°84212 show a change in the catchment hydrology, including:

- Decrease in mean annual runoff,
- Decrease in monthly low flow,
- Decrease in daily minimum flow,
- Increase in daily maximum flow.

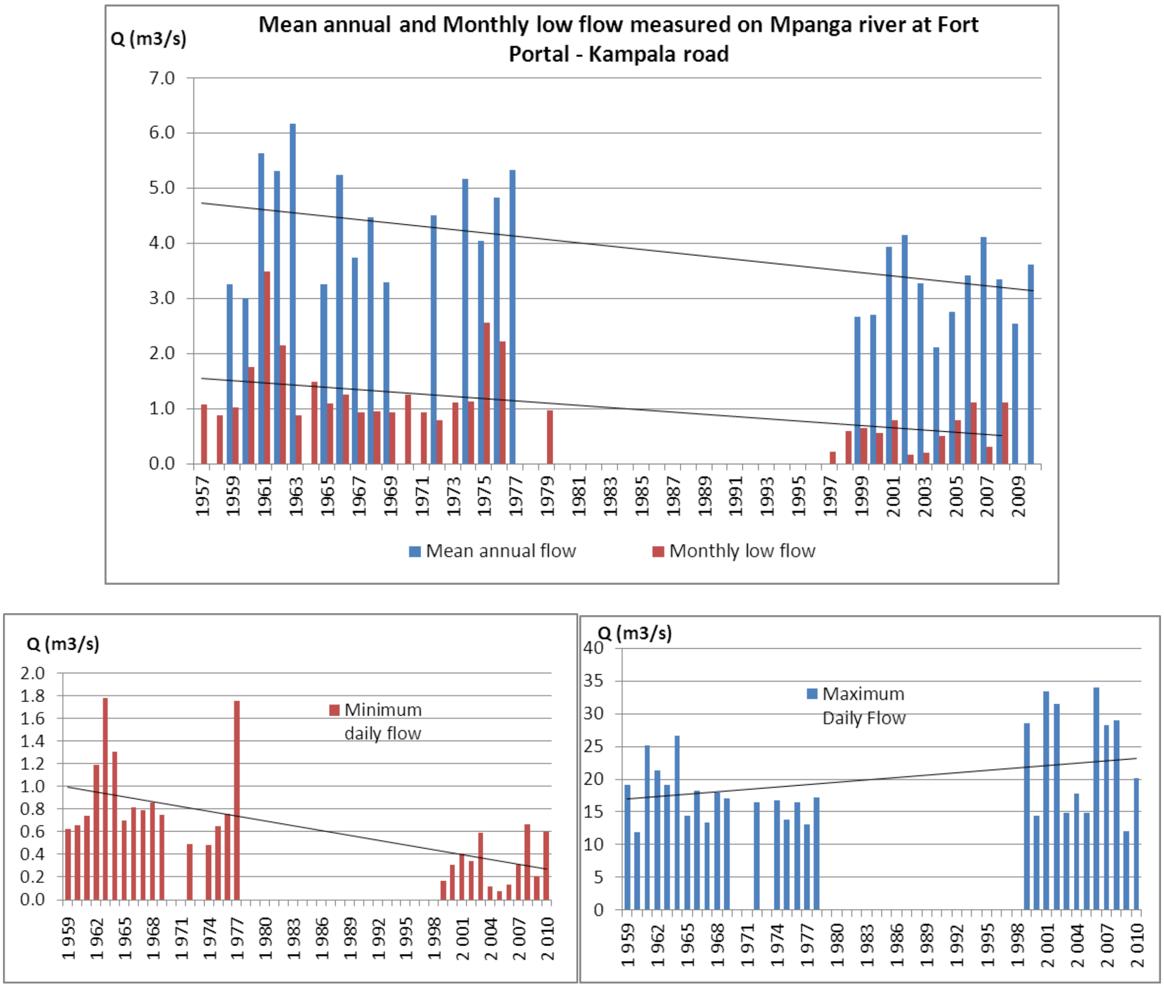


Figure 6 : Evolution of flows measured on Mpanga river at the gauging station n°84212

Possible causes for this difference between 1947-1981 period and 1998-2010 period could be:

- Quality of the data collected
- Change in rainfall. However rainfall doesn't seem to have changed significantly. No trend appears in annual total nor in minimum and maximum monthly rainfall amounts (see Figure 6).
- Change in land use resulting in a change in the relation between rainfall and runoff

The issue of data quality may well be relevant for the higher flows. As already indicated, a lack of discharge measurements at high flows means that there can be a significant margin of error when flood condition water levels are converted into discharges. However, given that there has been no apparent decrease in precipitation, the observed decrease in minimum flows is clearly a result of major changes in land-use over the last 50 years. A reduction in land cover has resulted in reduced infiltration and a reduced baseflow, dependant as it is on a groundwater table that feeds water into the river in during the dry season. The same mechanisms are the cause for the increase in daily flows.

The observed decrease in mean annual runoff is, however, surprising and contrary to what would normally have been expected. It is suggested that in fact the high flows may actually have increased to even higher levels that those apparently measured. This would be due to significant error in the upper part of the stage/discharge rating curve. Given the large volume of water associated with flood events, an error of only a few percent would have a significant impact on the total annual runoff.

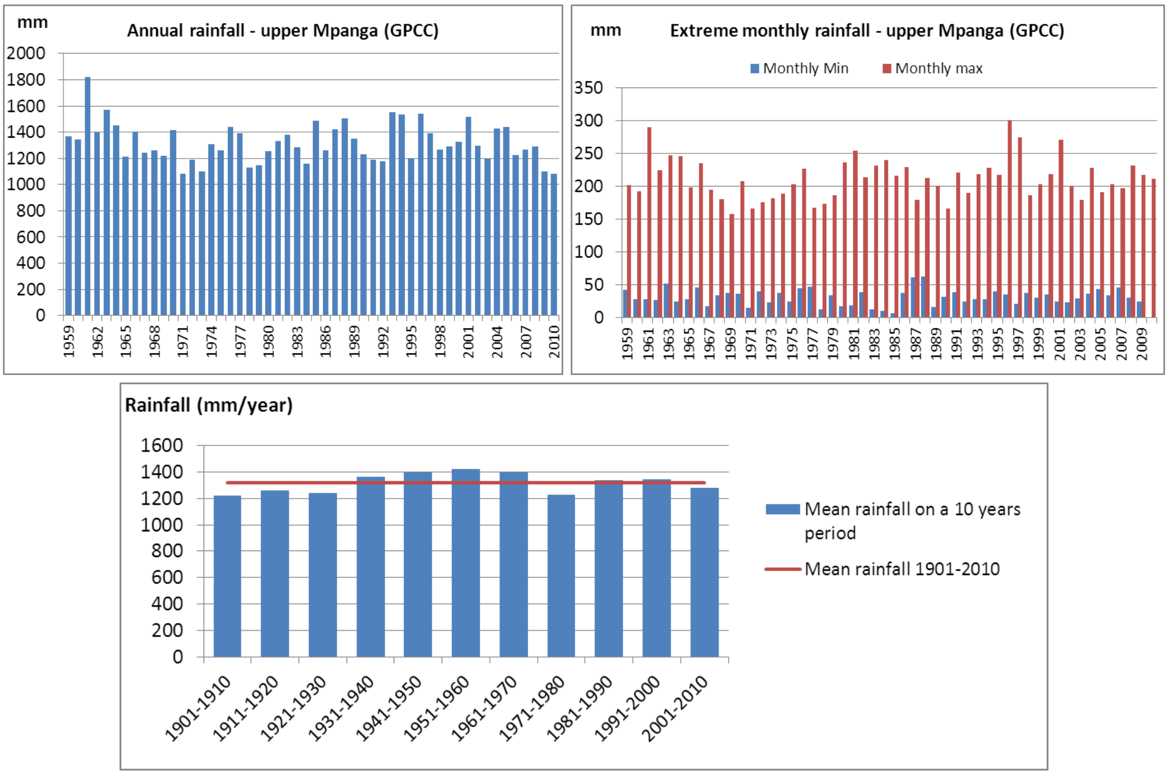


Figure 7 : Evolution of rainfall on upper Mpanga sub-catchment (GPCC)

Ignoring the 1975-1980 period for which data have been identified as unreliable (see §2.2), mean annual runoff measured at the downstream station on the Mpanga river on Fort Portal – Ibanda road (gauging station n°84215) doesn't show similar trends to the one measured at gauging station n°84212.

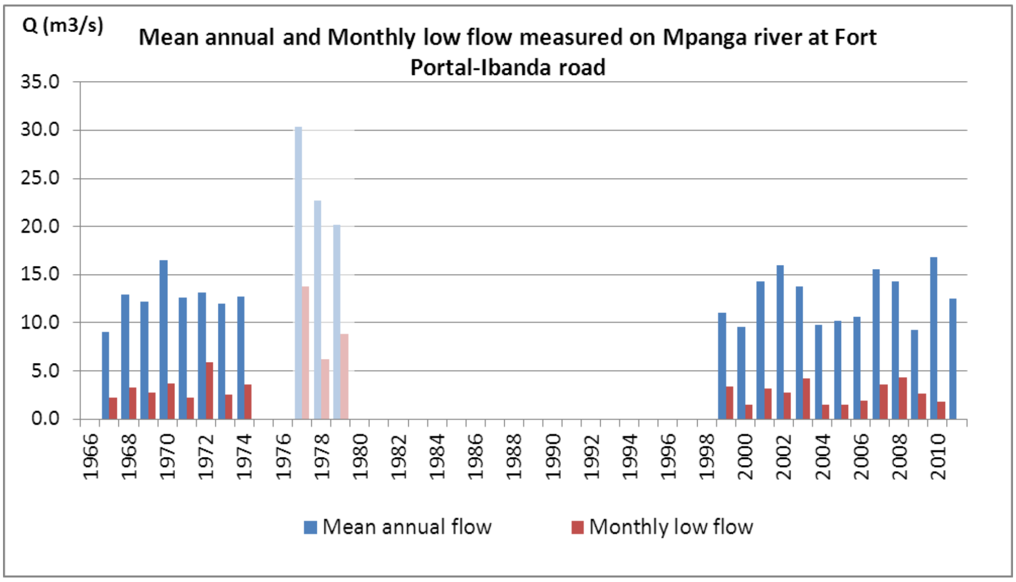


Figure 8 : Evolution of flows measured on Mpanga river at the gauging station n°84215

Tables below show the statistics calculated on observed flow at the three stations. Statistics have been calculated on 1998-2010 period for gauging station n°84212, and on 1966-1974 & 1998-2010 for gauging station n°84215. Given that few data are available for the Rushango station, only mean flows have been calculated

Table 12 : Statistical analysis of observed flow on Mpanga River at gauging station n°84212

Statistical analysis on 1998-2010 period (12 years))

River Mpanga at Kampala - Fort Portal Road
Station : 84 212 Area of the sub catchment 401 km²
Type Observed flow

Flow in m3/s

													Annual	
(experimental frequency)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	m3/s	l/s/km²
Mean	1.8	1.1	1.9	3.3	3.7	2.0	1.1	1.6	2.9	6.2	8.9	4.3	3.2	8
T=10 years low flows	0.9	0.5	0.8	2.5	1.8	0.8	0.2	0.5	1.3	3.4	6.2	2.3	2.6	6
T=5 years low flows	1.6	0.6	0.8	2.6	2.3	0.9	0.5	0.8	2.1	3.8	6.6	2.7	2.7	7
T=2 years	1.8	0.9	1.6	3.3	3.6	1.9	0.7	1.5	2.8	5.4	8.2	3.9	3.3	8
T= 5 years high flows	2.3	1.1	2.3	4.2	6.1	2.8	1.8	2.2	4.1	7.7	11.1	6.3	3.9	10
T=10 years high flows	2.5	2.3	2.5	4.6	6.3	3.8	2.1	2.7	4.5	8.0	12.5	7.2	4.1	10

	Min monthly low flow	
(experimental frequency)	m3/s	l/s/km²
Mean	0.6	1.5
T=10 years low flows	0.2	0.5
T=5 years low flows	0.2	0.6
T=2 years	0.6	1.4
T= 5 years high flows	0.8	2.0
T=10 years high flows	1.1	2.7

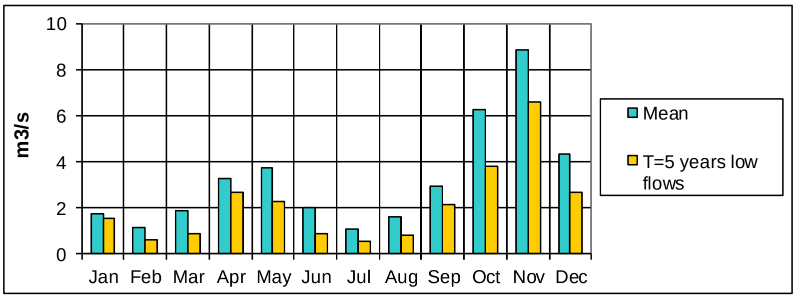


Table 13 : Statistical analysis of observed flow on Mpanga River at gauging station n°84215

Statistical analysis on 1966-1975 and 1998-2010 periods (22 years)

River Mpanga at Fort Portal Road Ibanda Road
Station : 84 215 Area of the sub catchment 4 670 km²
Type Observed flow

Flow en m3/s

(experimental frequency)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual m3/s	Annual l/s/km²
Mean	8.2	4.7	6.5	12.5	17.8	8.8	5.5	5.8	12.5	20.0	28.8	19.6	12.6	3
T=10 years low flows	3.5	2.2	3.0	6.4	7.6	4.5	1.9	2.7	5.2	13.9	20.4	9.0	9.5	2
T=5 years low flows	4.6	2.7	3.5	7.3	8.8	5.8	2.8	3.4	6.0	14.8	21.6	11.3	10.2	2
T=2 years	7.4	3.9	5.9	9.9	14.0	8.5	4.5	5.5	10.9	18.7	27.0	17.4	12.6	3
T= 5 years high flows	10.9	5.8	8.0	14.2	28.5	11.4	8.1	6.7	16.5	24.9	34.1	28.3	14.3	3
T=10 years high flows	12.8	8.6	10.0	20.4	34.4	13.9	8.4	8.4	23.5	28.6	42.9	32.6	16.0	3

(experimental frequency)	Min monthly low flow m3/s	Min monthly low flow l/s/km²
Mean	2.8	0.6
T=10 years low flows	1.5	0.3
T=5 years low flows	1.8	0.4
T=2 years	2.7	0.6
T= 5 years high flows	3.6	0.8
T=10 years high flows	4.2	0.9

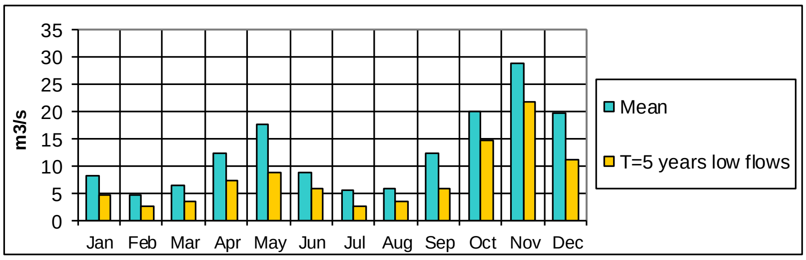


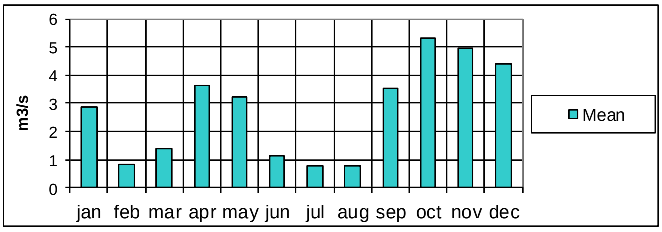
Table 14 : Statistical analysis of observed flow on Rushango River at gauging station n°84276

River Rushango
Station : 84 276 Area of the sub catchment 3 012 km²
Type Observed flow

Flow en m3/s

(experimental frequency)	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	Annuel m3/s	Annuel l/s/km²
Mean	2.8	0.8	1.4	3.6	3.2	1.1	0.8	0.8	3.5	5.3	5.0	4.4	2.4	1

(experimental frequency)	Min monthly low flow m3/s	Min monthly low flow l/s/km²
Mean	0.4	0.1



3.2 Rainfall Run-off modelling

The model used for rainfall-ETP-runoff modelling is GR2M, a description of which is provided in Annex 3.

