NILE BASIN INITIATIVE

Nile Equatorial Lakes Subsidiary Action Program

Kagera River Basin Management Project

FEASIBILITY STUDY FOR *BUYONGWE* WITHIN THE FEASIBILITY STUDIES FOR 4 SMALL MULTIPURPOSE DAMS IN THE KAGERA RIVER BASIN

FEASIBILITY STUDY REPORT - Final version

DECEMBER 2012

TRACTEBEL Engineering GDF SUEZ *acting under the commercial trademark of* COYNE ET BELLIER Ingénieurs Conseils

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Our ref. : P.003214.RP27
Entity : HSP
Imputation: P.003214.0001

Client : NILE BASIN INITIATIVE

Project : **Feasibility studies for 4 small multipurpose dams in the Kagera River Basin**

Subject : **Feasibility Study Report – Final report about Buyongwe site in Burundi**

Comments : **The following names will be used from the inception report for the 4 dam sites: Taba-Gakomeye in Rwanda, Karazi in Tanzania, Buyongwe in Burundi, and Bigasha in Uganda**

This report includes the detailed findings of the various water use and water demand studies, the environmental and social examination and the detailed technical, financial and economic assessment of Burundi site.

This study was carried out by Tractebel Engineering with the following contributions:

- *CACG (compagnie d'aménagement des coteaux de Gascogne) for all the study about irrigation ;*
- *GEOGEOPHY for all the geophysical investigations ;*
- *Southern Mapping Company for all the aerial survey (LiDAR);*
- *Technical Resources Services for the studies about geotechnical investigations, socio-economic survey, water supply, aquaculture and livestock watering studies as well as economic and financial analysis.*

04	12/12/14	Revised as per comments	Final	JMB/NTO	Jean-Luc Pigeon	Nathalie Tomczak
03	12/11/21	Economic and financial analysis included	Draft	ATA/XMO/JMB/MMK/NTO	Jean-Luc Pigeon	Nathalie Tomczak
02	12/10/26	Report by country	Draft	XMO/JMB/MMK/NDA/NTO	André Tavarès	Jean-Luc Pigeon
01	12/09/21		Draft	ATA/ELA/JMB/MMK/NDA/PYB	Nathalie Tomczak	Jean-Luc Pigeon
REV.	**YY/MM/DD**	**SUBJECT OF THE REVISION**	**STAT.**	**WRITTEN**	**VERIFIED**	**APPROVED**

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INITIALS AND ACRONYMS

ASTER	Advanced Space-borne Thermal Emission and Reflection Radiometer
CDC	Community Development Committee in Rwanda
CWR	Crop Water Requirement
DEA	Directorate of Environmental Affairs in Uganda
DEM	Digital Elevation Model
DRC	Democratic Republic of Congo
EAC	East African Community
EBCR	Economic Benefit to Cost Ratio
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
ENPV	Economic Net Present Value
ENSAP	Eastern Nile Subsidiary Action Program
ESIA	Environmental and Social Impact Assessment
ETo	Potential Evapotranspiration
FWL/FSL	Full Water Level/ Full Supply Level
GIS	Geographic Information System
GPS	Global Positioning System
GWh	Giga Watt hour
HH	Household
HV	High Voltage
ICOLD	International Commission on Large Dams
IESE	Initial Environmental and Social Examination
IMP	Irrigation Management Plan
IWR	Irrigation water requirement
IWRM	Integrated Water Resources Management
KRBMP	Kagera River Basin Management Project
kV	Kilo Volt
LiDAR	Light Detection And Ranging
LSU	LiveStock Unit
LVBC	Lake Victoria Basin Commission
LVEMP	Lake Victoria Lake Victoria Environmental Management Project
MAF	Mean Annual Flow
MAR	Mean Annual Runoff
MINAGRI	Ministry of Agriculture and Animal Resources of Rwanda
MININFRA	The Ministry of Infrastructures of Rwanda
MINIRENA or MINELA	The Ministry of Natural Resources of Rwanda
MOL	Minimum Operating Level
Mm^3	Million Cubic Meters
MW	Mega Watt

MWL	Maximum Water Level
NBI	Nile Basin Initiative
NEA	National Environment Act in Uganda
NEL-COM	Nile Equatorial Lakes Council of Ministers
NEL-CU	NELSAP Coordination Unit
NELSAP	Nile Equatorial Lake Subsidiary Action Program
NEL-TAC	Nile Equatorial Lakes Technical Advisory Committee
NEMA	National Environmental Management Authority in Uganda
NEMC	National Environment Management Council of Tanzania
NGO	Non-Governmental Organization
NWL	Normal Water Level
OP	Operational Policies
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMU	Project Management Unit
REMA	The Rwanda Environment Management Agency
RGPH	*Recensement Général de la Population et de l'Habitat* General Census of Population and Habitat
RN	*Cote de Retenue Normale* Full Water Level
SAP	Subsidiary action program
SRTM	Shuttle Radar Topography Mission
SSR	Sequential Stream flow Routing
SVP	Shared Vision Program
ToR	Terms of Reference
TIWRMD	Trans-boundary Integrated Water Resources Management and Development
UICN	*Union Internationale pour la Conservation de la Nature* International Union for Nature Conservation

EXECUTIVE SUMMARY

The administrative area for the entire Project is located within the north eastern part of the Ngozi Province, few kilometres downstream the township of Kiremba, on the Buyongwe River, an affluent of the Akanyaru and Nyabarongo Rivers.

The aim of the study was to undertake the feasibility study for a dam with emphasis on agricultural development (irrigation, livestock and fisheries production), water supply, energy and other uses.

The first investigations gave the following results:

- The topographical survey was undertaken to produce rectified colour images and a digital terrain model (DTM) of the areas of interest for the project. Digital colour images were also taken and rectified to produce colour orthophotos of the project area. The survey was flown at a height of approximately 800m and an image pixel size of 10cm has been produced. The results of such level of accuracy offered by the LiDAR survey were an asset for the performance of numerous engineering activities of this study including the irrigation study and the environmental and social studies.
- Geophysical investigations have checked the suitability of the selected site for the construction of the dams and appurtenant structures. The used methodology was the electrical resistivity techniques based on the response of the earth to the flow of electrical current. 2D geological profiles were generated with stratification and water table readily usable in the study. The investigation depth was about 25 meters.
- Complementing the geophysical investigations, the Consultant performed geotechnical investigations in the form of six test-pits dug to 3 to 8m depth in naturally consolidated soils in order to sample the composition and structure of the subsurface. The geophysical and geotechnical investigations show that the potential Buyongwe dam axis is composed of 4 to 7 m depth of peat followed by clay and sandy clay, then the underlying weathered and solid bed rock. The peat soil, having no bearing capacity, could be an issue for the foundation of dam.
- The hydrological study has included inflows assessment, determination of the flood hydrographs, sediment transport study and climate change features. The study shows that the catchment area is 265 km² and altitude is in the range 1 880 – 1 345 m above sea level. Average annual rainfall is about 1 205 mm/year with the Probable Maximum Precipitation = 350 mm/day.
    - The hydrological regime is rather smooth with a Maximum discharge occurring in April. The annual runoff within the period 1962-2009 is about 2,75 m^3/s; the ratio of maximum monthly discharge (April) to minimum monthly discharge (July) is equal to 1,97.
    - With a storage capacity of about 10 Mm^3 (in case of a 14m dam height), the ratio of storage capacity to mean annual inflows would be very poor (13%). As a consequence, the annual sedimentation rate is quite important.
    - The net losses due to evaporation is about 0,8% of the annual inflow for a reservoir surface area of 1,27 km^2 (in case of a 14m dam height).

- Hydraulically, without taking into consideration environmental and social issues, the optimization leads to a dam height close to 24 meters for this site. However, the water demand for all the uses leads to a maximum of 54 Mm^3/year, meaning 1,72 m^3/s. As the natural guaranteed discharge of the Buyongwe River is 1,80m^3/s, it would be therefore possible to provide all the water demand with the River without dam as the natural inflows is sufficient all the year (even during the dry season) to satisfy the maximum water demand.
- It should be as well noticed that the Kiremba 65kW recently refurbished hydro power plant will be flooded in case of the construction of a 14m high dam.
- Furthermore, the analysis of the aerial survey lead to find 117 ha of cultivated land, 55 ha of plantations and 24 buildings flooded by the reservoir in case of the construction of a 14m high dam, which represents about 430 affected households according to the estimation of the plot size in the area.

Thus, it has been decided to carry out the project without dam construction:

- For irrigation, the first investigations about irrigation lead to find a large (around 1000Ha) potential command area suitable to increase the local food production. However, the peat extraction in this area has made any improvement impossible in the past and the flow of the Buyongwe River can be blocked by the one of the Akanyaru River by a backwater effect, which may flush rice cultivation. Thus, the designed perimeter for the first stage covers a geographical area of 535 ha. The net irrigated area could be estimated between 428 and 482 ha taking into account the irrigation infrastructures to be built. Due to sanitary issues affecting rice cultivation in this area, it is recommended to grow only one crop of rice per calendar year and to introduce a crop rotation. Rice could be followed by either maize or bean crop which will be sown during July/August. Irrigation will be required during this dry period. The cropping pattern could alternate these two crops on a same field, one year maize, the next year bean with an expected yield of 3 t/ha for rice, 2,5 t/ha for maize and 1,5 t/ha for beans.
- Kiremba Commune has already five water networks for drinking water. Without taking into account the urban towns, the proposed water supply in Ngozi Province could be estimated to reach about 74 000 households. Large scale water network has been designed as well including Kirundo and Muyinga Provinces, estimated to reach about 138 000 households.
- The livestock are mainly located on the hills in order not to destroy the cultures. Thus, implementing livestock watering should be considered with cautious. Livestock is mainly composed of cattle, sheep and goats. 15 water point locations have been identified at first for the livestock population, which could increase to 25. However, as Burundi promotes a zero grazing policy, it has been decided to include this use in the water supply scheme.
- Taking into consideration that aquaculture was expressed as a least priority water use by the local Authorities, that there is no use in the Project area for such activity and that the Lake Tanganyika is in close proximity with available fishes, this activity could be a least priority to be developed. However, about 27 fish pond locations have been identified.
- The possibility to develop hydropower has been focused on the development of the capacity for the existing Kiremba hydropower by adding a new turbine. However, the benefit of this upgrading is questionable as the benefits do not exceed the costs of such new turbine.

Economic analysis concludes the no-viability for the upgrading of the hydro-power plant, leading not to design expansion of Kiremba micro hydropower plant as the estimated total of 949 000 US$ for the extension of the existing power plant is quite the same amount of the benefit after 30 years of exploitation.

The irrigation development is questionable as Buyongwe irrigation scheme cost is high compared to other schemes, mainly due to the length of main canals and the huge lateral tributaries to be crossed by siphons. The designed perimeter has focused on the first area as the first stage. With indirect revenues, the economic indicators are estimated as follows:

- EIRR: 18,38%
- ENPV: US $ 5 151 000
- EBCR: 1,29

The economic analyse for the implementation of water supply network in Ngozi Province, shows positive economic performances taking into consideration indirect revenues and collective increased incomes related to project nature and activities (such as fetching distance saving, appreciation of land, economic growth, employment). With indirect revenues, the economic indicators are estimated as follows:

- EIRR: 37,47%
- ENPV: US $ 46 248 000
- EBCR: 1,578

The aquaculture shows low economic performances. For memory, aquaculture was expressed as a least priority water use by the local Authorities, as there is no use in the project area for such activity and as the Lake Tanganyika is in close proximity with available fishes. Thus, the development of such activity is questionable

The costs for the components of the project are included in the following table.

Water Use Component	**Capital Investment Costs US $ for the first stage**	**Capital Investment Costs US $ for the next stage**	**Capital Investment Costs US $ TOTAL**
Irrigation	13 020 000	10 830 000	23 850 000
Aquaculture	1 826 000		1 826 000
Potable Water Supply (in Ngozi Province)	41 890 000		41 890 000
Sub-total	**56 736 000**	**10 830 000**	**67 566 000**

1. INTRODUCTION

1.1. Preamble remarks

Following the inception mission in October 2011, the names of the four dams have been renamed as follows:

- Taba-Gakomeye (Rwanda),
- Karazi (Tanzania),
- Buyongwe instead of Kiremba (Burundi),
- Bigasha instead of Omumukura (Uganda).

1.2. Background of the study

The Nile Basin Initiative (NBI) is a partnership of the riparian states[1] of the Nile, which endeavours to develop the River Nile in a cooperative way, to share socio-economic benefits, and to promote regional peace and security. The NBI's Strategic Action Program is composed of two complementary programs: the basin wide Shared Vision Program (SVP), which aims at building confidence and capacity all over the basin, and Subsidiary Action Programs (SAPs), which initiate concrete investments on the ground in the Eastern Nile and in the Nile Equatorial Lakes sub-basins.

The Nile Equatorial Lakes Subsidiary Action Program (NELSAP)[2] implements three river basin projects, among which the Kagera River Basin Management Project (KRBMP). Its objective is "to establish a sustainable framework for the joint management of the water resources of the Kagera river basin and prepare for sustainable development oriented investments, in order to improve the living conditions of the people and to protect the environment". The Kagera River Basin lies West and Southwest of Lake Victoria, and its total area of 59 800 km² is distributed among Burundi, Rwanda, Tanzania and Uganda. It has a population of nearly 15 million people.

The Kagera basin is characterized by a low productive peasant agriculture and water scarcity for grazing and household. In many places, the population pressure is increasing and triggers off land degradation, deforestation, loss of soil fertility and over exploitation of wetlands. Eventually, climate change and its various impacts are likely to make the situation even more stressful.

[1] Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. Eritrea is as an observer.

[2] The countries of the NELSAP: Burundi, DR Congo (DRC), Egypt, Kenya, Rwanda, Sudan, Tanzania, and Uganda.

The link between poverty and water scarcity is nowadays acknowledged and well known. According to the International Water Management Institute, the whole area is going to suffer from economic water scarcity in 2025. These countries could have enough water resources to meet their needs, only by setting up infrastructures and regulation systems. Hence, improving water infrastructures and management will be of a crucial importance.

Furthermore, agriculture remains the economic mainstay: there is an increasing need to develop irrigation in the area. As for livestock and aquaculture, they remained relatively underdeveloped in most of the places. Eventually, in rural areas, the population has a very low access to electricity and safe water supply, which dramatically impedes the development of the Basin.

Thus, to tackle the abovementioned basin issues, the NELSAP and the KRBMP procured Tractebel Engineering - Coyne and Bellier to undertake a feasibility study of 4 small dams, that is to say below 15m according to World Bank classification criteria, one in each country:

- Taba-Gakomeye dam in Rwanda,
- Bigasha dam in Uganda,
- Karazi dam in Tanzania,
- Buyongwe dam in Burundi.

This study is carried out in parallel with an Environmental and Social Impact Assessment (ESIA).

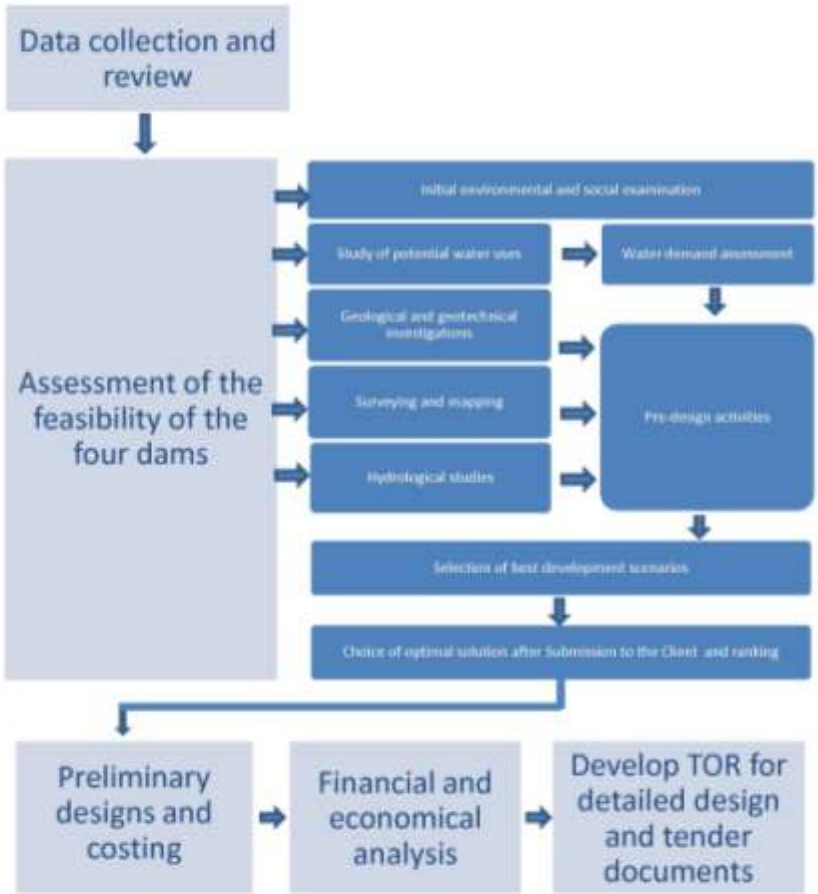
1.3. Study objective

According to the Terms of Reference (ToR), the following objectives for this study are as follows:

- To carry out detailed feasibility studies including preliminary designs and cost estimates for the four small dams, with emphasis on agricultural development (irrigation, livestock, aquaculture and fisheries production), water supply, energy and other uses, as found to be permitting;
- To undertake preliminary environmental and social examinations in order to comply with the international standards and environmental and social requirements of the national environmental management agencies and the World Bank's safeguard policies;
- To develop Terms of Reference for the detailed designs and tender documents for implementation of the selected dam projects.

To fulfil these objectives, the following activity flow chart (see Figure 1) has been followed all along the study.

Figure 1: Activity flowchart of the feasibility studies for Kagera Project



1.4. Place of the feasibility study report within the Project cycle

This report comprises, as requested by the ToR,

- The technical studies, including:
    - Description of multipurpose storage reservoir projects;
    - Detailed technical, financial and economic assessment of the site; and
- The preliminary concept of a local water development program, including:
    - the detailed findings of the various water use studies regarding agriculture, fisheries, livestock, hydropower, water supply, etc;
    - the detailed findings of water demand assessment,
    - the recommended project implementation approach;
- The initial social & environmental examination of the projects.

1.5. Main constraint in the project cycle

The inception report mentioned that one of the main issues was the Light Detection Aerial Ranging (LiDAR) topographical survey. The LiDAR survey was critical in the schedule of the Project in order not to delay the overall project activities.

Due to the constraint to get all the flight clearances for the aerial surveys, the LiDAR survey results for Burundi was received early April instead of February. It should be noticed that the interpretation of the data from aerial survey takes time. Thus, the uses of these data have delayed the overall study. However, the precision of the topographical maps from LiDAR saves time for the overall project.

2. DESCRIPTION OF THE KAGERA PROJECT

2.1. Regional context

The countries of the NELSAP have identified a number of projects to promote poverty alleviation, economic growth, and reversal of environmental degradation in the sub-basin. The investments are grouped into two major programs: Natural Resources Management and development of projects, and the Power Trade and Development program. The two programs target investments in agricultural development, fisheries development, water resources management, water hyacinth control, hydropower development and transmission interconnection. The Natural Resources Management sub program consists of three Integrated River Basin Management projects, namely Kagera, Mara and Sio – Malaba - Malasiki River Basin Trans-boundary Integrated Water Resources Management and Development Projects. The Projects are aimed at poverty reduction and achieving socio-economic development through the rational and equitable use of the shared water resources of their respective River Basins.

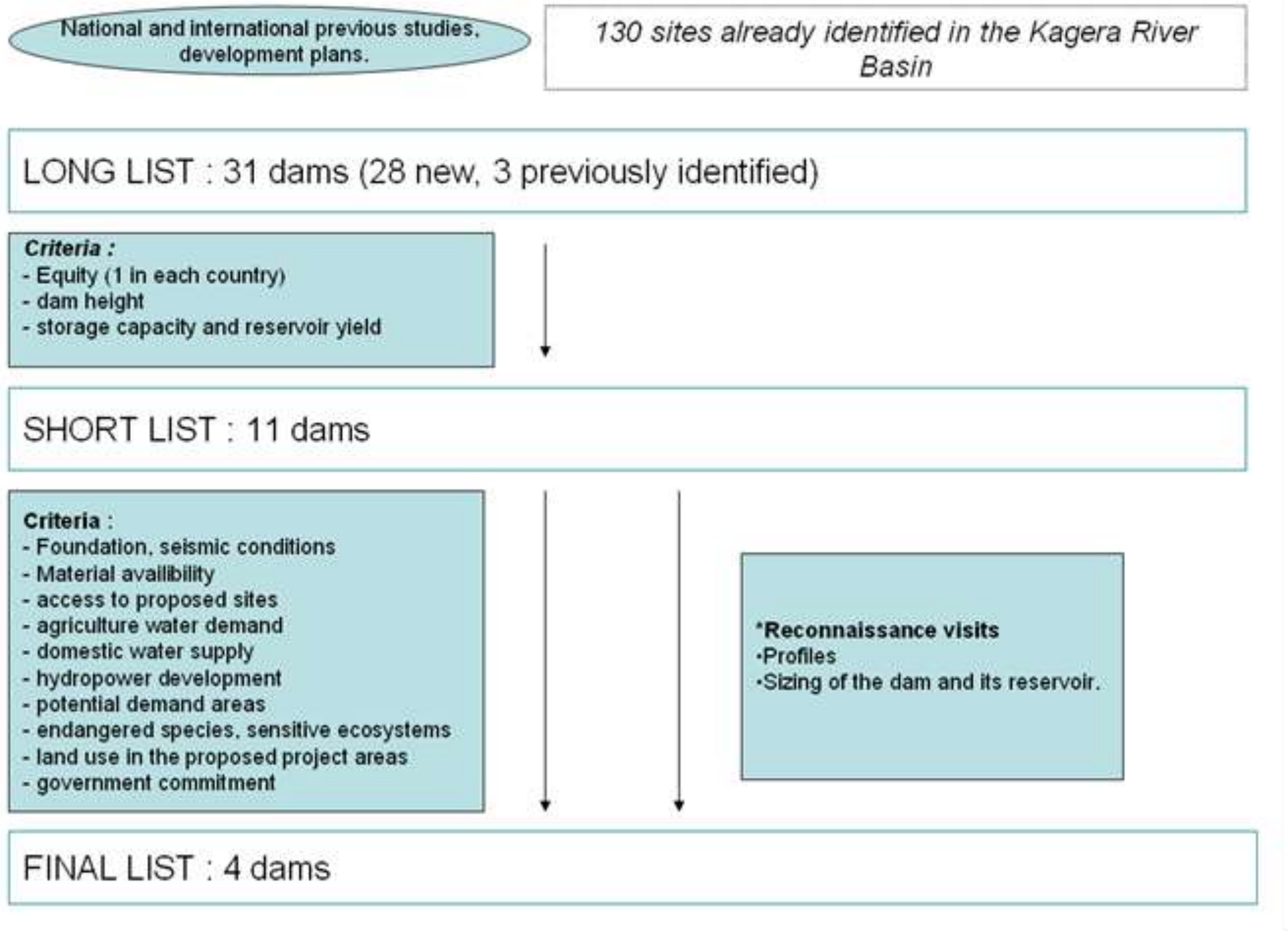
The project objective of the Kagera Trans-boundary Integrated Water Resources Management and Development Project is to establish a sustainable framework for management of water resources of Kagera River Basin, in order to prepare for sustainable development oriented investments that will improve the living conditions of people while protecting the environment.

The NBI/NELSAP has received grant financing from the World Bank Nile Basin Trust Fund towards preparation of a strategic portfolio of regional water resources investment projects in the Kagera River Basin and has applied part of the proceeds of this grant to undertake consultancy services for a feasibility study for development of four small multipurpose dams/reservoirs with emphasis on agricultural development (irrigation, livestock, aquaculture and fisheries production), energy, water supply and other uses, which is the purpose of this study.

2.2. Project history

The Kagera River Basin Management Project recently completed a study [a] for identification and rapid assessment of potential small dams for the multipurpose uses of agricultural development, hydropower generation, water supply, etc. The study identified 28 new dam sites and made preliminary assessment of 3 previously identified dams from the Rwanda Irrigation master plan. From this list of 31 sites, 11 sites were selected. From the shortlist of the 11 sites, after applying technical considerations, four sites, one for each country, have been finally selected. The scheme below highlights the identification process:

Figure 2: identification process for the four dam sites

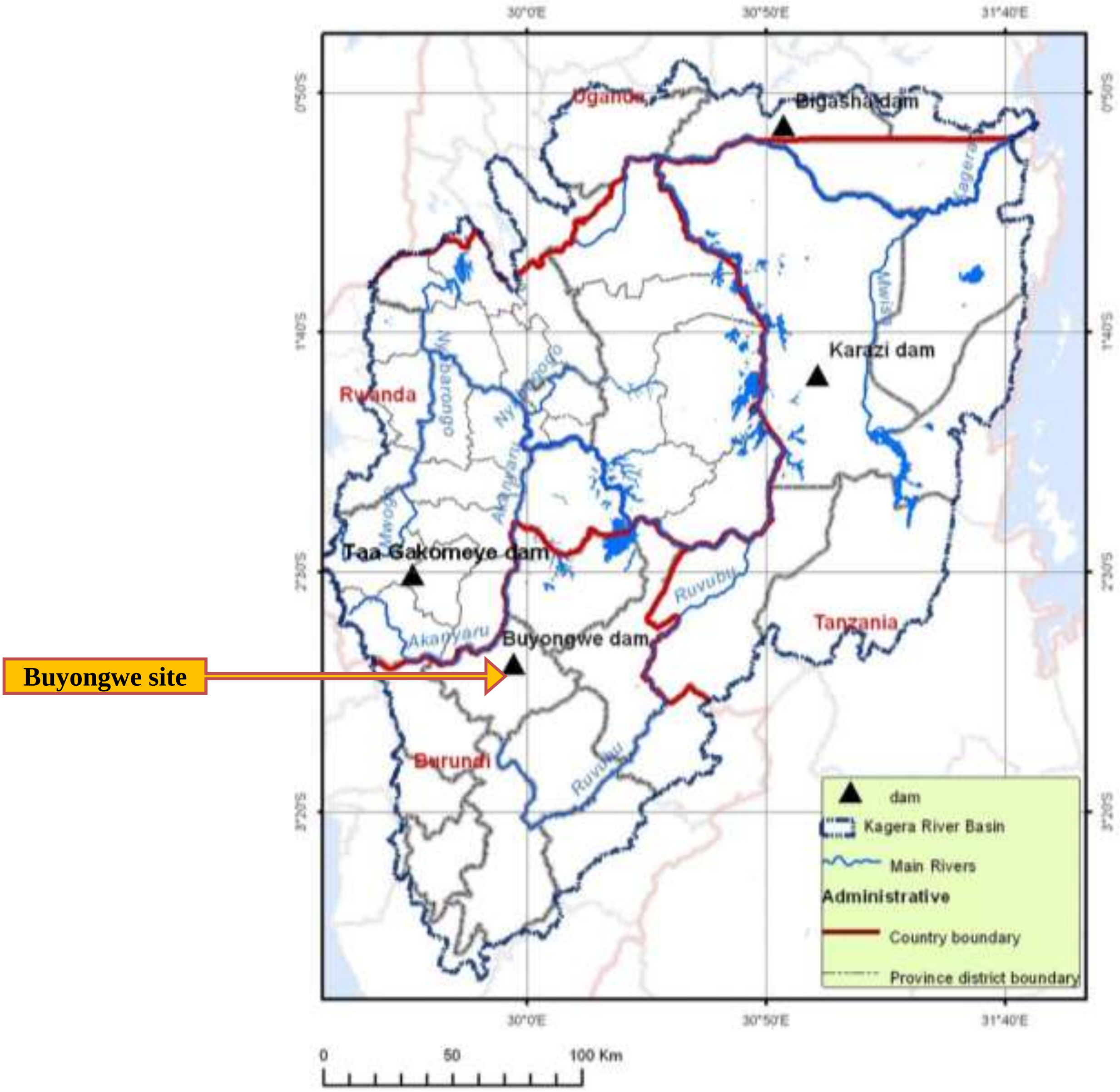


However, the study did not consider environmental and social economic considerations in the identification of the dam sub-projects. Thus, the aim of this present study is the feasibility studies for these four priority multipurpose dam sites, which study will assess the technical, social, economic & financial, and environmental viability of these multipurpose dam projects.

2.3. Location of Kagera Project

The location of the sites is shown on the following map within the Kagera River Basin.

Figure 3: location of the four sites within Kagera Project



Source: terms of reference of this study (from USGS-SRTM-NVE-CGIS-NUR)

The coordinates for the axis of each dam based on the terms of reference have been recorded as follows:

Table 1: Coordinates of the four dam sites

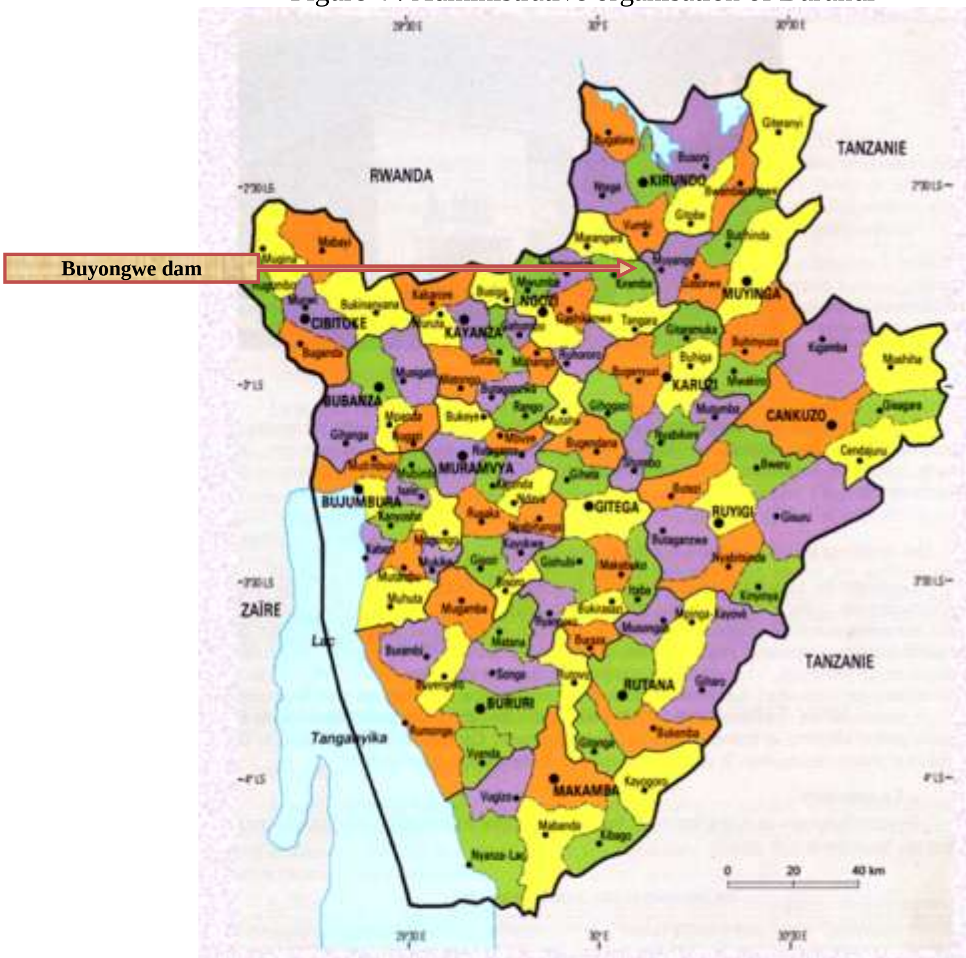
(WGS84 system)

Country	Dam site	Y (DD)	X (DD)	Z (m)
Rwanda	Taba-Gakomeye	-2,50775	29,60169	1659
Burundi	Buyongwe	-2,81669	29,95647	1382
Tanzania	Karazi	-1,82336	31,01526	1324
Uganda	Bigasha	-0,94818	30,89745	1261

2.4. Location of Buyongwe site

Burundi is divided into 17 provinces, subdivided into districts, “communes”, “collines” and “sous-collines”. The following map highlights the location of the Buyongwe dam within the administrative organisation of Burundi:

Figure 4 : Administrative organisation of Burundi



Source: Netpress, Burundi

The administrative area for the entire Project is located within Ngozi Province. The planed dam was located few kilometres downstream the township of Kiremba in Kiremba commune, in the north eastern part of the Ngozi Province, which is composed of 9 communes. Kiremba commune is subdivided into 4 zones and 45 collines.

As the dam site is located on the Buyongwe River, the local communities recommended referring Buyongwe dam instead of Kiremba dam mentioned in the previous study and in the terms of reference. The Buyongwe River is an affluent of the Akanyaru and Nyabarongo Rivers.

Based on the field mission, the coordinates for the axis of the dam was recorded as follows:

Table 2: Buyongwe dam axis coordinates

DAM AXIS COORDINATES					
Site	WGS 84 (DD)		UTM / WGS 84 (m)		Bank
	Longitude	Latitude	X	Y	
			UTM 35S		
Buyongwe - Burundi					
	29,95727	-2,81475	828822,05	9688466,04	Right
	29,95579	-2,81842	828656,31	9688060,26	Left

3. METHODOLOGY

This chapter will present the methodology used all along this report for each specific investigations.

3.1. Methodology for the LiDAR surveying and mapping

3.1.1. Context

The existing maps mentioned in the ToR are 1/50 000 scale (probably 10/15m interval isohyets) and therefore not usable as reference for the tasks under consideration, in particular for dam and appurtenant workings as well as for irrigation design.

A Light Detection And Ranging (LiDAR) survey was undertaken covering reservoir footprint and working areas as specified in the Terms of Reference. LiDAR is an optical remote sensing technology that can measure the distance to, or other properties, of a target by illuminating the target with light, often using pulses from a laser. Another advantage of this technology was the possibility of getting high definition aerial pictures which are of high interest for the social and environmental as well as for the irrigation studies.

3.1.2. Methodology

3.1.2.1. LIDAR POINT PROCESSING

For the purpose of processing the laser points, the ITRF2008 Geographical ellipsoidal coordinates were used. This is necessary as GPS works in the ITRF2008 datum with ellipsoidal heights.

The trajectory was calculated using *Precise Point Positioning* (PPP) as no base stations were occupied for the duration of the aerial survey. The trajectory for each flight was post processed using *Waypoint DGPS* software, which combines the 1 Hz GPS readings with the 200Hz inertial measurement system (IMU) readings and outputs a smoothed "best estimated" trajectory for the laser scanner and camera positions.

Following this, the laser points were processed into raw ENH points, using Optech's *DASHMap* Survey Suite. The output was in the ITRF2008 UTM36 South projection but with ellipsoidal heights.

The final output is in the required ITRF08 UTM36 South projection, with orthometric heights based on the EGM2008 geoidal model.

3.1.2.2. LIDAR CALIBRATION

Overlapping LiDAR points from adjacent aircraft trajectories were used to check the LiDAR calibration for heading, roll, pitch and scale. These values were then used to make small flight-specific adjustments to the LiDAR data.

3.1.2.3. LIDAR POINT TRANSFORMATIONS

The LiDAR points were transformed from the ITRF2008 UTM36 South ellipsoidal coordinate system to the ITRF08 UTM36 South orthometric coordinate system using the EGM2008 geoidal model.

3.1.2.4. LIDAR POINT EDITING

A "1st run" automatic classification was carried out on the raw LiDAR points using *TerraSolid's TerraScan* software to separate the LiDAR points into ground hits and non-ground hits. This results in a greater than 95% correct classification. After this, a manual classification was done over the required area to edit the points with gross classification errors that may have occurred in the automatic classification process.

As requested, the points were also thinned into "key points":

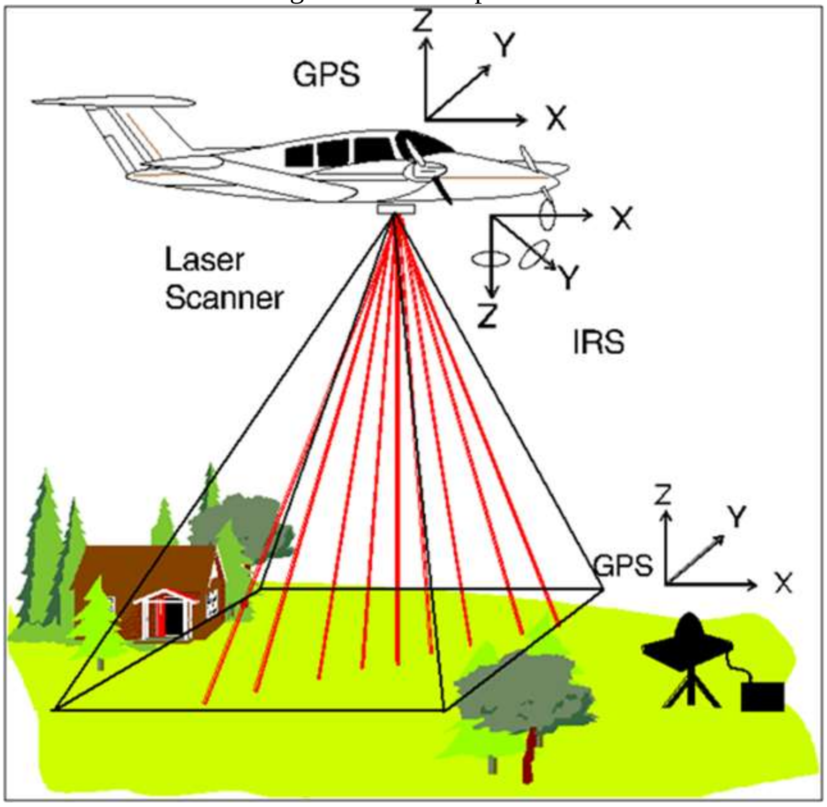
- *Ground* key points are defined in such a way that where a rapid change in elevation occurs, the density of the points is maintained and as such the slope is always well defined. However, where there is relatively little change in elevation the density of the points is reduced because of the fact that far fewer points are required to accurately define the surface.
- *Non-ground* key points are thinned in such a way that the density of point clusters, such as those that define a tree, will be reduced in a manner that still accurately defines the random shape. Points that define elements with a more linear (and less random) shape, such as a power line, will not be as extensively reduced however, so as to maintain the accuracy in the changes of elevation and position relative to the ground surface.

3.1.3. Results

The topographical survey was undertaken in Burundi to produce rectified colour images and a digital terrain model (DTM) of the project area. The survey was carried out using an aircraft mounted LiDAR system that scanned the ground below with a 70 kHz LiDAR resulting in a dense DTM of the ground surface and objects above the ground as shown on the following figure.

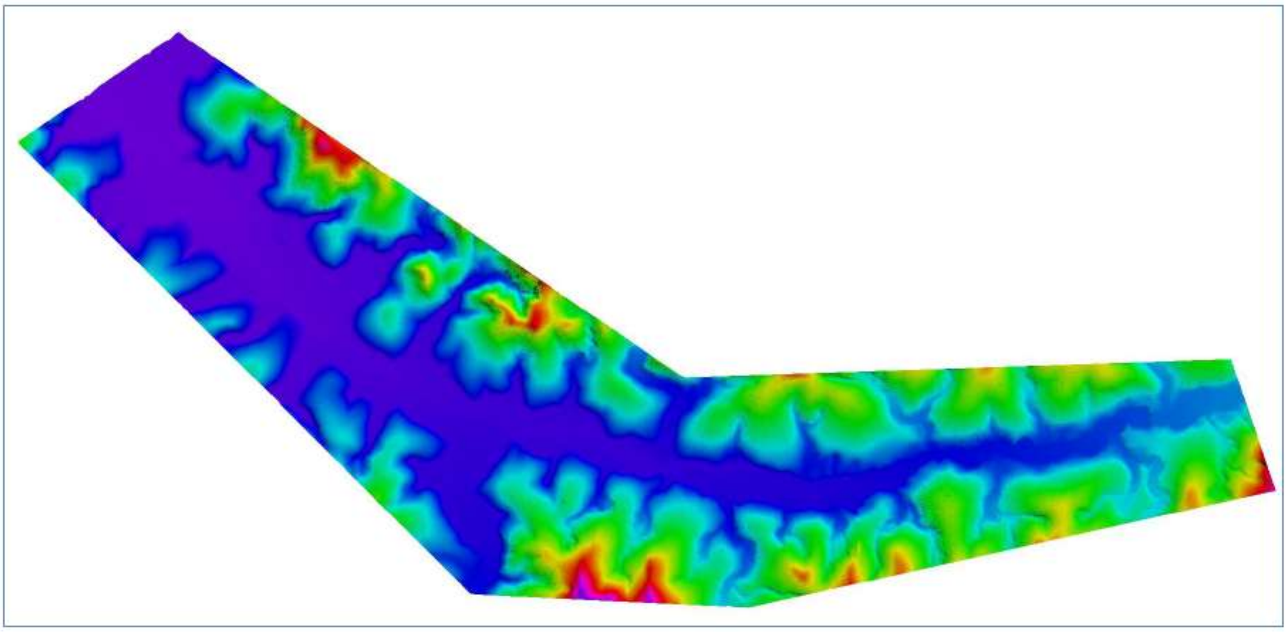
Digital colour images were also taken from the aircraft and rectified to produce colour orthophotos of the project area. The survey was flown at a height of approximately 800m and an image pixel size of 10cm has been produced.

Figure 5: LiDAR process



The project extent was defined on the basis of existing map as well as inception field mission taking into account the potential control area for irrigation. The shaded relief map for the project area is represented as follows.

Figure 6: Buyongwe site shaded relief map in Burundi



Topographical maps based on the LiDAR data have been produced for the dam site (see maps in Appendixes). The data could lead different size of topographical maps that has been used all along this report.

3.2. Methodology for the geophysical and geotechnical investigations

3.2.1. Introduction

Geophysical and geotechnical investigations have been performed geo-referencing the essential soil and rock features so as to establish the engineering properties of rocks and soils, check surfacial deposits and reveal tectonic-structural patterns.

Geophysical investigations have checked the suitability of the selected site for the construction of the dams and appurtenant structures. The geotechnical investigation campaign gave a factual picture of the site and of their characteristics so that the setting out of the workings can be adapted.

3.2.2. Geophysical methodology

The geophysical investigations took place from the 21 to the 31 of January 2012. The following methodology was carried out: Electrical resistivity techniques are based on the response of the earth to the flow of electrical current. Measurements are made by placing four electrodes in contact with the soil or rock. A current is caused to flow in the earth between one pair of electrodes while the voltage across the other pair of electrodes is measured. The depth of measurements is related to the electrode spacing. Several types of electrode configuration and survey geometry exist in resistivity measurements.

Figure 7: Measurements at site

A 2D resistivity profiling consists in a succession of vertical electrical sounding, but interpreted by inversion, with a calculation of the lateral and the topographical effects. In this case, the distance between two electrodes is 5 m on the dam site. The number of electrodes varies from 24 to 48. The investigation depth is about 25 meters.

In these geological contexts, refraction seismic is not adapted. The fresh rock, which is outcropping, presents a very fast velocity. If weathered rocks underlay, it is invisible. On the other hand, the resistivity method is able to visualise this possible geology. More, it is able to locate faults which are difficult to determine with the seismic refraction method.

3.2.3. Geotechnical methodology

In addition to the geophysical investigations presented above, the Consultant performed geotechnical investigations in the form of 10 test-pits dug to 5m depth in naturally consolidated soils in order to sample the composition and structure of the subsurface. The test-pits aim at complementing the geophysical investigations and at checking the potential permeability of the reservoir so that the geological hazards are mitigated.

The location of the test-pits were properly selected with the Geophysical Engineer and the Civil Infrastructure Engineer and recorded by GPS. The procedures and methods used in the profiling of the test pits adhere to internationally accepted codes.

Test pitting was undertaken manually to the maximum depth (about 5m) or refusal, whichever occurs first.

After excavation all test pits were photographed and profiled by a qualified engineering geologist. Soil samples were taken where required, following which test pits were backfilled:

- Soil Classification (5 samples per test pit):
  - Specific gravity
  - Sieve analysis
  - Water absorption
  - Silt content
  - Moisture content
  - Atterberg Limits

- Strength and Deformation Test (2 per pits):
  - Direct Shear Test
  - Compaction MDD
  - California Bearing Ratio – 3 ptd 97% MDD
  - Consolidation Test - Œdometer
  - Permeability Test – constant Head

Figure 8: Light Dynamic Cone Penetrometer tests used in Burundi

The Consultant identifies, geo-references possible source of construction materials and took samples for laboratory testing to assess their engineering properties. The aggregate tests (2 per quarry) will consist on:

- Los Angles Abrasion
- Aggregate Crushing Test
- Sodium Sulphate
- Specific gravity + Water Absorption
- Soluble salts
- Aggregate Impact Value
- Alkali reaction.

3.3. Methodology for the hydrological study

3.3.1. Context

The availability of hydrological records has conditioned the way of executing the studies: if no direct data is available, the determination of the classic parameters has been carried out by correlation to neighbouring known catchments or through internationally accepted methods.

The results included in this report are the main results for Burundi in order to understand the findings of the entire report. The hydrological report is annexed in the Appendix E.

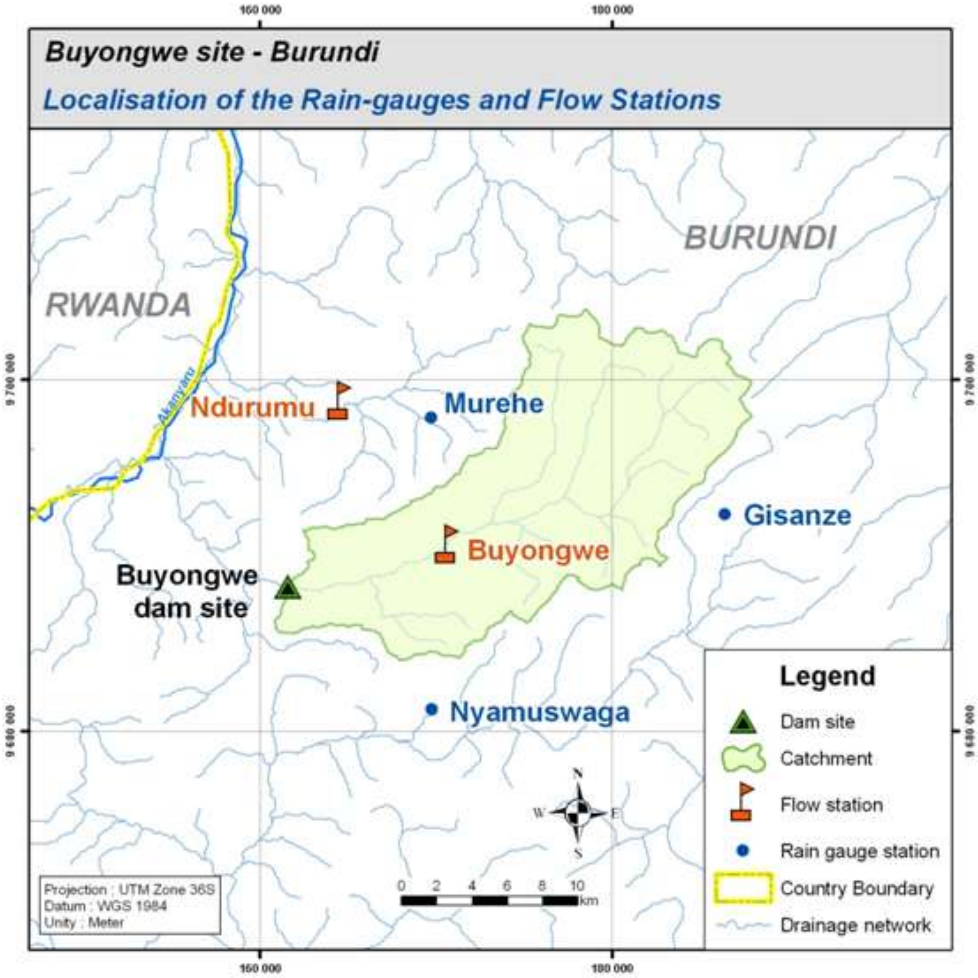
3.3.2. Data

Hydrological and rainfall information has been collected from the AQUALIUM database provided by the Client:

- Rainfall stations are Nyamusgawa, Gisanze and Muruhe (mission) stations, all located in the close vicinity of the catchment (Figure 9).
- Gauging stations of interest are Buyongwe GS (186 km²), Ndurumu (111 km²), and Gitega (6 250 km²).

Buyongwe GS and Ndurumu gauging stations are of major interest here since they are expected to be representative of the Buyongwe dam catchment hydrology. Unfortunately, the records are dramatically short, respectively 7 and 13 years. For both stations, gaugings and gauge records have been processed to obtain daily and monthly discharges for the observation period. After that, monthly records at Buyongwe GS and Ndurumu have been extended to the 1940-2009 period by correlation between both stations and Gitega monthly discharge records. A key point was to obtain a reliable hydrological regime.

Figure 9: Localisation of rain gauges and gauging stations for Buyongwe dam site



3.3.3. Monthly discharge record

The monthly discharge record has been obtained using Ndurumu and Buyongwe GS records in the following manner:

$$Q\ Buyongwe = \frac{\frac{Qyr\ (Buyongwe)}{Qyr\ (Ndurumu)} \times Q\ Ndurumu + \frac{Qyr\ (Buyongwe)}{Qyr\ (Buyongwe\ GS)} \times Q(Buyongwe\ GS)}{2}$$

3.3.4. Methodology for the sediment measurements

For the sedimentation issues, guidelines from World Meteorological Organization and Dr. Mkhandi S.H. report from Department of Water Resources Engineering recommended that the sampling points for suspended sediment have to be located at the hydrometric stations. Indeed, sediment measurements have to be coupled to discharge measurements to compute relationships between liquid and solid discharge measurements. Unfortunately, the gauging station of Buyongwe dam site catchment is not gauged any more. A sedimentological measurement campaign will not be relevant without gauging.

Thus, in order to assess the sedimentation rate, the Consultant has used existing sedimentation data within the catchment area. As mentioned in the hydrological study (see Appendix E), Buyongwe dam site is located in the upstream half part of the basin (zone I and II) as well as Upper Ruvubu, Ruvyironza, Kanyaru and Nyabarongo reservoir projects. Sediment data from Nyabarongo and Ruvubu Rivers have been considered representative of the sedimentation rate of Buyongwe dam site.

3.3.5. Methodology for the optimization of the reservoir capacity

3.3.5.1. OBJECTIVE OF THE OPTIMIZATION

Dams mainly serve to ensure an adequate supply of water by storing water in times of surplus and releasing it in times of scarcity, thus also preventing or mitigating floods. Dams that have small storage capacity in relation to the gross Mean Annual Runoff (MAR) are known as “annual dams”. They are likely to fill from empty every year except the very worst seasons or even single floods.

The methodology adopted is a Sequential Stream flow Routing (SSR) and according to this method a continuity equation of the water volumes is applied to calculate reservoir levels and therefore reservoir volumes, evaporation and outflows from spillway and outlet structure.

The erratic inflow of the river passes through the storage reservoir will be delayed and attenuated as it enters and spreads over the reservoir surface. Water is then released through a controlled outlet.

The optimization consists of determining the minimum reservoir capacity which allows an average constant water release with an acceptable deficiency.

3.3.5.2. METHODOLOGY

The aim of the reservoir operation simulation is to determine the total reservoir capacity which will meet the downstream demand. The methodology used to perform the reservoir operation studies was as follows:

- A series of monthly water inflows at the dam site, over a number of years sufficient to be representative of the long-term flow pattern was established;
- The downstream water demand with the aim of allocated all inflows available was established;

- The balance between the water flowing into the reservoirs and the water flowing out of the reservoirs (water demand, spillage, and evaporation) was determined on a monthly time-step basis. The results of the balance are the volume and the levels of the reservoir at the end of each month, and the water provided to meet the demand.
- The simulations were performed assuming that the reservoirs capacity is constant throughout the whole period of simulation (38 years). Allocation for sediment storage has been taken into account by setting the outlet structure threshold above the dead storage level.
- A criterion defining the ability of the reservoirs to meet the water demand has been established. This criterion quantifies the frequency and the volume of shortfalls that might occur and answers the question regarding the risk of not meeting the demand. The definition of water demand shortfall (deficiency) is the number of month when the water demand is not satisfied divided by the total number of month of the simulation.

Several reservoir capacities were tested for which the deficiency has been evaluated. For each of those reservoir capacities, the discharge guaranteed 10% of the time has been computed.

3.4. Methodology to define the water uses and water demand

3.4.1. Methodology for the water demand

The chapter about water uses and water demand aims to describe at first the existing water uses in the Project area (irrigation, water supply, livestock watering, aquaculture, hydropower), then to assess the potential demand and finally check the technical and economic constraints of the associated installations and finally state about a feasibility development level for each potential water use.

3.4.1.1. IRRIGATION WATER DEMAND METHODOLOGY

Irrigation water requirement:

Irrigation water requirement (IWR) depends on several factors, including cropping patterns, crop-growth periods, crop coefficients (Kc), potential evapotranspiration (ETo), effective rainfall and deep percolation for rice paddies.

Irrigation water requirement is calculated by multiplying crop area and crop water requirement (CWR) of respective crop. CWR is usually measured in terms of evapotranspiration and depends on climatic conditions and constraints in each area. The irrigation water requirement for each crop is estimated as follows:

$$IWR = \Sigma Crop\ Area \times [CWR - Effective\ rainfall]$$

CWR of the paddy crop is estimated as:

$$CWRrice = [\Sigma(KcricexETo) + Deep\ percolation]$$

Crop water requirement (CWR) for other crops is estimated as:

$$CWRother\ crops = \Sigma\ (Kcother\ crops\ xETo)$$

Water demand forecasting for irrigation:

Agricultural water demands are primarily a function of the following:

- Meteorological conditions;
- Crop type;
- Cropped area for each type of crop;
- Type of irrigation method and irrigation efficiencies;
- Water charges (to be discussed with the local Authorities).

In estimating future agricultural demands the changes in one or more of the above factors must be predicted. Owing to the potential for changes in the future and the relatively few variables, component analysis is the forecasting methodology likely to yield the best results.

Component analysis is a forecasting method based upon the usage of water by individual components. The expected trends in water demand of each component (e.g. changes in irrigation technology, climatic changes, crop type and irrigation area) should be analysed separately and the overall result assessed.

Meteorological conditions are yet changing due to the effects of global warming. For agriculture, the basic factors are rainfall and evaporation rate. As rainfall decreases and/or evaporation rates increase, the irrigation needs increase or vice versa.

Changes in crop type may also have a significant impact on water demands, which may or may not be positive. High value crops such as bananas and garden vegetables generally have higher water requirements than, for example, grain crops.

Changes in cropped area may either be a difference in total surface, if new land is developed or cultivated land becomes fallow, or be the result of variations of crop type, if the surface of one crop type is changed to accommodate changes in another type.

Losses and inefficiencies usually account for a significant proportion of total irrigation requirements both for lack of proper drainage and for improper technologies. Their impact may be alleviated through various improvement programmes and the specialist will have to determine the chances and extent of these.

Creating water user associations can also affect water demand and use. The main purpose behind water user associations is to assure better access to water and unbiased equity in distribution. Hence, while water user associations are beneficial in many ways, their establishment may increase water demands. Water charges have a significant impact on water demands because of the incentive to reduce waste in water application, though consideration must be given to willingness to pay and ability to pay on the part of the water users (but this would not be applicable to the conditions prevailing in the four sites concerned).

Changes in irrigation technology may also affect the water demand. Modern technologies that deliver water to the plant more efficiently reduce overall demand by diminishing field losses and non-beneficial evapotranspiration.

Improvements of water management and irrigation system operation at field level also reduce irrigation water use by improved efficiency and reduced losses.

Other means of limiting agricultural water uses is practising new techniques such as precision irrigation and deficit irrigation, though the aptitude of farmers to adopt such techniques must be assessed and assistance extension services supplied if too low.

3.4.1.2. WATER SUPPLY DEMAND METHODOLOGY

Water supply requirement:

In general estimating rural water demand and use is difficult because the majority of rural domestic water supply systems are manpowered or unmetered, data concerning domestic rural water demand and use is often expensive and time consuming to collect and the level of service provided by the water supply system is often unknown.

There are two key methods of assessing rural domestic demand and use. These are:

- Indirect methods, where the quantity of water consumed is calculated from population levels and estimated demand levels in terms of per capita consumption;
- Direct methods where socio-economic surveys and participatory techniques involving the relevant stakeholders are used to estimate the current and future water demand and use.

The Consultant has followed indirect approach which is considered as the most practical method. For such approach, the following information is required:

- Population data;
- Per capita water demand;
- Unaccounted for water levels i.e. the difference between the total quantity of water abstracted and the quantity of water consumed.

Uganda and Rwanda's national water sector policies have a target per capita water demand of 20 litres/person/day for rural water supply.

Forecasting water supply demand:

Historical information for domestic water demand and use in rural zones is unlikely to be available. This means that it is impossible to directly assess the future rural domestic water demand and use through trend analyses. The two most important factors that affect future domestic water demand and use are:

- Population growth (the annual ratio of the area is very high);
- Change in the level of service due to an upgrading trend in the water supply needs.

Population growth can be estimated from national, regional or local trends. It should however be noted that improvements in infrastructure, such as multipurpose water schemes, may step up the population growth above the average.

Upgrading of water supply schemes and the consequential changes in the level of service are difficult to predict. It has been postulated that the upgrading of rural water supply schemes is related to Tariff levels where distribution metered network can be planned (in suburban zones).

For sake of simplicity and accounting for the inaccuracy of statistical data, the Consultant will make assumptions concerning the upgrading (e.g. from a reservoir connection to a communal borehole to house connection).

The increase in water demand may also be estimated from other areas where similar upgrading of the water and sanitation infrastructure has occurred.

Tanzanian Water Design Manual provides following data per capita demand based on levels of service. The following table has been finally adopted for this assignment.

Table 3: Water supply data per capita demand

Water Supply	Urban	Peri-urban	Rural
Communal Water Points / others	30%	60%	80%
Yard Taps	20%	20%	20%
Multiple Taps House Connection	50%	20%	0%

This document provides as well the levels of services, based on affordability, meaning income levels. The following table provide the level of services per capita demand.

Table 4: Level of services per capita

Levels of Services	Litres / person / day (Lpd)
Communal Water Points / others	25
Yard Taps	70
Multiple Taps House Connection	150 for high income 100 for middle income as a mean – 120 lpd

On these data, it is normal practice to add 30% to the domestic water demand for non-domestic demand.

This Manual in Section 4.7 reports as well system losses that have to be accommodated for in the production end. It states that the 25% is grossly underestimated. For piped system therefore, a 30% is added to total water demand for losses.

Table 4.21 of the Manual gives peak day factor for various users varying between 1,00 and 1,50 and the weighted one normally used is 1,15, as the climate variance is not significant in the tropical climate.

3.4.1.3. WATER DEMAND FOR LIVESTOCK

<u>Water requirement for livestock:</u>

The livestock water requirement is estimated by multiplying the number of livestock animals times the water use per head of livestock (Litre/day per animal).

<u>Water demand forecasting for livestock:</u>

The forecasting of the future water demand for livestock will be primarily based on the assumption that the water use per head is kept constant (according to the breed and purpose of the stock) and the livestock number is projected on the base of the growth trend in past years.

Section 4.6.4 of *Tanzanian Water Supply Design Manual* is dedicated for livestock water demand assessment. The livestock unit is defined as follows:

One Livestock Unit (LSU) is equivalent to:

- one head of cattle
- 2 donkeys
- 5 goats or sheep
- 30 heads of poultry (hens, ducks etc)
- 0,5 or 0,33 high grade dairy cow

Livestock growth depends on land carrying capacity and water availability. If both conditions suffice, then 10 years growth can be up to 25% and 20 years growth up to 50% at an annual rate of 2,6% for cattle and 2% for goats / sheep.

The Manual recommends 25 litres/LSU/day and segregated as follows:

- Dairy Cow: 50 - 90 litres/day (50 adopted)
- Local Cattle: 25 litres/day
- Sheep and goat: 5 litres/day
- Donkey: 12,5 litres/day
- Pig: 10 litres/day
- Poultry: 30 litres/100 birds/day

This methodology has been used for this study.

3.4.1.4. WATER DEMAND FOR FISH FARMING

The section will deal with fish production using ponds (closed system) and neither cage nor continuous (open system) flow. In addition, the ponds that will be proposed will not be mechanized for aeration or pelleted feeds.

According to the “Inland fisheries and aquaculture” report (Patrick Dugan et al., 2007), mechanically aerated and pelleted feeds can produce fish up to 10 000 kg/Ha. The cage production can produce up to 100 kg/m3. On the other hand normal pond fish production is as follows:

- regularly stocked and fertilized Tilapia: 1 000 to 2 000 kg/Ha of pond/year
- as above but with brewery waste, oil seed cakes, brans and manure: 3 000 to 5 000 kg/Ha/year
- unfertilized ponds: 320 kg/Ha/year

In the “Guiding principles for promoting aquaculture in Africa” (FAO and Worldfish Paper No 28, 2006), full fish ponds design procedure has been provided. The tank size is normally L:W:D = 30:3:1 in order to maximize the flushing. Fish farming water demand is not significant after catering for evaporation and percolation into soils and will mainly depend on space available for ponds installation. Alternatively, the ponds size should be dependent on the demand for fish in the locality and the existing marketing system.

In the “Strategic assessment of warm water fish farming potential in Africa” (FAO by Kapetsky, Technical Paper 27), the relationship between population density and the occurrence of fish farming is studied: based on assumptions about farm-gate sales, population density is interpreted as local market potential.

Fish farms do occur at densities of <5 person/km^2 and a limited amount of data from Zambia and Tanzania indicates that even at these densities, there are commercial activities.

There is a tendency for the density of fish ponds per district to increase with increasing population density. However, because the population data are in rather broad ranges, attempting to develop a regression relationship was not possible. To examine the effect of local demand on fish farming potential, the following assumptions were made to estimate the number of *subsistence* and commercial farms that could be supported by farm-gate sales at given population densities.

The assumptions were:

- Pond area of 0,04 ha sizes and an output of 2 t/ha/year for a subsistence farm; respective area and output for a modest commercial farm at 0.4 ha pond sizes and 3 t/ha/year;
- Farm-gate sales confined to an easy walking distance: a 2 km radius of the farm for a subsistence farm; a 4 km radius for a commercial farm due to an implicit proximity to an all-weather road, making a commercial farm more easily accessible for walk in and drive in customers than for a subsistence farm.
- A potential market of 1 kg of fish/person/year for a population within a 2 km radius for a subsistence farm and the same for a population within a 4 km radius for a commercial farm. One kg of fish/per caput is about 10% of all Africa mean fish consumption per caput.
- 50% of the output sold at the farm-gate for a subsistence farm and 25% of the output for a commercial farm.

The population density has been used to establish demand for fish and by extension demand for fish ponds.

3.4.1.5. HYDROPOWER DEVELOPMENT

Simulation has been carried out for power generation at the dam site. The methodology is the same as described in chapter 3.3.5 about optimization of the reservoir capacity, except that the water demand is now defined by the requirement of energy production.

Initially, the firm energy at the dam is determined, that is to say energy production that can be provided by the reservoir at a given failure rate (failure admitted here: 10% of the maximum time). This production is the average energy response, assumed constant throughout the year.

In the simulations, the firm energy is determined by iteration according to a monthly time step, changing the value of the demand to obtain the rate of deficit (or failure) desired.

The calculation allows for variations in the height of the reservoir between the Full Supply Level (FSL), above which the excess water spilled, and the Minimum Operating Level (MOL) below which energy can be produced (deficit).

In a second step, the secondary energy produced is computed. Secondary energy is the energy obtained by turbine of excess water, once the energy product is guaranteed and the reservoir is full.

The total energy is then defined as the sum of firm energy and secondary energy.

Every month, the energy produced is determined by the following formulae:

$$E = P \times Nb \times 24$$
$$P = Q \times g \times \Delta H \times \rho$$

Where:
P: Power in kW
E: Energy in kWh
Nb: Number of days in the month
g: 9,81 m/s²
ΔH Net head
ρ Turbine efficiency

It is to be noted that in this simulation, the power demand is constant and the water demand varies accordingly depending on the available net head (reservoir water level). The head losses has been assumed to be 10% of the total head and the turbine efficiency equal to 0,8.

3.4.1.6. ENVIRONMENTAL FLOW REQUIREMENT

The Hydrological Index Method is one of the various approaches used to estimate environmental flow requirements. This method is based on simple indices, as a percentage of average annual flow or a percentile from the flow duration curve, on monthly basis. The indices used for environmental flow assessment in various countries of the world are provided below:

• France: A hydrological index is used in France, where the freshwater fishing law (June, 1984) required that residual flows in by-passed sections of river must be a minimum of 1/40 of the mean annual flow (MAF) for existing schemes and 1/10 of the MAF for new schemes (Souchon and Keith, 2001).