Calibrated on current hydrology, the rainfall-runoff modelling will permit:

- The generation of a longer data series of flows under current climate,
- The estimation of flows under different climate scenarios, changing rainfall and evapotranspiration data entered as input.

It means that impact of climate change (rainfall and temperature) is the only parameter taken into account; the state of the catchment and the way rainfall relate to runoff is not used as a variable changing between reference and future period.

3.2.1 Calibration and validation at gauging station n°84212

Figure 9 shows the simulated flows at station n°84212 (calibration period is 1999-2004).

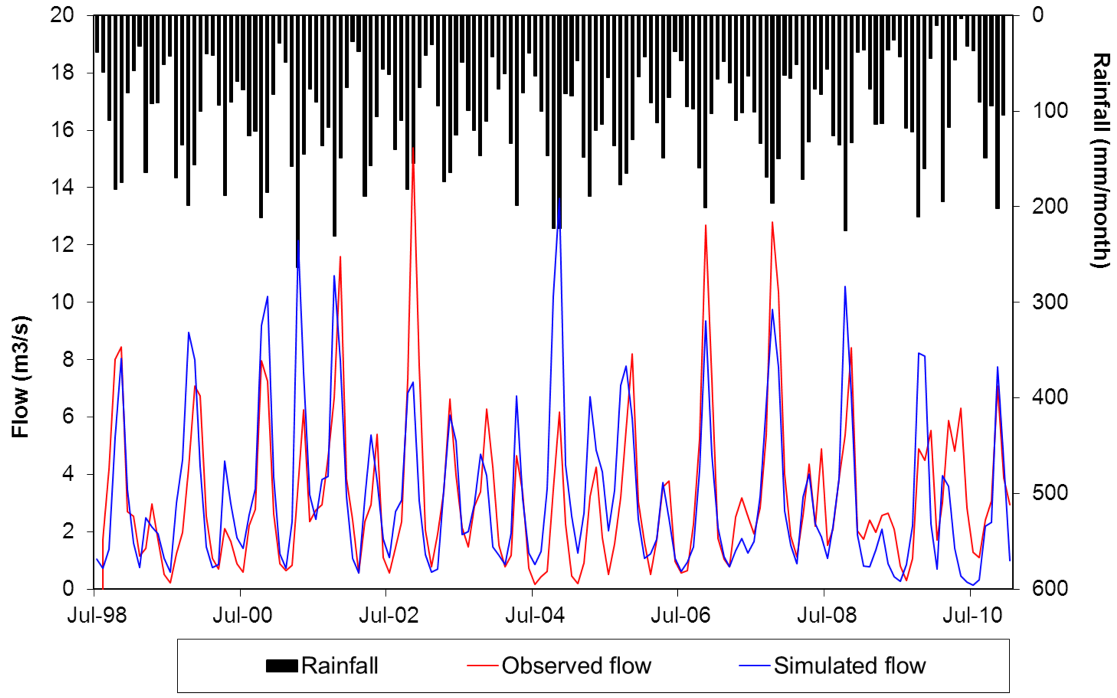


Figure 9 : GR2M simulation of the discharge at gauging station n°84212

The following validation criteria can be examined:

Table 15 : Calibration and validation of the rainfall ruin-off model, gauging station n°84212

Calibration period : 1999-2004			
Nash(Q) for the calibration period	24%		
Nash(vQ) for the calibration period	43%		
Nash (Q) for 1998-2010	36%		
Nash(vQ) for 1998-2010	47%		
Flows in m3/s	**Observed**	**Simulated**	**Difference**
Mean annual runoff, calibration period	3.4	3.6	6%
Mean annual runoff, 1998-2010	3.4	3.4	0%
Mean monthly low flow, calibration period	0.7	0.7	2%
Mean monthly low flow, 1998-2010	0.7	0.7	0%
Mean monthly high flow, calibration period	9.0	9.5	5%
Mean monthly high flow, 1998-2010	9.1	9.2	1%

The visual comparison of the observed and simulated curves is good, apart from prediction of high flows. The Nash coefficients are not good, this may be explained by the difference between simulated and observed flow during high flows which have an important weight on the Nash criteria. Moreover there is a high uncertainty on the values of observed high flows, as in this range of flows, rating curves are theoretical[4]. This apparent lack of accuracy for high flows doesn't call the use of the

[4] Only 16 gaugings (over a total of 215) were done on flows over 10 m^3/s, including only 2 done after 1968. Those two both divert from the rating curve established for the station.

rainfall-model into question, as the difference between observed and simulated flow remains low (to within 5 or 6%).

3.2.2 Calibration and validation at gauging station n°84215

Figure 10 shows the simulated flows at station n°84215 (calibration period is 1999-2004).

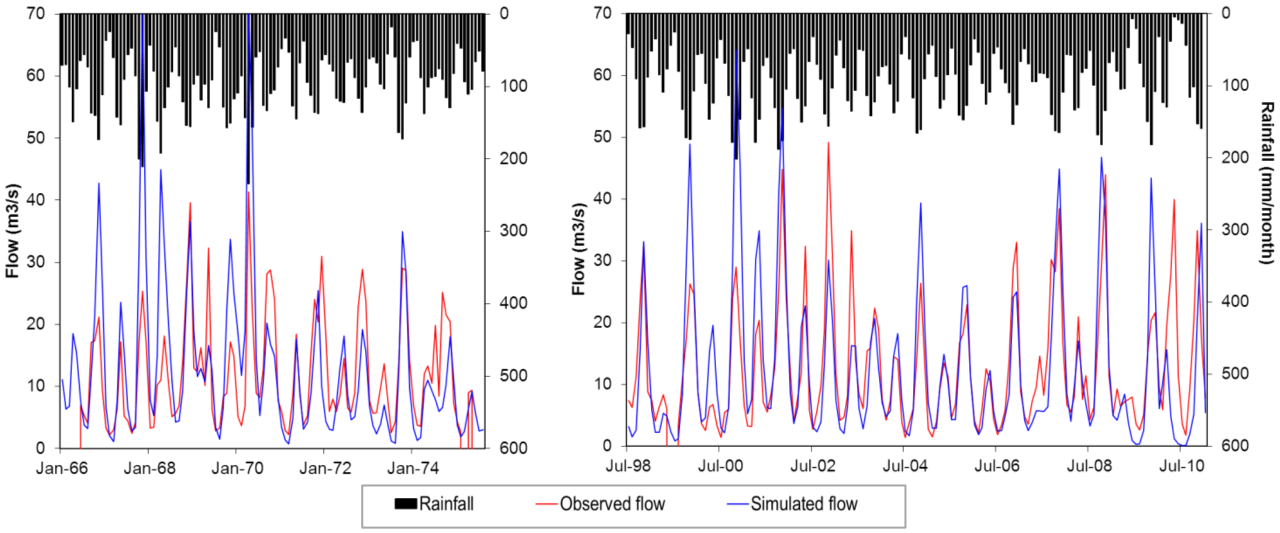


Figure 10 : GR2M simulation of the discharge at gauging station n°84215

The following validation criteria can be examined:

Table 16 : Calibration and validation of the rainfall run-off model, gauging station n°84215

Calibration period : 1999-2004			
Nash(Q) for the calibration period	24%		
Nash (√Q) for the calibration period	50%		
Nash(Q) for 1966-1975 & 1998-2010	16%		
Nash (√Q) for 1966-1975 & 1998-2010	41%		
Flows in m3/s	**Observed**	**Simulated**	**Difference**
Mean annual runoff, calibration period	12.8	14.6	14%
Mean annual runoff, 1966-1975 & 1998-2010	12.8	12.8	0%
Mean monthly low flow, calibration period	2.6	2.7	3%
Mean monthly low flow, 1966-1975 & 1998-2010	2.6	2.2	-15%
Mean monthly high flow, calibration period	36.8	41.8	14%
Mean monthly high flow, 1966-1975 & 1998-2010	34.9	39.3	13%

The visual comparison of the observed and simulated curves is fair. Nash coefficients calculated on flow are not good, mainly due to the difference between simulation and observation during high flows (Nash calculated on √Q remain low but are much better). However, even for high flows the statistical difference between observation and simulation is considered acceptable (less than 15% of difference).

Running the rainfall-runoff model calibrated allowed the generation of a longer data series of flows on the River Mpanga on Kampala-Fort Portal road, and on Ibanda – Fort Portal road. The results are showed in the Figure 12.

3.2.3 Estimation of the hydrology of lower Mpanga and Rushango sub-catchment

Table 12 and Table 13 show that the upper part of Mpanga catchment is much more productive than the rest of the basin, unit runoff is around 8 l/s/km² (annual mean) whereas it is only 3 l/s/km² on Mpanga at Ibanda-Fort Portal road. Unit runoff seems even lower on Rushango.

Although records are very shorts at gauging station 84276 (Rushango River), and with no common period with the gauging stations on Mpanga river there is clearly a difference in the basin productivity.

- Relatively low flows observed on Rushango compared to flows measured on the Mpanga don't seem to be linked with particularly dry conditions (see Figure 11) during the years for which flow data are available.

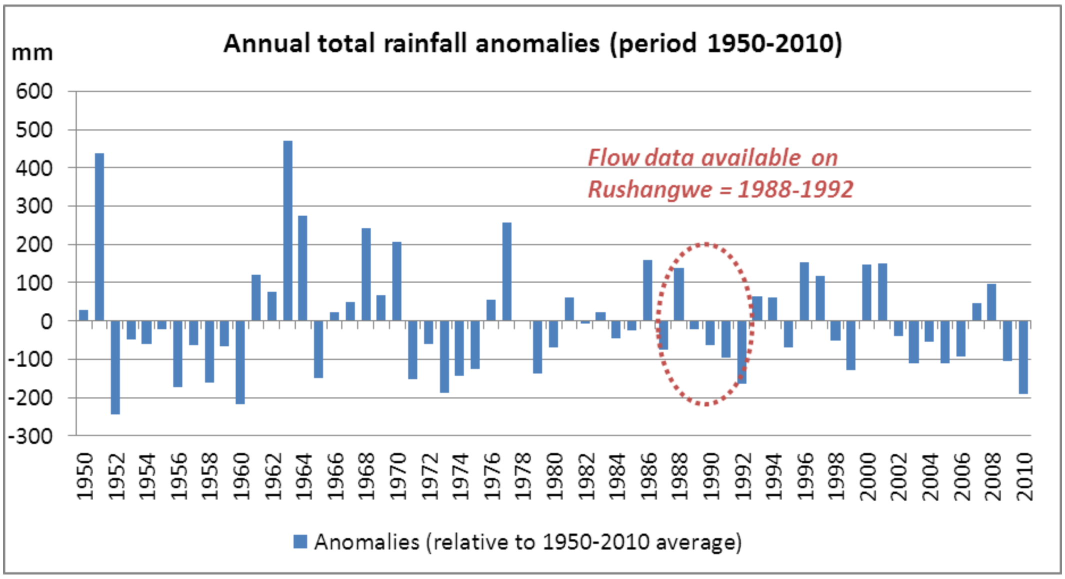


Figure 11 : Annual total rainfall anomalies in Rushango sub-catchment (GPCC)

- Visual observations done during the 1st field visit (September 2014) confirm this difference. Flows observed on the different tributaries of river Rushango were very low compared to equivalent streams (same area) feeding the upper Mpanga River. This must be qualified, however, by the fact that 2014 rainy season was delayed in the Rushango and the downstream part of Mpanga catchment and had hardly started during the visit. In the upper Mpanga the rainy season was well underway. This will definitely have exaggerated the apparent difference in productivity between sub-catchments observed while in the field and measured during the gaugings (see bullet point below). The flow observed in the upper part of Rushango River was close to base flow conditions.
- Gaugings were undertaken by DWRM staff during this field visit (see mission report). They also show a great difference in catchment productivity, with upper Mpanga being much more productive. One-off measurements should, however, be used with caution as they are subjected to measurement error and can't give a complete picture of the behaviour of one catchment compared to another.

Table 17 : Analysis of unit runoff

		Observed data			
		Annual flow		Monthly low flow	
		m3/s	(l/s/km²)	m3/s	(l/s/km²)
84212 – Mpanga Kampala – Fort Portal *(1)*	401 km²	3.2	8	1.3	3.1
84215 – Ibanda – Fort Portal (2)	4670 km²	14.1	3	3.6	0.8
84216 – Rushango *(3)*	3012 km²	2.4	1	0.4	0.1
Ratio : Rushango / Mpanga at Ibanda-Fort Portan road (84215)	64%	17%	-	11%	-

An estimate of flows has been carried out for the Rushango sub-catchment, considering that 15% of the surface water resource on Mpanga river at Ibanda-Fort Portal road comes from Rushango part, based on the ratio calculated in Table 17. **This estimate is approximate due to the lack of information available on the hydrology of Rushango River and must be taken with caution.** A better knowledge of the hydrology of this part of the basin can only be achieved through the implementation of a gauging station on the Rushango River and the concurrent measurement of flows in the Rushango and Mpanga Rivers over an extended period

An estimate has also been done for the lower part of Mpanga but as for Rushango these estimations will be approximations due to absence of flow measurement on the lower Mpanga.

The assumption made is that the productivity of the Lower Mpanga sub-catchment is similar to the one of Rushango sub-catchment. The flow on Mpanga River at the outlet is then calculated as the sum of flow at gauging station 84212 and the flow generated on the lower Mpanga sub-catchment.

The figure below show the mean monthly water flow in the different part of the Mpanga basin, calculated on the simulated flow on the 1956-2010 period.

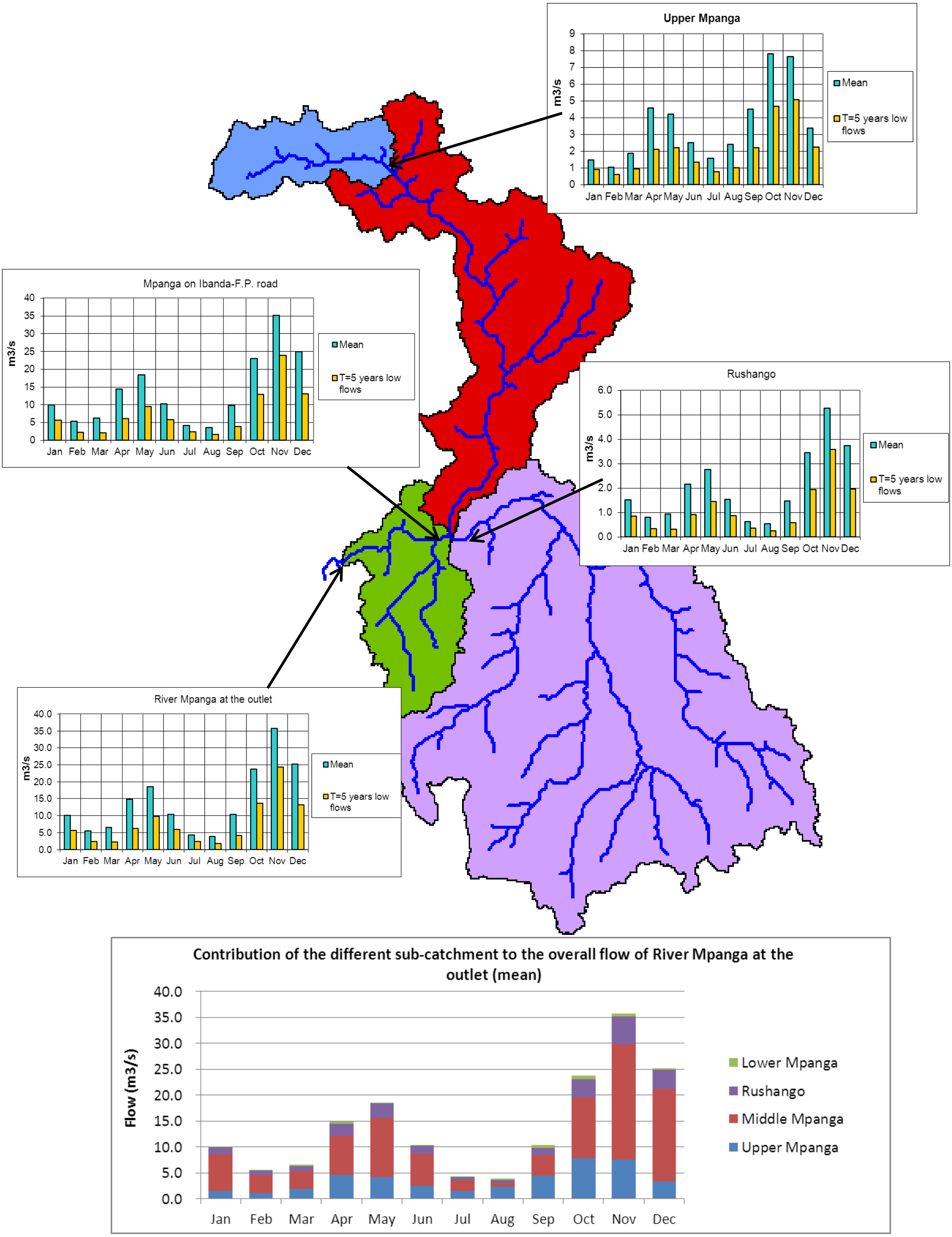


Figure 12 : Current water resources of Mpanga River basin

4. Test of different climate change scenario

4.1 Presentation of the climate scenario tested

4.1.1 Generality on climate change modelling

Prediction of future climate depends on many different hypotheses: hypothesis on future greenhouse gases emission; hypothesis on reaction and interaction of physical, atmospheric and climatic parameters etc. The schematic below shows the main steps of climate change modelling.