• United Kingdom: In regulating abstractions in UK, an index of natural low flow has been employed to define environmental flow. Q95 (i.e. that flow exceeded 95% of the time) is often used. The figure of Q95 was chosen purely on hydrological patterns. However, the implementation of this approach often includes ecological information (Barker and Kirmond, 1998)

• USA (Tennant method): Tennant (1976) developed a method using calibration data from hundreds of sites on rivers in the mid-western states of the USA to specify minimum flows to protect healthy river environment. Using USGS data, this method is based on aquatic habitat being very similar when they are carrying the same proportion of the average flows. Ten per cent of the average flow is a minimum instantaneous flow recommended to sustain short-term survival habitat for most aquatic life forms (Poor or minimum habitat). Thirty per cent is recommended as a base flow to sustain good survival conditions for most aquatic life forms and general recreation (fair and degrading habitat). Sixty per cent provides excellent to outstanding habitat for most aquatic life forms during their primary periods of growth and for the majority of recreational uses. In a large river, it can be useful in developing a quick response, such as for evaluating water right application potential impacts.

Taking into account that Buyongwe site is characterized with poor or minimum habitats, an environmental flow of 10% of the MAF have been retained for the site. Furthermore, such a criterion is also applied in France for new schemes.

3.4.2. Methodology for the evaluation of each potential water use

3.4.2.1. CONTEXT

SWECO has carried out the "Development of Kagera Integrated River Basin Management and Development Strategy" study for NELSAP in 2010. In the table 1.5 of the main report, a water use prioritization exercise has been carried for each district or province and has been expressed in the following summary table. This table shows that the water supply is always the main prioritization.

Figure 10: Water use prioritization

No.	Administration	Water Supply and Sanitation	Soil and Water Conservation	Irrigation and Drainage	Fisheries	Flood Mitigation	Drought Mitigation
1	2	3	4	5	6	7	8
	Burundi						
1	Kirundo	H	H	H	H	H	H
2	Ngozi	H	H	H	L	H	M
3	Kayanza	H	H	M	L	M	M
4	Muramvya	H	H	L	X	L	M
5	Bujumbra R.	H	H	X	X	X	L
6	Mwaro	H	H	L	X	L	M
7	Bururi	H	H	X	X	X	L
8	Rutana	H	H	X	X	X	M
9	Gitega	H	H	H	L	H	M
10	Ruyigi	H	H	L	L	L	M
11	Karuzi	H	H	M	L	M	H
12	Cankuzo	H	M	L	L	L	M
13	Muyinga	H	M	M	L	M	H
	Tanzania						
1	Ngara	H	M	L	L	L	H
2	Biharamulo	H	M	L	L	L	H
3	Karagwe	H	M	H	H	H	H
4	Muleba	H	L	L	H	L	H
5	Bukoba	H	L	H	H	H	M
	Uganda						
1	Rakai	H	M	L	X	L	H
2	Isingiro	H	H	M	L	M	H
3	Mbarara	H	H	L	X	L	H
4	Ntungamo	H	H	M	X	M	H
5	Kabale	H	H	L	X	L	M
6	Kisoro	H	H	X	X	X	H

H = *high* M = *medium* L = *low* X = *insignificant*

No.	Administration	Water Supply and Sanitation	Soil and Water Conservation	Irrigation and Drainage	Fisheries	Flood Mitigation	Drought Mitigation
1	2	3	4	5	6	7	8
	Rwanda						
1	Musanzi	H	H	M	H	M	L
2	Gakenke	H	H	M	L	M	L
3	Rulindo	H	H	L	X	L	L
4	Gikumbi	H	H	L	X	L	L
5	Nyabihu	H	H	M	X	M	L
6	Ngororero	H	H	L	L	L	L
7	Rutsiro	H	H	X	X	X	L
8	Karologi	H	H	L	L	L	L
9	Nyamagabwe	H	H	L	X	L	M
10	Nyaroguru	H	H	H	X	H	M
11	Gisagara	H	H	H	L	H	H
12	Huye	H	H	L	X	L	H
13	Nyanza	H	H	H	L	H	H
14	Ruhango	H	H	H	L	H	H
15	Muhanga	H	H	H	M	H	M
16	Kamonyi	H	H	H	L	H	H
17	Nyarugenge	H	H	H	L	H	H
18	Kicukiro	H	H	H	L	H	H
19	Gasabo	H	H	M	X	M	H
20	Bugesera	H	H	H	H	H	H
21	Rwamagana	H	H	H	H	H	H
22	Ngoma	H	H	H	H	H	H
23	Kirehe	H	L	H	H	H	H
24	Kayonza	H	L	M	H	M	H
25	Gatsibo	H	L	M	H	M	H
26	Nyagatare	H	L	M	H	M	H

H = *high* M = *medium* L = *low* X = *insignificant*

Source: "Development of Kagera Integrated River Basin Management and Development Strategy" by SWECO in 2010

3.4.2.2. ANALYSIS

This above study and the socio-economic survey reported in appendix G lead to prioritize the water demand. However it should be taken as well into consideration the technical feasibility of each use as well as the economic analysis.

3.5. Methodology for the Initial Environmental and Social Examination (IESE)

3.5.1. Position within the Study and goals

The environmental and socio-economic analysis has been carried out since the beginning and concurrently with the engineering studies. Consequently, the former will orientate the latter in order to develop the most needed water uses according to requirements and capacities of the riparian population, to minimize and mitigate the impacts of the dam and reservoir construction on physical, biological and human environment and to reduce such impacts.

Planned at the early stage of the project development, the IESE may also orientate and bring inputs (and reciprocally) to the regulatory ESIA studies (carried out independently by another consultant), if the time schedules of both allow for.

Regarding environmental issues, the present study is to be considered as preliminary since environmental feasibility, identify environmental challenges, main impacts and mitigation actions will be actually addressed by the ESIA consultant.

The overall output is the Initial Environmental and Social Examination Report concluding on the "environmental feasibility" of the scheme. Conclusions have been based on the impact assessment for the project and the justification of fatal flaws or critical impacts, if any, for the concerned project.

3.5.2. Regulatory context of projects financed by the World Bank

3.5.2.1. LARGE DAM DEFINITION CONTEXT

The World Bank distinguishes between small and large dams in the Operational Policy 4.37 as follows.

(a) Small dams are normally less than 15 meters in height. This category includes, for example, farm ponds, local silt retention dams, and low embankment tanks.

(b) Large dams are 15 meters or more in height. Dams that are between 10 and 15 meters in height are treated as large dams if they present special design complexities--for example, an unusually large flood-handling requirement, location in a zone of high seismicity, foundations that are complex and difficult to prepare, or retention of toxic materials. Dams under 10 meters in height are treated as large dams if they are expected to become large dams during the operation of the facility.

This definition of "large dams" is based on the criteria used to compile the list of large dams in the World Register of Dams, published by the International Commission on Large Dams (ICOLD).

3.5.2.2. WORLD BANK OPERATIONAL POLICIES

The World Bank group has served as a forerunner by defining Operational Policies (OP) that serve as guides as part of the assessments of the projects submitted to this body for financing. The Bank classifies each proposed project to determine the appropriate extent and type of Environmental Assessment. The World Bank classifies the proposed project into one of four categories, depending on the type, location, sensitivity, and scale of the project and the nature and magnitude of its potential environmental impacts.

The main directives and policies that apply here are the following:

- OP 4.01: "Environmental assessment";
- OP 4.04: "Natural habitats";
- OP 4.11: "Physical cultural resources"
- OP 4.12: "Involuntary resettlement": For Kagera Project, it is worth to mention that:
  - "Involuntary resettlement should be avoided where feasible, or minimized, exploring all viable alternative project designs";
  - "Where impacts on the entire displaced population are minor, or fewer than 200 people are displaced, an abbreviated resettlement plan may be agreed with the borrower".
- OP 4.37: In this OP, the World Bank considers that "generic dam safety measures designed by qualified engineers are usually adequate" for small dams.
- OP 7.50: "Projects on international waterways".

3.5.3. Regulatory context within the NBI

The NBI has taken steps to put in place systems and mechanisms to ensure environmental and social safeguards in all its interventions at the following three key levels:

- Basin-wide level,
- Sub-basin (SAP) levels,
- Project level.

The NBI has issued an Environmental Assessment Framework for Regional Power Projects and a Preliminary Environmental and Social Management Framework for Project Preparation and Implementation.

It should be noticed that, as a rule, any project funded through development partner funding will be subject to internationally accepted environment screening, following Wold Bank guidelines and / or development partner requirements.

It is specified that some environment and socio-economic key issues should be taken into consideration for mitigation measures during the ESIA.

4. TECHNICAL STUDIES

4.1. Introduction

This report will take into consideration the findings of the previous reports, which has changed the design of the project. Thus, this chapter will present at first the main findings of all investigations and surveys for the site, meaning:

- Aerial survey;
- Geophysical and geotechnical investigations;
- Hydrological analysis;
- Water uses and water demand.

The preliminary design and costing could then be presented taking into account the previous results and the decision of the country following these findings.

Based on these design results, the initial environmental and social examination will then give the first results mainly based on the aerial survey.

4.2. Aerial survey for Buyongwe site area

4.2.1. Context

The topographical survey was undertaken on the 4th March 2012 to produce rectified colour images and a digital terrain model (DTM) of the project area following the methodology described in the chapter 3.1.

The survey was carried out using an aircraft mounted LiDAR system that scanned the ground below with a 70 kHz LiDAR resulting in a dense DTM of the ground surface and objects above the ground.

Digital colour images were also taken from the aircraft and rectified to produce colour orthophotos of the project area.

The survey was flown at a height of approximately 800m and an image pixel size of 10cm has been produced.

4.2.2. Results

Two beacons were placed, constructed and painted for the site. The points are SMCA120207 and SMCA120208.

The values of these surveyed points are as follows in the coordinate system:

<u>ITRF08 Geographic</u>

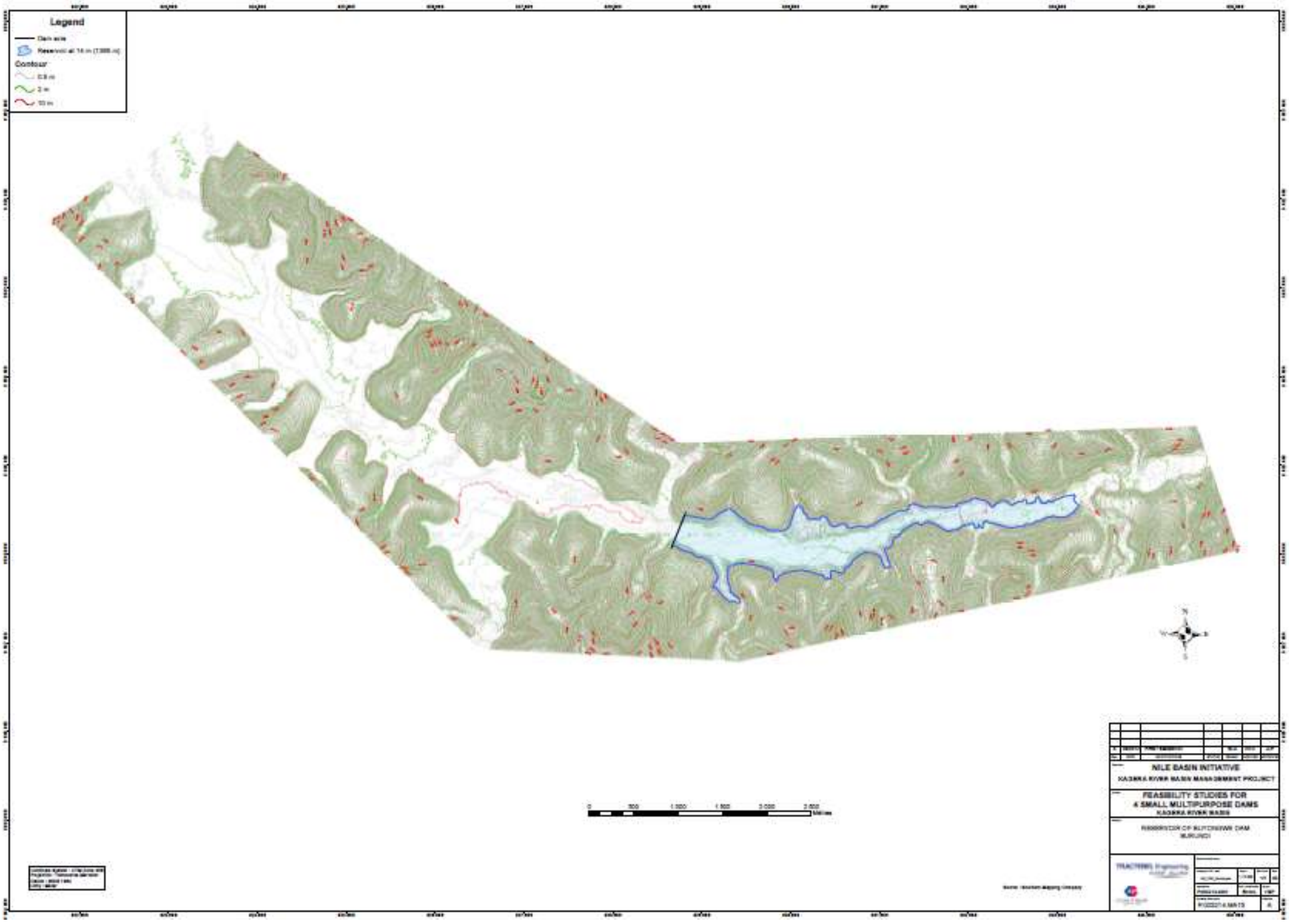
Name	Longitude	Latitude	Ellipsoidal Height (m)	Orthometric Height (m)
SMCA120207	-2 47 21.8453	29 55 23.5696	1445.97	1454.43
SMCA120208	-2 48 50.3227	30 00 9.45800	1400.03	1408.70

<u>Coordinate system: ITRF08 UTM35 South</u>

Name	Easting	Northing	Ellipsoidal Height (m)	Orthometric Height (m)
SMCA120207	825038.99	9691281.10	1445.97	1454.43
SMCA120208	833870.19	9688538.53	1400.03	1408.70

The following topographical map has been defined based on the aerial survey. This map includes the reservoir drawn at FWL for a 14m dam as requested by the Terms of reference. It will be used for the first analysis of the potential impacts in case of 14m dam construction. The aerial survey of the downstream area was as well carried out in order to take into consideration the potential irrigation area.

Figure 11: Buyongwe topographical map based on LiDAR survey



Aerial survey leads to provide detailed topographical map for the overall project, which will be used for the different components of the project (dam, irrigation scheme, etc) as well as the identification of the main environmental and social impacts. Aerial orthoimages leads to provide detailed aerial views of the different infrastructures which will be taken into account in the project and for the land use.

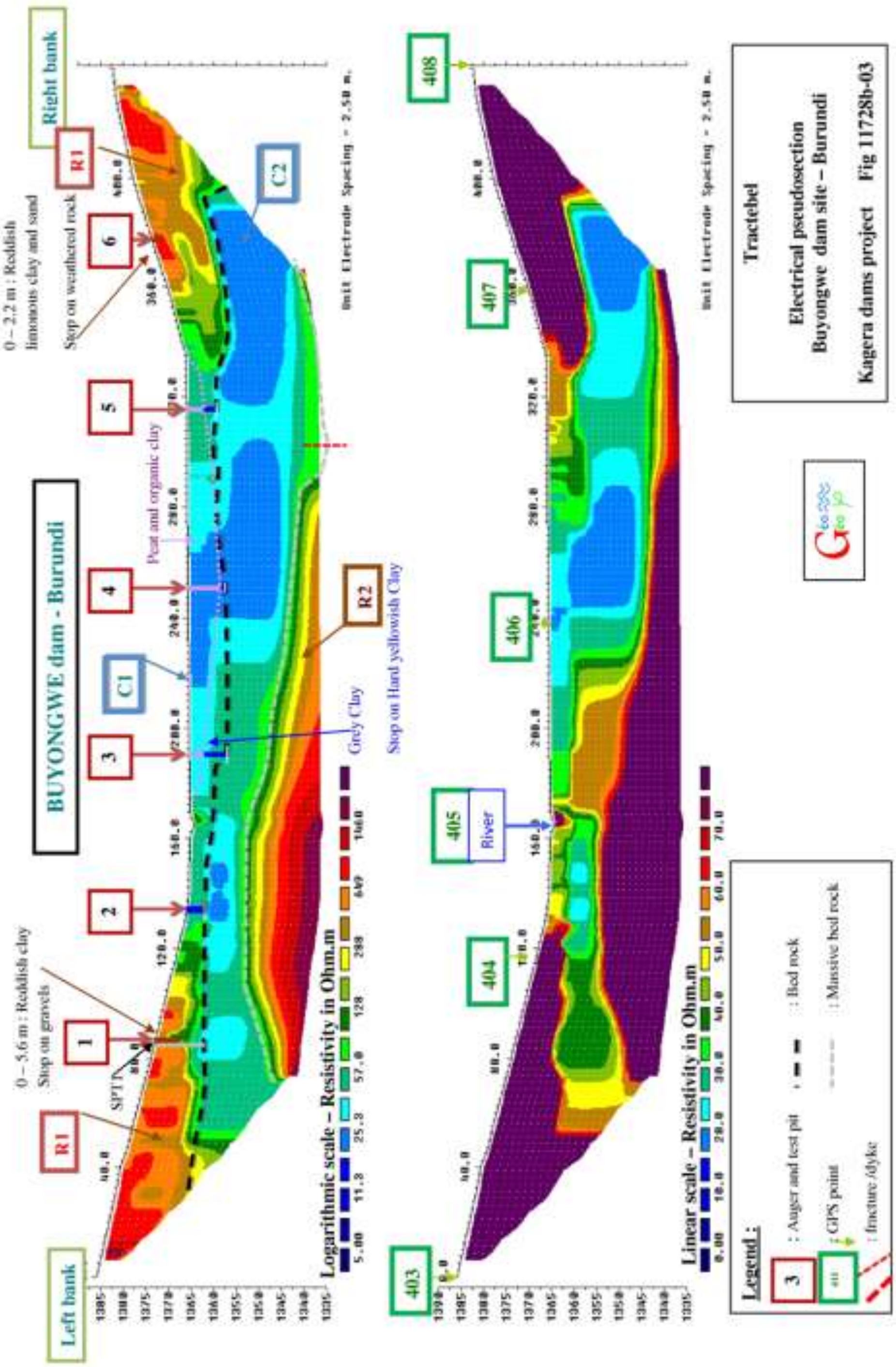
4.3. Geophysical and Geotechnical Investigations

This chapter is an extract of the geotechnical report (see appendix F). The hypothesis taken was a 14m high dam located as stated in the terms of reference.

4.3.1. Geophysical investigations

The geophysical survey carried out on Buyongwe dam site was calibrated by six boreholes and tests pits located along the proposed dam axis (see Figure 12). The appendix F includes all the results of the investigations.

Figure 12: Geophysical profile of Buyongwe dam axis



The main findings following the geophysical survey are the followings:

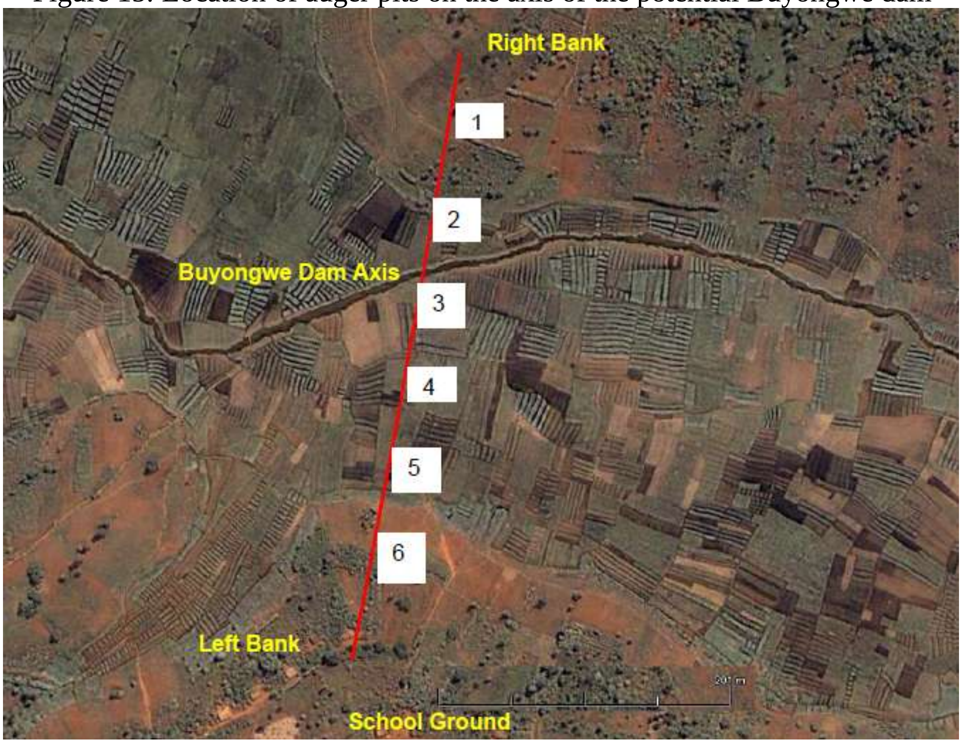
- In the valley, the 0 – 8.4 meters are composed of peat and organic clay laying and grey clay (see the following figures). The peat and organic soils and clay could be an issue for the construction of a dam below the foundations. The weathered part is roughly 10 to 20 meters thick.
- On the banks, 0-20 meters are composed of reddish clay to sand and gravels, which correspond to lateritic soils. There are laying on C2 entity of the previous figure, attributed to saprolite and weathered bedrock, then massive rock R2.

Figure 13**:** Soil Type Auger 2 - Clay	Figure 14**:** Soil Type Auger 3 - Peat
Source: Geotechnical investigations – March 2012	
	

4.3.2. Geotechnical investigations

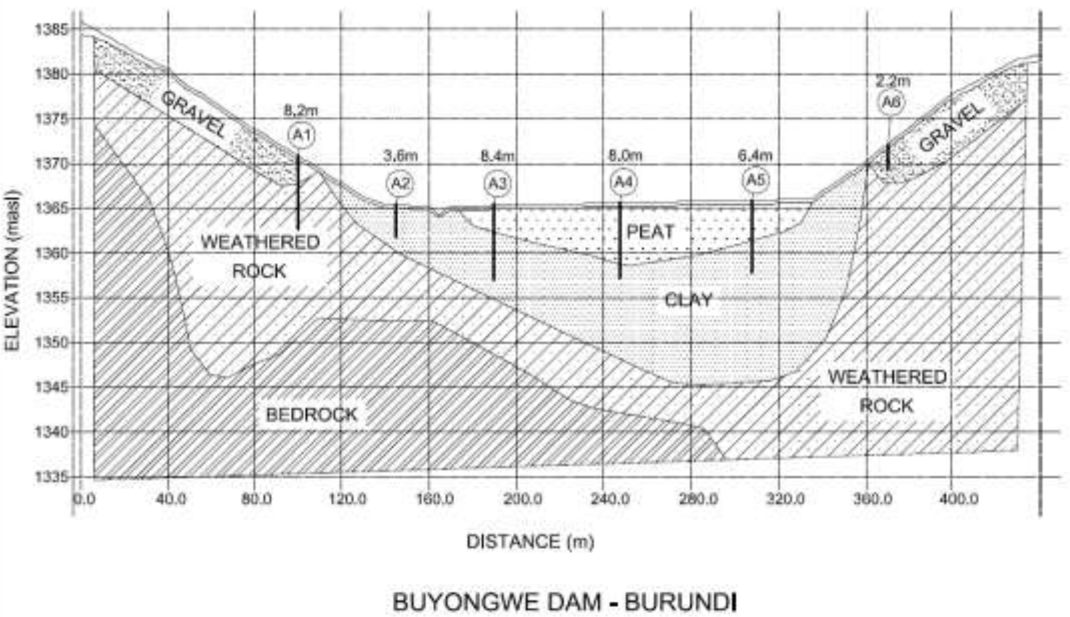
The auger pits for the geotechnical investigations are located as follows on the potential axis of the dam as defined by the ToRs.

Figure 15: Location of auger pits on the axis of the potential Buyongwe dam



The following figure shows the profile of the dam axis based on the results of the geotechnical investigations detailed in the appendix F.

Figure 16: Buyongwe dam axis profile



The profile of the axis on the Figure 16 shows that the axis is composed of 4 to 7 m depth of peat followed by clays and sandy clays, then the underlying weathered and solid bed rocks. The peat soils have no bearing capacity and should be an issue for the foundation of the dam, as the peat has a high seepage rate.

The underlying clays would be suitable for foundation supported by weathered and solid rock bottom.

The geophysical and geotechnical investigations shows that the Buyongwe dam axis is composed of 4 to 7m depth of peat followed by clay and sandy clay, then the underlying weathered and solid bed rock. The peat soil, having no bearing capacity, could be an issue for the foundation of the dam.

4.4. Hydrological results for Buyongwe dam site

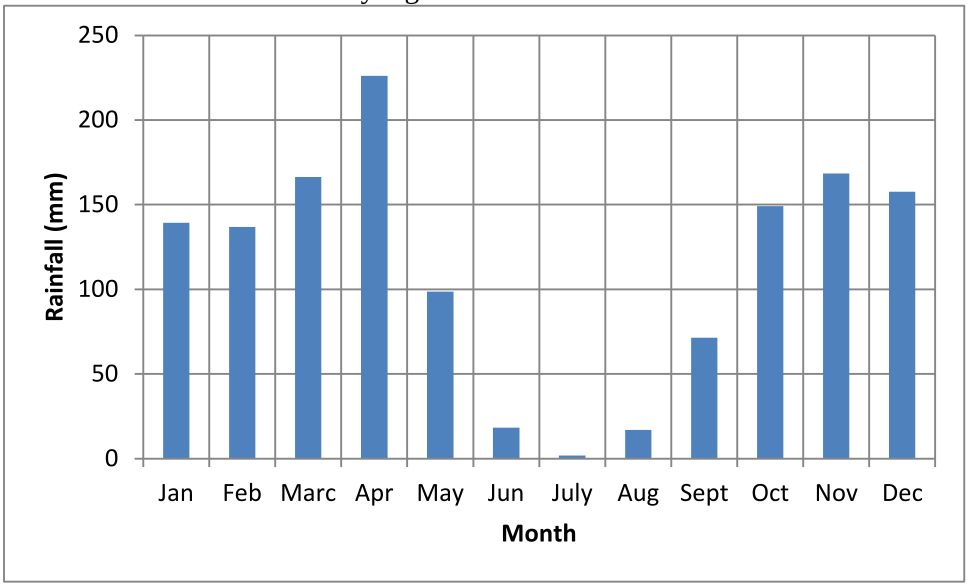
This chapter is an extract of the hydrological report (see appendix E). The hypothesis taken for the hydrological analysis was a 14m high dam as stated in the terms of reference.

4.4.1. Context

Buyongwe dam site is located on Kiremba (Buyongwe) River, which is a tributary of Akanyaru River.

Catchment area is 265 km² and altitude is in the range 1 880 – 1 345 m above sea level. Average annual rainfall is about 1 205 mm/an. There are two rainy seasons with the longer south-easterly monsoon between February and May with the peak occurring in April and the shorter north-easterly monsoon from about September to November as seen in the following figure.

Figure 17: Monthly rainfall at Nyamusguwa meteorological station in the vicinity of Buyongwe dam site



4.4.2. Inflows

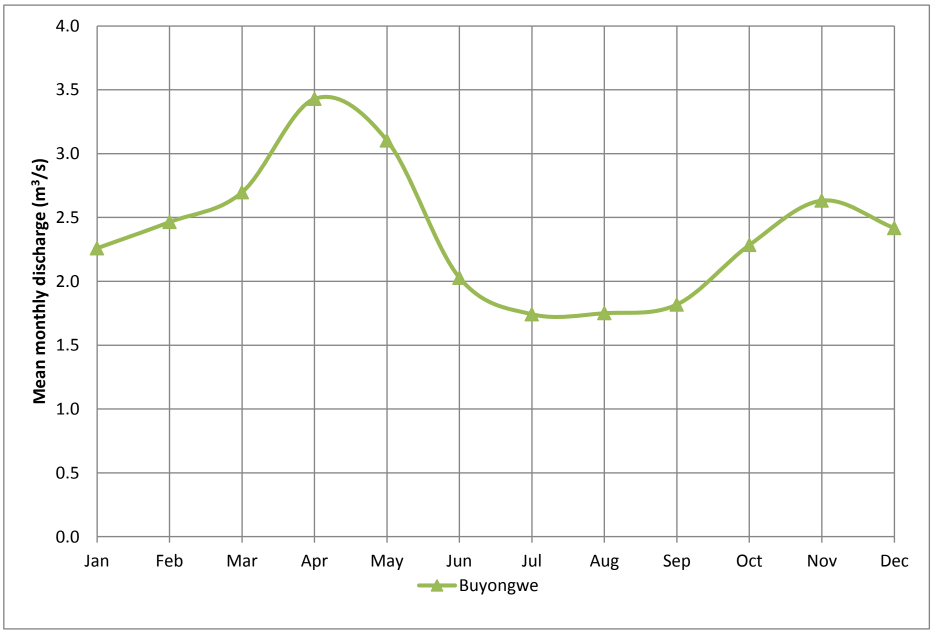
The mean annual discharge at Buyongwe has been estimated as follows in the Table 5. It relies on water balance with mean annual rainfall equal to 1 205 mm/year and a runoff coefficient equal to the average of those calculated for Buyongwe and Ndurumu gauging station (respectively 0,214 and 0,273).

Table 5: Reference for Buyongwe dam site inflows estimates

Dam site (DS)	Area	Pyr	Period	Reference	Reference Area	Reference Pyr	Reference Qyr	Runoff Coefficient CRO
	(km²)	(mm/yr)			(km²)	(mm/yr)	(m3/s)	-
Buyongwe	256	1 205	1940-2009	Ndurumu and (Buyongwe GS) stations	111 (186)	1 220 (1 190)	1.17 (1.50)	0.273 (0.214)

Mean monthly inflows are presented in Figure 18. Two peaks corresponding to rainy seasons can be observed in April and in November. This focuses on the strong response to rainfall for Buyongwe catchment, which is generally observed for Kagera upper tributaries. Otherwise, the hydrological regime is rather smooth. Flows occur all along the year. Maximum discharge occurs in April. Minimum discharge occurs between July and September. The ratio of maximum monthly discharge (April) to minimum monthly discharge (July) is equal to 1,97.

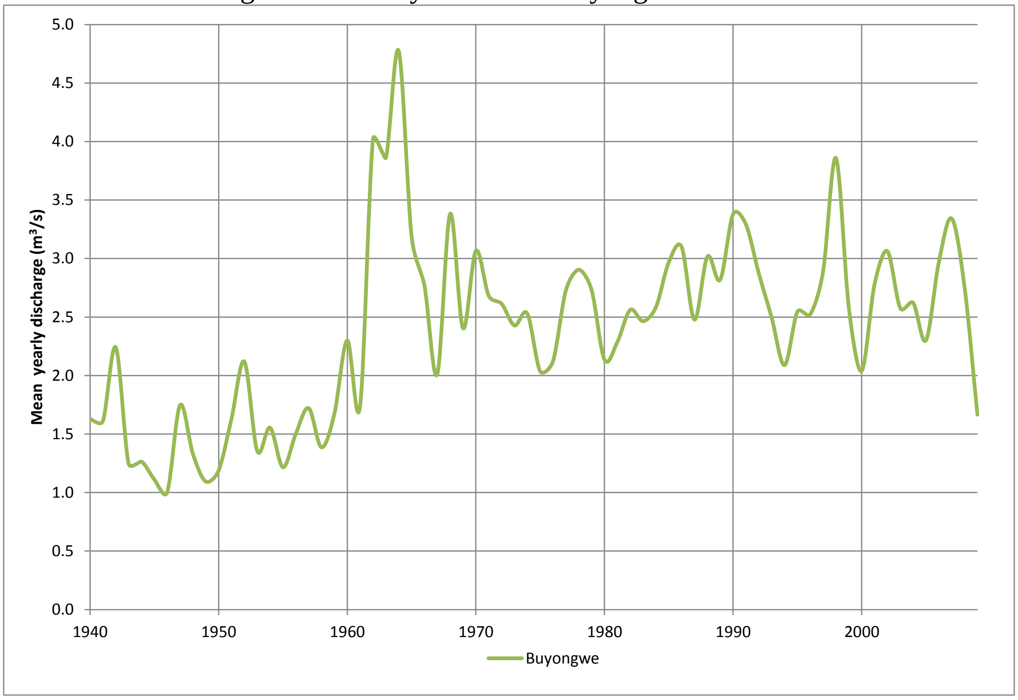
Figure 18: Mean monthly inflows at Buyongwe dam site for the 1940-2009 period



Yearly inflows at Buyongwe dam site are presented in the Figure 19. The rise in runoff observed in the Nile Equatorial Lakes region in the early 1960ies appears clearly. Two periods can be distinguished: a pre-1960 period with moderate runoff level (mean discharge = 1,52 m^3/s) and a post-1960 period with a high runoff level (mean discharge = 2,76 m^3/s).