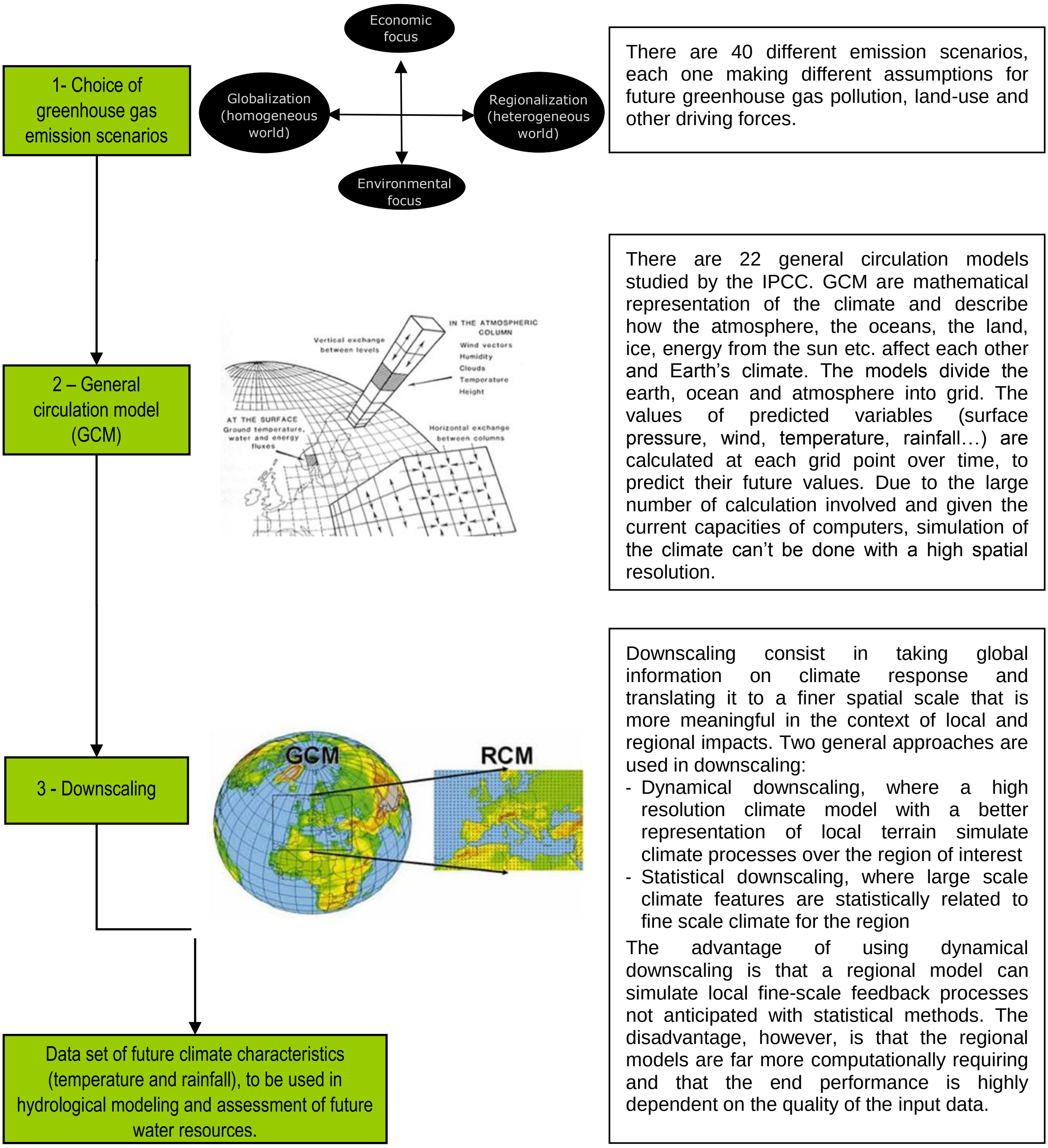


Figure 13 : Main steps of climate change modelling

Each emission scenario can be tested with each one of the 22 selected existing Global Circulation Model, and each of these possibility can then be regionalized using a different downscaling method. There are therefore many different possible results.

The choice of a combination of an emission scenario, a GCM and a downscaling method gives a set of future climatic data. The more consistent are the results given by different combinations the more reliable are the climatic prediction for a given location.

4.1.2 Climate scenarios used for the study

Two main sources of data have been used to represent possible future climatic conditions (rainfall and temperature) on Mpanga basin. They are described below.

The "Regional-scale Climate Change Projections of Annual, Seasonal and Monthly Near Surface Temperature and Rainfall in Uganda" (University of Pretoria, Baastel, May 2014).

This climate change modelling work was undertaken in the context of the study "Economic Assessment of Climate Change in Uganda" in the objective to generate projections of future temperature and rainfall at regional scale for different greenhouse gas emission scenario; and to proceed to downscaling in specific regions of Uganda used as case-studies, the Mpanga river basin is one of them.

Two realistic greenhouse gas emission scenarios have been studied under the regional scale Climate Change study: a moderate concentration pathway (RCP 4.5), and a more extreme concentration pathway (RCP 8.5).

Four Global circulation Model were considered to generate historical and future climate projection (HadGEM2-ES, EC-EARTH, CNRM-CM5, MPI-ESM-LR, see the Regional scale Climate Change projection study report for more information on these model);and one downscaling method was then applied, to give climate projections at a 0.44°x0.44° grid resolution. Mpanga river basin is divided into 2 different parts (Mpanga North and Mpanga south) for which climate projections are available.

Both future rainfall and temperature data have been generated.

For more information on the methods and results of the climate change modelling, refer to the "Regional-scale Climate Change Projections of Annual, Seasonal and Monthly Near Surface Temperature and Rainfall in Uganda" report.

"Tools and guidelines for Climate Change Adaptation Mainstreaming in water Infrastructure development" NELSAP/NBI

Under its "Tools and guidelines for climate Change Adaptation" study, NELSAP/NBI included different components, including a future climate modelling study that provides downscaled rainfall data under different climate change scenario at a 0.5°x0.5°grid resolution [5].

The simulations were carried out with 2 GCMs (ECHAM5 and HadCM3) for 3 greenhouse gas scenarios (A1B, A2, B1), and with 3 climatic references for the statistical downscaling (precipitation datasets from GPCC, CRU or University of Delaware).
Only future rainfall data series have been generated. For evolution of temperature, the study recommends the use of two temperature evolution scenarios presented in the table below.

---

5 "Regional Downscaling of Precipitation and Temperature Data for Climate Change Impact Assessment in the Nile Equatorial Lakes (NEL) Region" – University of Stuttgart - 2011

Table 18 : Future temperature trends in Nile Equatorial Lake area

	scenario 1	scenario 2
DJF	2.5	4.1
MAM	3.1	4.9
JJA	3.5	5.8
SON	2.8	4.5
Annual	3	4.8

Scenarios using GPCC data as reference have been selected, in coherence with the work undertaken earlier in this study (analysis of rainfall and calibration of rainfall-runoff model).

7 scenarios have finally been chosen in this study to be used to assess the impact of climate change on water resources. Their characteristics are summarized in the table below.

Table 19 : Characteristics of the climate change scenarios to be tested

Name given	Source of data	Emission scenario considered	Global circulation model	Reference used for downscaling / bias correction
RCP 4.5	Baastel study	RCP 4.5	Ensemble mean of 4 different GCM	GPCC
A1b-ECHAM	NELSAB/NBI study	A1b	ECHAM5	
A2-ECHAM		A2		
B1-ECHAM		B1		
A1b-HadCM3		A1b	HadCM3	
A2-HadCM3		A2		
B1-HadCM3		B1		

Apart for the RCP 4.5 scenario for which specific future temperature data series were available and have been used, the different scenarios have been tested with the 2 possible evolutions of temperature as presented in Table 18.

The graphs below compare present rainfall (reference period, 1981-2010) and future possible rainfall (2021-2050) given by the different climate scenarios.

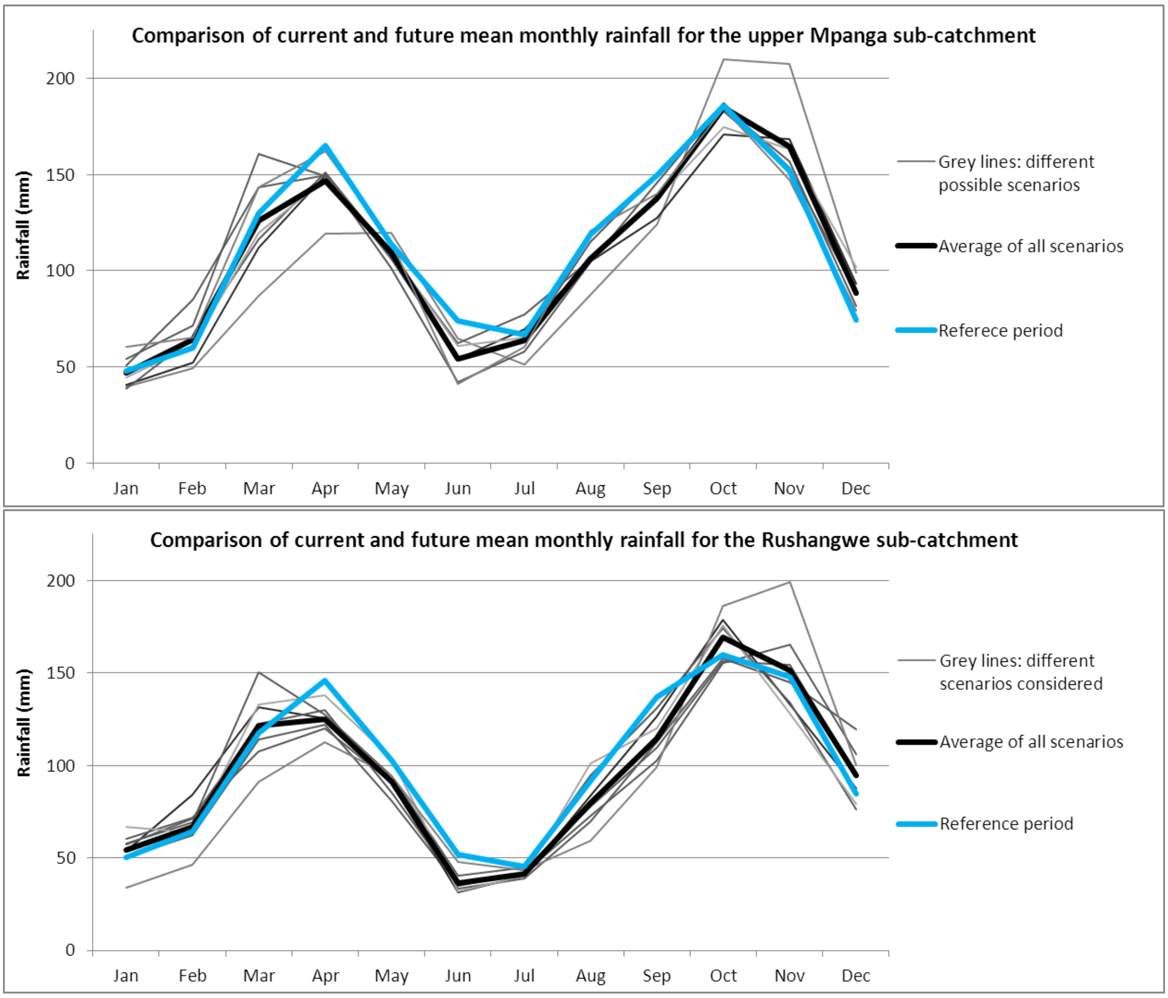


Figure 14 : Comparison of current (reference period) and future rainfall

All the climate modelling works undertaken in the Nile Equatorial Lake area indicate **a positive evolution of the temperatures,** the uncertainty remaining is about the intensity of this evolution. On the other hand, the **trend for precipitation is very difficult to ascertain**: the modelling output does not converge in the area.

Future rainfall has been differentiated at the scale of the sub-catchment when possible (depending on the resolution used for the different climate modelling). Table 20 shows the evolution of rainfall for the different scenarios for the overall Mpanga basin (including Rushango).

Table 20 : Evolution of rainfall under different climate scenarios

	Mpanga basin												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
RCP 4.5	-24%	-24%	-30%	-29%	-1%	-15%	-21%	-35%	-23%	15%	36%	24%	-7%
A1b-ECHAM	-4%	-7%	-8%	-16%	-17%	-36%	-4%	-18%	-23%	-4%	12%	23%	-8%
A1b-HadCM3	9%	37%	12%	-14%	-12%	-48%	-15%	-10%	-7%	8%	-5%	8%	-2%
A2-ECHAM	3%	10%	-2%	-12%	-13%	-30%	2%	-14%	-17%	0%	5%	10%	-5%
A2-HadCM3	16%	12%	28%	-13%	-8%	-27%	-4%	2%	-4%	5%	-5%	-6%	0%
B1-ECHAM	11%	8%	-9%	-17%	-9%	-33%	-11%	-19%	-16%	-3%	2%	37%	-5%
B1-HadCM3	33%	2%	13%	-5%	1%	-48%	-13%	9%	-12%	6%	-9%	-2%	-1%
Average of all scenario	**6%**	**5%**	**1%**	**-15%**	**-9%**	**-34%**	**-9%**	**-12%**	**-15%**	**4%**	**5%**	**13%**	**-4%**
Range	-24% to +33%	-24% to +37%	-30% to +28%	-29% to 5%	-17% to +1%	-48% to 15%	-21% tp 2%	-35% to +9%	-23% to 4%	-4% to +15%	-9% to +36%	-6% to +37%	-8% to 0%

The different scenarios indicate no or little change (decrease) in annual total, but rainfall distribution during the year is likely to change. Although some scenarios lead to the opposite conclusion**, the period from April to September is likely to be dryer than what it used to be, whereas October to February tend to be wetter.**

4.2 Comparison of current and possible future water resources

Future rainfall and evapotranspiration of the different climate change scenarios have been used as input for the rainfall-runoff models already calibrated (see section 3.2) and allowed the generation of different future water resources scenarios. Evapotranspiration data have been generated using future temperature scenarios and using the Oudin formula[6].

The following graphs compare the current flows (average 1980-2010) (black line on the graphs) and

- the range of possible future flow (average 2021-2050) in Figure 14;
- the detail for all the scenarios tested (Figure 15).

The results are presented at 4 locations:

- River Mpanga on Kampala – Fort Portal road (current location of gauging station 84212)
- River Rushango just before the confluence with River Mpanga
- River Mpanga on Fort Portal-Ibanda road (gauging station 84215)
- River Mpanga at the outlet

[6] See: Oudin, L., Hervieu, F., Michel, C., Perrin, C., Andréassian, V., Anctil, F. and Loumagne, C., 2005. Which potential evapotranspiration input for a rainfall-runoff model? Part 2 - Towards a simple and efficient PE model for rainfall-runoff modelling. Journal of Hydrology 303(1-4), 290-306

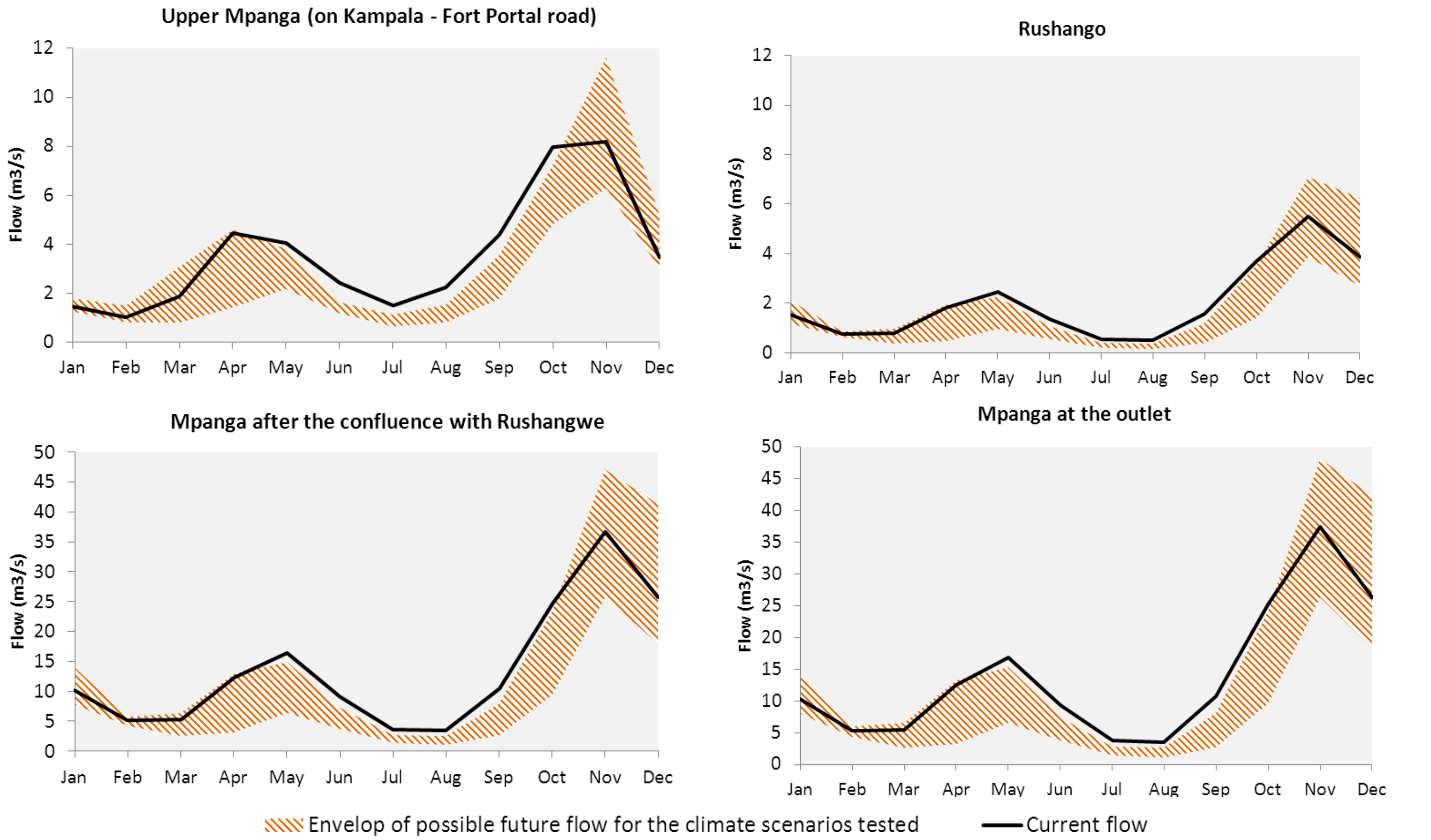


Figure 15 : Comparison of current average monthly flows and possible future average monthlly flows at different locations in river Mpanga basin (future flows shown as a range)

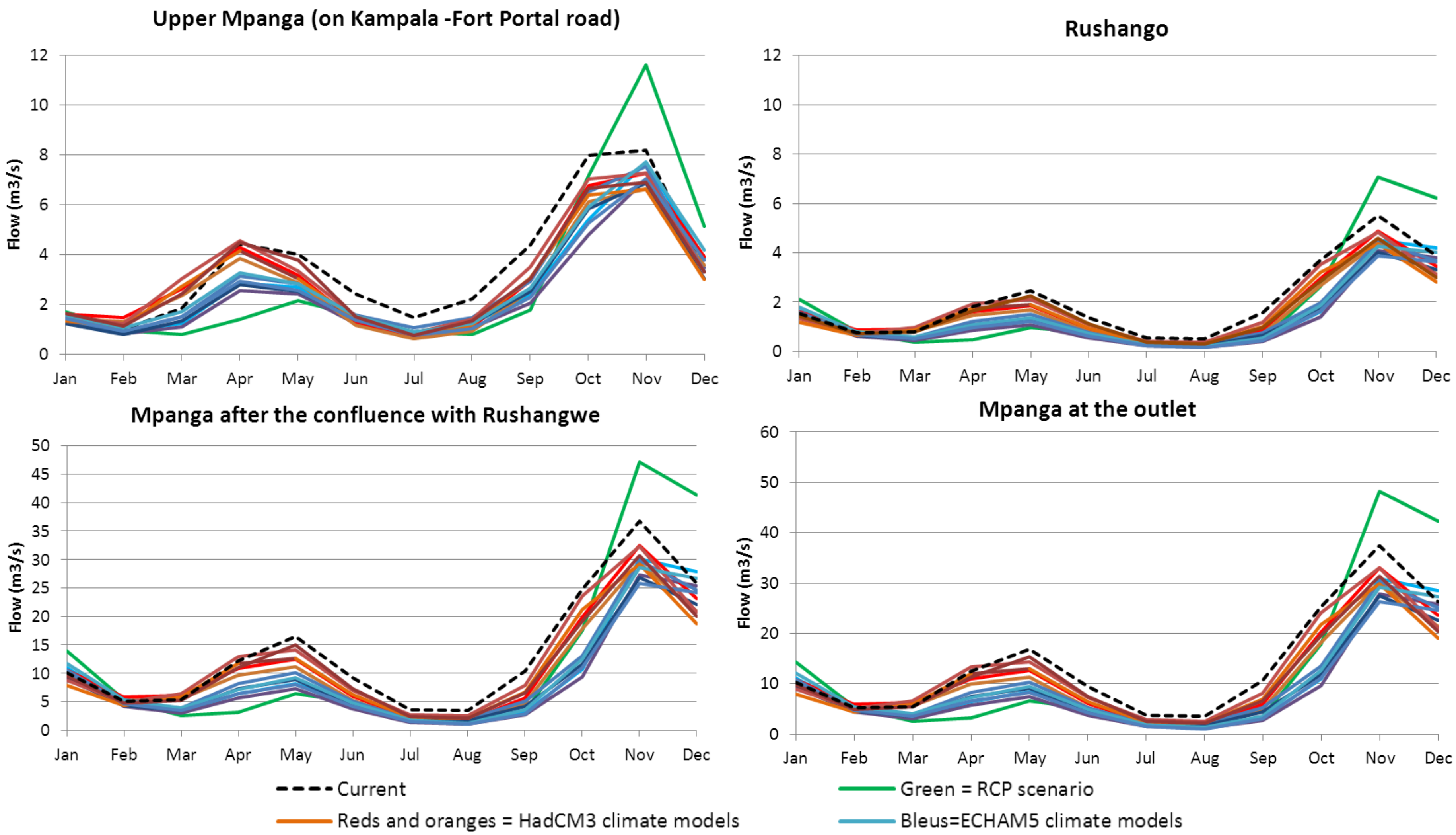


Figure 16 : Comparison of current average monthly flows and possible future average monthly flows at different locations in river Mpanga basin (detail for the different scenarios)

As a consequence of the high uncertainty regarding the trend of future rainfall, there is also a wide range of possible future water resource scenarios. **The combined effect of the evolution of rainfall and temperature leads to a decrease in flows from May to October. This decrease is particularly clear for the upstream part of Mpanga basin. The evolution of flows during the November to April period is not as clear, some scenario indicating a decrease in flows and some an increase.**

All the scenarios tested indicate **a decrease in mean annual runoff** (see Figure 17), going from a -9% to a 38% decrease.

Figure 17 : Evolution of mean annual runoff

4.3 Water distribution model and water demand / water resource balance

The uncertainty on the water resources (especially for Rushango sub-catchment) and on water demands estimates should be kept in mind when reading the following paragraphs.

4.3.1 Comparison of annual water demand and water resources

The table and graph below compare the annual water demand and the annual runoff generated (in Mm^3) at different location in the Mpanga catchment.

Table 21 : Comparison of annual water demand and water resources

In Mm3/year	Current		Future water demand (2035)		Mean annual run-off		
	Annual water demand	**Net annual water demand** (total –return flows)	**Annual water demand**	**Net annual water demand** (total –return flows)	**current**	**CC min** [7]	**CC max**
Upper Mpanga (SubC1)	1.6	0.6	4.1	1.5	113	76	102
Mpanga before the confluence (SubC1 + Sub C 2)	4.7	2.2	19.7	9.1	333	226	322
Rushango (SubC 3)	9.1	4.0	38.3	13.5	64	40	59
Mpanga at the outlet (SubC-1 to SubC-4)	17.9	6.8	61.1	23.8	438	271	400

* Except hydropower

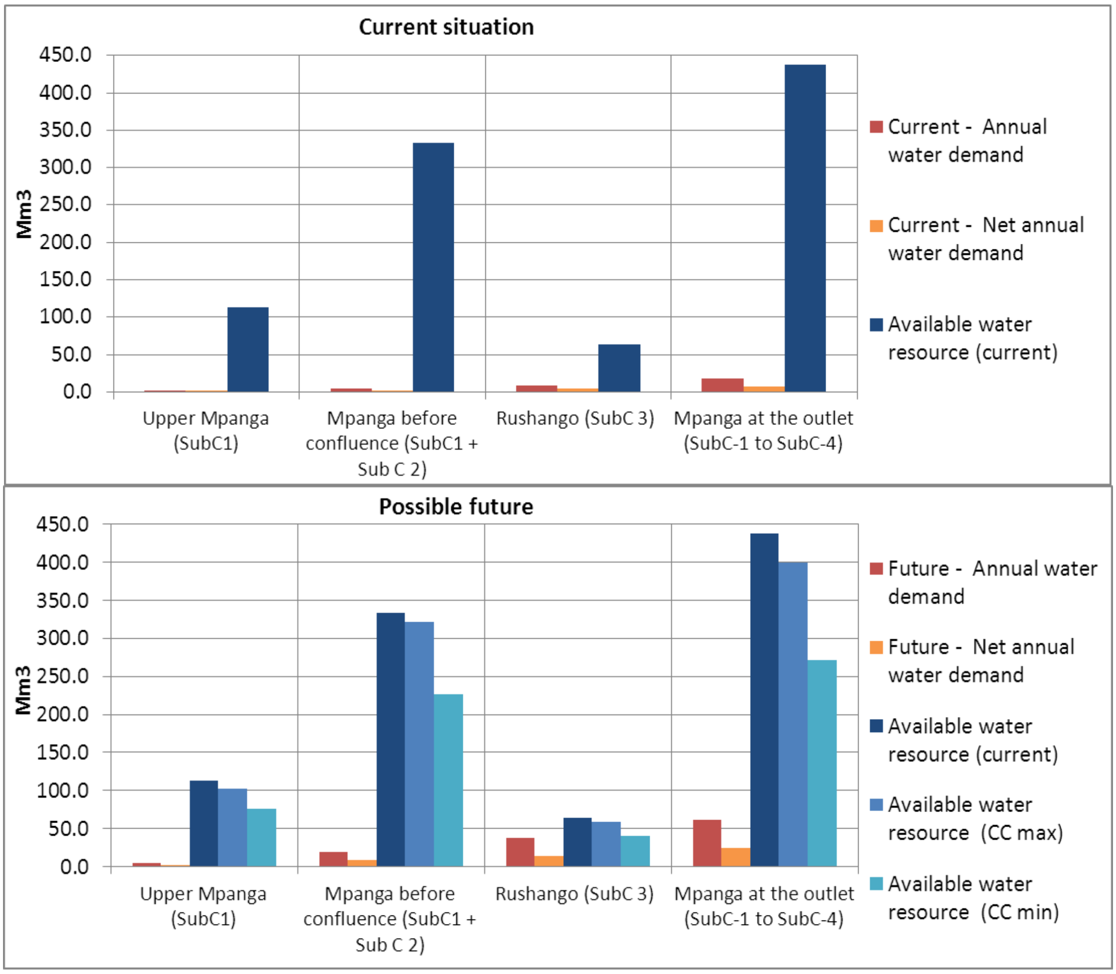


Figure 18 : Comparison of annual water demand and water resources for current and possible future situations

---

[7] CC min and CC max correspond to the climate change scenarios giving the minimum and maximum mean annual run-off..

Under the current situation scenario, the overall quantity of water available in a year in the catchment is largely sufficient to meet the demand.

Under future climate scenarios, water is still largely sufficient to meet the demand (including future projected water demand) at the different level of Mpanga River itself. Of course, flow variability needs to be looked at more closely (see next section) but this shows that the implementation of appropriate storage facilities and adequate water management at the catchment level should permit the satisfaction of demand. The situation is more difficult in Rushango sub-catchment where water resource is less and where water demand is expected to rise sharply.

4.3.2 Water resources / water demand balance under different climate scenario

A water allocation model has been implemented in the catchment in order to look at the water balance in the catchment more into detail.

The rainfall runoff modelling work (see section 3) permits the generation of a 30 years monthly flow sequence representative of the current hydrology, and 30 years of monthly flows representative of future hydrology for each one of the different climate change scenarios. This information, together with estimates of water demand have been used as inputs ton the model that can then calculate the possibilities of meeting the demand taking into account the flow variability; give the assurance of water demand met, and the frequency of failure. This work has been done at the scale of the 4 sub-catchments delineated in Figure 1.

The following choices have been made:

- **A minimum flow requirement (= minimum flow left in the river at all time for the environment) of 1 m^3/s has been applied in the model at the hydropower plant intake.** That is to say that if 5 m^3/s arrive at the intake, 4 are diverted to the hydropower plant and 1 m^3/s is left in the river (this corresponds to the current functioning of the intake).
- **No other minimum flow requirement has been entered into the model** (the consultant hasn't heard of any other agreed value). It means that in the model, water demands are satisfied as long as there is still water in the river, until their demand is entirely fulfilled. The Q90 could be applied as minimum flow requirement but in a river like the Mpanga River with a very high flow variability, it represents a quite strong constraint for the water users (water uses are not possible at all during one month or more, more than 1 in every 5 years if the Q90 system is applied). It will be important in the future to agree on minimum flow requirement to be left in the river at different strategic points of the river using a more appropriate system than the Q90 system. It will also be important in order to monitor and control water uses development in a sustainable and integrated way.
- Parameters of the model have been defined in a way that the satisfaction of water demand function the same way as it currently works: **upstream water users take water until their demand is fully satisfied, water demands downstream remain with what is left.** This is the closest way to the reality to model the current functioning of the Mpanga river catchment. With other parameters, the model could also distribute the deficit in between all the sub-catchment in order to leave more water for the downstream water demands.

Current situation

As mentioned in section 4.3.1, on an annual basis, water resources of the Mpanga basin are largely sufficient to meet the current water demand. However, when the intra-seasonal flow variability is taken into account some difficulties become evident, especially in Rushango sub-catchment.

Table below sums up the number of years[8] and months when the water resources are unable to meet the demand.

Table 22 : Frequency of unmet demand

Sub-catchment	**Number of years with difficulties to meet the demand** (over a total of 30 years)	**Number of months with difficulties to meet the demand** (over a total of 360 months)
Upper Mpanga	0	0
Middle Mpanga	0	0
Rushango	14	24
Lower Mpanga	0	0

*Except hydropower

Demands of the upper, middle and lower Mpanga sub-catchments can be met even in particularly dry conditions (no deficit in any of the 30 years tested).