Annual variability is rather high. Maximum mean yearly discharge (4,76 m^3/s in 1964) represents a +99% increase of the mean discharge (2,39 m^3/s), and minimum mean yearly discharge (1.00 m^3/s in 1946) a -58% decrease of the mean discharge.

Figure 19: Yearly inflows at Buyongwe dam site

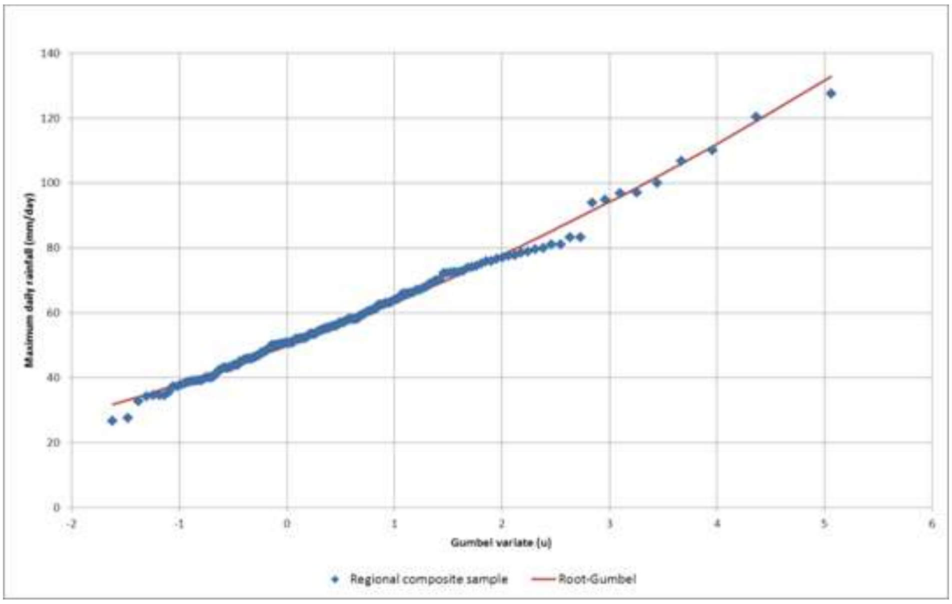


4.4.3. Floods

4.4.3.1. MAXIMUM DAILY RAINFALL

For Buyongwe dam site, daily rainfall records at 6 rainfall stations located in Rwanda and Burundi are processed. The station year method is applied to establish one regional composite sample of maximum daily rainfall. The sample has a size of 158 station-years. A root-Gumbel distribution is convenient to describe this sample (Figure 20).

Figure 20: Buyongwe dam site - Regional composite sample of maximum daily rainfall and Root-Gumbel distribution



Maximum daily rainfall for return periods ranging from 2 to 10 000 years are deducted from the root-Gumbel distribution. The Probable Maximum Precipitation (PMP) is calculated using the Hershfield's formula.

The 24-hour rainfall over the catchment is deducted from maximum daily rainfall by applying both an area reduction factor and the Weiss correction factor equal to 1,13 (Table 6).

Table 6: 24-hour rainfall over Buyongwe catchment for different return periods

T	Pdmx(T)	P24(T)	P24-Buyongwe
(year)	(mm/day)	(mm)	(mm)
2	55	62	49
5	70	79	63
10	82	92	74
20	94	106	84
50	110	125	99
100	124	140	111
200	138	155	124
500	157	178	142
1 000	173	195	156
2 000	189	214	171
5 000	212	240	191
10 000	230	260	208
PMP	350	396	316

4.4.3.2. FLOOD HYDROGRAPHS

The Consultant made use of the USSCS approach to compute the flood hydrographs. Broadly speaking, this approach consisted in deducting flood hydrographs from 24-hour rainfall distributed according to a given storm profile. Results are given in Appendix E. The calculated Francou-Rodier's indexes for peak discharge are in the range 2,44 (return period T=20 years) – 4,51 (PMF).

Table 7: Buyongwe dam site - Discharge

Return period T	T=20	T=50	T=100	T=1000	T=10000	PMF
t (hours)	Hourly discharge (m3/s)					
Peak discharge (Qp) (m3/s)	29	48	65	163	338	513
Mean daily discharge (Q24) (m3/s)	13	22	29	70	130	197
Qp/Q24	2.23	2.17	2.22	2.32	2.61	2.61
K(Qp)	2.44	2.79	3.02	3.68	4.21	4.51

4.4.4. Sedimentation

Due to the lack of local sediment sampling data (see chapter 3.3), the Consultant made use of a regional sediment database and an empirical formula to estimate the sediment yields at Buyongwe dam site. Broadly speaking, the empirical formula is a relation between the sediment yields and the runoff. The catchment area is also taken into account. The regional sediment database is first processed in order to calibrate this relation. Then, the relation is applied to Buyongwe catchment in order to estimate the sediment yields. Eventually, the sedimentation rate of the reservoir is assessed by applying Brune's approach. The sedimentation rate is highly dependent of the storage capacity of the reservoir. Thus, these results should be revisited when the design changes. Main results are given in the following table for different sizes of dam.

With a storage capacity of about 10 Mm^3 (14 meters dam height), the ratio of storage capacity to mean annual inflows is very poor (13%). As a consequence, the annual sedimentation rate is quite important and the site is likely exposed to siltation.

Table 8: Buyongwe - Sediment yields and sedimentation rate of the reservoir

Dam Site	Area	Rainfall	Runoff	Sediment Yield (in suspension)	Total sediment Volume	Dam Height	Storage Capacity (C)	Mean annual inflows (I)	Capacity Inflow ratio (C/I)	Trap efficiency (Brune)	Annual sedimentation rate
	(km²)	(mm)	(mm)	(t/km²/year)	(m3/year)	(m)	Mm3	Mm3	-		
Buyongwe	256	1 205	295	674	152 645	14	9.8	76	0.13	87%	1.4%
						18	16.8	76	0.22	92%	0.8%
						26	36.5	76	0.48	95%	0.4%

4.4.5. Climate change features

The assessment in climate change on hydrology and water resources is now common in the hydrology community. The methodology to assess the chain of impacts from climate to water resource is well established. This is still a challenging task, because the computation chain produces a lot of possible future scenarios and a lot of uncertainties. For example, the hydrological modelling for climate change assessment relies on some strong hypothesis such as the non-evolution of the land cover.

In the area of the project, some previous studies, as mentioned in the appendix E, suggested the hypothesis of a reduction of runoff when others concluded that an increase in runoff was expected.

Thus, a serious assessment of climate change at the regional scale should take into account a large range of possible future scenarios. The relation between rainfall and runoff is not linear so that more rainfall does not mean necessarily more runoff. At the current time, such a task should rely on the research field.

4.4.6. Optimization of the reservoir capacity for Buyongwe site

4.4.6.1. OBJECTIVE OF THE OPTIMIZATION

Dams mainly serve to ensure an adequate supply of water by storing water in times of surplus and releasing it in times of scarcity, thus also preventing or mitigating floods. Dams that have small storage capacity in relation to the gross Mean Annual Runoff (MAR) are known as "annual dams". They are likely to fill from empty every year except the very worst seasons or even single floods.

The methodology adopted (see chapter 3.3) is a Sequential Steam flow Routing (SSR) and according to this method a continuity equation of the water volumes is applied to calculate reservoir levels and therefore reservoir volumes, evaporation and outflows from spillway and outlet structure.

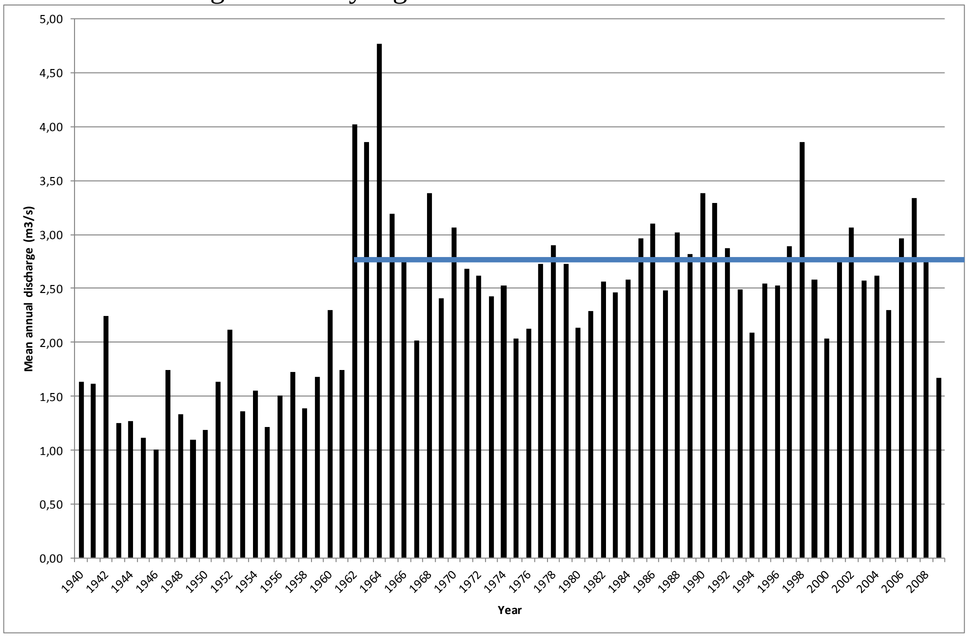
The erratic inflow of the river passes through the storage reservoir will be delayed and attenuated as it enters and spreads over the reservoir surface. Water is then released through a controlled outlet.

The optimization consists of determining the minimum reservoir capacity which allows an average constant water release with an acceptable deficiency.

4.4.6.1. RUNOFF

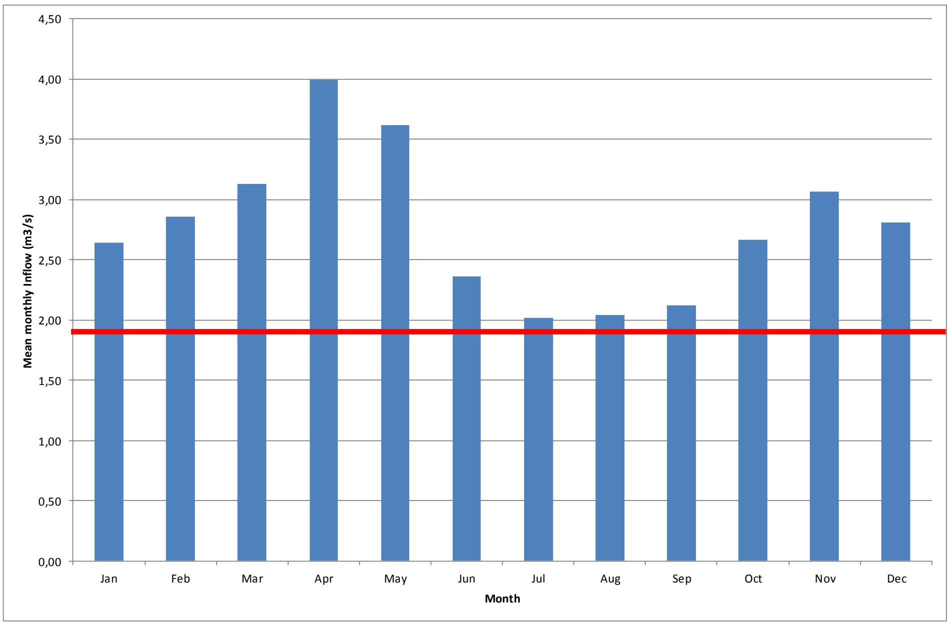
For Buyongwe dam site, the monthly discharge record has been obtained using Ndurumu and Buyongwe records. As observed in the region since 1940, the rise in runoff in the early 1960ies appears clearly. Two periods can be distinguished: a pre-1960 period with a moderate runoff level and a post-1960 period with a high runoff level. It has therefore been decided to simulate the reservoir only over the period 1962-2009, corresponding to a long series of 48 years.

Figure 21: Buyongwe Annual Inflows



The annual runoff within the period 1962-2009 is about 2,75 m^3/s. Two peaks corresponding to rainy seasons can be clearly identified. However, the hydrological regime is rather smooth. The ratio of maximum monthly discharge to minimum monthly discharge is equal to 1,97.

Figure 22: Mean monthly discharges at Buyongwe dam site



4.4.6.2. EVAPORATION

The following table summarize the result of the computed Net Evaporation at the Buyongwe dam site. The net losses due to evaporation is about 0,8% of the annual inflow for a reservoir surface area of 1,27km^2 as stated in the ToR.

Table 9: Estimated evaporation at Buyongwe reservoir

	Buyongwe	Precipitation		Original evapotranspiration (mm)	Evaporation (mm)	Net Evaporation (mm)	Catchment Area (km²)	Runoff (mm)	Reservoir Surface Area (km²)	Net losses due to evaporation /Inflows
	Altitude (m)	Yearly Amount(mm)	Distribution (%)	based on CRO=	Nyabarongo River					
	1388	1205		0,2435			256	295	1,27	0,8%
January		124	10,3%	91	109	18				
February		122	10,1%	89	98	9				
March		148	12,3%	109	106	-3				
April		202	16,7%	148	97	-51				
May		88	7,3%	65	104	39				
June		16	1,4%	12	113	101				
July		2	0,1%	1	133	132				
August		15	1,3%	11	148	137				
September		64	5,3%	47	124	77				
October		133	11,0%	98	116	18				
November		150	12,5%	110	100	-10				
December		141	11,7%	103	106	3				
Total		1205	100%		1 354	471				

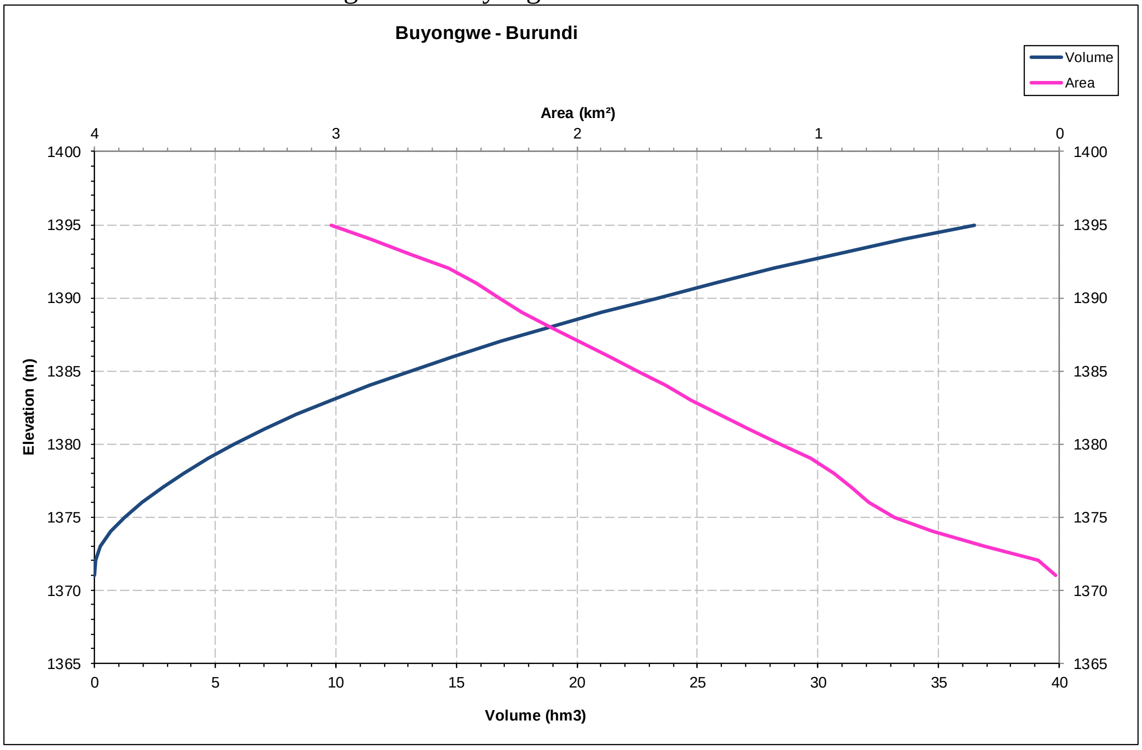
4.4.6.3. MAXIMUM MEAN WATER RELEASE

The objective of the optimization is to determine what should be the reservoir capacity which will allow the complete runoff hydrograph to be routed through the reservoir. The maximum water release is therefore the mean annual Inflow minus the loss due to the evaporation. According to the two previous chapters, the maximum discharge is 2,72 m^3/s (2,75 – 0,8%).

4.4.6.4. RESERVOIR DATA

Based on the new topographical data, the surface and the volume of the reservoir versus the height of the dam were determined according to the height-volume-surface (HSV) curve as follows.

Figure 23: Buyongwe Reservoir HSV Data



4.4.6.5. MINIMUM OPERATION LEVEL

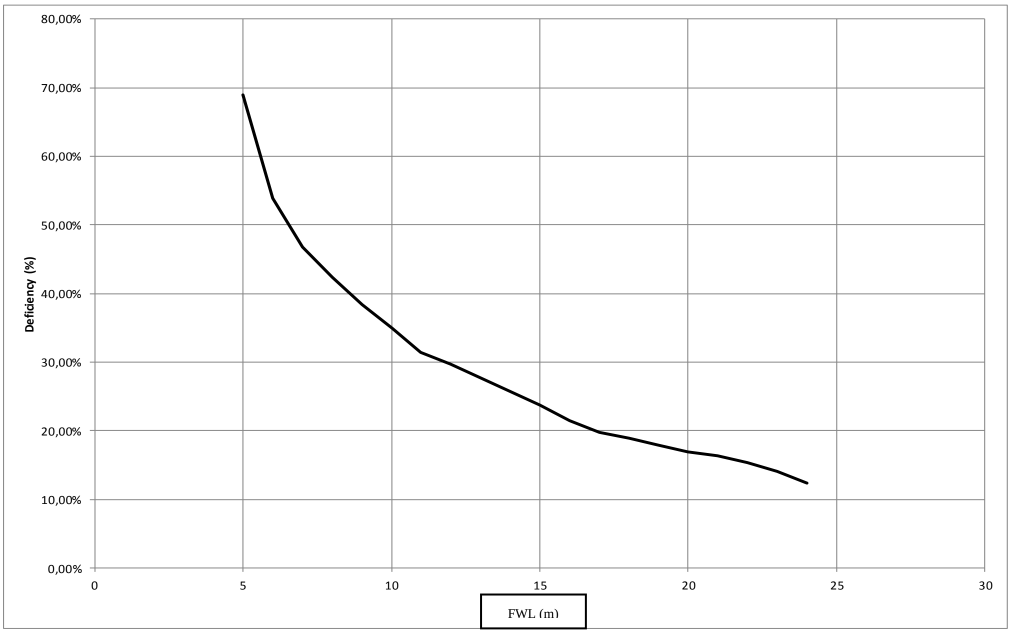
As sediment will be trapped, the reservoir storage capacity will decrease. Therefore, in case of dam construction, the outlet structure should be set at an elevation above the expected siltation level. Under this level, the stored water will not be used and commonly called as “dead storage”.

The annual sedimentation rate at Buyongwe site is about 0,15 Mm^3 per year. Therefore, the outlet threshold should be set 7m above the minimum ground elevation, giving a dead storage representing more than 24 years of sedimentation storage.

4.4.6.6. DEFICIENCY AND GUARANTEED DISCHARGE

The following figure represents the deficiency (percentage of months when the demand is not satisfy) versus the dam height. More the reservoir capacity is big, more reliable will be the reservoir to satisfy the demand.

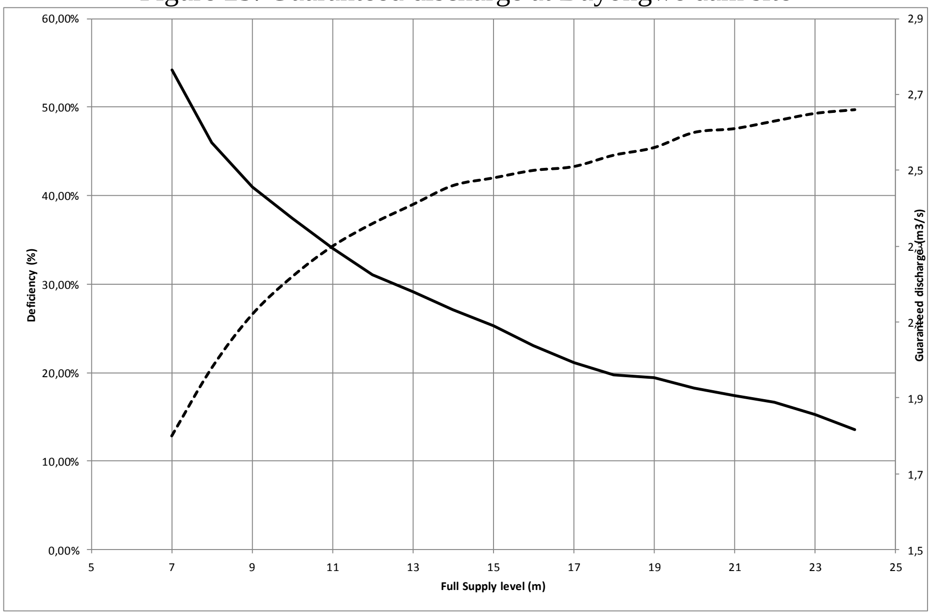
Figure 24: Deficiency versus Dam Height for Buyongwe Dam



This curve clearly shows that the deficiency is quite high. Usually, the recommended yield risk level is 10% for irrigation dams. Thus the optimise Full Supply level should be 25m above the natural ground level.

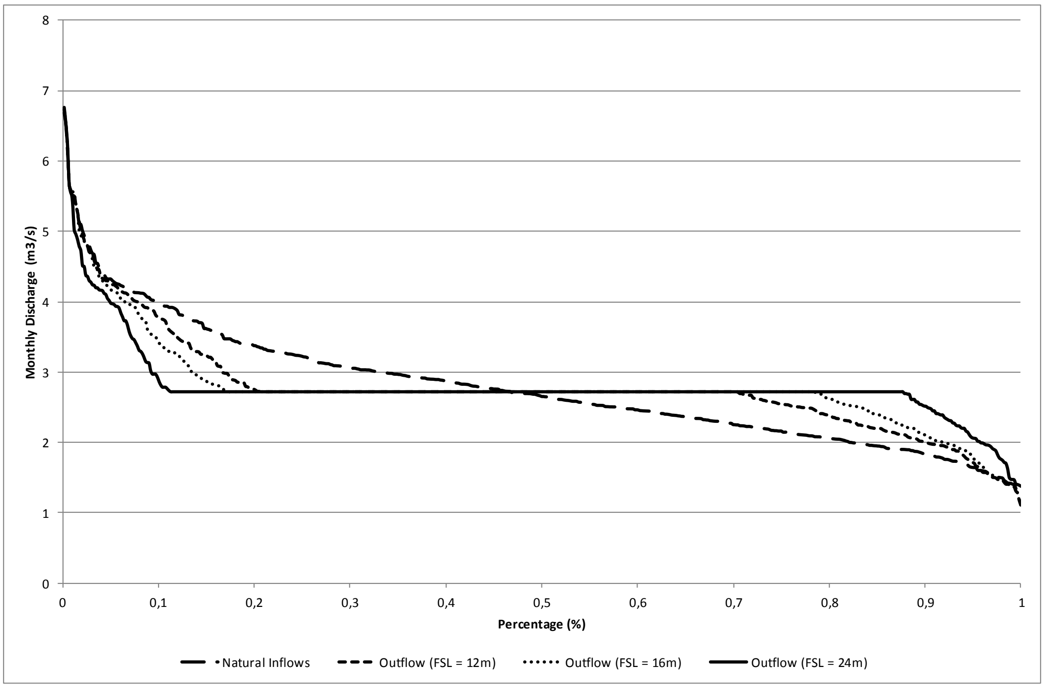
The following figure shows the guaranteed discharge depending on the Full Supply Level. The guarantee is variable from 1,8 to 2,66 m^3/s respectively for a Full supply Level from 7 to 24 meters.

Figure 25: Guaranteed discharge at Buyongwe dam site



The following figure shows the flow rating curve at different Full Supply Level (respectively 12, 16 and 24) compared to the natural inflows.

Figure 26: Flow duration curve at Buyongwe dam according to the dam's height



The figure shows the increase of the reservoir's reliability with the dam's height.

Nevertheless, according to the topographical map (see map MA09 in the appendix C), the existing micro power plant located upstream of the dam axis will be inundated with a FSL higher than 12 meter above the ground level (FSL=1383m). Thus, the Full Supply Level should be under 12 meters in order to keep this micro power plant in operation.

4.4.6.7. MAIN CONCLUSIONS FOR THE OPTIMIZATION OF BUYONGWE RESERVOIR

The following table summarizes the main result of the optimization for Buyongwe dam based on the new topographical data.

Table 10: Main Result of the simulation for Buyongwe dam site

Full Supply Level above ground level (m)	Mean annual Runoff (Mm3)	Storage Capacity (Mm3)	Storage ratio (%)	Mean annual inflow (m3/s)	Deficiency (%)
12	86,63	9,81	11,32%	2,75	29,69%
16	86,63	16,83	19,43%	2,75	22,40%
24	86,63	36,49	42,12%	2,75	13,54%

The above table shows that a minimum storage ratio of 50% is required to have a reliable reservoir regards to acceptable guarantee water release.

Hydraulically, the optimisation leads to a dam height close to 24 meters for this site. Nevertheless, the environmental and social examination shows that the existing micro power plant located upstream of the dam axis will be inundated with a FSL higher than 12 meter above the ground level (FSL=1383m). However, the water demand should be taken as well into consideration to lead the choice of the Full Supply Level.

Buyongwe dam site is located on Buyongwe River, which is a tributary of Akanyaru River. Catchment area is 265 km² and altitude is in the range 1 880 – 1 345 m above sea level. Average annual rainfall is about 1 205 mm/year with the Probable Maximum Precipitation = 350mm/day.

The hydrological regime is rather smooth with a maximum discharge occurring in April. The annual runoff within the period 1962-2009 is about 2,75 m^3/s; the ratio of maximum monthly discharge (April) to minimum monthly discharge (July) is equal to 1,97.

With a storage capacity of about 10 Mm^3 (in case of a 14m dam height), the ratio of storage capacity to mean annual inflows would be very poor (13%). As a consequence, the annual sedimentation rate is quite important.

The net losses due to evaporation is about 0,8% of the annual inflow for a reservoir surface area of 1,27km^2 (in case of a 14m dam height).

Hydraulically, without taking into consideration environmental and social issues as well as the water demand, the optimisation leads to a dam height close to 24 meters for this site.

4.5. Water uses and water demand for Buyongwe site

4.5.1. Context

As seen above, the objective of the project, and consequently the scenario depends mainly on the water demand as well as the environmental and social impacts.

4.5.2. Irrigation

4.5.2.1. CONTEXT

These below field findings have been carried out before the results of the aerial survey. Thus, some results will be reviewed in the chapter about the detailed description of the proposed development irrigation scheme (chapter 5) taking into account the detailed topographical maps issued from the LiDAR survey.

4.5.2.2. INSTITUTIONAL FRAMEWORK

The Ministry of Agriculture and Livestock (*Ministère de l'Agriculture et de l'Elevage*) is in charge of designing, planning and implementing the National Policy related to agriculture and livestock.

For the Burundian government, rice is nowadays the priority crop.

4.5.2.3. WATER USES FOR IRRIGATION

Literacy context

According to the Large Scale Irrigation Practices report [b], Ngozi district, where the dam site is located, is the best large scale irrigation practices district in the country. No description of particular irrigation schemes is given. Thus, it is important for the project to identify these irrigation schemes in Ngozi district. The large scale proposed Kanyaru reservoir is located in the same district. It should be taken into consideration in the next report.

Field context

Buyongwe envisaged dam site is located on the River Buyongwe (see the below map in the Figure 30), around 3 km downstream from the bridge of Kiremba village. Around 12 km downstream from this site, the Buyongwe River flows into the Akanyaru River (at the top in the left corner of the map) which is itself an affluent of Nyabarongo River, the confluence of these two latter being around 75 km to the North, in Rwanda.

The Gisuma, an important left-bank tributary, joins the Buyongwe River around 2km downstream from the dam. The Buyongwe valley is rapidly widening downstream of the dam, and becomes a wide swampy area at the level of Birambi village, around 6 km downstream from the dam. It is around 250 m wide at the dam level, 400 m at the confluence with the Gisuma, 600 m at Birambi, and then more than 1000 m.

<u>Soils and land present use:</u>

There is a marked transition between the flat valley and its sides (see Figure 27). Slopes bear red ferrallitic soils with some staple crops such as sweet potatoes. The valley bears organic hydromorphic soils and even peat soils. Peat is extracted in the potential command area of the dam.

Everywhere where it is possible or where a slight improvement allows it, the valley is cultivated with rice and some plots of beans. The wettest areas remain with natural vegetation of swampy tall grasses or even permanently under water (see the following figures).

Figure 27 : Buyongwe valley, upstream of the dam site

Figure 28 : Buyongwe valley, around Birambi area

Figure 29 : Buyongwe valley, marshy area close to Akanyaru confluence

4.5.2.4. IRRIGATION POTENTIAL ASSESSMENT

Two important features are of great influence on the potential development of the valley:

- Firstly, the peat extraction in this area has made any improvement impossible in the past, following an information of the Direction of the Agricultural Production;
- Secondly, as the flow of the Buyongwe River can be blocked by the one of the Akanyaru River when the water level is high, the valley is temporarily flooded by a backwater effect during the rainy season. The flood rises up roughly until Buyongwe/Gisuma confluence, its maximum occurring during the heaviest rainy month of April (see Figure 32). The flood may flush rice cultivation.

As a consequence, farmers adapt their cropping pattern depending on this risk. Roughly upstream of the Buyongwe/Gisuma confluence, farmers grow rice from January (transplanting) to May/June, which is considered as the "normal" crop cycle. Then, they grow beans and maize, which are sown in July/August. Downstream of this confluence, farmers are transplanting rice at June-July in order to harvest it at October-November. Thus, they avoid growing during the main rainy season. Nevertheless, the poor adaptation to these difficult local conditions lead to low present rice yields, around 0.5 t/ha.

Land availability:

A large potential command area is suitable to supply and to increase the local food production thanks to surface irrigation. Based on the available map (1/40 000) at the time of the field mission, the rough extent of this command area has been first estimated:

- 760 ha downstream from the dam up to the first potential axis of control structure;
- An additional 640 ha down to the second potential axis, for a total of 1 400 ha.