In Rushango sub-catchment a deficit (demand overpassing resource) almost appears in one over 2 years. These deficits can appear in both dry seasons but are more important during the July-August one. The situation observed in the Rushango catchment during the first mission, reported by stakeholders as being exceptionally dry, supported this conclusion.

Water reaching the hydropower plant and then feeding Lake George is highly dependent on the water management in the rest of the catchment both in term of water quality and water quantity.

The hydropower plant has been included in the model assuming that it has to leave at any time a minimum flow of 1 m^3/s in the river and if flow allows, it diverts 16 m^3/s (maximum capacity).

The graph below shows the mean flow reaching the hydropower plant (taking into account the 1 m^3/s left in the river for the environment, and the maximum capacity of the plant), and the mean flow reaching Lake George.

[8] A year is counted as "with difficulty to meet the demand" if during one month or more during this year water demand exceeds water resources.

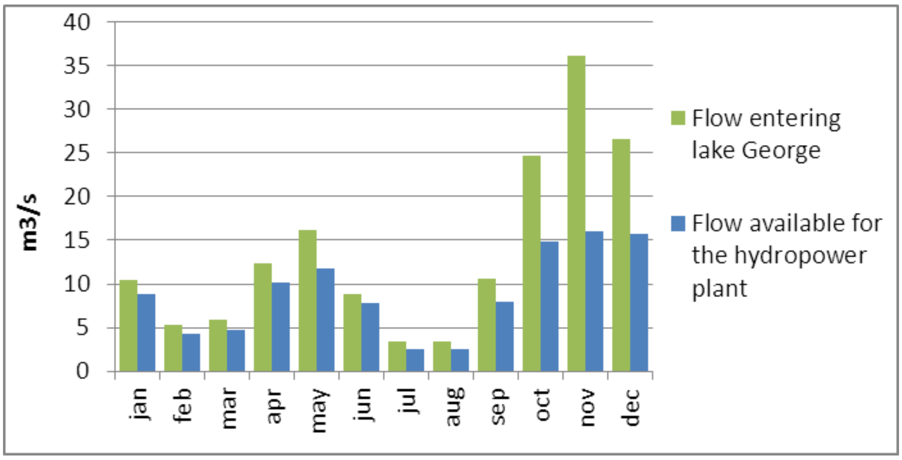


Figure 19 : Mean flow available for the hydropower plant and entering lake George (current situation)

On average, the hydropower plant can function at 90% or more of its maximum capacity for only 3 months a year. During the months of February March, July and August flows can drop to as low as 30% or less of the maximum capacity.

The total amount of water entering Lake George is in average 430 Mm^3/year, it can drop to around 340 Mm^3/year during dry years (5 year return period)

Impact of climate change and of the evolution of water demand

Figure 20 shows the percentage of months when water demand exceed water resources available, and the percentage of years when deficit occur one month or more. For example, for the Rushango sub-catchment under the reference scenario (current climate and current water demand), deficits occur for 24 of the months tested (7% of the 360 months tested), distributed on 14 years (occurring for at least one month of 47% of the 30 years tested).

.

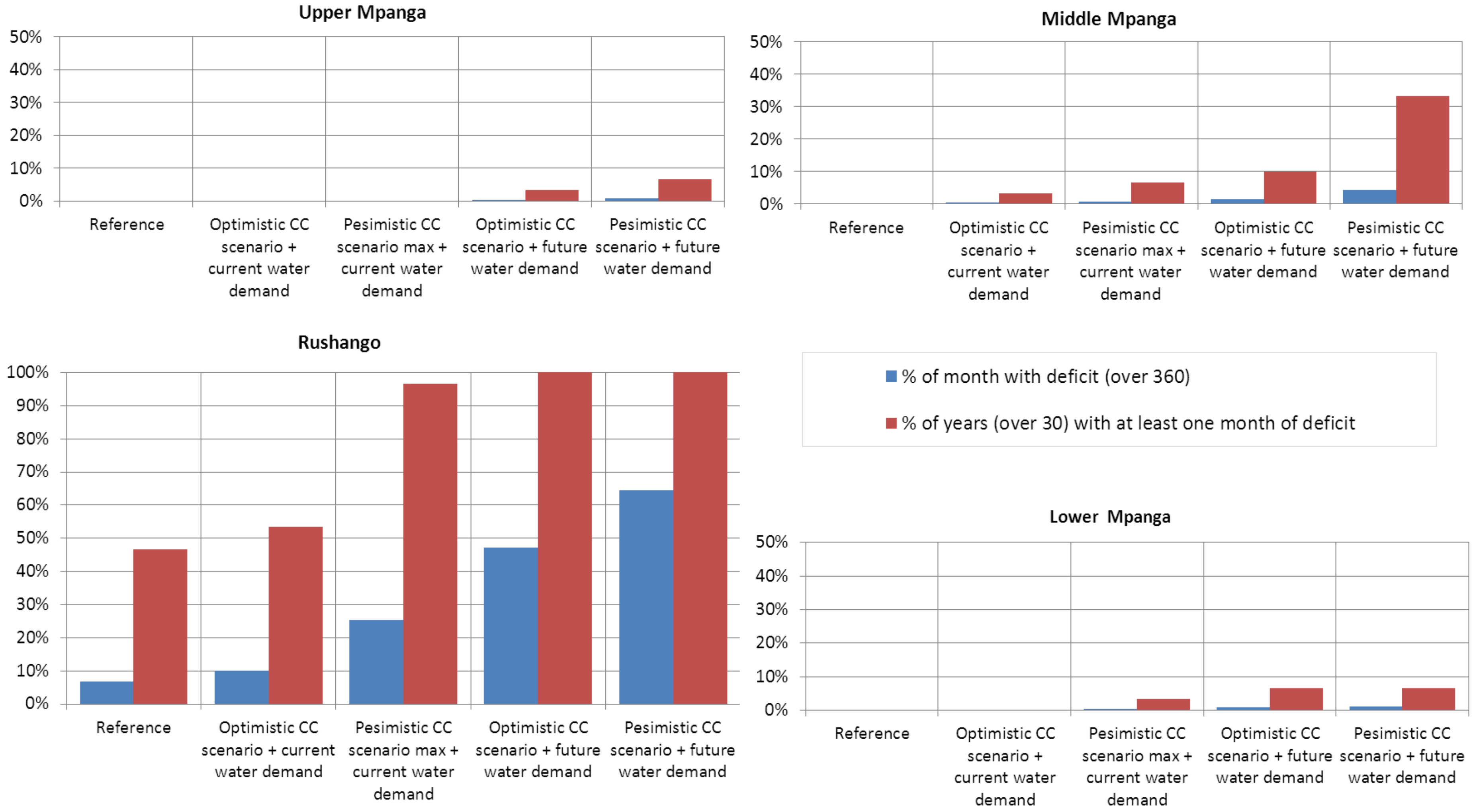


Figure 20 : Frequency of deficits (water demand>water resources) under different climate and water demand scenarios

Unmet demand for each one of the catchment has been calculated for a normal year (median) a dry year (5 years return period) and for a very dry year (10 years return period). Results are shown in Figure 21 for middle Mpanga and Rushango sub-catchment. (For the upper and lower Mpanga, even for dry year condition of a 10 years return period, water demand is met, see Figure 20).

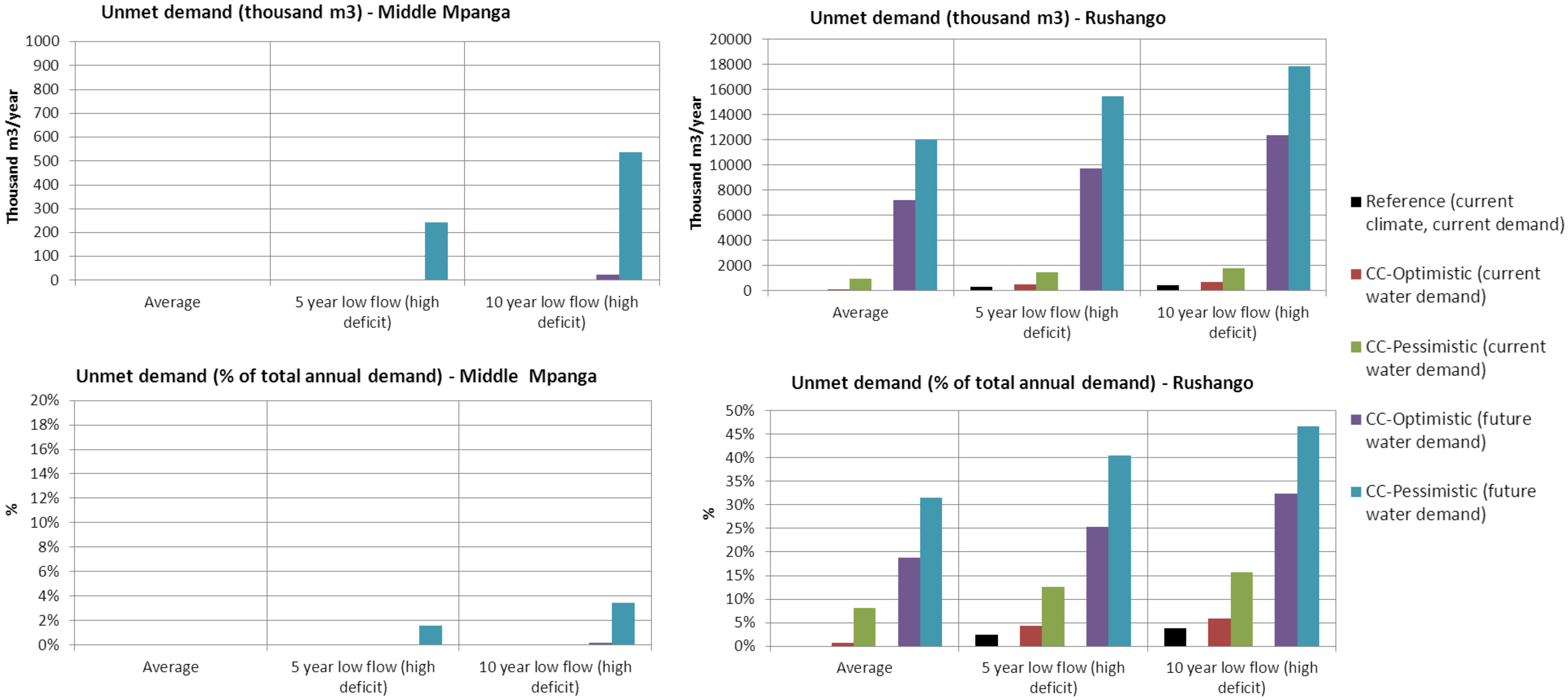


Figure 21 : Unmet demand for the different sub-catchment under different climate scenario (current water demand)

The annual water volume coming from river Mpanga and entering Lake George is on average around 430 Mm^3/year. If water demands remain the same, the impact of climate change could go from a 5 to 10% decrease for the less penalizing scenario, to a more than 40% decrease for the most pessimistic scenario (see Figure 22). The impact of the evolution of water demand is of secondary importance compared to the impact of climate change or of inter-annual variability.

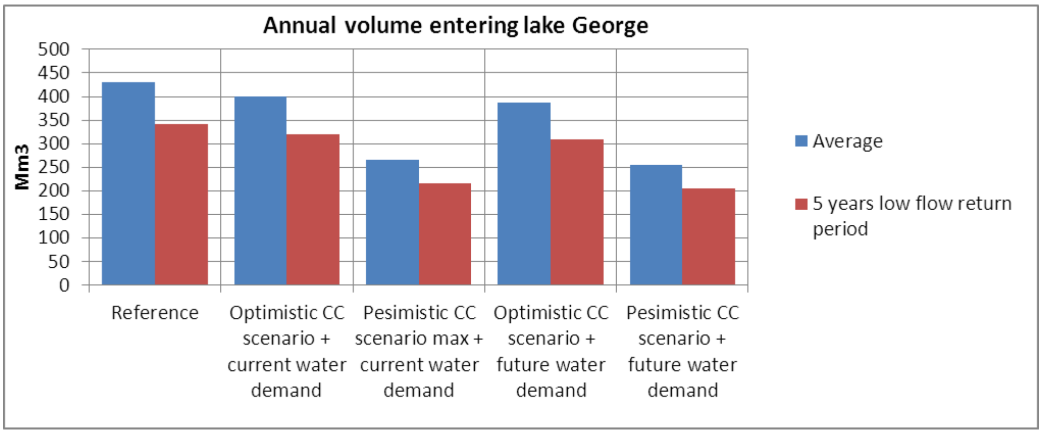


Figure 22 : Flow entering lake George under different climate scenario (current water demand)

In the current version of the model, no minimum flow requirement have been applied, apart from the one existing at the hydropower plant intake. Although there is no deficit in satisfying the water demand, it's clear that there is sometimes very little water remaining in the river. Figure 23 shows the monthly flows simulated on Mpanga River at Kampala-Fort Portal road; this monthly flow can sometimes go as low as 200 l/s.

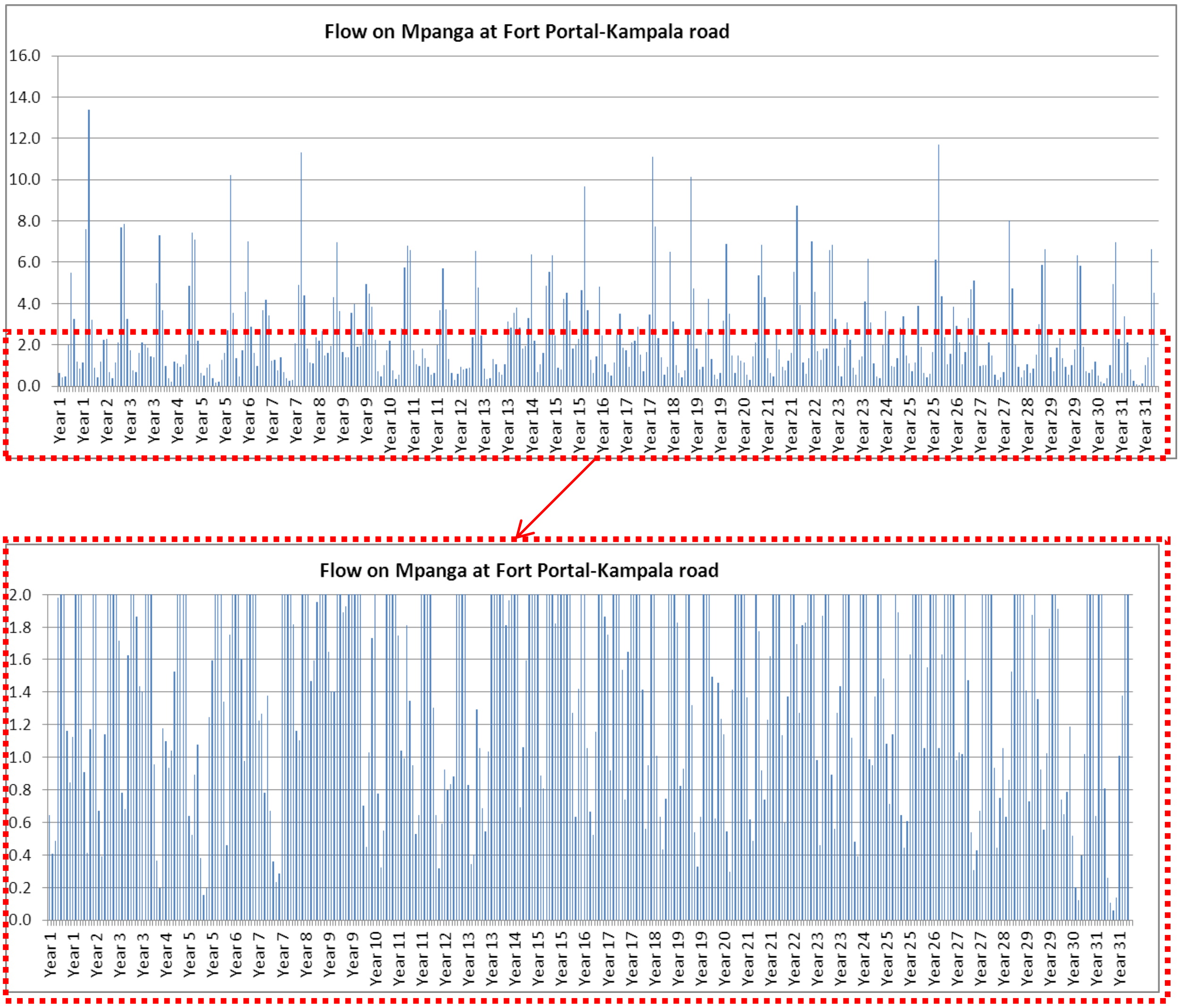


Figure 23 : Flows simulated under the CC most pessimistic scenario on Mpanga at Kampala-Fort Portal road,

5. Conclusions

While there is a high degree of uncertainty attached to the findings of the study, due to a paucity of reliable precipitation and flow data and considerable divergence between climate change models, a number of conclusions (some tentative) can be drawn;

- Over recent years (+/-30 years), it would appear that high flows have increased and low (base) flows have decreased in the upper part of the Mpanga basin. According to the available data, the mean annual runoff has reduced. However, this conclusion should be treated with caution since the apparent reduction may be the result of an error in the upper part of the rating curve. During the same period precipitation has not apparently reduced. The implication is that the problems encountered during the dry season are more likely due to catchment degradation (increased cultivation, poor farming practices and deforestation) than to climate change. Without either/both reversing this trend or building storage, shortages are likely to become increasingly frequent in the future as demand increases and the possible impacts of climate change are felt.

  Putting a stop to the continued deforestation of the source areas, improving farming practices and providing alternative rural and urban-based livelihoods should be regarded as a priority and ongoing efforts in this respect should be encouraged and further supported.

  The monitoring of groundwater at selected sites in the source areas is advisable and would give better insight into the relationship between groundwater levels and river base flows

- The Mpanga catchment is situated in an area where the magnitude of the effect of climate change on precipitation is very unclear. Since this understanding is unlikely to improve in the near future there is a strong argument for improving the quality and density of the rain gauge network. In this way it should gradually become possible to identify climate change trends as they develop

- As a consequence of the high uncertainty regarding the trend of future rainfall, there is also a wide range of possible future water resource scenarios. The combined effect of the evolution of rainfall and temperature leads to a decrease in flows from May to October. This decrease is particularly clear for the upstream part of Mpanga basin. The evolution of flows during the November to April period is not as clear, some scenario indicating a decrease in flows and some an increase. All the scenarios tested indicate a decrease in mean annual runoff ranging from a 9% to a 38% decrease.

- Without, mitigatory action (building of storage and/or rehabilitation and protection of the wetlands in the source areas), the worst water shortages will occur in the Rushango catchment. This catchment is considerably less well-watered than the Mpanga catchment and the population is higher.

- The most critical area of the catchment, the Rushango sub-catchment, is also the area where there is least confidence in the river flow data. It is also the area of highest population and abstraction (especially of groundwater). Given the potential costs that could be incurred to develop storage in the Rushango sub-catchment, the highest priority should be given to:

  - Improving the accuracy of stream flow records. The rehabilitation and operationalization of the closed river gauging station (as a minimum) on the Rushango should be carried out as a matter of urgency.
  - Design and implementation of a groundwater monitoring network aimed at identifying and closely monitoring areas where groundwater is under pressure during the dry season.
  - The monitoring of springs should be undertaken. For example the bulk water supply to the rapidly growing town of Ibanda is entirely supplied from springs in the mountains several kilometres away. While there has been no failure in supply this far, it is important to monitor the condition of these springs.

- There may be a need to consider the construction of some intra-seasonal storage in the upper parts of the Rushango and Mpanga sub-catchments. While this may not be required in the immediate future, it would be useful to investigate potential sites. The aim should be to have relatively small storages with flexible release systems so that shortages during dry years can be mitigated against. The alternatives are i) to increase the use of groundwater through the development of bulk water schemes for villages and individual water points (handpumps/solar etc) and ii) the conjunctive use of groundwater and surface water storage.
- Given that all the GCModels point to a decrease in the mean annual runoff of the Mpanga River entering Lake George, it would be useful to investigate the potential impact on the lake.
- Work is required to investigate and better define environmental flow requirements, especially in the upper part of the basin. Satisfaction of these requirements would be a priority (over upstream uses) and would therefore provide a better level of equity between upstream and downstream users (including the environmental flow requirements downstream.

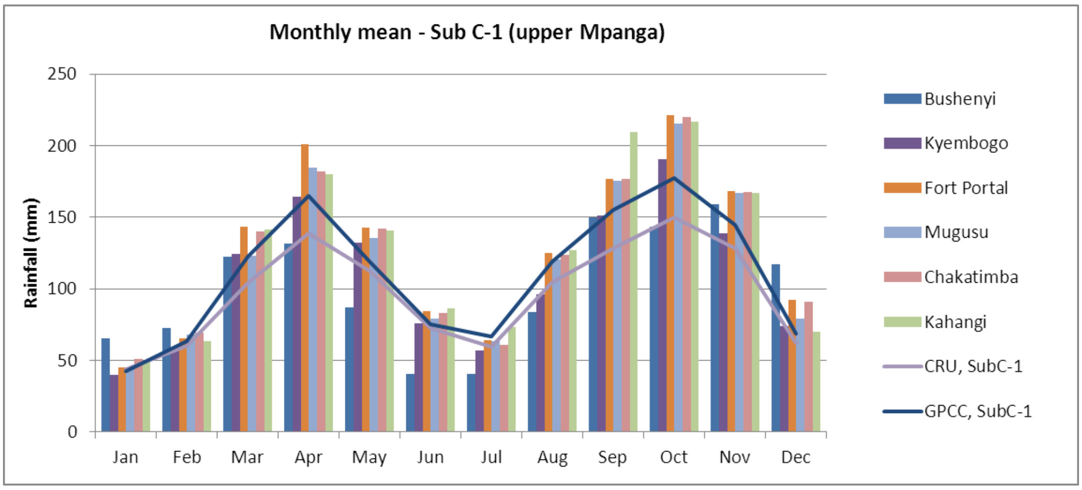
Annexes

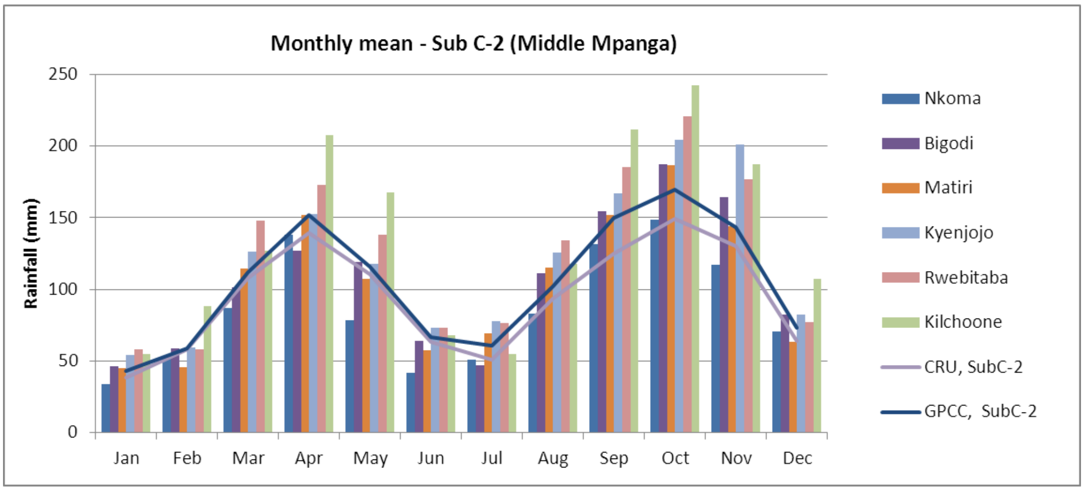
Annex 1: Choice of the rainfall data set used for the rainfall-runoff modelling

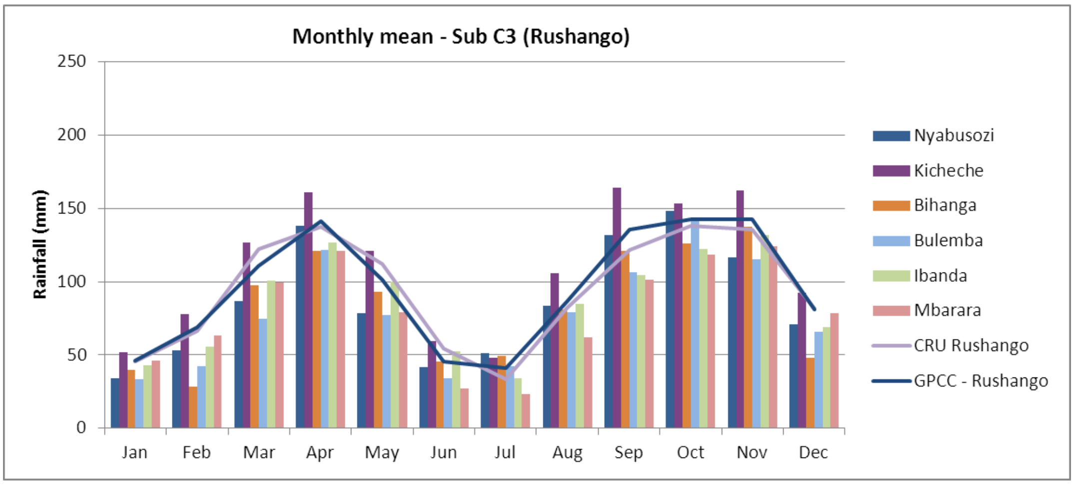
Rainfall data observed station and from CRU and GPCC databases have been crosschecked in order to see if CRU and/or GPCC can be used to represent rainfall of the Mpanga River basin.

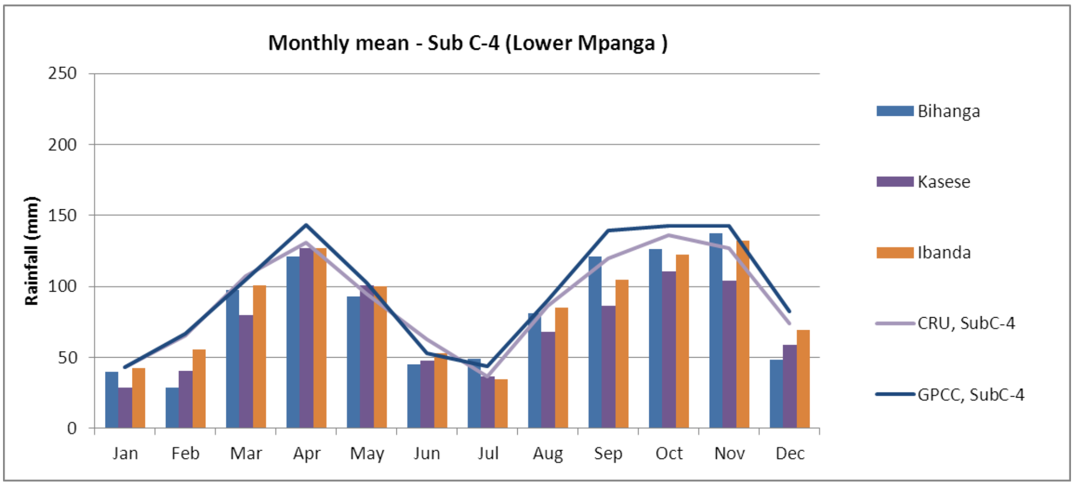
Comparison of mean monthly rainfall

For different sub-catchments, mean monthly rainfall given by CRU and GPCC at the sub-catchment scale has been compared to mean monthly rainfall measured at different station in or near the sub-catchment. Period of data availability at all the station is heterogeneous, which can influence the means calculated. To reduce this bias, only rainfall stations with more than 20 full years of data have been considered.









CRU and GPCC rainfall data correctly reproduce the seasonality of the rainfall observed in the catchment.

Calculation of Nash criteria

In order to assess which of the two databases is best to represent the rainfall on the catchment, an analysis has been performed.

For both CRU and GPCC, Nash-Sutcliffe criteria (E) with each rainfall station have been calculated, with:

$$E = 1 - \frac{\sum_{t=0}^{T} (R_o^t - R_m^t)^2}{\sum_{t=1}^{T} (R_o^t - \bar{R}_o)^2},$$

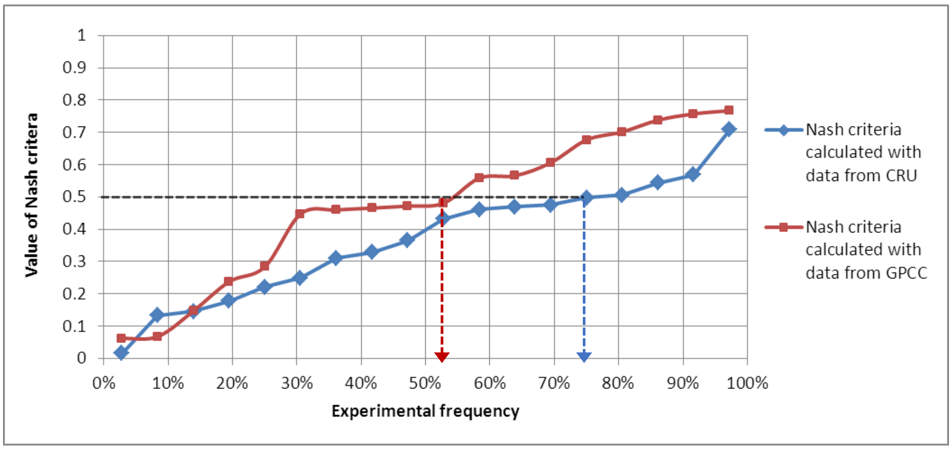
Where R_o is the observed rainfall, R_m, re-analysed rainfall (from CRU or GPCC), $\bar{R}_o$ the mean observed rainfall. Nash–Sutcliffe efficiencies can range from −∞ to 1. An efficiency of 1 ($E = 1$) corresponds to a perfect match of modelled to the observed data. An efficiency of 0 ($E = 0$) indicates that the model predictions are as accurate as the mean of the observed data.

As mentioned in the main report, CRU and GPCC databases are gridded at a 0.5°*0.5° resolution. The various rainfall stations of the catchment have been compared to CRU and GPCC data depending on which part of the grid they are including in, and the Nash coefficient corresponding has been calculated. The calculation of a Nash criterion for all the rainfall station with rainfall from

(1) CRU, and (2) GPCC, gives a set of Nash values for each one of the databases. The values vary from a few % (poor linked between rainfall values observed at the stations and re-analysed rainfall) to very good Nash (over 0.7).

The two sets of values have been compared as shown in the following graph that gives the repartition of the Nash values calculated. It shows for example that around 53% of the Nash values obtained with GPCC are below 0.5 and 47% above; whereas for CRU around 75% of the Nash values are below 0.5 and only 25% above.

Data from GPCC therefore seem better related with observed data and have been chosen for this study.



Annex 2: Analysis of flow data

Observed flow data have been looked at in order to assess their overall quality and reliability and to choose the most adequate period for calibration of the rainfall-runoff model.

Gauging station 84212 – River Mpanga at Kampala – Fort Portal road

Figure 24 shows the daily flows measured at the gauging station n°84212. A quick looked at these data show an obvious data anomaly from year 2011 to present: flows are at least twice as high as they usually are, (whereas rainfall hadn't been particularly high during this period).