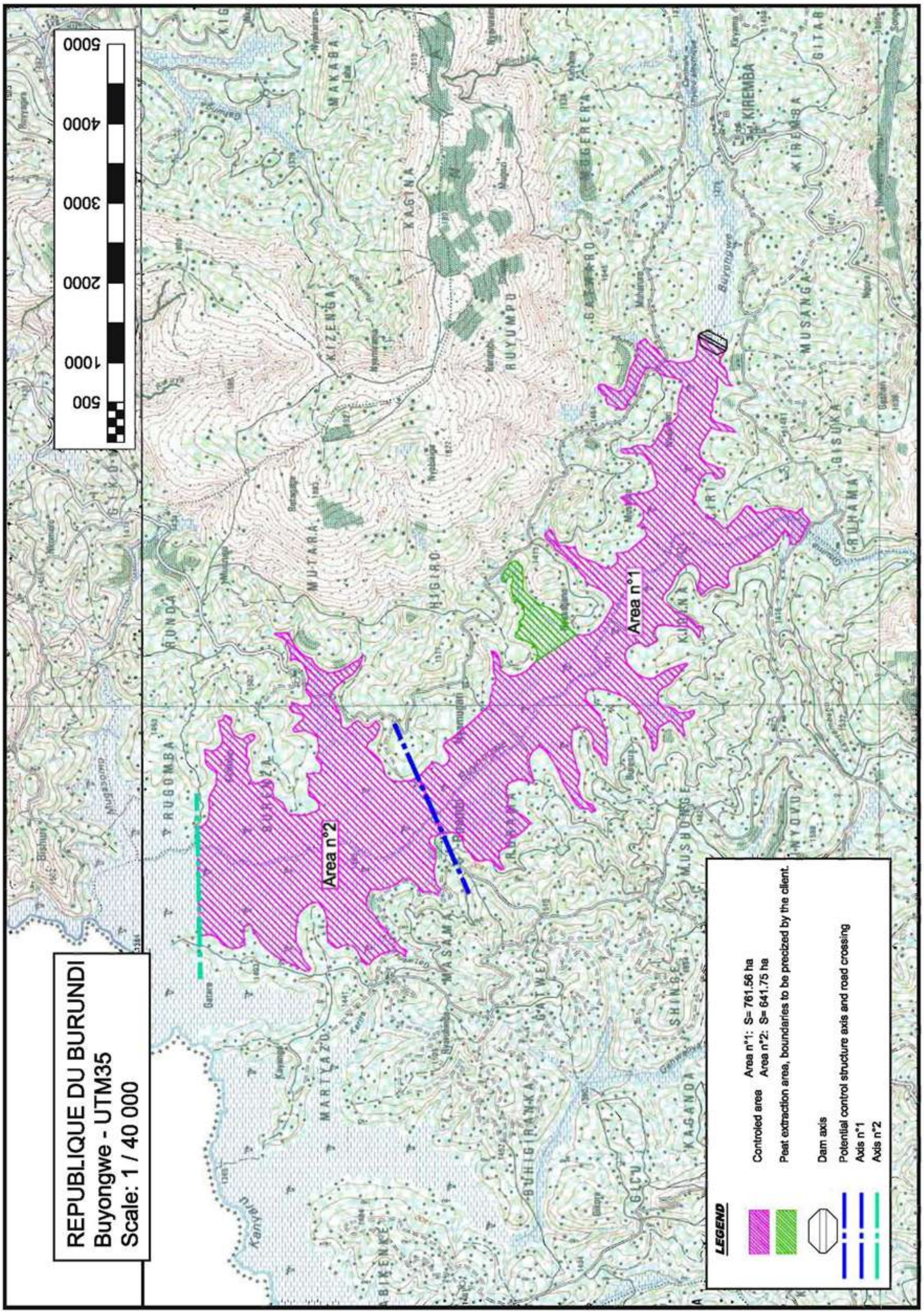
These estimates are taking into account a gross area. If developed, it is expected that the reduction between gross controlled area and net irrigated area is in the range of – 20% to – 40%. Therefore, the net irrigated area could be:

Hectare	Maximum net irrigated area	Minimum net irrigated area
Upstream axis 1 (area 1)	608	456
Downstream axis (area 1+2)	1 120	840

However, it shall be kept in mind that all this land is either already grown or unusable because of swampy conditions. Thus, any improvement shall be previously discussed with the farmers.

An area of 50 ha is as well available upstream of the dam, up to the Kiremba bridge. Without dam, this area could be added to the command area. It is also an area not affected by the flood from Akanyaru River and which is already fully grown with rice.

Figure 30: Potential irrigation area for Buyongwe site



Local demand expressed by the principal adviser to the Governor of Ngozi, whom had been met on 29th of February 2012, is to better use the marsh for rice cultivation.

Both this wish and the natural conditions of the area are orientating the project toward rice production as a first objective. This requires a good control of the water conditions. This will be reached by the means of several improvements and by keeping some buffer swampy areas which will be able to store a part of the excess water.

Health crop issues:

Due to sanitary issues affecting rice cultivation in this area, it is proposed to grow only one crop of rice per calendar year and to introduce a crop rotation.

Phytosanitary problems threaten the rice crop in the Burundi marshes. Bacteriosis usually appears under cold conditions and pyriculiarosis (a disease caused by fungus to aerial parts of the rice) under warmer ones. They may cause heavy yield losses. These two diseases are present in the Buyongwe area. They may be increased by intensification and thus it is recommended to grow only one rice crop per year in the same ground.

Yunnan 3 rice cultivar is locally used as it is resistant to bacteriosis, but it is sensitive to pyriculiarosis.

Should these problems be addressed by appropriate pesticides or soil management, it will then be possible to grow two rice crops a year.

Potential crops and cropping pattern:

The main crop will be rice which will be grown during the main rainy season, i.e. sowing in nursery in November, then transplanting the seedlings in January, and harvesting in May/June. Irrigation will be used for nursery, to secure the water needs at the beginning of the crop cycle, and to flood the crop.

Rice will be followed by either maize or bean crop which will be sown during July/August. Irrigation will be required during this dry period. The cropping pattern will alternate these two crops on a same field, one year maize, the next year, beans.

It is expected to reach a yield of 3 t/ha for rice, 2.5 t/ha for maize and 1.5 t/ha for beans. These yield figures come from the local agricultural adviser in Kiremba for rice, and from the Rwanda Marshland Masterplan for maize and beans.

Crops water requirements:

Irrigation water requirements are computed by calculating a water balance for every period of 10 days (hereafter called a decade). The Reference Evapotranspiration ETo (Penman-Monteith formula) is very close for all regions of the four dams and it has been taken an average of 5 stations of the FAO climwat database: Rubona and Butare in Rwanda, Biharamulo and Bukoba in Tanzania, Mbarara in Uganda. The nearest station Muyinga in Burundi has not been taken into account, because it has very high figures during the dry season, which seem overestimated.

The mean annual ETo reaches 3.6 mm/day. The total annual ETo reaches 1297 mm (see Figure 31). ETo is slightly lower during the rainy months and slightly higher during the driest ones.

Rainfall has been considered at the station of Muyinga in Burundi (altitude 1755 m, latitude -2.83°, longitude 30.33°) (see Figure 32). The total annual rainfall reaches 1125 mm and the effective rainfall (Pe) reaches 895 mm after correction using the FAO method.

In Burundi, the meteorological year is usually divided into four periods: a short dry season in January-February, the long wet season from March until May, the dry season from June until September and a short wet season from October until December. The chart (Figure 32) shows that the "short" seasons are little marked on site.

A set of crop coefficients was selected for each crop all along the crop development.

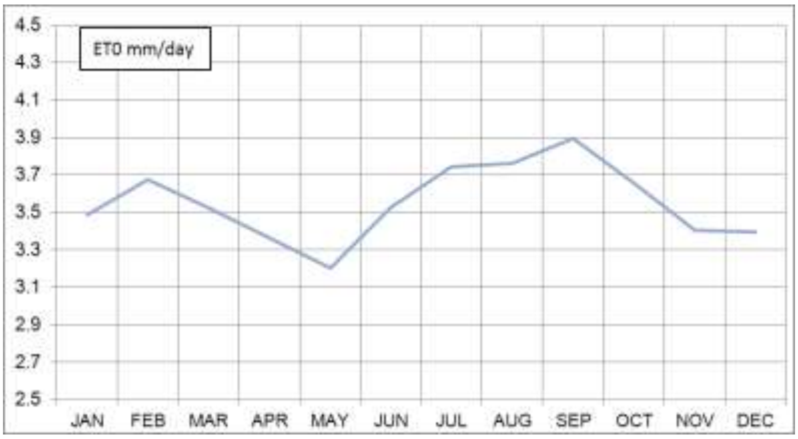
The irrigation water requirements (I) are calculated as follows:

I = kc Eto – Pe where kc is the crop coefficient

I = 0 if Pe of the considered decade > kc Eto

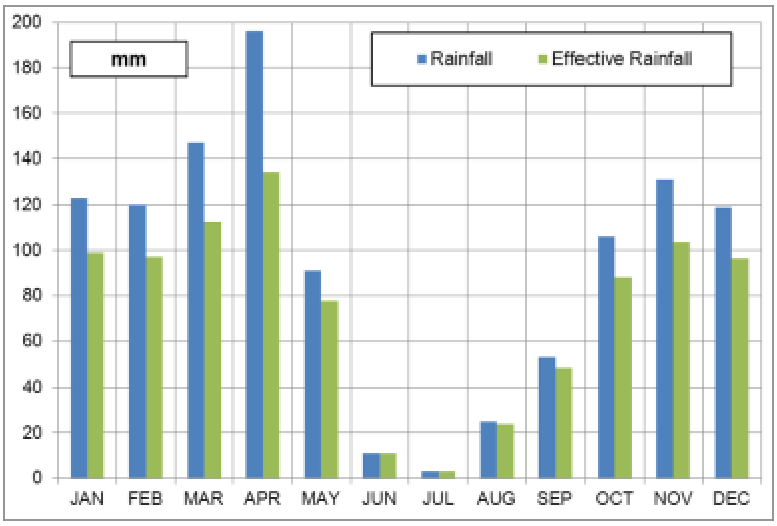
In the case of rice, it shall be added an amount of water to saturate the soil before transplanting the seedlings, and other amounts for percolation losses and to maintain a water layer in the field.

Figure 31 : Mean daily reference evapotranspiration in the region of the projects



(source: Climwat FAO)

Figure 32 : Rainfall and effective rainfall at Muyinga, Burundi



For each possible crop, the Table 11 summarizes the total irrigation water requirement, expressed in m^3/ha for the whole crop cycle, and the maximum base flow in l/s/ha.

The base flow (specific flow) is the hypothetic flow which would be required to meet the irrigation amount of the decade while taking into account a daily irrigation duration of 24 hours. It is expressed in l/s/ha (litre per second per hectare).

This basic unit flow will be later proportionally increased while considering the real possible daily irrigation time to define the irrigation duty. This later depends on the way which is chosen to irrigate.

Table 11: Crops, expected yields and water requirements

Crop	planting time	length of development	expected yield	irrigation water per ha	maximum unit flow l/s/ha
		days	t / ha	m^3 / ha	at 24 h / day
Rice 1	20th Jan	150	3,0	9 000	1,1
Rice 2	1st Jul	150	3,0	12 000	1,6
Maize	1st Jul	150	2,5	2 000	0,3
Beans	1st Aug	120	1,5	1 000	0,3

Volume of irrigation water:

Large volumes of water appear necessary for rice. They are not strictly crop water requirements, as the sole crop evapotranspiration is quite secured by the effective rainfall, in the case of rice1. They are mostly required for the initial saturation of the soil (200 mm) and then to compensate percolation (hypothesis to provide 120 mm every month) and to maintain a water layer (100 mm).

Two cases are taken into considerations which are called “rice1” and “rice 2”:

- Rice 1 represents what is locally considered as the normal cultivation season i.e. during the main rainy season.
- Rice 2 is a cultivation implanted during the dry season in an attempt to grow two rice crops a year, thus driving the perimeter towards a greater intensification.

As a consequence, the required volume of irrigation water is markedly higher in the case of rice 2.

In the case of a crop rotation, maize or beans will be grown during the dry season as they require less irrigation water.

Base flow (specific flow):

It reaches 1,1 l/s/ha in the case of wet season rice cropping and 1,6 l/s/ha in the case of dry season rice cropping. As usual, it is much lower in the case of other non-flooded crops.

Thus, a base flow of 1,6 l/s/ha is required if we want to provide the possibility of a double rice cropping.

Cropping pattern

The cycles of the wet and dry season crops do not overlap. So it is realistic to apply double cropping on the whole area of the project, that is to say one wet season crop followed by a dry season one. Two kind of systems can be carried out, either a rice monoculture with two crops a year, or a rotation with rice cropping during the wet season followed by maize or beans.

Due to the sanitary issues with rice, we recommend to begin with the development of the second system. It means that the irrigation perimeter will be grown at 100% with rice during the first six months of the year, and then at 50% with maize and at 50% with beans.

Project discharge:

Canals system must be designed to meet the peak base flow by taking into account both real possible irrigation duration and system efficiency. This will define the scheme irrigation duty.

With a surface irrigation system, it is usually preferable to avoid night time irrigation because human presence is required for controlling the flows in the furrows or basins. Thus, the maximum duration is set at 12 hours per day.

Regarding efficiency, which is the ratio of water delivered at the plot to water withdrawn from the reservoir, thus revealing the overall transfer losses, we propose to take 60% efficiency into account.

Then, the irrigation duty is computed as follows:

Irrigation duty = Specific flow (24 hours l/s/ha) / Irrigation duration (hours/24) / Efficiency

The irrigation duty will depend on the wish to grow rice only during the wet season or to be able to move to double cropping rice.

Table 12: Design irrigation duty

Irrigation system	Maximum irrigation duration	Efficiency	Irrigation duty
	hours	%	l/s/ha
Surface irrigation 1	12	60	3,7
Surface irrigation 2	12	60	5,4

1 *possible rice cropping only during wet season ;* ***2*** *possible double rice cropping, during wet and dry season*

Development constraints:

Development of peat marshlands has to face two main constraints:

- Peat is subject to ignition if not wet.
- If not submerged for a long period, peat is prone to degradation (mineralization) that sterilizes the soil.

Therefore, water level management is a central issue in peaty marshlands development. To address this issue, the construction of a water level control structure across the valley is compulsory. This structure could be sluices gates and / or tidal flaps associated with a bridge and an access road which will also act as a dike. This will prevent backwater effect from the Akanyaru River and will control the water level upstream.

Several places are suitable for such a structure. A structure near Biremba will be useful both for traffic and water level control, but will reduce the area where water level will be controlled efficiently. A downstream structure will increase command area but will maybe be useless for traffic and could cause more water level constraints downstream. Further studies at later stage, not in this scope, will be necessary to choose the best alternative.

4.5.2.5. IRRIGATION WATER DEMAND

Assuming a cropping pattern of rice in the wet season, followed by half maize and half beans in the dry season, the water used for irrigation amounts to the following volumes depending on the irrigated area:

Table 13: Total yearly irrigation water consumption for the scheme

Irrigated area	**gross volume of water m^3 ***			
ha	Rice	Maize	Beans	**TOTAL**
456	6 840 000	760 000	380 000	**7 980 000**
608	9 120 000	1 013 000	507 000	**10 640 000**
840	12 600 000	1 400 000	700 000	**14 700 000**
1 120	16 800 000	1 867 000	933 000	**19 600 000**

***** *taking into account the conveyance efficiency*

4.5.2.6. ENVIRONMENTAL AND SOCIAL ISSUES IN CASE OF IRRIGATION

The main constraints for the future development of Buyongwe River valley are identified below.

- Land tenure: The entire valley is cultivated at present. To develop irrigation infrastructure (canals, drains, division boxes…) it will be necessary to reduce the area under cultivation. This will need a participatory approach since the early stages of project implementation to commit the beneficiaries to the project. Also, the peat extraction company has rights on one area that must be excluded from any development. The boundaries of their concession must be given by the client to complete the feasibility design.
- Environment: development of peat marshlands must be undertaken with precautions regarding drainage and water level management to avoid drying of the peat. Such drying is causing risks of ignition, sterilization of top soil and subsidence. Also, flooding in the Akanyaru River is supplying water by a backwater effect to a downstream lake that hosts preserved birds. It will be essential to ensure that the planned development is not threatening the hydraulic behaviour of the whole system.
- Social: As previously mentioned, social issues regarding land availability and sharing will be crucial for the success of the project.

The first investigations about irrigation lead to find a large (around 1 000 Ha) potential command area suitable to increase the local food production. However, the entire valley is already cultivated, the peat extraction in this area has made any improvement impossible in the past and the flow of the Buyongwe River can be blocked by the one of the Akanyaru River by a backwater effect, which may flush rice cultivation.

Due to sanitary issues affecting rice cultivation in this area, it is recommended to grow only one crop of rice per calendar year and to introduce a crop rotation. Rice could be followed by either maize or bean crop which will be sown during July/August. Irrigation will be required during this dry period. The cropping pattern could alternate these two crops on a same field, one year maize, the next year bean with an expected yield of 3 t/ha for rice, 2,5 t/ha for maize and 1,5 t/ha for beans.

Assuming a cropping pattern of rice in the wet season, followed by half maize and half beans in the dry season, the water demand for irrigation could reach a maximum of 19,6Mm^3*.*

4.5.3. Livestock watering

4.5.3.1. LIVESTOCK RESOURCES

Province's livestock information could not be obtained.

The country in 2008 had following livestock population: cattle (471 614), Goats (1616873), Sheep (281 190), Pigs (166 721), Poultry (1 524 007) and Rabbits (390641). An assumption is made to apportion the national livestock in the same proportion as the population. It is assumed that Ngozi Province would have 10% of the livestock population.

- Indigenous cows: 48 000
- Goats: 162 000
- Sheep: 28 000
- Pigs: 17 000
- Poultry: 152 000
- Rabbits: 39 000

The hypothesis was that about 30% of them are located in the project impact area. The population density is very high and therefore the livestock carrying capacity is very much restricted. In the same note as well, population growth will be limited through culling. However a less than 1% annual growth rate is assumed in the event safe land carrying capacities continue to be exceeded. A flat rate 25% increase is assumed to year 2037.

4.5.3.2. LIVESTOCK WATER DEMAND ASSESSMENT

Livestock water demand

The present livestock population is based on the methodology described in the chapter 3.4.1.3 and on Province data with an estimation of about 40% assuming to be located in the project area. It is also assumed that by year 2037, the population will increase by 25%. The maximum present and future livestock water demand is estimated as follows:

Table 14: Maximum livestock water demand estimation in Buyongwe area

Type	**Demand (litre/day)**	**2012**		**2037**	
		Numbers	**m^3/day**	**Numbers**	**m^3/day**
Beef Cattle	25	14 400	360	18 000	450
Dairy Cattle	40	0	0	0	0
Pigs	10	5 100	51	6 375	64
Sheep and Goats	5	57 000	285	71 250	356
Poultry	30 per 100 birds	45 600	14	57 000	17
TOTAL m^3/d			710		887
Annual Demand m^3/year			0,26 million m^3		0,32 million m^3

This estimation should be considered cautiously due to the lack of data in the Project area.

Technical constraints
As seen during the social survey, the project area is mainly dedicated to agricultural uses. The livestock are mainly located on the hills in order not to destroy the cultures. Thus, implementing livestock watering should be considered with cautious. Technical assessment should be reviewed in case of implementing this use.

The livestock are mainly located on the hills in order not to destroy the cultures. Thus, implementing livestock watering should be considered with cautious.
Livestock is mainly composed with cattle, sheep and goats. The maximum livestock water demand has been estimated to 0,32 Mm^3 in Buyongwe area.

4.5.4. Aquaculture

4.5.4.1. WATER USES

There is no fish production in the Project area. DAPA Project introduced fish ponds in the commune, but the activity stopped as soon as the Project was closed.

However, the government agenda included development of fishing and revitalization of fish farming according to Poverty Reduction Strategy Paper – 2nd Implementation Report – IMF 2010.

4.5.4.2. WATER DEMAND ASSESSMENT

Aquaculture water demand

Water demand has been calculated without taking into consideration the water uses for aquaculture.

The project area has an estimated population density of about 470 person/km^2 increasing to 850 persons/km^2 in year 2037. The following table gives two options of ponds, subsistence or commercial fish farming.

Table 15: Estimation of water ponds need

	2012		2037	
	subsistence 2 km radius 2t/Ha/year size 0,04Ha	commercial 4 km radius 3 t/Ha/year size 0,4 Ha	subsistence 2 km radius 2t/Ha/year size 0,04Ha	commercial 4 km radius 3 t/Ha/year size 0,4 Ha
population density	470	470	850	850
population	5 907	23 628	10 683	42 731
fish consumption kg @ 1kg/person/year	5 907	23 628	10 683	42 731
Pond Area Ha	2,95	7,88	5,34	14,24
Numbers of ponds	74	20	134	36

The required gross area for the ponds may be 2 to 3 times the net pond area.

Taking into consideration that each pond has an average depth of 1,20m, that the annual evaporation is assumed to be 1 300 mm, that soil percolation is assumed to be 1 500 mm/year for sandy clays at a percolation rate of 0,5 x 10^{-7}/sec., the fish farming theoretically estimation are therefore as follows and the maximum volume of water required for fish farming is also calculated below:

Table 16: Estimation of maximum water demand

Parameters	2012		2037	
	subsistence size 0,04 Ha	commercial size 0,4 Ha	subsistence size 0,04 Ha	commercial size 0,4 Ha
Numbers of ponds	74	0	95	10
Volume	35 442	-	45 600	49 325
10% exchange daily / annually	1 293 624	-	1 664 400	1 800 355
Evaporation 1.3m/ year	38 395	-	49 400	53 435
Seepage 1.5m/year	44 302	-	57 000	61 656
Volume m3/year	1 411 763	-	1 816 400	1 964 771
Total Volume m3/year	1,4 Mm3		3,8 Mm3	

The theoretically estimation of the volume required for fish farming is estimated to 1,4 million m3 for 74 fish ponds without taking into consideration the phases of the implementation.

Technical constraints for aquaculture

It should be considered that aquaculture was expressed as a least priority water use by the district officers and that there is no use in the Project area for such activity. It should be as well noted that Lake Tanganyika is in close proximity with available fishes.

Taking into consideration that aquaculture was expressed as a least priority water use by the local Authorities, that there is no use in the Project area for such activity and that the Lake Tanganyika is in close proximity with available fishes, this activity could be a least priority to be developed.

The maximum water demand for aquaculture was estimated to 3,8Mm^3 based on population density. However, more detailed studies should be carried out in case of development of such activity.

4.5.5. Hydropower development

4.5.5.1. INSTITUTIONAL FRAMEWORK

The Ministry of Energy and Mines (*Ministère de l'Energie et des Mines*) is responsible for planning and monitoring rural development programs concerning hydraulics and energy projects.

4.5.5.2. ENERGY SUPPLY

The major sources of energy in the Kiremba commune are mainly from:

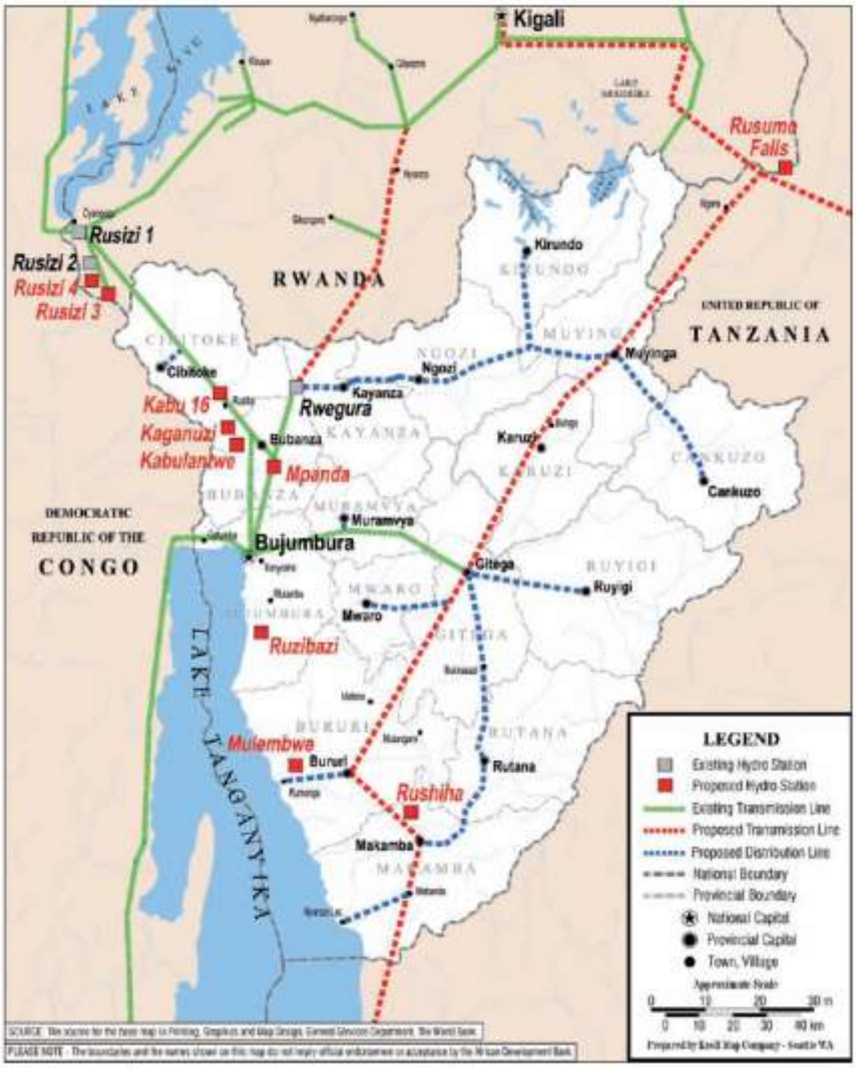
- Wood and paraffin;
- Small power generators;
- Electricity from 18MW Rwegura hydroelectric plant (under rehabilitation);
- A small private 65kW hydro-electric plant located 6km upstream the dam site on the same river. It is used to generate power for the Kiremba hospital. However, this hydroelectric Project could be flooded by the Buyongwe reservoir (see the following figure).

Figure 33: micro Kiremba hydro- power house

Source: Tractebel Engineering – October 2011

The Figure 34 shows that a distribution line crossing Ngozi province is being considered.

Figure 34 : Hydropower development in Burundi



Source: World Bank

4.5.5.3. HYDROPOWER POTENTIAL ASSESSMENT

The methodology used to define the potential energy production is described in the chapter 3.4.1.4. . It is the same as described in chapter 3.3.5 about optimization of the reservoir capacity, except that all the water demand is defined by the requirement of energy production.

Energy production

The results are summarized in the following table with a dam height of 14, 18 and 26m:

Table 17: Energy production results for Buyongwe site

Full Supply Level above ground level (m)	Firm Power (kW)	Mean Power (kW)
12	143	232
16	205	307
24	339	454

Economic analysis

The aim is to present the economic profitability of the project through simple criteria such as cost per kWh delivered and the benefit / cost ratio.

The economic analysis requires two assumptions which are the discount rate and the selling price per kWh.

The discount rate "a" compares expenditures or revenues that are not performed at the same time. It represents an interest rate reflecting the preference for the present of any investor. Thus a cash flow occurring in n years will be the same value as the same financial flows occurring in the current year divided by (1 + a)n. The discount rate is usually set by the authorities for its investments by domestic companies or financial institutions. It usually ranges between 5% and 15% and is even higher than the financial resources are scarce. The update makes it possible to make comparable financial flows including schedules of revenues and expenses are different.

In this study, the hypothesis was a value of 10% for the discount rate which is often taken as a reference.

If the cost per kWh is estimated equal to 0,15 Euros/kWh, the benefit after 30 years of exploitation is given in the following table:

Table 18: Benefit of energy selling for Buyongwe site

Full Supply Level above ground level (m)	Firm Energy (kWh/year)	Benefit after 30 year (Euro)
12	1 253 538	1 948 470
16	1 797 030	2 793 261
24	2 971 674	4 619 099

Each of these potential benefits must be compared to the overall cost of investment cost of the construction of the micro-powerhouse (civil engineering, site facilities, access road, civil works, hydro-mechanical equipment, transmission line…) plus the annual expenses required for the maintenance. According to the experience of the consultant on similar project, all these cost will not be less than 1,2 millions of Euros.

Consequently, the expected benefit at Buyongwe site allows the possibility for development of micro-powerhouse of an installed capacity between 250 kW to 450 kW depending on the dam height, the exact installed power being proportional to the dam height.

Technical constraints for hydropower development

As seen in the environmental and social examination, the development of such micro-powerhouse would lead to flood Kiremba recently refurbished hydropower plant with a full supply level above ground level higher than 12m. The possibility to develop hydropower will be therefore limited, and should therefore focus on the development of the existing Kiremba hydropower.

The development of a 250-450kW micro-powerhouse would lead to flood Kiremba recently refurbished 65kW hydropower plant with a full supply level above ground level higher than 12m. The possibility to develop hydropower will be therefore limited, and should therefore focus on the development of the capacity for the existing Kiremba hydropower.

4.5.6. Water supply

4.5.6.1. CONTEXT

In the country, 72% of the population have access to drinking water source, 38% to 58% in rural areas. 84% of the population at Ngozi have access to potable water, 70% to drinking water.

Kiremba Commune has 5 water networks for drinking water:

- Cagwa-Nyamarobe-Bunogera-Bunywana-Kidasha-Kibuye stream with 13 water points and 1 536 households;
- Ruyumpu-Gatwaro-Kiremba runs with 17 water points with 1 481 households;
- Mugerera-Kiremba, with 17 water points;
- Mugerera-Kiremba;
- Kiremaba, 2km.

The fetching distance to find water is about 1km, estimated to be 15mn.

People have to pay for the maintenance of the water infrastructures.

4.5.6.2. WATER SUPPLY POTENTIAL ASSESSMENT

The below proposal foresee the following components:

- Intake at the Dam
- Water Treatment Plant at the Dam (if feasible)
- Transmission Main to Tanks located at high elevations – potential locations
    - Kigarama / Mugazi (N9684000 E488000) 1803 masl
    - Musumba (N9683000 E493000) 1730 masl
- Gravity Trunkmains to Villages and to Urban Centres – two mains as follows
    - West to Birambi centre
    - Westward towards Ngozi town
    - Eastwards toward Kiremba centre and then split to northeast towards Kirundo town and eastwards to Muyinga town
- Booster pumping along the route may be involved and additional storage tanks for the villages and urban centres will be required.

As shown in the below table, the proposal will cover the villages west, south and east of the dam, and the villages that are located along the gravity trunk main route for supply to the towns of Ngozi in the west, Kirundo in the northeast and Muyinga in the east.

4.5.6.3. POTABLE WATER DEMAND

Water demand calculation is based on a water demand per capita of 20 litres/person/day (lpd). The present and future water demand is estimated as follows:

Table 19: Water supply demand estimation for Buyongwe site

Water Supply	Urban	Peri-urban	Rural	2012			2037		
				Urban	Peri-urban	Rural	Urban	Peri-urban	Rural
Population	levels of services			450 706	103 502	586 514	1 354 564	187 262	1 061 151
Communal Water Points / others	30%	60%	80%	135 212	62 101	469 211	406 369	15 180	848 921
Yard Taps	20%	20%	20%	27 042	12 420	93 842	270 913	5 060	212 230
Multiple Taps House Connection	50%	20%	0%	13 521	2 484	0	677 282	5 060	0
Water Demand m3/d	per capita lpd			m3/d	m3/d	m3/d	m3/d	m3/d	m3/d
Communal Water Points / others	25			3 380	1 553	11 730	10 159	380	21 223
Yard Taps	60			1 623	745	5 631	16 255	304	12 734
Multiple Taps House Connection	120			1 623	298	-	81 274	607	0
Sub-Total m3/d				6 625	2 596	17 361	107 688	1 290	33 957
Non-domestic 30% m3/d				1 988	779	5 208	32 306	387	10 187
Total m3/d				8 613	3 375	22 569	139 994	1 677	44 144
30% losses m3/d				2 584	1 012	6 771	41 998	503	13 243
Grand Total m3/d				11 197	4 387	29 340	181 992	2 181	57 387
				44 924 m3/d			241 560 m3/d		
Annual demand m3/year				16,4 million m3			88,2 million m3		
Option without towns				12,3 million m3			21,7 million m3		
Option with only rural areas of Ngozi Province				6,6 million m3			12 million m3		
Option with 50% of the rural area of Ngozi Province				3,3 million m3			6,4 million m3		

These data should be considered with cautious and should be considered as a maximum.

Kiremba Commune has already five water networks for drinking water. Without taking into account the urban towns, the water demand for water supply in Ngozi Province could be estimated to 21,7Mm^3 as a maximum.

4.5.7. Environmental flow requirement

Following the methodology mentioned in the chapter 3.4.1.6, the environmental flow has been estimated to 8,7 Mm^3 taking into account the mean annual flow of 86,63 Mm^3.

The environmental flow has been estimated to 8,7 Mm^3 based on 10% of the mean annual flow.

4.5.8. Evaluation of Development scenarios

During the socio-economic survey, the district officers as well as local communities expressed the following point of view about the priorities water uses:

1) potable water supply
2) electricity
3) livestock water
4) improved agriculture and irrigation
5) aquaculture

The following table summarizes the merits and demerits of each water use based on the above chapters. The main uses will be analysed, environmental flow being considered in all dam sites.

Table 20: Evaluation of the water uses scenarios for Buyongwe site

Water uses	Existing Use	Demand assessment	Feasibility of installation
Water supply	**Medium**	**High**	**Medium**
Irrigation	**Medium**	**Medium**	**Low**
Livestock watering	**Low**	**Medium**	**Low**
Aquaculture	**Low**	**Low**	**Low**
Hydropower	**Medium**	**Medium**	**Medium**

Thus, aquaculture and livestock watering seems to be the less relevant use to implement for this site.