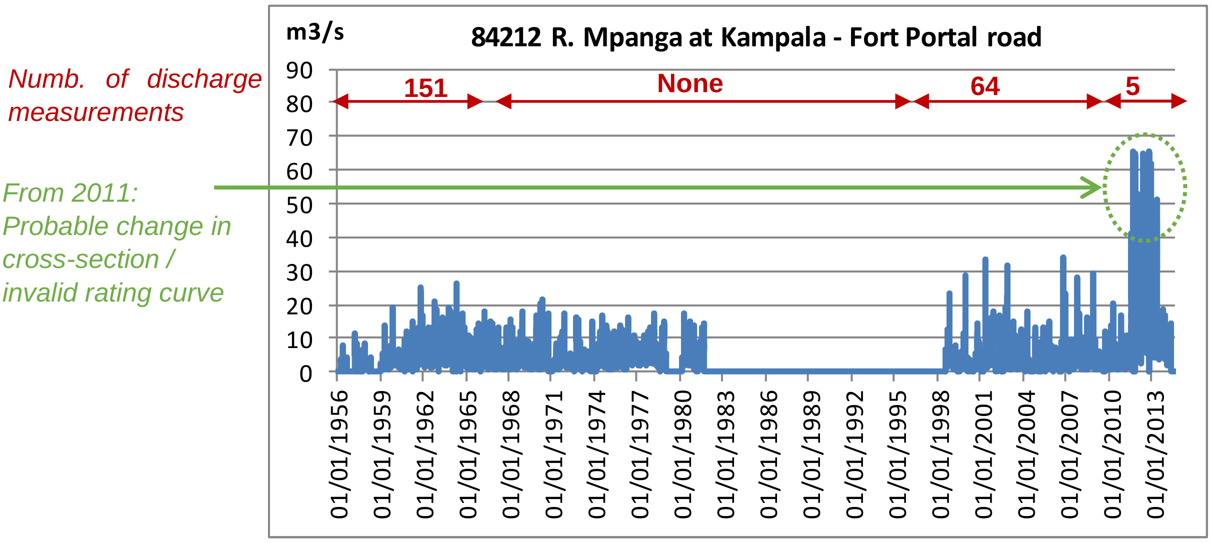


Figure 24 : Daily flow measured at gauging station n°84212

The discharge measurement performed at the gauging station show that the relation between water level and flows had change: all the measurements performed after 2011 (in red on the graph below) digress from the rating curve used during the 1998-2014 period. Discussion with DWRM staff during the field visit also confirmed that recent road works took place on the bridge located immediately downstream the gauging station (see first mission report) and probably changed the cross section at the gauging station.

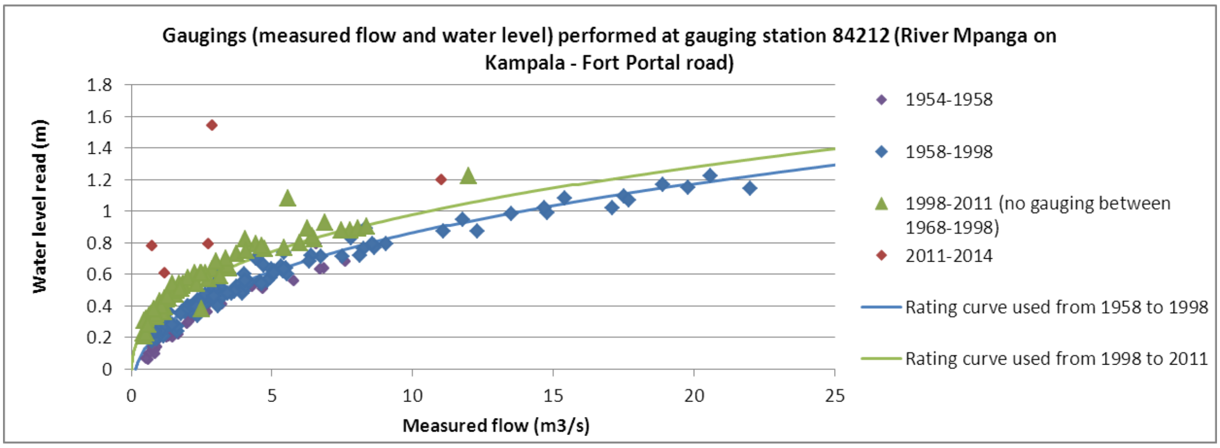


Figure 25 : Rating curve and discharge measurements performed at gauging station n°84212

Discharge measurements have been undertaken regularly from 1955 to 1968 (151 measurements, more than 10 measurements per year in average), showing that the gauging station seems to have been well monitored during this period. The gauging station kept taking records from 1968 to 1983 but no discharge measurement was done during this period.

Between 1998 and 2014, it seems that the gauging station has been correctly monitored, with a total of 69 discharge measurements (an average of 4 per year) however, the measurements done during the last 3 years show that the rating curve currently used must be revised.

Gauging station 84215 – River Mpanga at Ibanda – Fort Portal road

Figure 26 shows the daily flows measured at the gauging station n°84215.

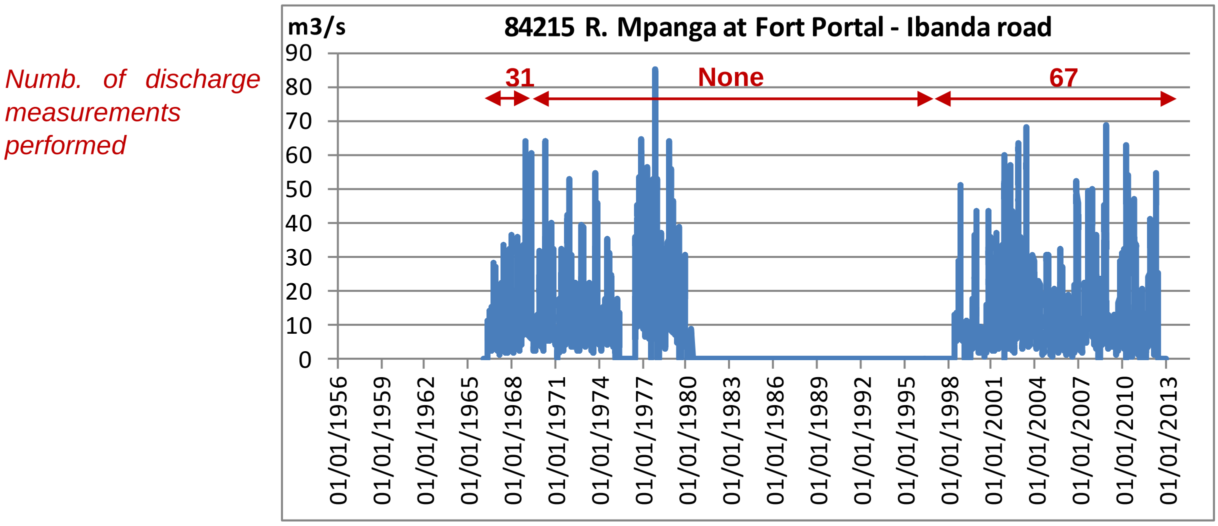


Figure 26 : Daily flows measured at gauging station n°84215

From 1969 to 1980 records were taken at the gauging station n°84215 but no discharge measurement were done to check the validity of the rating curve used to convert water level measurements in flows. Data during this period should therefore be taken cautiously.

Cross checks between data observed at gauging stations 84212 and 84215 confirm the unreliability of flows measured during this period, especially between 1977 and 1998:

- Double mass curve show a change in the relation between flows measured at the two station (see Figure 27)
- Annual runoff during the 1977-1980 period is not consistent with annual runoff calculated during the rest of the records, whereas no change in rainfall can explain it and no similar trend is noticed on gauging station n°84212 (see Figure 28)
- Correlation of monthly flow measured at gauging station 84212 show

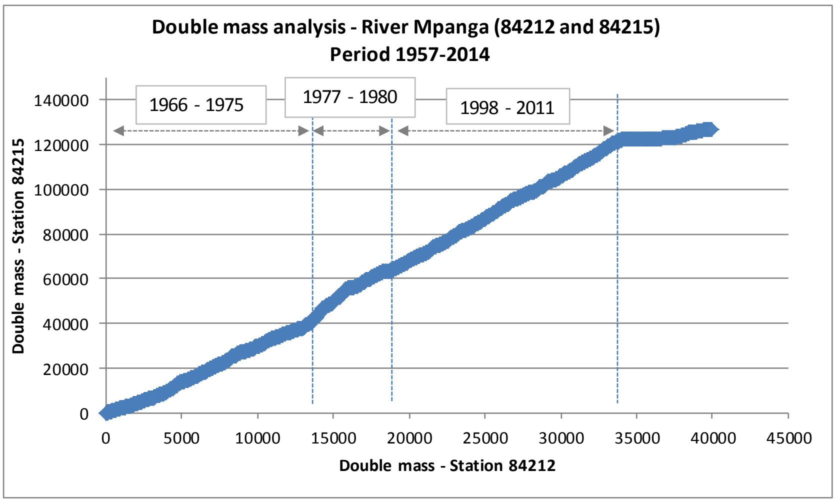


Figure 27 : Double mass analysis on gauging stations n°84212 and 84215

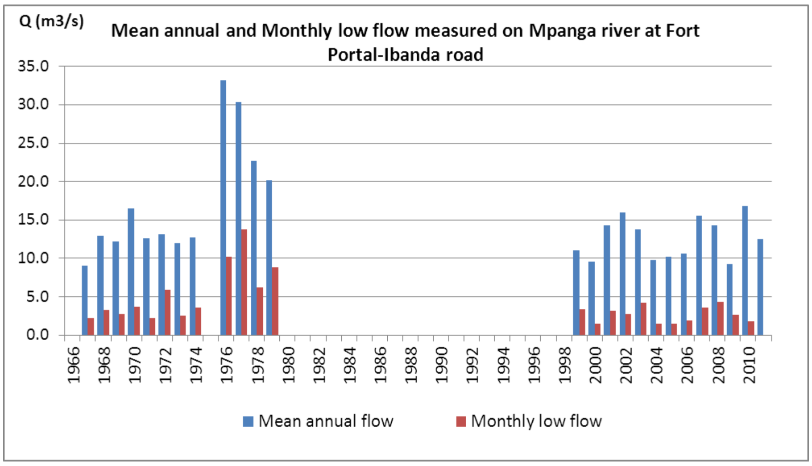


Figure 28 : Mean annual and Monthly low flow measured on Mpanga River at Fort Portal – Ibanda road

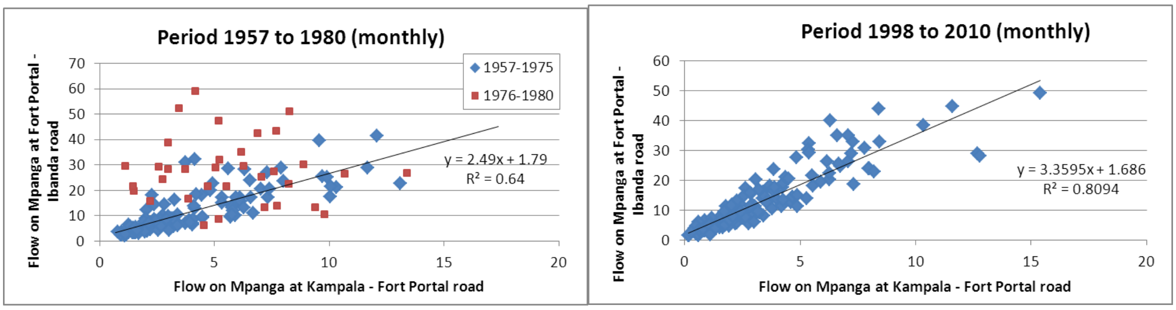


Figure 29 : Correlation of monthly flows at gauging stations n°84212 and n°8215

Gauging station 84276 – River Rushango at Buteraniro

Figure 30 and Figure 31 shows the daily flows measured at the gauging station n°84276 (the same scale as the one used for the two other gauging station, in Figure 24 and Figure 26 is used to ease comparison). The records taken spread on only 5 years including only 2 without gaps.

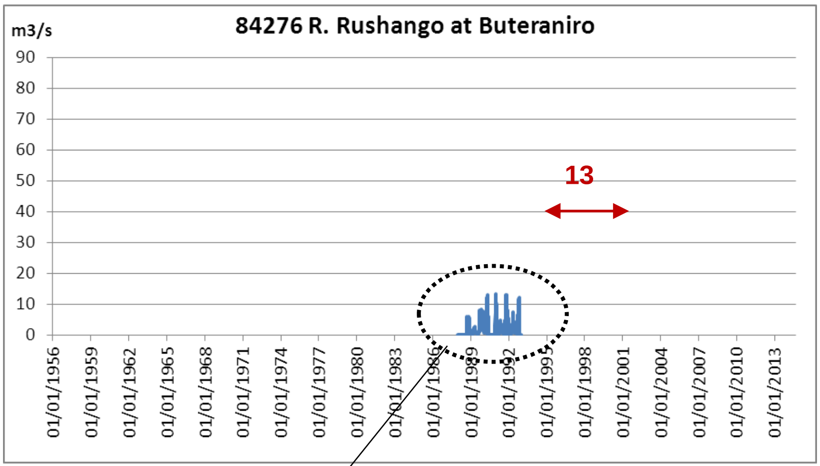


Figure 30 : Daily flows measured at the gauging station n°84276, on River Rushango

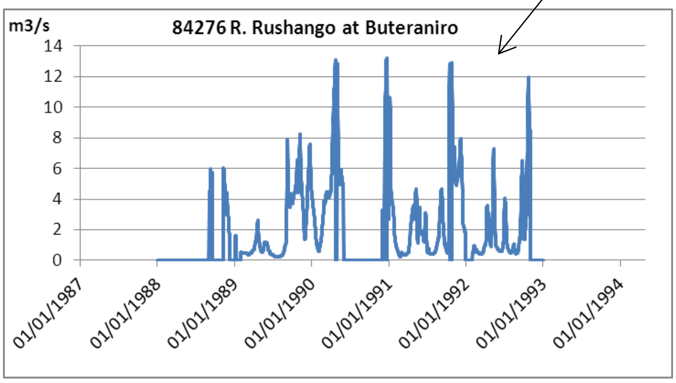


Figure 31 : Daily flow measured at the gauging station n°84276 (zoom)

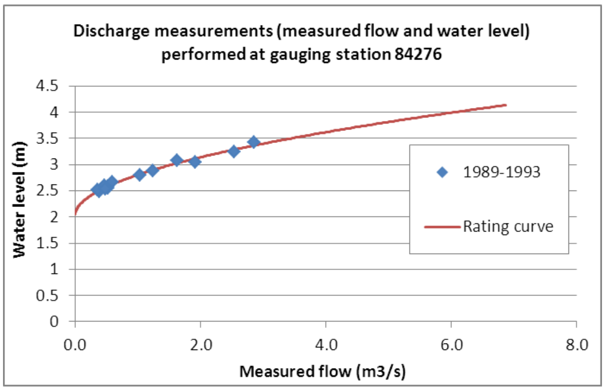


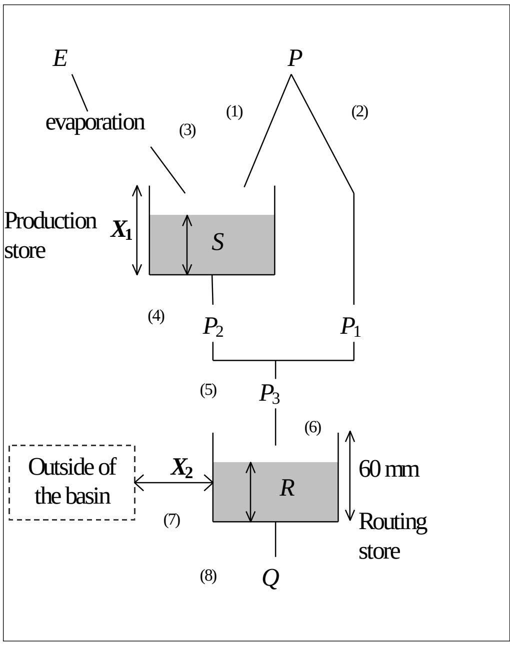
Figure 32 : Discharge measurements performed at gauging station 84276

13 discharge measurements were done between 1989 and 1993; all of them for flows lower than 3 m^3/s (see Figure 32). The validity of the rating curve for high flows is therefore unsure and the values of high flows recorded at the gauging station must be considered with caution.

Annex 3: Description of GR2M

GR2M model is a monthly time step conceptual model which only has two calibration parameters [9]

- X1: the maximum capacity of the store, is positive and expressed in millimetres;
- X2: is positive and has no dimension, it can be interpreted as a water exchange term.



(1) $$S_1 = \frac{S + X_1\varphi}{1 + \varphi\frac{S}{X_1}} \quad \text{with} \quad \varphi = \tanh\left(\frac{P}{X_1}\right)$$

(2) $$P_1 = P + S - S_1$$

(3) $$S_2 = \frac{S_1(1-\psi)}{1 + \psi\left(1 - \frac{S_1}{X_1}\right)} \quad \text{with} \quad \psi = \tanh\left(\frac{E}{X_1}\right)$$

(4) $$S = \frac{S_2}{\left[1 + \left(\frac{S_2}{X_1}\right)^3\right]^{1/3}} \qquad P_2 = S_2 - S$$

(5) $$P_3 = P_1 + P_2$$

(6) $$R_1 = R + P_3$$

(7) $$R_2 = X_5.R_1$$

(8) $$Q = \frac{R_2^2}{R_2 + 60} \qquad R = R_2 - Q$$

- Due to rainfall P, the soil moisture storage, S, becomes S_1 (1)
- Excess rainfall is then calculated (2)
- Due to evaporation (the calculation of actual evapotranspiration depends on the potential value E), S_1 become S_2 (3)
- Then, soil moisture storage releases water P_2 and takes its new value, S, ready for the next month (4)
- Net rainfall P_3 is then calculated as the sum of percolation (P_2) and rainfall in excess (P_1) and enter the routing part of the model (5)
- Level in the reservoir, R, then becomes R_1 (6)
- An exchange term is then calculated (F = (X_2 – 1) x R_1), level in the reservoir becomes R_2=X_2 x R_1
- The reservoir releases a flow Q (8)

[9] See the following references for more details concerning the GR2M model:

Mouelhi, S., 2003. Vers une chaîne cohérente de modèles pluie-débit conceptuels globaux aux pas de temps pluriannuel, annuel, mensuel et journalier. Thèse de Doctorat, ENGREF, Cemagref Antony, France, 323 pp.

Mouelhi, S., C. Michel, C. Perrin, and V. Andréassian (2006), Stepwise development of a two-parameter monthly water balance model, J. Hydrol., 318, 200-214, doi:10.1016/j.jhydrol.2005.1006.1014.

ANNEX 3: SECOND MISSION REPORT

MISSION REPORT

Supporting low carbon development and climate resilient strategies

Capacity building regional project

[Uganda]

STUDY ON CURRENT AND FUTURE POTENTIAL WATER RESOURCES, UNDER DIFFERENT CLIMATE SCENARIOS, FOR THE MPANGA RIVER BASIN (UGANDA)

adetef
Assistance Technique France

February 2015

In association with

AGENCE FRANÇAISE DE DÉVELOPPEMENT

FFEM

BRL ingénierie

Study on current and future potential water resources, under different climate scenarios, for the Mpanga River Basin (Uganda)

2ND MISSION REPORT

February 2015

TABLE OF CONTENTS

1. Introduction

This second mission of the project team to Uganda and to Fort Portal and the Mpanga River Basin in particular, took place within the context of the *Study on current and future potential water resources, under different climate scenarios, for the Mpanga River Basin.* A first mission had already taken place in September 2014, and a first mission report was already compiled to report on the findings of that mission.

The objective of the study is to assess the impact of different climate change scenarios on the water resources of the Mpanga River. The results of this study will be used as a basis for future Integrated Water Resources Management (IWRM) processes within Mpanga catchment area, hence supporting the sustainable management of the water resource. In particular, work will start soon on the re-drafting of the Catchment Management Plan for the Mpanga Basin[1]. A better understanding of the basin's water resources under both present and future climatic conditions will provide essential information for this plan.

This second mission had the following main objectives:

- Presenting the results and findings of the study to the main stakeholders within the basin and getting their comments
- Discussion of all the ongoing water resources developments and management initiatives ongoing and planned within the basin.
- Discussions with key stakeholders such as the Manager of the Albert Water Management Zone

The itinerary followed

- 24 February 2015: Arrive Entebbe, drive via Kampala to Fort Portal, visiting river gauging station, River Mpanga on Kampala Road
- 26 February 2015: Workshop in Fort Portal
- 27 February 2015: Discussions with stakeholders in Fort Portal
- 28 February 2015: Return to Entebbe

This Mission report essentially covers the proceedings of the Stakeholder Workshop. The stakeholder workshop was convened as a full catchment management committee meeting which meant that stakeholders had the opportunity not only of discussing this project on its own merits, but also as a part of the overall water resources development and management context and planning process as a whole.

2. Stakeholder Workshop; Fort Portal – 26 February 2015

2.1 Organization of the workshop

The workshop was organized in collaboration with the MoWE, the Albert Water Management Zone, PROTOS (NGO) and Baastel. This joint collaboration meant all there were adequate funds to invite a complete cross-section of stakeholders. In particular, and importantly, it was possible to invite

[1] The current (and perhaps the future) draft of the Mpanga Basin Catchment Management Plan does not include the Rushangwe sub-catchment

stakeholders from the Rushango sub-catchment. The workshop was organized as an official meeting of the Catchment Management Committee so that the report was presented within the context of overall management of the basin. The workshop was also the occasion to give all the stakeholders an overview of the different initiatives going on in the catchment (catchment management plan, work with catchment management organisations, water resources assessment and economic assessment of the impacts of climate change in the basin).

Various stakeholders also provided a considerable quantity of useful information including maps and/or GIS layers on land cover, land use, administrative boundaries etc).

2.2 Agenda and Participation

The agenda for the workshop is shown in Table 2-1.

Table 2-1 : Agenda for the Mpanga Stakeholders Meeting

TENTATIVE PROGRAMM FOR MPANGA STAKEHOLDERS MEETING AWMZ
26th FEBRUARY 2015 – ATACO COUNTRY RESORT –FORT PORTAL

TIME	ACTIVITY	FACILITATOR
	Session 1	
8:30 – 9:00	Registration	Secretariat
	Chair	**Commissioner, WRR**
9:00 – 9:10	Introductions and workshop objectives	Team Leader, Albert WMZ
9:10 – 9:20	Welcome remarks	LV Chairman - Kabarole
9:20 – 9:30	Opening remarks	Director, DWRM
	Session 2	
	Chair	**LC V- IBANDA**
9:30 – 10:00	Overview of water resources management in Uganda	Commissioner, WRRD
10:00 – 10:45	Mpanga Economic Study on the Impacts of CC findings	BAASTEL
10:45 –11:00	Discussions	
11:00 –11:15	**Tea Break**	**Secretariat**
	Session 3	
	Chair	
11:15 – 12:05	Current and future potential of CC on Water Resources of the Mpanga River Study findings	BRL
12:05 – 13:00	Discussions	
13:10 – 14:10	**Lunch Break**	
	Session 4	
	Chair	**Assistant Commissioner - WUP**
14:10 – 14:35	Ongoing activities in Mpanga	PROTOS
14:35 – 14:55	Planned activities in Mpanga	AWMZ
14:55 – 15:15	Way forward and discussions –	Commissioner, WRRD
15:15 – 15:30	Closing Remarks	Director, DWRM
15:30 – 15:45	**Tea Break and departure**	**Secretariat**

Figure 2-1 : Stakeholder workshop in Fort Portal on 26 February 2015

The workshop was attended by a total of 58 persons, including representative of the project teams (BRLi, Protos, Baastel). The complete list of participants is provided as Annex 1

In line with the agenda, presentations were made by the Team Leader of the Albert Water Management Zone, who provided a detailed overview of the workshop objectives. This was followed by a presentation by Dr Callist Tindimugaya who provided a comprehensive overview of the current status of water resources management in Uganda.

Dr. Tom Mwebaze of Baastel provided a short introduction to the *Mpanga Economic Study on the impacts of climate change findings*. This study will use the results of the *Current and future potential of CC on water Resources of the Mpanga River Study findings* as a point of departure

Steve Crerar of BRLi provided a detailed presentation on the findings *Current and future potential of CC on water Resources of the Mpanga River Study.* This was the main presentation of the day and it was very well-received. The main points of discussion can be summarized as follows:

- PROTOS have had some experience in the development of handpumps using groundwater in the area around Kamwenge and their perception is that the groundwater table has been declining. It was agreed that it would be useful to have a better knowledge of groundwater.
- It was pointed out the river name "Rushango" should be used throughout the reports and not "Rushangwe" or other similar ones.
- It was agreed that the Rushango sub-basin has to be included in all future Mpanga basin management plans and planning
- There was a question on why the impact of increased temperature resulting from climate change was not mentioned in the presentation. The Consultant pointed out that this is covered in the report, in particular with respect to the impact on evaporation
- It was pointed out that there is a rainfall station at Kirahua and that data have been collected since 2004.
- Stakeholders agreed with Consultant's conclusion that there were already periods of extreme scarcity in part of the Rushango sub-catchment.
- It was pointed out that water quality is becoming an issue in the basin and that it should receive adequate attention in the management plan.
- There was some discussion on the importance of getting a better understanding of the environmental flow requirements.
- The Consultant was asked whether there would be training as part of the consultancy, especially on the water resource modelling that had been undertaken using "WEAP". The Client intervened to say that efforts would be made to follow up the possibility of further support from the donor in order to facilitate this and perhaps some other activities.

- The Client expressed their satisfaction with the presentation and the report but requested the Consultant to make sure that groundwater was covered in the final version.

The main messages and recommendations of the report were all agreed. These conclusions and recommendations are included in the Final Report and the Task 3 report (Annex 2).

Lieven Peeters of PROTOS provided an overview of PROTOS activities, both recent and ongoing. These include.

- Since 2006 – Sector undertaking – Memorandum of Understanding with MWE through DGD funding
- Supporting the formation of the Catchment Management Committee
- Undertaking of a number of investments (water, sanitation, environment) on the ground, including sensitization and capacity building
- Climate change assessment – UNEP program
- Climate change sensitization and capacity building campaigns within the catchment
- Bottom up planning processes
- Implementation of selected pilot projects in hotspots

Albert Orijabo, Manager of the Albert WMZ made the final presentation of the day on the work plan for the CMC. There are three main themes:

- Theme One: Improved WRM in the WMZs
- Theme Two: Integrated CBWR Planning
- Theme Three: Implementation of CBWRM Plans

ANNEX 1: LIST OF PARTICIPANTS

List of Participants at the Mpanga Catchment Management Stakeholder Meeting in Fort Portal; 26 February 2015

S/N	Name	Organisation	Title	Email	Tel. Contact
1	Maate Jackus	Bundibugyo District LG	DNRO	maatejackus@gmail.com	0770281622
2	Dr. Tom Mwebaze	MuK/Baastel	Consultant	Tm200ing@yahoo.com	0772467821
3	Koozi Augustine	Kasese DistrictLocal Government	SEO	Koozi.augustine@yahoo.com	0772997158
4	Joseph Katswera	Kasese District Local Government	DNRO	katswera@yahoo.com	0772997158
5	M.W.S Sanjewa	Mpanga Hydro Power Plant AEMS Leila	Eng Sanjewa	sansjewa@saems.co	0772221890
6	John Nyakoojo	Protos	Program Assistant	John.nyakoojo@protoshxo.org	0772417063
7	Thomas Legay	BRL	Water management Engineer		0783919553
8	Steve Crerar	BRL	Consultant Team Leader	stevecrerar@brl.fr	
9	Lieven Peeters	PROTOS	Director	lieven.peeters@protosh2o.org	
10	Irene Makkeozi	AKMZ	Sociologist		
11	Dr Callist Tindimugaya	DRWM, MWE	Commissionner, WRR, MWE	Callist.Tindimugaya@mwe.go.ug	
12	Ndinawe Scollastee	DWRM/AWMZ	Social scientist	ndinawescola@gmail.com	
13	Ebbu Emmanuel	DWRM/MWZ	SWA	Emmauel.ebbu@mwe.go.ug	
14	Kitamirwe Jackson	DWRM/AWMZ	SR analysis		
15	Albert Orijabo	Albert WMZ	Manager	Albert.orijabo@gmail.com	0701566535
16	Brian Guma	Albert WMZ	Hydrologist	Brian.guma@mwe.go.ug	
17	Hannelane Martens	Protos	P.O. m&e	Hannelone.martens@protoshxo.org	
18	Kabaseke Clovis	We-Consult	Agro-ecologist Consultant	cloviskabaseke@gmail.com	
19	Tuhamwe Gertrude	Kamwenge	DSDO	gtuhamwe@yahoo.com	0772496228
20	Rovence Bagarukayo	Kamwenge	U/C/PLCU	tibimparovence@gmail.com	0774771672
21	Ruyonga Godfrey	SEO Kabarole District Local Government	SEO	gmruyonga@gmail.com	0782673188
22	Matthew Coopv	TBG	Project Manager	matthewcoopv@hotmail.fr	0794402148
23	Angumye Rebecca	JESE Fort Portal	Project officier	angkbeeky@gmail.com	0782764223
24	Petter Opwanya	MWE/TS06	Team leader		0787644077
25	Karatunga Joseph	Atomz/TSU6	Office manager		0782149340
26	Tibenda John	NWSC – Fort Portal	Area Manager		0772589743

S/N	Name	Organisation	Title	Email	Tel. Contact
27	Kyomuhendo Edson	Kyenjojo DLG	DWO		0702590080
28	Moses Mwirumubi	Kabarole	Acao		0702065300
29	Muhumuza Richard	Kiamara Estate (TAMTECO)	Group manager		0772398516
30	Thaddeo Kahiigwa	Satnet	Prog. Manager	Tadsiima2000@yahoo.com	0782313068
31	Ellinor Isgren	Satnet	Phd Student	Ellnor.isgren@lucsus.lv.se	0788997318
32	Agasa Henry	NWSC Kamwenge	manager	henryagasa@gmail.	
33	Kalule S. Bruno	Kamwenge DLG	DWO	sbnkalule@gmail.com	0772654257
34	Bigasma Juliens	Kyenjojo DLH	SEO	jbigaswa@gmail.com	0772665633
35	Gladys Natugonza	Fort Portal MC	MEO	natugladi@yahoo.com	0782665633
36	Kamuhanda Herbert	Neoro/co	DEO	kamuhandah@gmail.com	
37	Namara Deborah	Kiruhura	DEO	debbienamara@yahoo.fr	0701027083
38	Nkwatsibwe	Kiruhura	Chairperson		0772869007
39	Nballo Fortunate	Kiruhura DLG	CDO	???	0701909836
40	Ssesanga Vincent	Kiruhura DLG	DWO	Vincentssesanga@yahoo.com	
41	Kisakye Violet		Lecturer / PhD student		0782853289
42	Birungi Kobusinge	Hewasa Caritas Fort Portal	Programme Engineer		0782814284
43	Tusiime ???	MWE/TSU	CDS		0702560113
44	Namirembe Ruicia	Rwenzori commodities LTA (Mukwano team)	HRM		0772419589
45	Ikagobya Moses	Kabarole DLG	Vice Chairman LC V		0772419589
46	Mgamwa Deneth	MWE/AWMZ	Social scientist		0782364604
47	Aujo Josephine	DWRM	Communication water officer		0776275720
48	Mundeke Evarist	DWRM			0782441626
49	Mugisha Micharles	Kyenjojo DLG	DNRO		0782300062
50	Christine Annet Tuhaise	Kyenjojo District LGT	Chairperson		0773217015
51	Twoori Yafebe	Kyenjojo district	DCDO	ytwoli@yahoo.co.uk	0772570801
52	Kaba??? Evelyo	Kyenjojo DLG	CDO ???		0782737992

S/N	Name	Organisation	Title	Email	Tel. Contact
53	Tumwine Venansio	Naro Rwebitaba Tea Research	RO/Crop entomology	Vmtumwine6@yahoo.co.uk	0772911115
54	SP. Mbabazi Martha B	APC KJJO	APC		0714667935
55	Byabasaija Rosemary	Office of the president	D/RDC	rosemarymuka@gmail.com	0772914292
56	George Kaihura	Mpanga Tea factory	Field manager		0772557720
57	Kamara Charles	Rwenzori Commodities	Manager		0772197443
58	Nambirige Monika	DWRM	Secretary		0787213555
59	Dr. Moses Muhumuza	Mountain of the moon university	Director. Post graduate student and research	musacot@gmail.com	0772565565
60	Mwebaze Caroline	Hydrologist/DWRM	Hydrologist AWMZ		0772921034
61	Turyasiima Christine	DWRM	Secretary		0772601442
62	Ahimbisibwe Vincent	Kamwenge DNRO-KDLG	DNRO		0782603271
63	Marimda Jackline	IDLG	CDEO		0782111458