4.5.9. Analysis of findings and selection of best development scenario for Buyongwe site

The water use review allows estimating the appropriate dam height to deliver the required water demand with an acceptable deficiency.

The below table gives the maximum water demand option excluding the urban towns such as Muyinga, Kirunda and Ngozi towns from the potential water supply use for Buyongwe dam as other water sources are available close to these towns.

Table 21: Summary of the water demand for Buyongwe site

Water Use Type	Water demand (m3/year)	
	2012	2037
Water supply demand	12 310 000	21 742 000
Irrigation water demand	7 980 000	19 600 000
Livestock water demand	260 000	320 000
Aquaculture demand	1 410 000	3 800 000
Environmental requirement	8 700 000	8 700 000
Total (m3/year)	**30 660 000**	**54 162 000**
Total (m3/s)	0,97	1,72

However, the natural guaranteed discharge of the Buyongwe River is 1,80m^3/s. It would be therefore possible to provide all the above mentioned water demand with the River without dam as the natural inflows is sufficient all the year (even during the dry season) to satisfy the maximum water demand.

For energy supply, a small hydropower plant just recently refurbished is already in operation, supplying the local hospital. A dam with 12m FWL would flood this plant. Thus the study has therefore focused on the development of the existing Kiremba hydropower.

For irrigation, it should be noticed as well that the valley is already cultivated leading to a limited irrigation development area, taking into account the peat extraction and the backwater effect of Akanyaru River.

As mentioned above, the development of multipurpose use for this River, meaning the aim of this project could be reached without dam. Thus, following the recommendation of the Consultant, the client has decided improving the irrigation perimeters with multiple dikes and upgrading the water supply for rural areas without building dam. The existing Kiremba power plant has been studied as well for upgrading.

The water demand for all the uses leads to a maximum of 54Mm^3/year, meaning 1,72m^3/s. However, the natural guaranteed discharge of the Buyongwe River is 1,80m3/s. It would be therefore possible to provide all the above mentioned water demand with the River without dam as the natural inflows is sufficient all the year (even during the dry season) to satisfy the maximum water demand.

5. DETAILED DESCRIPTION OF THE PROPOSED DEVELOPMENT SCHEMES AND COSTING

5.1. Introduction

The development schemes below follow the decision taken by the country as mentioned above.

5.2. Irrigation scheme

5.2.1. Main outcomes from the field mission

These outcomes have been detailed in the above chapter 4.5.2. Based on the available map (1/50 000 map) during the field mission, the rough extent of the command area was estimated as:

- 760 ha downstream from the dam up to the first potential axis of control structure,
- An additional 640 ha down to the second potential axis for a total of 1400ha.

These estimates were taking into account a gross area. If developed, it was expected that the reduction between gross controlled area and net irrigated area was in the range of – 20% to – 40%, leading to the following net irrigated area:

Table 22: Crops, expected yields and water requirements

	Maximum net irrigated area	Minimum net irrigated area
Upstream axis (area 1)	608	456
Downstream axis (area 1+2)	1 120	840

Cropping pattern used for irrigation water demand assessment and calculation of irrigation duty was given in the below table:

Table 23: Crops, expected yields and water requirements

Crop	planting time	length of development (days)	expected yield (t / ha)	irrigation water per ha (m^3 / ha)	maximum unit flow (l/s/ha) at 24 h / day
Rice 1	20th Jan	150	3,0	9 000	1,1
Rice 2	1st Jul	150	3,0	12 000	1,6
Maize	1st Jul	150	2,5	2 000	0,3
Beans	1st Aug	120	1,5	1 000	0,3

From the previous point is coming the following assessment of water demand over the year:

Table 24: Total yearly irrigation water consumption for the scheme

Irrigated area	gross volume of water m^3 *			
ha	Rice	Maize	Beans	TOTAL
456	6 840 000	760 000	380 000	7 980 000
608	9 120 000	1 013 000	507 000	10 640 000
840	12 600 000	1 400 000	700 000	14 700 000
1 120	16 800 000	1 867 000	933 000	19 600 000

***** *taking into account the conveyance efficiency*

Finally, the following values have been proposed for irrigation duty (the reference discharge used to design canals systems by simply multiplying the area served by a canal by the value of irrigation duty).

Table 25: Design irrigation duty

Irrigation system	Maximum irrigation duration	Efficiency	Irrigation duty
	(hours)	%	(l/s/ha)
Surface irrigation 1	12	60	3,7
Surface irrigation 2	12	60	5,4

1 *possible rice cropping only during wet season*
2 *possible double rice cropping, during wet and dry season*

5.2.2. Topographical data analysis

There is a serious gap between documents (1/50 000 map) used during the field visit as reported in the water demand analysis and the up to date data (LIDAR contour lines on orthophotographs): the controlled and net irrigable areas specified in the above tables should be reduced to take into account the definitive elevations of the marshland and the actual availability of water due to the non-construction of the dam.

Furthermore, LIDAR survey is not covering the whole valley: flight restrictions are imposed in the border area between Burundi and Rwanda. Therefore 5 km are missing downstream of the valley, on the most suitable area for irrigation development. This is a gap to design the irrigation perimeter as the only data from this missing area is the 1/50 000 map that shows differences with LIDAR survey on the upstream area. The tradeoff used is to reduce the developable area by the same factor as the one calculated on LIDAR surveyed area, by comparing the first estimate based on the 1/50 000 map and the second one based on LIDAR survey.

On later stages of the design, a land survey will be compulsory to complete the topographical data with a reasonable accuracy, so important in this flat area.

Table 26: Evolution of controlled area during the project

	First estimate based on 1/50 000° map	Second estimate based on Lidar survey	Reduction (%)
Upstream axis (area 1)	760	576	24,2%
Downstream axis (area 1+2)	1 400	1 013	27,6%

Switching from low accuracy 1/50 000 topographical maps to high resolution LIDAR surveys associated with orthophotographs triggered a reduction in controlled area (ie. the area where the water derivate upstream in the main canal can flow to irrigate plots) of about ¼ of the total first estimate.

Even though this drop in the area suitable for development is usual, the value is high at that stage, because others reductions are likely to happen during later stages of design, due to general arrangement of blocks (although works are man-made and therefore it is easier to adapt to uneven shape of elementary plots), the necessity to have a drainage system, some high or low spots, access, etc.

In addition, the construction of a diversion structure across the Buyongwe to supply water to main canals is becoming compulsory to (i) raise the elevation of water to allow the main canals to control the whole marshland area and (ii) create a buffer water body, so that irrigation could be run only 12 hours a day with a discharge superior to the available discharge of the river (using a night storage / daily release cycle).

5.2.3. Design standards

- **Irrigation duty**

As shown on the Table 25, the first estimate of the irrigation duty gave a value of 5,4 l/s. This estimate has been calculating using the following assumptions:

- Rice double cropping on the whole area
- Irrigation time: 12 hours a day
- Overall efficiency (canals + on plot): 60%

A regional analysis of the commonly adopted irrigation duties values showed a range between 3,7 and 4,2 l/s, much lower than the first estimate.

Therefore, as the peak requirement is, as usual for rice cropping, the soil preparation (mudding), it has been decided to adopt for that period only a daily irrigation time of 16 hours. This is allowing a reduction of the irrigation duty down to 4,05 l/s, hence approximately 20%.

This of course has also implication on canal cross-sections: according to Manning's formula, a reduction in the discharge triggers a reduction in canal cross-section, assuming longitudinal slope and Manning's coefficient are invariant.

- **Diversion weir / water level control structure**

Hydraulic design
The diversion weir will be designed for routing without damage or overtopping of earth sections a flood of 50 years return period. The weir will certainly operate downstream submerged for high floods, but at that early stage energy dissipation is calibrated to dissipate the energy of 50 years flood. Evacuation capacity of downstream control structure has been designed to route a 500 years flood without overtopping.

Cross section
Crest width will be 4 m to allow small vehicles crossing for the diversion weir (because main bridge across the Marshland is quite close), 6 m for the downstream water level control structure, because the structure will also be used as a major crossing of the marshland. Concrete sections will be only 4 m wide (single circulation lane), as they are short.

In the earth section, side slopes will be 1,5/1. Minimum freeboard will be 0,3 m.

Compaction criteria will be 95%OPM except for fill around or under concrete structures, where it will be 98%.

The cross section will consist in 4 sections, from right bank to left bank:

- Earth section with right bank canal intake (trashracks, upstream or central shaft, sliding gate, culvert);
- Security spillway, masonry made and including a downstream stilling basin made also of masonry;
- Desilting and/or drainage sliding gate, eventually flap gate for downstream water level control structure.
- Earth section with left bank canal intake (trashracks, upstream or central shaft, sliding gate, culvert);

Foundation is not known at this early stage, to be conservative a 4 m deep cut off trench has been taken into account in the design.

- **Canals**

Main canals

General arrangement / longitudinal slope
Main canals (one on each bank) are designed for an irrigation duty of 4,05 l/s/ha, taking into account all losses and irrigation needs of rice crop. Due to the very flat area, it is necessary to build the canal with a minimum longitudinal slope of 1/1000. This will be challenging for construction (only 50 cm difference in elevation for 500m length), but compulsory to actually control the whole area.

Construction materials
Main canals will be built with selected materials, with some minimum requirements in terms of plasticity index and watertightness. These values will be proposed during final design.

Freeboard
Standard freeboard is taken equal to 0,3 m.

Standard section
In cut and fill
While building in cut and fill (ie. along a contour line), main canal will have the following features:

- Side slopes 1,5/1
- Crest width : 1 m upstream, 3 m downstream

In fill
While building in fill (ie. across a thalweg), main canal will have the following features:

- Side slopes 1,5/1
- Crest width : 1,5 m upstream, 1,5 m downstream

Secondary and tertiary canals

General arrangement / longitudinal slope
Secondary canal are mainly built perpendicular to the river, to supply water to tertiary canals parallel to the general direction of the river. The longitudinal slope will follow the natural transverse slope of the marshland (1/1000 to 3/1000), except if water speed is too high. In that case, drop structures will be built. Secondary canals are designed to supply tertiary canals with a minimum 20 cm elevation difference in the worst case.

Tertiary canal are mainly built parallel to the general direction of the river. Others canal are built along contour lines, especially along the lateral thalwegs. The longitudinal slope will follow the natural long slope of the marshland (1/1000 to 2/1000), except if water speed is too high. In that case, drop structures will be built. Tertiary canals are built with a water level 30 cm above the natural ground, to allow for a headloss of 10 cm and a water level inside the basins of 20 cm.

Construction materials
The construction materials will be built using materials locally extracted, especially from drains, to minimize transport and increase production. Hence, maintenance requirements and infiltration rate are likely to be higher. However, the short length of theses canals will keep the efficiency to acceptable values.

Freeboard
Standard freeboard is taken equal to 0,2 m.

Standard section
Fill and cut and fill sections will be similar.

- Side slopes 1,5/1
- Crest width :
    - 1 m both banks for secondary canals
    - 0,5 m both banks for tertiary canals

- **Crossing structures**

Culverts or box culverts
These structures are used for road and drain crossings, the design is made according to pilot drawing in the appendix C.

Siphons
Siphons are used to cross major lateral thalwegs, where the construction cost for a canal is prohibitive due to its height above natural ground. The siphons comprise one inlet shaft with silting facility and trashracks, a concrete pipe with eventually manholes every 100 m, an outlet shaft. In principle, the inside diameter is more than 800 mm to allow human visits for cleaning or maintenance purposes. Typical long section of a siphon is given in drawing in the appendix C.

- **Control and security structures**

Security spillways
Security spillways are inserted at the end of canals and on the main canal, when the section is reduced. It consists in a surface weir and an evacuation canal to the nearest drain. It could be associated to a discharge limitation structure to limit the downstream discharge to the capacity of the reach.

Division boxes
Division boxes are used for regulating the discharge at secondary and tertiary canals intakes. A typical drawing, in the appendix C describes the structure.

Drop structures
Drop structures are used to accommodate too high slopes on canals. In this project, they will mainly be used between main and secondary or tertiary canals, downstream the division boxes. They are described by typical drawing in the appendix C.

5.2.4. Layout of the scheme

- **Diversion structure**

It will be built 600 m downstream from the existing bridge, using the right of way from a small crossing of the marshland, which includes a small bridge as well. The choice of this section has been made due to its narrowness and the pre-existence of this crossing, minimizing the need for resettlement.

The diversion structure will create an approximate 100 000 m^3 and 7 ha pond, with a backwater effect up to the existing bridge. This volume will be used as a buffer to regulate the water level upstream the intake and create a reserve to balance day withdrawal and night impoundment. The 2,5*1,5 sluice gate will route a 10 years flow. The additional security spillway will be able to route a 250 years flow without overtopping of the embankment's crest.

- **Main features of the perimeter**

The designed perimeter is covering a geographical area of 576 ha, out of which the bulk area is 535 ha. It is expected a reduction of 10 to 15% in the net irrigated area, due to the right of way of canals and drains, and minor adjustments to be done at final design stage. Therefore, the net irrigated area could be estimated between 428 and 482 ha.

The perimeter is spreading on a 10 km distance between the upstream diversion weir and the downstream water level control structure. It is divided in 10 sectors, ranging from a bulk area of 2,4 ha up to 181,2 ha.

Table 27: Area by sector

Sector n°	Left Bank / Right bank	Bulk area
1	LB	2,4 ha
2	RB	11,3 ha
3	LB	47,3 ha
4	RB	13,9 ha
5	RB	26,8 ha
6	LB	181,2 ha
7	RB	25,2 ha
8	RB	10,3 ha
9	LB	119,3 ha
10	RB	97,6 ha

- **Main canals**

Two main canals, one on each bank, are designed to supply water all along the valley. They will follow the edge between the marshland and the surrounding hills, 1,5 to 3 m above the elevation of the marshland, and be mainly build in cut and fill section.

Left bank canal has a length of 12,9 km and a total discharge (at the intake) of 1 418m3/s, allowing the irrigation of 350 ha split in 4 blocks.

Right bank canal has a length of 10,4 km and a total discharge (at the intake) of 0,75 m3/s, allowing the irrigation of 185 ha split in 6 blocks.

- **Secondary canals**

As the perimeter is quite narrow, the length of secondary canals will be short. Most of the time, they will be perpendicular to the general direction of the valley. In some cases, they will be built along the main canal.

- **Tertiary development**

Tertiary development includes tertiary canals and drains, basins terracing (form dykes and field ditches), as well as land levelling (+/- 10 cm). Elementary plots dimensions are taken equal to 50 m x 20 m for a hectareage of 0,1 ha. It could be split in 25mx20m. Typical arrangement of a block is given in drawing in the appendix C.

- **Downstream control structure**

This structure will be designed to control the water level in the marshland, to avoid submersion (as long as floods in Buyongwe and Akanyaru Rivers are not synchronised) and drying of the area. It will be designed with 4 sluices 3,2*2,5 m which will route a 500 years flow without overtopping of the embankments. During high floods period in Akanyaru, it will as well avoid the backwater effect to flood back the Buyongwe marshland.

- **Drainage system**

Drainage system will consist in the remodelling of Buyongwe River bed, so that it is possible to route a 10 years flow without submersion of plots for more than 3 days. A secondary and tertiary drainage system will be collecting water coming from the plots as well as the tributaries.

Only one tributary has a catchment over 5 km^2 (actually 55 km^2). It will be necessary to build a dyke upstream the valley to avoid submersion, then to recalibrate its river bed down to the Buyongwe junction.

5.2.5. Cost estimate

Table 28: Proposed bill of quantities for Buyongwe irrigation scheme

Items	Unit	Quantity	Unit Price US $	Total Cost US $
Preliminary and general items (15% of total cost)				
Miscellaneous	15%	1	1 697 983	1 697 983
Sub total				**1 697 983**
Canals & drains (main - primary - secondary)				
Clearing and grubbing area of works	m^2	243 000	0,18	43 740
Common excavation in canal and form compacted embankments (OPM 95%)	m^3	223 000	15	3 411 900
Common excavation in borrow pits and form compacted embankments (OPM 95%)	m^3	16 000	36	576 000
Laterite layer for roads (thickness10 cm)	m^3	500	54	27 000
Formwork rough face	m^2	1 980	14	28 512
Class C25/C30 concrete for reinforced concrete - supply and placement	m^3	198	405	80 190
Reinforcement	T	12	2 700	32 400
Stone masonry for small structures	m^3		135	0
Concrete pipes 1500 mm	ml	1 251	765	957 015
Concrete pipes 1200 mm	ml	480	585	280 800
Concrete pipes 1000 mm	ml	582	473	274 995
Miscellaneous	10%	1	571 255	571 255
Sub total				**6 283 807**
Tertiary development				
Form tertiary canals and drains	m3	115 000	9	1 035 000
Land levelling +/- 10 cm without topspoil removing	ha	500	4 500	2 250 000
Land levelling +/- 10 cm with topspoil removing	ha	0	13 500	0
Miscellaneous	10%	1	328 500	328 500
Sub total				**3 613 500**
Diversion weir+ control structure				
Clearing and grubbing	m^2	12 000	0,18	2 160
Excavation in loose material	m^3	64 000	5	288 000
Class C20 mass concrete - supply and placement	m^3	30	383	11 475
Class C25/C30 concrete for reinforced concrete - supply and placement	m^3	580	405	234 900
Reinforcement	T	57	2 700	153 900
Backfill homegeneous material (sandy clay) using excavated	m^3	44 000	7	316 800
Backfill Transition/Filter	m^3	500	90	45 000
Rip Rap	m^3	900	146	131 220
Miscellaneous	10%	1	118 346	118 346
Sub total				**1 301 801**
Hydromechanical Equipment				
Stoplogs 2,5 m x 1,5 m	U	1	7 200	7 200
Sliding gate 3,2 m x 2,5 m	U	4	18 900	75 600
Sliding gate 2,5 m x 1,5 m	U	1	9 000	9 000
Trashracks 1,5 m x 1 m	U	2	4 500	9 000
Sliding gate 1,5 m x 1 m	U	2	4 500	9 000
Miscellaneous	10%	1	10 980	10 980
Sub total				**120 780**
			Total	**13 017 871**

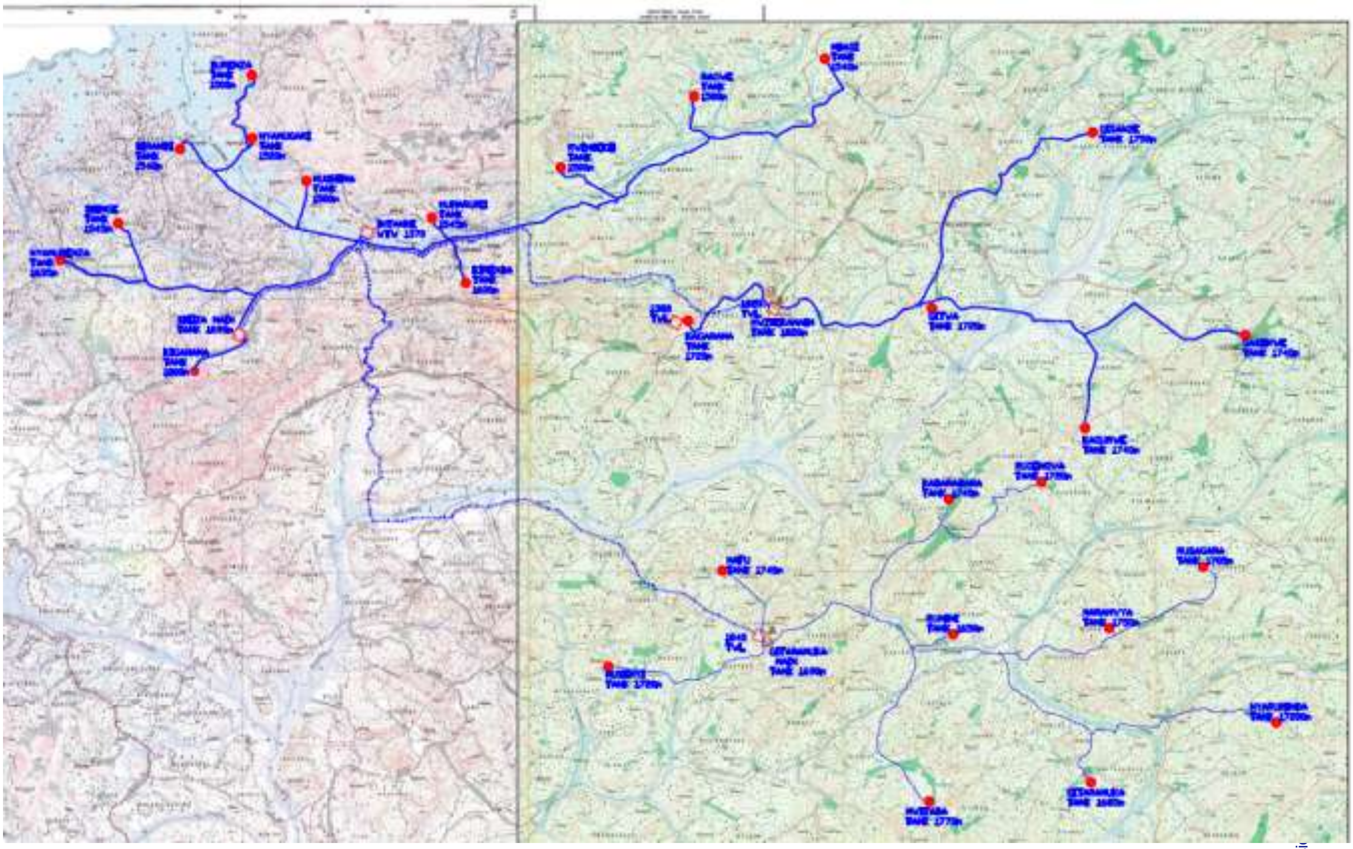
The cost per hectare developed is therefore estimated at 28 929 $/ha. Compared to other schemes, this cost is high, mainly due to the length of main canals and the huge lateral tributaries to be crossed by siphons.

5.3. Water supply scheme

5.3.1. Layout of the scheme

The scheme for the development of the water supply has been designed as follows following the findings and the recommendations of the client, meaning with Ngozi, Muyinga and Kirundo Provinces. Details designs should be carried out at later stage during the detailed design.

Figure 35: water supply scheme



5.3.2. Design of the water supply

The proposed scheme as shown in the above Map covers the following communes:

- Ngozi Province [Kiremba, Marangara, Nyamurenza and Tangara Communes]
- Kirundo Province [Vumbi Commune]
- Muyinga Province [Gashoho and Gasorwe Commune]

The project will comprise the following items:

- Intake on Buyongwe river of capacity 0,69 m^3/s but may be phased
- Water treatment plant of total capacity 60 000 m^3/d and may be phased as follows
    - Ngozi - 32 000 m^3/d in Phase I
    - Muyinga and Kirundo – 30 000 m^3/d in Phase II (if funding not available)
- Low lift pumps – 0,69 m^3/s, 5 nrs pumps (each Q – 0,173 m^3/s, H – 15m and Power 40 Kw – 4 nrs duty and 1 standby). Phase I – 3 nrs, Phase II – 2 nrs

- High lift pumps following three stations (the static heads are too high and therefore booster pumps are proposed along the transmission mains
    - Ngozi Pump Stations – two booster sets (each of 0,33 m3/s capacity) one at river level 1 370 masl and second at 1 515 masl– each station to have 4 nrs pumps (each Q – 0,11 m3/s, H – 165m and Power 275 Kw – 3 nrs duty and 1 standby).
    - Kirundo Pump Stations – three booster sets (each of 0,16 m3/s capacity) one at river level 1 370 masl, second at 1 520 masl, third at 1 670 masl – each station to have 3 nrs pumps (each Q – 0,08 m3/s, H – 160m and Power 195 Kw – 2 nrs duty and 1 standby).
    - Muyinga Pump Stations – three booster sets (each of 0,23 m3/s capacity) one at river level 1 370 masl, second at 1 527 masl, third at 1 684 masl – each station to have 3 nrs pumps (each Q – 0,12 m3/s, H – 167m and Power 290 Kw – 2 nrs duty and 1 standby).
- Transmission mains – three sets as follows :
    - Ngozi Transmission Main - 700 mm and length 5,5 km to Shoza Main Tank 1 690m
    - Kirundo Transmission Main - 500 mm and length 17 km to Mwiteka Main Tank 1 820m
    - Muyinga Transmission Main - 600 mm and 24 km to Gitaramuka Main Tank 1 690m
- Main Storage tank – 3 nrs tanks r.c concrete tanks (Shoza 5,700 m3, Mwiteka 2,800 m3, Gitaramuka – 4,000 m3)
- Distribution - Gravity mains from main tanks to village tanks

Pipe diameter (mm)	Length (m)
100	-
150	31 000
175	5 500
200	39 300
250	37 500
300	11 000
350	7 000
400	3 500
450	10 500
500	8 000
Total	**153 300**

- Villages storage tanks are elevated masonry tanks comprising as follows:
    - 800 m^3 – 18 nrs
    - 750 m^3 - 10 nrs
- Secondary & tertiary mains:

Pipe diameter (mm)	Length (km)
50	400
75	288
90	256
150	208
Total	**1 152**

- Meters and communal kiosks:
    - Zonal meter – 18 nrs
    - Domestic meters – 3,100 nrs
    - Communal kiosks – 2,880 nrs

- Electrical Transmission:
  - transmission cable – 35km
  - sub-station with transformers – 3 sets

The project could be phased with Ngozi to be implemented in Phase 1 and Kirundo and Muyinga in Phase 2.

5.3.3. Cost estimate for the water supply scheme

The cost estimate for the water supply as designed above has been estimated as follows taking into account the two phases of the implementation of the project.

Table 29: Cost estimate for Buyongwe water supply

	Components	KIREMBA			MUYINGA			KIRUNDO			TOTAL BUYONGWE		
	SUMMARY	**Total**	**Phase I**	**Phase II**	**Total**	**Phase I**	**Phase II**	**Total**	**Phase I**	**Phase II**	**Total**	**Phase I**	**Phase II**
A	Water Treatment	5,617,500	5,617,500	0	3,370,500	0	3,370,500	2,247,000	0	2,247,000	11,235,000	5,617,500	5,617,500
B	Pumping Stations	2,225,000	2,225,000	0	714,250	0	714,250	508,000	0	508,000	3,447,250	2,225,000	1,222,250
C	Transmission Mains	3,300,000	3,300,000	0	11,376,000	0	11,376,000	7,293,000	0	7,293,000	21,969,000	3,300,000	18,669,000
D	Storage Tanks	3,617,250	3,617,250	-	2,940,000	-	2,940,000	1,926,000	-	1,926,000	8,483,250	3,617,250	4,866,000
E	Gravity Transfer Mains	7,792,600	7,792,600	0	7,739,000	0	7,739,000	6,680,000	0	6,680,000	22,211,600	7,792,600	14,419,000
F	Secondary & Tertiary Distribution Mains	15,048,000	15,048,000	0	10,488,000	0	10,488,000	8,960,000	0	8,960,000	34,496,000	15,048,000	19,448,000
G	Meters and Communal Kiosks	3,925,500	3,925,500	0	2,742,500	0	2,742,500	1,907,500	0	1,907,500	8,575,500	3,925,500	4,650,000
H	Power to WTW and PS	367,650	367,650	0	535,483	0	0	459,483	0	0	1,362,617	367,650	0
	TOTAL	**41,893,500**	**41,893,500**	**0**	**39,905,733**	**0**	**39,370,250**	**29,980,983**	**0**	**29,521,500**	**110,785,250**	**41,893,500**	**68,891,750**

Detailed costs are described in the appendix J.

5.4. Improvement of the Existing Power plant

5.4.1. Introduction

The chapter 4.5.9 clearly demonstrated that the development of multipurpose use of the River at Buyongwe dam site can be reached without dam. This chapter comments on the possibility to improve the production at the existing power plant without construction of a dam.

5.4.2. Existing Power Plant

The existing power plant of 65 kW capacity consists of:

- A small weir across the river bed creating a small pond

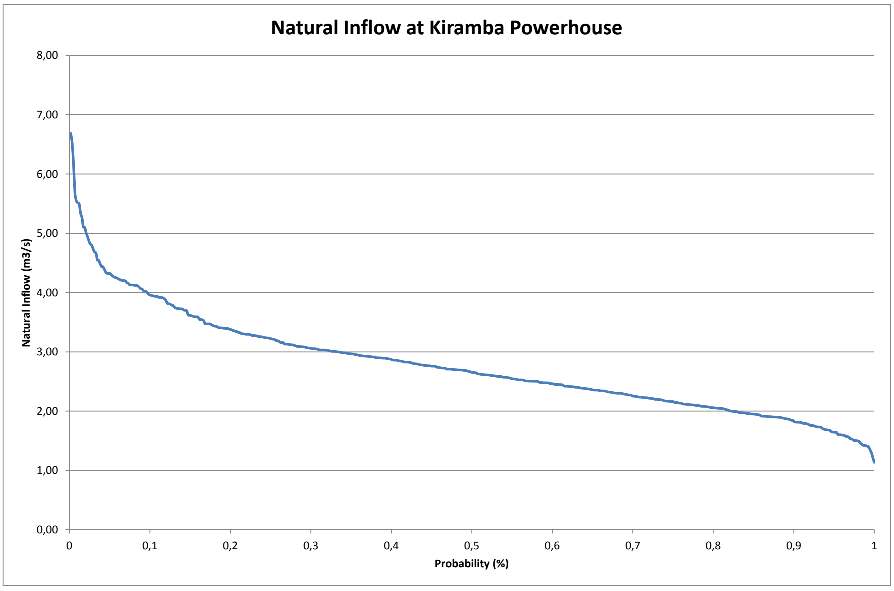
- A lateral canal approximately 1km long up to an intake tower

- Intake tower with lateral spillway and flash gate

- Underground penstock 0,8m of diameter
- A small powerhouse with a 65 kW turbine and a maximum discharge capacity of 1,1 m3/s

- with a 65 kW turbine and a maximum discharge capacity of 1,1 m^3/s

The natural river flow is always larger than the turbined discharge as the weir is always submerged (see previous picture). The following flow duration curve clearly showed that the natural river flow is always larger than the maximum discharge capacity of the existing turbine. The minimum recorded discharge is 1,14 m^3/s since 1940.

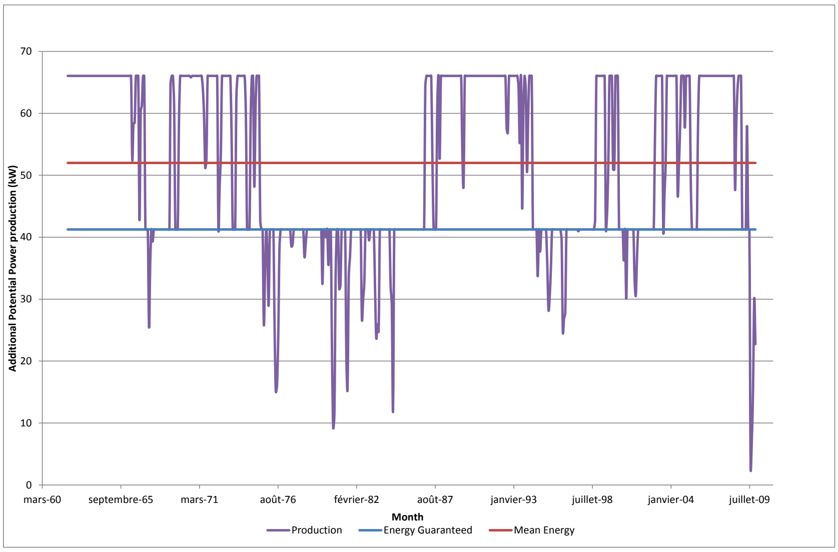


In other words, the turbine can run at its 100% capacity, 24 hours per day and 365 days per year. Therefore, it is not possible to improve the existing capacity by only civil works (rising of the weir, enlargement of the canal and the penstock), but it will be necessary to study the possibility to add a second turbine of same capacity.

5.4.3. Additional Energy Simulation

Simulation of energy production has been performed with the series of monthly natural inflow at the Kiremba site since 1962. To each monthly inflow, 1,1 m^3/s have been subtracted to take into account only the extra water available. Thus, only the potential additional energy production is computed.

The gross head is the same as for the existing turbine, i.e. 8 m. This cannot be improved as it depends only on the local topography. The result of the simulation is shown in the following chart:



The guaranteed energy (10% deficiency) is 41,25 kW while the mean energy is 51,99 kW. The annual mean energy production can be 455 744 kWh/year.

The power generation is limited to 65 KW due to the limited installed capacity (1,1 m3/s).

5.4.4. Cost estimate

The overall cost of investment meaning the cost of the extension for the existing power plant has been estimated as follows:

Installation of new turbine similar to the existing one:	585 000 US$
Heightening of the existing weir and canal:	65 000 US$
Replacement of the existing penstock to allow double flow:	234 000 US$
Civil Works Powerhouse extension:	65 000 US$

Thus, a total of 949 000 US$ has been estimated for the extension of the existing power plant.

5.4.5. Economic feasibility about the extension

Before detailed description of the proposed development, economic analysis has been carried out. The aim is to present the economic profitability of the project through simple criteria such as cost per kWh delivered and the benefit / cost ratio.

The economic analysis requires two assumptions which are the discount rate and the selling price per kWh.

The discount rate "a" compares expenditures or revenues that are not performed at the same time. It represents an interest rate reflecting the preference for the present of any investor. Thus a cash flow occurring in n years will be the same value as the same financial flows occurring in the current year divided by (1 + a)n. The discount rate is usually set by the authorities for its investments by domestic companies or financial institutions. It usually ranges between 5% and 15% and is even higher than the financial resources are scarce. The update makes it possible to make comparable financial flows including schedules of revenues and expenses are different.

In this study, the hypothesis was a value of 10% for the discount rate, which is often taken as a reference.

The cost per kWh is estimated equal to 0,20 US$/kWh. The benefit after 30 year of exploitation could be estimated to 920 000 US$.

This potential benefit must be compared to the overall cost of investment which has been estimated as 949 000 US$ (see the chapter above) which is on the same range as for the benefit. It therefore may appear that the upgrading of the installed capacity for the existing powerhouse is questionable.

Furthermore, this will divert nearly all the flow into the lateral canal, thus precluding any irrigation between the upstream weir and the powerhouse location. This will represent a potential loss of about 10 hectares of agricultural land. Thus the benefit of this upgrading could be therefore questionable taking into account the environmental and social impact.

Financial and economic analysis in the appendix I conclude the no-viability for the upgrading of the hydro-power plant, leading not to design expansion of Kiremba micro hydropower plant.

5.5. Livestock water points

5.5.1. Design of the livestock water points

The water supply scheme will be used to provide water for livestock, with the requested amount of water: 260 000m^3 in 2012 and 320 000 m^3 in 2037 as described in the chapter 4.5.3.

5.5.2. Cost estimate for the livestock water points

The cost of such supply is included as a part of the water supply system as the Burundi is promoting a zero grazing policy.

5.6. Fish farming

5.6.1. Design of the fish farming

The authorities and the communities wish to get aquaculture comprising fish farming in ponds and also integrated with paddy irrigation. The communities have no experience with both technologies and therefore pilot projects will be installed in the initial 2 to 3 years with a roll out plan along the whole valley.

Fish - Rice

During both rice growing seasons annually, fish will be introduced in the paddies. The paddies have to be modified a little by introducing deep (0.8m) ditches within the paddy to shelter the fish when the water levels in the paddies go down. Also screens made of bamboo or timber poles will have to be installed at the out lets to releasing water during the rain but not the fish.

Types of fish reared in the paddies include silver barb, common carp and catla. For feeding fish, rice bran, wheat bran, duckweed, cattle manure are commonly used. Fertilizers are also applied such as Triple Superphosphate and Urea are applied to enhance macrophytes growth that also acts as food for fish. The livestock watering points will generate significant manure for use as fish feed.

The fish farm may be started with 3 000 – 6 000 fingerlings/Ha and during harvest after about the yield is expected to be about 2 000 fish/Ha of average size 120 g every season of 4 to 5 months. The yield is about 250 kg/Ha/season. Higher stocking with larger and deeper ditches will require more intense feeding and will have increased yields of 4 000 to 6 000 fish of up to 600 kg/ha/season.

It has been found in the integrated fish and rice farming that the rice yield increases by about 10%.

However due to water logging necessary for the fish, high variety of rice such as BR-14 cannot be grown but instead BR-11 types survives better. The community will decide to choose fish with poor variety of rice.

We assume that 10% (98 Ha) of the paddy will have fish in the first two years as a pilot. In year 3 and 4, additional 40% (392 Ha) will be added as Phase 1. For Phase 2, the remaining 50% 490 Ha will be implemented in year 10 and 11 by which time all the irrigated paddies will have been integrated with fish farming.

Fish Ponds

The number of the required ponds was based on the population density. The present population density is about 470 persons/km2 and will increase to 850 persons/km2 in year 2037.

The following table gives two options of ponds:.

Table 30: fish farming proposal

	2012		2037	
	Option1 subsistence 2 km radius 2t/Ha/yr size 0.04Ha	Option 2 commercial 4 km radius 3 t/Ha/yr size 0.4 Ha	Option 1 subsistence 2 km radius 2t/Ha/yr size 0.04Ha	Option 2 commercial 4 km radius 3 t/Ha/yr size 0.4 Ha
population density	470	470	850	850
population	5 907	23 628	10 683	42 731
fish consumption kg @ 1kg/person/year	5 907	23 628	10 683	42 731
Net Pond Area Ha	2,95	7,88	5,34	14,24
Nrs of ponds	74	20	134	36
Gross Area Ha	7	15	12	25
Development Proposals	Initially 70	Initially Nil	Finally 134	Finally 36

In the future to year 2037 when the population increases, the numbers of ponds required will also increase, and commercial fish farming may be promoted.

The gross area required for the ponds may be 2 to 3 times the net pond area. It is noted that fish farming was expressed as a least priority water use by the district officers, due to the close proximity of available fishes in the Lake Tanganyika.

The main irrigation canals have outlets in the opposite (away from irrigation) side for filling up the fish ponds. The fish ponds are located in areas that are not used for irrigation. About 27 such locations have been identified as shown in the following map.

Figure 36: Fish ponds scheme in Burundi

Each pond is 15m x 30m in plan size while the commercial pond is about 45m x 90m generally depending on space available. Lime is added at the bottom to neutralize the acidic soils, and every month the ponds dosed with little lime.

The estimated yearly fish production could be between 5-20 tons/Ha depending on the types of fish as described in the appendix I.

5.6.2. Costs estimate for the fish farming

Based on the water demand, the development proposal includes:

- For Integrated Rice with Fish : (1) Year 1: 98 Ha as pilot project; (2) Year 2 & 3: 490 Ha in Phase 1; (3) Year 10 & 11: 445 Ha in Phase 2
- For Fish Ponds: (1) Year 1: 25 small ponds - 1 Ha as Pilot project; (2) Year 2 & 3: 45 small ponds – 1.8 Ha in Phase 1; (3) Year 10 & 11: 64 small 2,6 Ha and 36 large commercial ponds – 14.4 Ha in Phase 2

Detailed priced bills are presented in appendix I with unit cost estimated up to US $ 48 049 for fish pond and US $ 140 554 for commercial pond. For rice – fish farms, the cost per Ha is estimated to be US $ 9 200.

The summary capital costs are summarized in the following table:

Table 31: Cost estimate for fish farming

Fish Farm	**Rate US $**	**Phase IA Pilot**		**Phase IB**		**Phase 2**		**Total**	
SUMMARY		**Qty**	**Amount US $**	**Qty**	**Amount US $**	**Qty**	**Amount US $**	**Qty**	**Amount US $**
Small Ponds (Numbers)	44 811	25	1 120 275	45	2 016 495	64	2 867 904	134	6 004 674
Commercial Ponds (Numbers)	132 604	0	-	0	-	36	4 773 744	36	4 773 744
Rice Fish Ditches (Ha)	7 200	98	705 600	490	3 528 000	445	3 204 000	1 033	7 437 600
TOTAL			**1 825 875**		**5 544 495**		**10 845 648**		**18 216 018**

However, the scheme allows for the time being the implementation of only 27 locations. Thus, the phase IA will be kept in case of implementation of irrigation scheme.

6. INITIAL ENVIRONMENTAL AND SOCIAL EXAMINATION FOR BUYONGWE SITE

6.1. Context

The first examination has taken into account the dam project. However, the decision has been taken not to build a dam. Thus, for this report, the impacts on the two projects, with and without the dam, are presented.

6.2. National legislative and institutional framework

6.2.1. Environment

Legislative context in Burundi

The main text related to environmental impact studies in Burundi is the Environmental Code -"*Loi n°01/010 portant Code de l'Environnement de la République du Burundi*"- on 30 June 2000, in particular the title II, chapter 3:

- The Article 22 deals with environment impact assessment process. When a project is likely to impact the environment, an EIA has to be presented to the "administration in charge of Environment";
- The Article 23 sets out the mandatory content of EIAs;
- According to the Article 27, the power of enforcement and of ensuring compliance is vested in the Ministry in charge of Water, Environment, Territory Management and Urbanism.

The environmental impact assessment procedures defined in the Decree n°100/22 on the 7/10/2010 provides details about the EIA process.

International environmental treaties signed or ratified by Burundi

Burundi has ratified the following conventions:

- The Convention on International Trade in Endangered Species (CITES) implemented at national level through the Law No. 01/17 of 10/9/2011 on Measures for Implementing CITES;
- The United Nations Framework Convention on Climate Change translated into a National Action Plan;
- The Convention on Biological Diversity translated into a Strategy and National Plan of Action for Conservation of Biological Diversity and a National Strategy and Action Plan for Capacity Building in Biodiversity;
- The Convention on Wetlands of International Importance;
- The Convention on the Conservation of Migratory Species of Wild Animals;
- The World Heritage Convention converted into national law through the Law of 25/05/1983 on the Protection of National Cultural Heritage.

6.2.2. Water management

Legislative and institutional context in Burundi

The Ministry of Water, Environment, Territory Management and Urbanism (*Ministère de l'Eau, de l'Environnement, de l'Aménagement du Territoire et de l'Urbanisme*) is in charge of developing a national water resources policy. It defines standards in order to protect water resources. It monitors whether the regulations protection water resources are respected.

The Directorate of Water Resources and Sanitation is established by Presidential Decree No.100/95 of 28/03/2011 and is responsible for the implementation of the policy and strategy provisions on sustainable management of water resources, EIA, and collaboration in trans-boundary water issues. The Water Bill, 2011 elaborates these provisions.

Regulations regarding water uses in Burundi

- The National policy on Water, 2001 ("*Politique nationale de Gestion des Ressources en eau et Plans d'action, Juillet 2001*") is the main policy about the water uses. This plan focuses on access to domestic water supplies, rural hydropower development. It aims at increasing the use of water for agriculture and livestock.
- The Decree n'°1/41 of 26th November 1992 about water sector regulation ("*Décret-Loi portant institution et organisation du domaine public hydraulique*") considers a wide range of issues of water resources management: fisheries, water resources governance, irrigation and water supply.
- The Title III, chapter 2 of the above mentioned Environmental Code, 2000 highlights the importance of meeting with water quality standards
    - According to the Article 52, all dams are subject to EIA procedure.
    - The Article 53 mentioned that minimum flows have to be maintained in order to preserve the life circle and the circulation of living species in the river.
- The Law dealing with public water supply, 2000 ("*Loi N° 01/014 du 11 août 2000 portant libéralisation et réglementation du secteur de l'eau potable et de l'énergie électrique*") regulates the use of natural resources, including water management plans, water quality standards and licensing.

6.2.3. Land tenure management

Institutional context in Burundi

Land administration is shared between different ministries:

- The Ministry of Water, Environment, Territory and Urbanism (*Ministère de l'Eau, de l'Environnement, de l'Aménagement du Territoire et de l'Urbanisme*) is responsible for the cadastre and for titling.
- The Ministry of Agriculture (*Ministère de l'Agriculture*) is in charge of land use planning.
- The National Commission for Land and Other Properties was set up in 2006 temporarily. It is under the Office of the First Vice President. Its aims is to mediate and resolve land disputes related to refugees, to obtain compensation, to update the inventory of state-owned lands and to assist other vulnerable people to reclaim their land.

Legislative context in Burundi

The main texts about land tenure management in Burundi to be taken into account for the study are the followings:

- The Land Code of the Republic of Burundi (Law No.01/008 of 01/09/1986): The procedures for resettlement are provided within the Land Code. Responsibility for resettlement lies with the Ministry of Environment & Lands, but if the land is in a wetland, the responsibility lies with the Ministry of Agriculture.
- The Transitional Act of Constitution, 1998 (*Acte transitionnel de Constitution du 6 juin 1998*): the article 29 states that "every person is granted the right to property".
- The 2011 Land Act (*Nouveau code foncier*) recognizes private rights to land, permits usufruct rights, leasehold and concessions. Furthermore, rights over previously titled land are recognized as private property rights and land rights acquired and held under customary law are considered as legitimate. The article 407 provides the rules for the expropriation of land.
- The Ministry decree n°720/304 stated on March, 20th 2008 provides guidelines for compensation based on the market value and on land for land replacement.

Regulations regarding land tenure in Burundi

Burundi's formal law recognizes state land and private land. All land that is not occupied is considered as state land by the law. According to the 2011 Land Code, unregistered customary do not have the protection of the formal law. Nevertheless registration has hardly taken place.

Under customary law, land is usually held individually and household, rather than by lineage. Nowadays, most households obtained land through leasing, inheritance or purchase. Land transactions and succession are now regulated locally within families, possibly accompanied by a deed outlining the transaction which may have been witnessed by the local administration or by Bashingantahe, which is the customary institution in charge of village-level dispute resolution. This institution is an organized and local body of "wise men", known for being fair and responsible. Their decisions are not legally binding, but carry social weight.

As mentioned above, articles 40, 41 and 49 of Law N°1/014 of 11 August 2000 impose the obligation to put lands required for public use at the disposal of the State. Indemnities are set under the terms of the ministry decree n°720/304 stated on March, 20th 2008

6.3. Preliminary description of existing environmental and socio-economic conditions

Figure 37 : Administrative organization of Kiremba commune, 2005

Source: Monographie de la commune de Kiremba, 2006, Ministère de la planification du développement et de la reconstruction

6.3.1. Physical environment

Climate

Burundi in general has a tropical highland climate, with a considerable daily temperature range in many areas. However, four seasons can be distinguished: the long dry season (June–August), the short wet season (September–November), the short dry season (December–January), and the long wet season (February–May). Most of Burundi receives between 1 300 and 1 600 mm of rainfall a year. According to the Kagera River Basin Monograph [see references], the average rainfall is 1205 mm at Buyongwe site.

Hydrology

The dam is located on the Buyongwe River, an affluent of the Akanyaru and Nyabarongo Rivers. The main results have been presented in the chapter 4.4. It should be noted that the annual sedimentation rate is quite important and the site is likely exposed to siltation.

Ground water

According to Dr. Mkhandi S.H. [see appendix E], there has never been any groundwater monitoring in Burundi despite the medium to high groundwater potentials in the largest northern and central parts of the country.

Water quality

According to Dr. Mkhandi S.H. [see appendix E], there is neither systematic observation of water quality nor any monitoring programme in Kagera River Basin in Burundi, although Kagera River Basin covers the largest part of Burundi. However, it was notified that analyses on Buyongwe River at Kiremba were carried out in 1988 and 1989. Thus it is recommended to carry out a water quality survey on the Buyongwe River as water quality determination is an important element towards an understanding of River ecosystem health.

Geology

The Kagera River Basin consists mainly of detrital rocks, i.e. Precambrian shales and quartzites, folded and slightly metamorphic. These are Burundian age formations in Rwanda and Burundi. These formations lie on late Archean granites and gneisses. The general geological map of the country shows the basement complex, especially phyllites.

Following the site mission, at the dam site, the rocks are not outcropping. On the two banks, the soil consists in lateritic clay and sandy gravels. In the valley, the soil is clayey and swampy, with possible pit.

6.3.2. Biological environment

Flora and fauna

Most of the country is savannah grassland. There is little forest left. Of the remaining trees, the most common are eucalyptus, acacia, fig, and oil palms along the lake shores. Wildlife was abundant before the region became agricultural.

Kiremba commune is mainly the agricultural land area. Thus, the terrestrial flora and the fauna are very limited. Thus, the ESIA should focus on aquatic biodiversity.

Protected area

There are three national parks in Burundi: the Kibira National Park to the northwest, Rusuzi National Park and Rurubu National Park to the northeast (see Appendix A, map MA04):

- The Ruvubu National Park (50 000 ha, established in 1982), containing papyrus wetland with over 400 bird species is located in the Kagera River Basin in the North-eastern region of Burundi sharing a border with Tanzania. The National Park has been affected by poaching, whereby local people carry out illegal hunting and trapping of animals.
- The Kibira National Park, in Burundi, is estimated at 40 000 ha. However, a small part of the Park is situated in the Kagera River Basin (most of the Park is situated at the North East of the Kagera River Basin Burundian part).
- There is two Ramsar Wetlands: Rusizi Delta of the "*Réserve Naturelle de la Rusizi*" and the northern part of the Lake Tanganyika littoral area.

Wetlands are located around 10km downstream where the River joins the Akanyaru.

There are no protected area in the Kiremba District and no National Park in the vicinity of the Project area.

6.3.3. Socio-economic Environment

Characterisation of the population

According the 3rd general census of population and habitat, RGPH (*Recensement Général de la Population et de l'Habitation*) in 2008:

- The population in Burundi is estimated to be 8 053 574, meaning 310 inhabitants/km^2.
- The Ngozi Province has an estimated population of 660 717 inhabitants including 94 619 inhabitants in Kiremba, with 4,7 persons per household.

The spoken languages are Kirundi, Kiswahili and French.

Social environment

➢ Health facilities and health situation

The Kiremba commune has one hospital with the following service units: Theatre, Maternity, Internal medicine, Paediatric and Nutritional unit. The medical staff includes 45 nurses and 3 doctors.

The Kiremba commune has four health centres, namely:

- Kiremba at Kiremba hill: private infrastructure with potable water;
- Gakere at Kiyange: public infrastructure without potable water;
- Musasa at Musasa: public infrastructure without potable water;
- Nyamarobe at Nyamarobe: public infrastructure without potable water.

In Burundi, Malaria is the main cause of morbidity and mortality, being responsible for 40% of consultations in health centres and 47% of in-patient deaths according to World Health Organization. According to the 2010 Millennium Development Goals of Burundi, the incidence rate of malaria is 27,44% in Ngozi Province compared to 26,64% in the country. Thus, Malaria should be taken into consideration for this project.

➢ Land tenure

According to the socio-economic survey, all land is owned by a title deed in the area of the project.

No cultural heritage site has been found in the Project area.

Economic environment

The main economic activities are agriculture and animal production as described above. However, according to the World Food Program in 2008, 8,2% of households in Ngozi Province is affected by food insecurity, compared to the national rate of 4,8.

➢ Agriculture

Traditional subsistence agriculture is the main activity in Kiremba Commune such as in the Kiremba District (estimated as 95% of the activity in the District).

The average agricultural plot size is 0,4 acres per household.

The major food crops growing in the district are:

- Beans: 0,67 tonne/ha
- Sweet potatoes: 5 tonnes/ha
- Rice: 0,8 tonne/ha.
- Cassavas: 6 tonnes/ha.
- Irish potatoes: 5 tonnes/ ha

Coffee is the only cash crop grown in Kiremba district. There are six coffee washing stations in the commune: Ruhama, Kibuye, Gitaro, Masoro, Mufigi, Nyabikenke

Garden crops such as cabbage, aubergines, spinach, carrots, courgette, onions, green pepper, celery, parsley, are also cultivated as well as fruit production (papaya, pruners, avocadoes, guava, banana, maracuja). However, it is mainly for subsistence food.

The cultural practices are mainly the associations of 3 or 4 cultures by plot. The main cultures are banana (3 types), manioc and sweet potatoes. Bean and rice are also practiced. Little irrigation is being practiced in the Project area. Rice paddies were found as the season was the short rains and the groundwater table was high.

In Kiremba commune, agricultural extension services are carried out by one agronomist in the commune, four assistant agronomists at the zone level and 45 agricultural monitors at the village level. There is 1 veterinary office in Kiremba as well.

Kiremba district has 6 marsh lands with a total area of 1 429 ha (Buyongwe, Nyamuswaga, Munyakigina, Kamirampfizi, Kundugu, Mugatobo). The largest ones are Buyongwe and Nyamuswaga covering 600 ha.

- Animal production

According to the "*Monographie de la commune Kiremba, 2006*", the animal breeding sector is constituted of cattle (1 962 in 2005), small ruminants (11 098 in 2005), pigs (2 592 in 2005) and poultry (7 016 in 2005) in Kiremba Commune.

The milk production was an average of 65 Litres per day in 2008.

The herds are mainly located on the hills in order not to destroy the cultures. The size of herd is about 40 animals by owner.

6.4. Analysis of potential impacts

With dam

The preliminary potential impact examination identified the following impacts.

- About physical environment:
  - The erosion of river banks could be an issue due to the Project with the high agricultural activities around the reservoir;
  - Sedimentation transport could be an issue as the annual sedimentation rate (1,4%) is quite important, leading the site likely exposed to siltation. Thus, it should be taken into consideration as the area is highly cultivated.
  - Loss of water resources through evaporation will be a minor impact as the net losses due to evaporation is about 0,8% of the annual inflow.

- About biological environment:

  > No protected area or animal species is located in the Project area. Thus, there is no main issue about biological environment.
  > Due to the change of the hydrology of the River, the aquatic environment as well as the wetlands near the Project area should be taken in consideration;
  > The water hyacinth plant should be studied in case of presence in the area, especially upstream. However, no presence of hyacinth has been observed during the site mission.

- About socio-economic environment:

  > One of the main issues will be the loss of land due to the reservoir depending on the size of the dam as stated in the table below.
  The analysis of the LiDAR map lead to find 117 ha of cultivated land, 55ha of plantations and 24 buildings flooded by the reservoir at MWL (1 385m) for the 14m high dam, which represents about 430 households according to the estimation of the plot size in the area.
  The below table summarize the impact estimation according to the dam height following the orthoimages analysis (see Map MA09 and MA10 in the Appendix B). These numbers would be reviewed by the ESIA team.

Table 32: Estimation of affected households according to the dam size

Dam height (m)	Estimation of the Maximum Water Level (m)	Estimated agricultural land flooded (Ha)	Estimated number of flooded buildings	Estimated number of affected households
14	**1 385**	172	24	1 063
18	**1 389**	220	55	1 359
26	**1 397**	>300	>146	>1 853

Figure 38: Inundated buildings and plantations by the reservoir with 14m dam

> About infrastructures:
  - The laterite access road to Kiremba with the bridge will be flooded by the reservoir of the dam;
  - The Kiremba mini hydro power plant will be flooded with the 14m high dam: this infrastructure has been recently rehabilitated by a new turbine;
  - However, no cultural heritage site should be impacted.
> Water diseases should be studied as the reservoir is close to Kiremba in particular Malaria diseases;

The analysis of each impact will be carried out when the development scenarios and the dam design will be chosen by the client. Resettlement Action plan should be implemented for such project. As seen above, social issues could lead the choice of the dam design, before taking into consideration the objective of the dam.

Without dam

> The erosion of river banks could be an issue due to the Project with the high agricultural activities in the area;
> No infrastructure should be affected by the Project. However, the diversion structure will create an approximate 100 000 m^3 and 7 ha pond, with a backwater effect up to the existing bridge. This volume will be used as a buffer to regulate the water level upstream the intake and create a reserve to balance day withdrawal and night impoundment. With the build canals, an estimation of 10Ha could be estimated to be lost by the irrigation project. These lands are mainly agricultural land. In case of the upgrading of the hydropower plant, around 10Ha of irrigating land could be lost.

6.5. Elements of an environmental and social management plan

6.5.1. Elements for environmental measures

Measures against erosion should be taken into consideration such as the improvement and restoration of the watershed to reduce erosion and sediment ingress with land management measures as described hereafter.

6.5.1.1. MEASURES AGAINST EROSION

6.5.1.1.1. Irrigation scheme design

The irrigation scheme has already taken into account the potential erosion impacts by adapting the cross section as described in the chapter 5.2.3.

6.5.1.1.2. Sheet and rill erosion

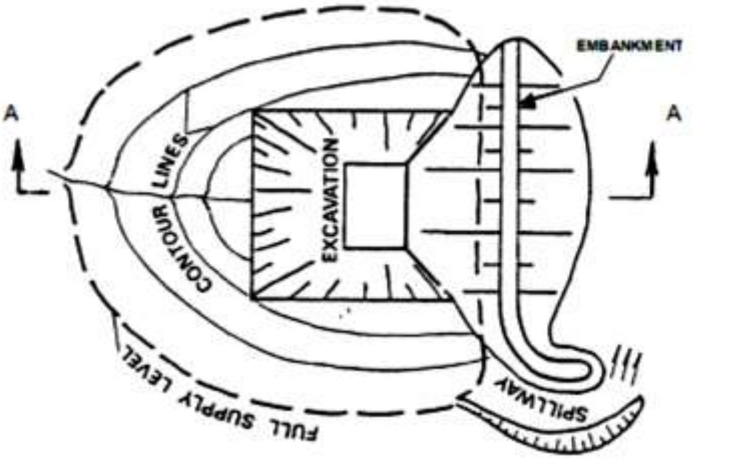
Non-structural measures

The most basic requirement for the control of sheet and rill erosion is to provide and maintain a dense, protective vegetative cover for as much of the time as possible. Special cropping methods and tillage (low till or no till to reduce breakdown of soils) cultivation practices can be employed to minimize the time periods during which the ground must be unprotected during land preparation and seed planting or after harvesting, or to reduce the total area of ground exposed to erosive rainfall at any time. In addition, farming practices or small-scale structural measures can be employed to improve infiltration, retard run-off and reduce the erosive energy of overland flow.

The retention of crop residues and stubble, or vegetative mulches provide a protective soil surface cover. Also cover crops, mixed crops where one crop provides protection for the other during cultivation or germination, or the use of green manure crops for incorporation into the soil, are commonly used for erosion control, particularly where intense rainfalls are experienced during wet seasons or where crops must be grown on steep side slopes. Rotational cropping can be employed for the dual purposes of erosion control, soil moisture control and the enhancement of soil fertility. Strip cropping and alley cropping, where alternating strips of different crop types and different stages of the cropping cycle are planted, are effective methods of erosion control which act not only to maintain effective crop cover but also to retard overland flow and reduce the erosive energy of run-off. All the above techniques are normally termed as “conservation farming”.

Structural Measures

Special cultivation techniques such as contour ploughing, listing or ridging with alternate furrows, provide the simplest and cheapest means of structural erosion control. Other methods for water control include basin listing or tied listing, which involves formation of small dams along the furrow to produce a multitude of small water-holding basins.



PLAN

CROSS SECTION A-A

Terrace-like structures comprising earth embankments, combined with channels that are constructed across sloping land at fixed intervals down the slope for run-off diversion, run-off detention, the slowing-down of overland flow velocity, the reduction of erosive slope length, improved infiltration and soil moisture retention and for slope stabilization. Other terraces types include: channel terraces (20% slope), contour or graded or bank terraces (gentle slope) and bench or step terraces (more common).

On grazing lands, ground cover can be improved by: management of stocking rates, the distribution of grazing pressures by installing more watering points, applying fertilizers, including trace elements for known deficiencies, and removing stock when ground cover levels fall below critical limits or if erosion levels are severe.

6.5.1.1.3. Gully erosion

The control and rehabilitation of gully erosion is undertaken in two phases:

- First: introduce land management measures (dense vegetation cover or strip cropping or grassed graded terraces) and install diversion structures (channels) upstream of the eroded gully area, to reduce the volume and velocity of run-off entering the eroded site.
- Second: structural measures in the gully itself – stabilization and restoration of side slopes and bottom with energy dissipaters at intervals. If severe and deep, then sand bags, timber logs, geotextile, gabions, concrete drop spillways, chute spillways or flumes may be necessary.

For extreme level of gully erosion, it may be necessary to change land use, such as stop cultivation and use as grazing land or natural vegetation / reforestation.

6.5.1.1.4. Wind Erosion

A good vegetative cover is the best protection against wind erosion but land use planning and control (changing of crop types or farming practices, replacement of arable farming with pastoral activities, and prevention of any kind of intensive land use) achieves better result at watershed scale. Two broad categories are proposed:

- use vegetative "structural" devices (wind breaks made of shrubs / trees, strip or alley cropping) to reduce wind velocities and control erosive forces;
- use of special tillage and farming practices aimed at reducing wind erosion by managing the aerodynamic nature of the ground surface.

Other techniques include: stubble retention, mulch incorporation, low till and no till cultivation as for sheet erosion.

On grazing lands, wind erosion control is effected principally through vegetative cover and management of stocking rates.

6.5.1.1.5. Mass Movement – Land Slides

Again a range of non-structural and structural or mechanical means are used. Land-use zoning (prohibition or restriction of agricultural development or urban settlement) in susceptible areas is most cost effective and least costly provide demand for productive land allows it.

There is a variety of structural or mechanical measures that can be used where prohibition is not practical:

- preventing or diverting run-off flows around critical sites
- de-watering sites using drainage systems
- planting trees or shrubs which remove sub-surface water by transpiration
- planting deep-rooted vegetation to bind sub-soil material
- underpinning foundations to stable rock
- battering slopes to stable grades
- constructing retaining walls along the toes of critical slopes

6.5.1.2. MEASURES FOR WETLANDS

Wetlands are located around 10km downstream where the River joins the Akanyaru. It would be recommended to keep the area 2 (around 400Ha) as reported in the Figure 30 for flora and fauna preservation.

6.5.2. Elements for social measures

No resettlement action plan should be carried out due to the project. However, the compensation for the lost lands (between 10 and 20 ha depending on the development of each component of the project) should be carried out in particular the flooded land.

7. FINANCIAL AND ECONOMIC ANALYSIS

7.1. Introduction

Following the findings in the chapter 5, the economic analysis has been carried out for each development scheme as the development of each component of the project will be carried out by different institutional departments. The elements for this analysis comes from the Appendix I.

For memory, the cost for the project is included in the following table.

Table 33: Summary of costs

Water Use Component	Capital Investment Costs US $ for the first stage	Capital Investment Costs US $ for the next stages	Capital Investment Costs US $ TOTAL
Irrigation	13 020 000	10 830 000	23 850 000
Potable Water Supply	41 890 000	68 890 000	110 780 000
Aquaculture	7 370 000	10 850 000	18 220 000
Sub-total	**62 280 000**	**90 570 000**	**152 850 000**

On this total should be added the total cost of the environmental and social management plan (ESMP) and the resettlement action plan (RAP) that has been estimated by the ESIA carried out by Newplan in parallel of this study as 1 565 000 US$, meaning around 1% of the total cost of the project. Thus, 1% of this cost has been added to the cost of each component of the project for the economic analyses.

The technical analysis has shown the water is large enough so that the different water uses are not in concurrence. Consequently, each component can be separately analysed.

To show the viability of the project, economic benefits have to exceed economic costs. The costs are divided between investments costs and Operations and Maintenance Costs.

The benefits accrued from such a multipurpose water resources development project involving mainly irrigation and water supply are improved food security, improved livelihood and therefore living condition. Other indirect benefits include health improvement, fall in infant mortality rates, fall in crime rates, appreciation of land value, and increased productivity.

7.2. For irrigation development

The economic analysis is based on costs (investments, operations and maintenance) and the benefits of the project. The benefits take into account the comparison of two situations: with or without project.

7.2.1. Investments Costs

The costs of the irrigation scheme have been evaluated according to the unit cost method. Unit costs have been derived from similar projects carried out in the lake region and elsewhere but by applying remoteness factors.

Two stages are foreseen for the irrigation project development. Stage 1 corresponds to an area of 535 Ha as detailed by the scheme, and Stage 2 to 445 Ha if developped.

The costs are evaluated to:

Stage 1 (535 Ha)	Stage 2 (445 Ha)	Total (980 Ha)
13 020 000 US$	US$ 10 830 000	US$ 23 850 000

7.2.2. Operating & Maintenance Costs

Maintenance costs cover for parts, spares, sundries and labour for the normal routine and periodic maintenance and also repairs. On the other hand operating costs are costs related to the operation of the irrigation scheme. This is not duplicated with the input required for the crops. These costs can be firstly estimated to 3% of initial investment.

	Investments costs	O&M costs	
Stage 1	US$ 13 020 000	3,25%	US$ 423 150
Stage 2	US$ 10 830 000	3,25%	US$ 351 975
Total	US$ 23 850 000	3,25%	US$ 775 125

7.2.3. Conversion Factors – Financial to Economic Costs

Economic costs are net of market distortions resulting from transfers such as taxes, levies, fees and/or subsidies, for which shadow values are applied. VAT and import duty on water supply components has therefore not been considered in unit costs. Also rent for leasing land and repayment of loan have been considered as transfer payments and therefore not included in the costs.

On the other hand, the proportion of crops grown that is consumed at home is also considered as a benefit and thus as sales revenue. Farm-gate sales are considered for the analyses against farm exported prices to city centres, which might be 2 to 3 times more.

Each category of capital costs and O & M costs are broken down into categories such as traded material, non-traded material, skilled labour, unskilled labour, others (such as transport, overhead costs) and transfer cost (taxes, subsidies, levies). These financial costs have been converted from domestic currency to US dollars currency and they are then multiplied with respective conversion factors, to obtain economic prices.

It is noted that the five countries Tanzania, Uganda, Kenya, Rwanda and Burundi have harmonized all their taxes, duties and levies.

Detailed information is no available to calculate accurately the conversion factors and they are therefore estimated as follows:

- Traded Materials (imported / exported goods) - 1,31 (The Standard Conversion Factor = 1 / 1,31 = 0,763 (includes fertilizers, pesticides, tools)
- Energy including electricity (subsidized otherwise unaffordable) – 1,25
- Non-Traded Materials (road, water, drainage etc) - 1,00

- Unskilled Labour – 0,70 reflected from high unemployment in the country and the readily available unskilled labour – the market wage rate is lower than the recommended wages (it is noted that the legislated minimum wage is BFr 160/day, unreasonably low last established in 1990s while the government recommends BFr 1500/day to investors, while it the market wage was BFr 1000/day). The shadow wage factor = 0,7
- Skilled Labour – 1,00
- Transfer Costs (taxes) – 0,00

For the project, the composite conversion factors used is:

- Capital Costs – 0,9
- & M Costs – 0,85

The economic costs are obtained from financial capital costs and O & M costs of the project by multiplying with the conversion factors discussed above. For crops, the input costs will be used to obtain gross margin and are calculated separately in crop production.

Table 34: financial and economic costs for irrigation development

PHASE	Financial Costs		Economic costs	
	Capital Cost US $	Annual O &M Costs US $	Capital Costs US $ CF 0,9	Annual O & M Costs US $ CF 0,85
Phase 1	13 020 000	423 150	11 718 000	359 678
Phase 2	10 830 000	351 975	9 747 000	299 179
Total	**23 850 000**	**775 125**	**21 465 000**	**658 856**

7.2.4. Benefits

7.2.4.1. CROPS

Without the project, about 30% less land is assumed to be cultivated with rice and instead other lower priced crops such as maize are grown. Two crops are grown: rice between January to May/June followed by beans in July / August. However, at downstream near the Akanyaro confluence, one rice crop is grown after the flood has subsided in October / November. The yield of both rice and beans is poor at 0,5tons/Ha.

Without irrigation crops are estimated as follow:

- Rice – 0,5 tons/ Ha for 70% of 980 Ha total yield 343 tons/year
- Beans – 0,5 tons/Ha for 35% of 535 Ha total yield 94 tons/year
- Maize – 0,5 tons/Ha for 35% of 535 Ha – total yield 94 tons/year

The cropping patterns proposed are as follows with the expected yield from the proposed Stage 1 of 535 Ha and Stage 2 of 445 Ha:

After 2014 - Phase 1 – 535 Ha and non-irrigated Phase 2 445 Ha

- Rice 1 – 3 tons/Ha for 535 Ha – total yield = 1 605 tons/year
- Maize – 2,5 tons/Ha for 50% of 535 Ha – total yield = 669 tons/year
- Beans – 1,5 tons/Ha for 50% of 535 Ha – total yield = 401 tons/year

Before phase 2 is implemented in 2020, the phase 2 land will continue to produce rice after the floods have receded but at a lower yield rates. In non-irrigated phase 2 area of 445 Ha

- Rice – 0,5 tons/Ha for 70% of 445 Ha – total yield = 156 tons/year
- After 2020 - Phase 1 and 2 – 535 Ha + 445 Ha = 980 Ha
- Rice 1 – 3 tons/Ha for 980 Ha – total yield = 2 940 tons/year
- Maize – 2,5 tons/Ha for 50% of 980 Ha – total yield = 1 225 tons/year
- Beans – 1,5 tons/Ha for 50% of 980 Ha – total yield = 735 tons/year

According to FAOSTAT, adopted output prices are as follows:

Year	Producer or Farm-gate Prices US $/ton			
	Maize	Beans	Rice	Live Cattle
2007	313	804	687	1 642
2008	325	805	814	1 712
2012 estimated	395	825	1 100	2 000

The production costs vary with and without irrigation. Their percentage compared to the final price is given in the following table:

Crop	Producer Price US$/ton	Rain-fed				Irrigated			
		Yield Ton/Ha	% of price	US$/Ha	US$/ton	Yield Ton/Ha	% of price	US$/Ha	US$/ton
Rice	1 100	0,5	65%	358	715	3.0	55%	1 815	605
Maize	395	0,5	40%	79	158	2.5	30%	296,3	118,5
Beans	825	0,5	40%	165	330	1.5	30%	371,3	247,5

The gross margin is calculated as follows:

Crop	Output Value Producer Price US $/ton	Rain-fed crops			Irrigated Crops		
		Input costs		Net Benefit US$/ton	Input costs		Net Benefit US$/ton
		% of price	US$/ton		% of price	US$/ton	
Rice	1 100	65%	715	385	55%	605	495
Maize	395	40%	158	237	30%	118,5	276,5
Beans	825	40%	330	495	30%	247,5	577,5

The irrigation scheme shows to increase the farmers'annual revenue of US $ 200589 to US $ 2 218 475, mainly due to higher yield per acreage.

7.2.4.2. LAND APPRECIATION

The irrigation project will result in increased yield and therefore appreciate in value.

The present average valley farm land market prices are assumed to be US $ 4000/Ha and after the irrigation project is implemented, the farms have been estimated to increase the value by at least 25%. This one-time benefit has to be taken into consideration in economic analyses even if land belongs to the government.

In Phase 1 for 535 Ha and in Phase for 2 445 Ha, the area will appreciate in value by 25% being net US $ 1000/Ha one time.

As discussed above, after irrigation, all the irrigated farms will appreciate in value by US $ 1000/Ha.

- In Phase 1 – 535 Ha x $1000 = US $ 535 000
- In Phase 2 – 445 Ha x $1000 = US $ 445 000

A total of US $ 980 000 as one-time benefit is estimated.

7.2.4.3. INCREASED INCOME DUE TO ECONOMIC GROWTH

The enhanced economic growth due to irrigation project will create more jobs or opportunities in business including chain value support for farm inputs and transportation of products.

Taking into account that 30% of the population being working age are unemployed in the project area, it is assumed that 20% of the unemployed will acquire job from the economic growth.

This reflects a benefit of 75 277 people x 30% x 20% x $1,2 /person/day wage x 365 = US $ 1 978 280/Year present. The benefits should be phased as with the investments.

7.2.4.4. INCREASED INCOME DUE TO PROJECT CONSTRUCTION ACTIVITIES

The construction in the villages and the town will create job opportunity for the communities. It is estimated that 20% of the projects costs require unskilled labour and during O & M, 20% of the activity includes unskilled labour.

PHASE	Financial Costs		Financial Benefits X = 20% x Cost	
	Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
Phase 1	13 020 000	423 150	2 604 000	84 630
Phase 2	10 830 000	351 975	2 166 000	70 395
Total	23 850 000	775 125	4 770 000	155 025

7.2.4.5. VAT BENEFIT

It is assumed that 10% of the construction costs and annual O & M costs remain at source attracting 18% VAT, making it a benefit as follows:

PHASE	Financial Costs		Financial Benefits X = 10% x 18% x Cost	
	Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
Phase 1	13 020 000	423 150	234 360	7 617
Phase 2	10 830 000	351 975	194 940	6 336
Total	**23 850 000**	**775 125**	**429 300**	**13 952**

7.2.4.6. SUMMARY OF ALL BENEFITS

The total economic benefits are estimated at US $ 1,84 million annually and US $ 3,2 million one-time upon completion of the project in Phase 1 and US $ 3,7 million annually and one-time $ 2,9 million in Phase 2 as detailed in the following table:

Table 35: Summary of all benefits

Benefit Type	**US $ / year**	**US $ once**
Irrigation Increased Yield Phase 1 Phase 2	 1 211 106 2 218 475	
Land Appreciation Phase 1 Phase 2		 535 000 445 000
Increased Income – Economic Growth Phase 1 Phase 2	978 280 1 978 280	
Project Construction Activities Phase 1 Phase 2	 84 630 155 025	 2 604 000 2 166 000
VAT remain in district Phase I Phase 2	 7 617 13 952	 234 360 194 940
TOTAL Benefits Phase 1 Phase 2	 2 281 633 4 365 732	 3 337 360 2 805 940
Conversion Factor because gross salaries and market prices used	0,874	0,874
Economic Benefits Phase 1 Phase 2	 1 994 147 3 815 650	 2 948 317 2 452 392

7.2.5. Economic analysis

For an economically viable project, the Economic Benefit to Cost Ratio (EBCR) must be more than unity. The Economic Internal Rate of Return (EIRR) should be greater than 12% being the opportunity cost of capital. The project as well should show a positive Economic Net Present Value (ENPV) when investments are discounted at a rate of 12%. A discount rate of 12% is appropriate assessed from the cost of capital based on interest rates, inflation rate and shadow pricing effect (government regulating prices).

For the economic analysis, outlay of costs and benefits from the earlier sections are presented over 25 years to year 2037. Three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

In addition, four sensitivity analyses are carried out as follows:

- Scenario I: increase costs by 15%;
- Sensitivity II: decrease benefits by 15%;
- Sensitivity III: increase cost by 15% and decrease benefits by 15%.

	Variations		EIRR	ENPV (US $)	EBCR
	Costs	Benefits			
Basic	-	-	18,38%	5 151 000	1,29
Scenario I	+15%	-	14,72%	2 515 000	1,12
Scenario II	-	-15%	14,17%	1 742 000	1,10
Scenario III	+15%	-15%	11,02%	- 893 981	0,96

Most of scenarios show that the irrigation is economically viable, except the scenario III. Compared to other schemes, Buyongwe irrigation scheme cost is high, mainly due to the length of main canals and the huge lateral tributaries to be crossed by siphons.

7.3. For water supply development

7.3.1. Investments Costs

The investment costs for water supply have been evaluated as follows:

- Stage 1 : US $ 41 890 000
- Stage 2 : US $ 68 890 000

These correspond to a total of US $ 110 780 000.

If the water supply is only implemented in Ngozi Province, the costs investments is US $ 41 893 500 and could be implemented in one phase.

7.3.2. O & M Costs

These costs have been estimated according to the review of financial performances of similar project in the region (Tanzania, Kenya, Gambia…).

Maintenance costs cover for parts, spares, sundries and labour for the normal routine and periodic maintenance and also repairs. These costs can be firstly estimated to 19% of initial investment.

	Investments costs	**O&M costs**	
Stage 1 (Ngozi)	US $ 41 890 000	19%	US $ 7 959 100
Stage 2 (Muyingo & Kirundo)	US $ 68 890 000	19%	US $ 13 089 100
Total	US $ 110 780 000	19%	US $ 21 048 200

7.3.3. Conversion Factors – Financial to Economic Costs

Based on the same analysis as in the chapter 7.2.3, the composite conversion factors used for the project will be:

- Capital Costs; 0,96
- O & M Costs: 0,88

The economic costs are obtained from financial capital costs and O & M costs of the project by multiplying with the conversion factors discussed above. For water supply, the input costs will be used to obtain gross margin.

Table 36: financial and economic costs for water supply

PHASE	Financial Costs		Economic Costs	
	Capital Cost US $	Annual O &M Costs US $	Capital Costs US $ CF 0,96	Annual O & M Costs US $ CF 0,88
Phase 1	41 890 000	7 959 100	40 214 400	7 004 008
Phase 2	68 890 000	13 089 100	66 134 400	11 518 408
Total	110 780 000	21 048 200	106 348 800	18 522 416

7.3.4. Benefits

The socio-economic assessment carried out in this study and in the ESIA study show following water supply coverage:

- Rural areas : 38 to 58% average to 48%
- Urban areas: Potable water - Muyinga 75%, Ngozi 84% and Kirundo 76%. Drinking water – Muyinga 30%, Ngozi 70% and Kirundo 28%

For Kiremba commune, about 25% of the existing water facilities are not functional thus reducing the coverage to 36%. Where water supply exists, the fetching distance is about 1 km. For areas not served or covered, the fetching distance is assumed to be 2 km and the water may not be safe.

The indirect benefits from such a water supply project might be at first the time saving and the improvement of health. The beneficiaries of the water supply project are detailed in the appendix I.

About 690 000 present population (138 000 Households) are expected to benefit from the project. The household incomes are assumed to be less than $100 per month.

7.3.4.1. TIME SAVING FOR FETCHING WATER

Improved water supply creates cost savings to the community due to time saving in fetching (walking + waiting) for water, reduced storage requirements and no boiling.

It is assumed more than 60% households use wells, water holes, ponds and direct rivers and streams. The per capita consumption in rural areas is estimated at 25 litres per day and per person. The average fetching distance is assessed as about 50 minutes for every 20 litres bucket. With the government recommended wage US$ 1,2/day, the productive time value gained is as follows:

The saving therefore is = 60% x 50/60 (time) x (25)/(20) (volume) x 1,2/8 (US $ wage/hour) x 5people/HH = US $ 0,47 per HH / day x 365 = US $ 171/HH/Year

This is a most significant benefit for the water supply project.

7.3.4.2. HEALTH BENEFITS

Health benefits from reduced health bills, reduced deaths and increased productive times resulting from this project.

Health Bills

ESIA survey records 18% of monthly income (making it US $ 18/HH/month) is spent on medical and health related expenses. The proportion is high implying that at least one member of the household is sick every two weeks. The district statistician expressed that diarrhea and intestinal worms are common after malaria.

The medical expenses are assumed to about US $ 15/HH/month in the project area. It is estimated a medical expenses reduction of 30% with the potable water supply. Thus the annual saving per HH could be US $ 15 x 12 x 30% = US $ 54 / HH/ year.

Productive time

The ESIA survey showed high proportion of medical expense implying that at least one member is sick every two weeks. A lower figure is assumed for analyses. It is assumed 30% of the households reported to have a person sick every two weeks.

The lost productive time = 30% x 5 people/HH x 4/2 weeks x 12 months = 36 person days/HH/year of lost productive time.

By improving health by 30%, the lost productive time will be reduced by 30% and thus a saving of 10,8 person days/HH/year. This saving is valued as = US $ 1,2 x 10,8 = US $ 13/HH/year

The total health saving is estimated to be US $ 67/HH/Year

7.3.4.3. SALE OF WATER SERVICE AS BENEFIT

The project is targeting rural areas where the existing water supply is not extensive and is assumed to be 20% coverage. The new proposed water supply project will therefore have non-incremental supply of 20% and incremental supply of 80%.

It is estimated that 4% of the household income (=100$/month) could be used for water supply, meaning that the water sales could reach US $ 48/HH/year as detailed in the Appendix I.

7.3.4.4. APPRECIATION OF LAND VALUES

It has been estimated that about 25% of the properties which are located near water points and along the pipe lines will increase in value incrementally by 25% after the water supply project is implemented.

It is assumed that in villages, the present land value is $ 0,2/m^2. A 25% increase is $0,05/m^2. Each household plot or premise is assumed to be 1 800 m^2.

The net increase in land value per HH in town assuming 25% properties has been estimated to appreciate up to US $ 22,5/HH.

7.3.4.5. INCREASED INCOME DUE TO ECONOMIC GROWTH

It has been estimated around 10% of the unemployed will acquire job from the economic growth with water supply project.

This reflects a benefit of = 1,50 X 10% x $1,2 /person/day wage x 365 = US $ 65,7/HH/Year

7.3.4.6. INCREASED INCOME DUE TO PROJECT CONSTRUCTION ACTIVITIES

It is estimated that 20% of the projects costs require unskilled labour and during O & M, 20% of the activity includes unskilled labour.

Table 37: income due to the project construction activities

PHASE	Financial Costs		Financial Benefits to HHs X = 20% x Cost/(138 000 HH)	
	Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
Phase 1 (Kiremba Province)	41 890 000	7 959 100	60,7/HH	$11,5/HH/year
Phase 2 (Muyingo & Kirundo)	68 890 000	13 089 100	99,8/HH	$19/HH/year
Total	110 780 000	21 048 200	160,6/HH	$30,5/HH/year

7.3.4.7. VAT BENEFIT

It is assumed that 10% of the construction costs and annual O & M costs remain at source attracting a 18% VAT, making it a benefit as follows:

PHASE	Financial Costs		Financial Benefits to HHs X = 10% x 18% x Cost/ (138000HH)	
	Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
Phase 1 (Kiremba Province)	41 890 000	7 959 100	$5,5/HH	$1,0/HH/year
Phase 2 (Muyingo & Kirundo)	68 890 000	13 089 100	$9,0/HH	$1,7/HH/year
Total	110 780 000	21 048 200	$14,4/HH	$2,7/HH/year

7.3.4.8. SUMMARY OF ALL BENEFITS

The total economic benefits are estimated to US $ 19,5 million annually and US $ 9,2 million one-time upon completion of the project for Kiremba Province and US $ 46 million annually and one-time $ 14,6 million for Muyingo and Kirundo Provinces as detailed below :

Benefit Type	US $ / HH/year	US $ /HH once	Total Benefits for 138 000 HHs
Fetching Distance Saving	171		US $ 23,598,000 / year phased
Health Improved	67		US $ 9,246,000 / year phased
Sales of Water with annual increase 1.7%	48		US $ 6,624,000 / year phased with annual increase 1.7% US $ 112,608
Land Appreciation		22,5	US $ 3,105,000 once
Increased Income – Economic Growth	65,7		US $ 9,066,600 / year phased
Project Construction Activities Phase 1 Phase 2	 11,5 30,5	 60,7 99,8	 US $ 1,587,000 / year and US $ 8,376,500 once US $ 4,209,000 / year and US $ 13,772,400 once
VAT remain in district Phase I Phase 2	 1,0 2,7	 5,5 9,0	 US $ 138,200 / year and US $ 759,000 once US $ 372,600 / year and US $ 1,242,000 once
TOTAL Benefits Phase 1 Phase 2	 163,5 384,9	 76,2 121,3	 US $ 22,563,200 / year and US $ 10,515,600 once US $ 53,116,200 / year and US $ 16,739,400 once Annual increase 1.7% US $ 112,608
Economic Benefits after 0,88 conversion factor Phase 1 Phase 2	141,5 336,4	66,6 106,0	US $ 19,855,440/ year and US $ 9,253,728 once US $ 46,742,256 / year and US $ 14,730,672 once Annual increase 1.7% US $ 98,419

7.3.5. Economic analysis

For an economically viable project, the Economic Benefit to Cost Ratio (EBCR) must be more than unity. The Economic Internal Rate of Return (EIRR) should be greater than 12% being the opportunity cost of capital. The project as well should show a positive Economic Net Present Value (ENPV) when investments are discounted at a rate of 12%. A discount rate of 12% is appropriate assessed from the cost of capital based on interest rates, inflation rate and shadow pricing effect (government regulating prices).

For the economic analysis, outlay of costs and benefits from the earlier sections are presented over 25 years to year 2037. Three economic indicators are calculated:

- Economic Internal Rate of Return (EIRR) that has to exceed 12% the economic cost of capital,
- Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

In addition, four sensitivity analyses are carried out as follows:

- Scenario I : increase costs by 15%;
- Sensitivity II : decrease benefits by 15%;
- Sensitivity III : increase cost by 15% and decrease benefits by 15%;

The water supply shall be performed by public funds, with high indirect benefits. The proposed water supply project is viable if developed in the 3 Provinces with the following positive economic indicators:

	Variations		EIRR	ENPV (US $)	EBCR
	Costs	Benefits			
Basic	-	-	37,02%	91 219 000	1,60
Scenario I	+15%	-	28,26%	68 382 000	1,39
Scenario II	-	-15%	26,96%	54 700 000	1,36
Scenario III	+15%	-15%	19,64%	31 864 000	1,18

The economic analyses, carried out for the implementation of water supply only in Ngozi Province, show as well positive economic indicators for all scenarios as follows:

Ngozi Province	EIRR	ENPV (US $)	EBCR
Basic	37,47%	46 248 000	1,578

The sales water corresponds to about 10 % of all benefits. It means that even if the proposed supply project is viable and shows positive economic indicators, the financial analysis for sale of water will not be positive.

7.4. Fish ponds development

As detailed in the appendix I, the fish ponds are questionable if developed at large scale.

The implementation of the first stage of the project (meaning 25 ponds as shown on the map on the Figure 36) need an investments cots of US$ 1 825 875 and shows low economic performances as follows:

	Variations		EIRR	ENPV (US $)	EBCR
	Costs	Benefits			
Basic	-	-	17,55%	368 000	1,20
Scenario I	+15%	-	13,17%	91 727	1,04
Scenario II	-	-15%	12,54%	37 000	1,02
Scenario III	+15%	-15%	8,99%	-239 000	0,88

Most of scenarios show that the aquaculture is economically viable, except the scenario III. For memory, aquaculture was expressed as a least priority water use by the local Authorities, as there is no use in the project area for such activity and as the Lake Tanganyika is in close proximity with available fishes. Thus, the development of such activity is questionable.

7.5. Summary of economic analysis

Economic analysis concludes the no-viability for the upgrading of the hydro-power plant, leading not to design expansion of Kiremba micro hydropower plant.

Most of economic scenarios show that the irrigation is economically viable. Compared to other schemes, Buyongwe irrigation scheme cost is high, mainly due to the length of main canals and the huge lateral tributaries to be crossed by siphons. It would be recommended to start the implementation of the component of this project by the first stage before deciding to implement the second stage.

The economic analyses, carried out for the implementation of water supply in Ngozi Province, show positive economic performances taking into consideration indirect revenues and collective increased incomes related to project nature and activities (such as fetching distance saving, appreciation of land, economic growth, employment).

The aquaculture shows low economic performances. For memory, aquaculture was expressed as a least priority water use by the local Authorities, as there is no use in the project area for such activity and as the Lake Tanganyika is in close proximity with available fishes. Thus, the development of such activity is questionable.

The costs for the components of the project are included in the following table.

Water Use Component	**Capital Investment Costs US $ for the first stage**	**Capital Investment Costs US $ for the next stage**	**Capital Investment Costs US $ TOTAL**
Irrigation	13 020 000	10 830 000	23 850 000
Aquaculture	1 826 000		1 826 000
Potable Water Supply (in Ngozi Province)	41 890 000		41 890 000
Sub-total	**56 736 000**	**10 830 000**	**67 566 000**

8. TOR FOR DETAILED DESIGN AND TENDER DOCUMENTS

This activity should be implemented in case of dam construction. However, as stated before, the proposed development schemes do not include the construction of dam. Thus, it is possible to implement each component of the project by each administrative department without taking into consideration the dam detailed design. It should be noticed that the irrigation scheme has been provided with detailed design due to the available LiDAR data.

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[a] NELSAP: Rapid identification and assessment of potential sites for multi-purpose storage reservoirs; Eng. Dr. Henry K. Ntale; March 2011.

[b] Bastianssen: Large scale irrigation practices in the Nile Basin, January 2009

The socio economic survey used the following documents:

S/No	Report Titles
A	**GENERAL**
1	A Report on the Assessment of Stakeholder Involvement in the Nile Equatorial Lakes Subsidiary Action Program and Projects – 2011 by Lucy Daxbacher
2	Country assessments on Environmental and Social Policies in the Nile Equatorial Lakes Region – Draft Country Report January 2012 by Judy Obitre-Gama Consultant
E	**BURUNDI**
67	Interim Strategic Framework for Accelerating Economic Growth and Reducing Poverty (Interim PRSP) – by Government of Burundi – 2003
68	Burundi – Poverty Reduction Strategy Paper – 2nd Implementation Report – IMF 2010
69	An Infrastructure Action plan for Burundi – Accelerating Regional Integration by African Development Bank – 2009
70	Burundi Environmental Threats and Opportunities Assessment (ETOA) – 2010 by USAID
71	Policies to Reduce Social and Environmental Costs of trade in tourism Services in the Nile Basin – SDBS – 2008
72	Access to Health Care in Burundi – 2004 by Medecins Sans Frontiers
73	Health and Civil War in Rural Burundi – The World Bank – 2008
74	Lake Victoria Region Water and Sanitation Initiative – Report on Mission to Burundi 2007 bu UN-Habitat
75	USAID Office of food for Peace – Burundi – Bellmon Estimation – 2009
76	State Legitimacy and MSP Service Delivery - Experiences from Burundi – Buhinyuza – Peace Security Development Network – by ACORD – 2011
77	Efficient Water Use for Agricultural Production (EWUAP) Project, Best Practices for Water Harvesting and Irrigation, Burundi by Dr. Ir Henry Niyongabo May 2008
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80	Energy Strategy and Action Plan for Burundi by European Union Energy Initiative 2011
81	EAC Strategy to Scale-up Access to Modern Energy Services – Burundi Country Baseline Report and Workplan by Godefroy Hakizimana 2008
82	An Infrastructure Action plan for Burundi – Accelerating Regional Integration by African Development Bank – 2009

The water use and water demand assessment used the following documents:

- *Power Sector:*

S/No	Report Title
A	**GENERAL**
1A	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2A	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenieur – Socioeconomic (pg 63 – 85), Energy & hydropower (pg 191 to 207), pg 192, 193, 205,
3A	Strategic / Sectoral, Social and environmental Assessment of Power Development Options in the Nile Equatorial Lakes Region – Synopsis Report – Stage 1 – Burundi, Rwanda and Western Tanzania – Feb 2005 by SNC Lavalin for NBI NELSAP
4A	An Infrastructure Action plan for Burundi – Accelerating Regional Integration by African Development Bank – 2009 pg 46, 55, 59, 62, 77 – 79, 90 – 91, 134 – 139, 156,
5A	Hydropower Development – Small Scale Hydropower for Rural Development – Nile Basin Capacity Building Network - 2005
E	**BURUNDI**
16A	Energy Strategy and Action Plan for Burundi by European Union Energy Initiative 2011
17A	EAC Strategy to Scale-up Access to Modern Energy Services – Burundi Country Baseline Report and Workplan by Godefroy Hakizimana 2008 pg 80 – 84
18A	An Infrastructure Action plan for Burundi – Accelerating Regional Integration by African Development Bank – 2009

- *Irrigation Sector:*

S/No	Report Title
A	**GENERAL**
1B	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2B	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenieur – Socioeconomic (pg 63 – 85), Agriculture Livestock and forestry (pg 121 – 167), pg 124, 126, 132, 138, 143, 145, 148 to 152
3B	Agriculture Water in the Nile Basin - Efficient Water Use for Agricultural Production (EWUAP) Project – for NBI by Ian McAllister Anderson – April 2008 Agriculture Water Use (pg 35 to 67) and Best Practices (pg 70 to 91)
4B	Large Scale Irrigation Practices in the Nile Basin - Efficient Water Use for Agricultural Production (EWUAP - NBI – Jan 2009 by Bastiaanssen and Perry pg 22, 25, 34, 44, 55 - 59, 71, 74, 76, 77, 136 – 140, Annex D, H, J and K.
5B	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82),
	Farm Management Handbook of Kenya Vol II Natural conditions and Farm Management Information – Part A West Kenya
E	**BURUNDI**
29B	Annex A – Burundi Country Overview - Efficient Water Use for Agricultural Production (EWUAP) Project, Agriculture Water in the Nile Basin April 2008 – pg 4, 5, 6
30B	Efficient Water Use for Agricultural Production (EWUAP) Project, Best Practices for Water Harvesting and Irrigation, Burundi by Dr. Ir Henry Niyongabo May 2008 page 45-55

31B	USAID Office of food for Peace – Burundi – Bellmon Estimation – 2009 pg 25 – 26, 29, 31, 49, 50, 59 – 63, 66 – 69,
32B	Efficient Water Use for Agricultural Production (EWUAP) Project, Best Practices for Water Harvesting and Irrigation, Burundi by Dr. Ir Henry Niyongabo May 2008

> *Livestock Development Sector:*

S/No	Report Title
A	**GENERAL**
1C	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2C	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenieur – Socioeconomic (pg 63 – 85), Agriculture Livestock and forestry (pg 121 – 167), pg 134, 135, 153,
3C	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82),

> *Fisheries and Aquaculture Sector:*

S/No	Report Title
A	**GENERAL**
1D	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2D	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenirie – Socioeconomic (pg 63 – 85), Fisheries and Aquaculture (pg 185 to 190), pg 188,
3D	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82),
	Fingerponds – Seasonal Integrated Aquaculture in East African Freshwater Wetlands – PhD Thesis by Julius Kipkemboi 2006
	Guiding Principles for Promoting Aquaculture in Africa – benchmarks for sustainable development - FAO and Worldfish Paper No 28 – 2006 pg 91 Design Procedure

> *Water Supply Sector:*

S/No	Report Title
A	**GENERAL**
1E	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2E	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenirie – Socioeconomic (pg 63 – 85), Potable water (pg 209 to 221), pg 210, 211, 213, 216, 218, 221,
3E	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Rural Domestic Water Demand and Use (pg 85 to 105), Industrial Water Demand and Use (pg 107 to 120), Urban Water Demand and Use (pg 121 to 156)
4E	Practice Manual for Water Supply Services in Kenya – Part A Water Supply Nov 2005 Chap 2 Water Demand – all sectors
E	**BURUNDI**

15E	Lake Victoria Region Water and Sanitation Initiative – Report on Mission to Burundi 2007 by UN-Habitat

- *Common Sectors:*

S/No	Report Title
A	**GENERAL**
1F	Rapid Identification and Assessment of Potential Sites for Multi-purpose Storage Reservoirs – Final Assessment Report for NELSAP – Kagera River Basin Management Project - by Dr. Henry Ntale March 2011.
2F	Kagera River Basin Monogoraph – Basin Development report – Transboundary Integrated Water Resources Management and Development Project – Kagera River Basin – July 2008 for NELSAP by BRL Ingenirie – Socioeconomic (pg 63 – 85), Agriculture Livestock and forestry (pg 121 – 167), Environmental use (pg 169 to 183), Fisheries and Aquaculture (pg 185 to 190), Energy & hydropower (pg 191 to 207), Potable water (pg 209 to 221), Transport & navigation (pg 223 to 230), Tourism (pg 231 to 238), Mining (pg 239 to 245),
3F	Development of Kagera Integrated River Basin Management and Development Strategy – Main Report – May 2010 by SWECO for NELSAP – Socioeconomic (pg 14-21), priority areas (pg 26), water use (pg 36-39), Water Demand (pg 54-59), pg 112, 117, Annex F,
4F	Country Assessments on Environmental and Social Policies in the Nile Equatorial Lake Regions – Draft Country Report – for NBI NELSAP by Judy Obitre-Gama Jan 2012. Sections 2.1 – Burundi, Sec 2.4 – Rwanda, Sec 2.5 – Tanzania, Sec 2.6 - Uganda
5F	Handbook for the Assessment of Catchment Water Demand and Use – HR Wallingford and DFID for Zimbabwe and Zambia – 2003 Environmental Water Demand and Use (pg 20 to 41), Agricultural Water Demand and Use (pg 44 to 82), Rural Domestic Water Demand and Use (pg 85 to 105), Industrial Water Demand and Use (pg 107 to 120), Urban Water Demand and Use (pg 121 to 156)
6F	Regional Transboundary Diagnostic Analysis of the Lake Victoria Basin – Lake Victoria Basin Commission – EAC March 2007
7F	Water and Agriculture in the Nile Basin – FAO 2000
8F	Environmental Water Requirements Rapid Assessment – by Tshimanga and Ndomba 2008
E	**BURUNDI**
21F	Efficient Water Use for Agricultural Production (EWUAP) Project, Best Practices for Water Harvesting and Irrigation, Burundi by Dr. Ir Henry Niyongabo May 2008
22F	Les Aspects Monographiques de la Kiremba – Annexe du plan Communal de Development Communataire de la Commune Kiremba – PCDC – 2008
23F	Recensement General de la Population et de L'Habitat 2008 for Ngozi Province – Statistician
24F	Food Security and Vulnerability analysis Report Burundi July – Aug 2004. for WFP
25F	Efficient Water Use for Agricultural Production (EWUAP) Project, Best Practices for Water Harvesting and Irrigation, Burundi by Dr. Ir Henry Niyongabo May 2008
26F	An Infrastructure Action plan for Burundi – Accelerating Regional Integration by African Development Bank – 2009