NILE BASIN INITIATIVE

Nile Equatorial Lakes Subsidiary Action Program

Kagera River Basin Management Project

FEASIBILITY STUDY FOR *BIGASHA* 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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Project : **Feasibility studies for 4 small multipurpose dams in the Kagera River Basin**

Subject : **Feasibility Study Report – Final report about Bigasha site in Uganda**

Comments : **The following names will be used from now 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 the project in Uganda, including the selected dam 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.*

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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
ESMP	Environmental and Social Management Plan
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
HSS	Hydro Steel Structure
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

Mm3	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
O&M	Operation and Maintenance
OP	Operational Policies
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PMU	Project Management Unit
RAP	Resettlement Action Plan
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 Project is located in Western Region of Uganda, in Isingiro District in Ngarama Sub-county, Bukanga County. The dam site is about 30 km from Isingiro town, on Bigasha River, which is a seasonal River.

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 of the project area including potential irrigation area and taking into account the country border. 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. The results have led to review the topographical data of previous studies such as reduction the potential control area for irrigation.
- 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.
- During the geotechnical investigations within the rainy season for the dam design, no water has been found. The geophysical investigation shows in the central part of the dam axis, on a length of about 200m, a decreasing profile of resistivity, that can be explained with the presence of highly weathered/highly jointed bedrock at a depth to 25-30 m. The discontinuous nature of the Bigasha River and the permeability of the bedrock along the dam axis should be further investigated at later stage.
- The availability of hydrological records has conditioned the way of executing the studies. Thus, the determination of the classic parameters has been carried out by correlation to neighbouring known catchments or through internationally accepted methods. Doing so, the hydrological study estimated the annual runoff about 0,41 m^3/s, with a quite pronounced seasonal pattern due to arid conditions and dry periods without flows. Taking into account the net losses due to evaporation as about 15,1% of the annual inflow, the maximum discharge is 0,35 m^3/s. Taking as well into account the annual sedimentation rate at Bigasha site as 0,062 Mm^3 and the maximum annual water demand as 15 Mm^3 , the dam height has been defined at 12 m with a Full Supply Level = 10m.
- The main impact of such project would be the loss of a large cattle grazing area, estimated as about 100Ha, with land tenure to take into consideration.

All the previous investigations led to carry out the detailed design scheme for Bigasha dam with the following characteristics:

Dam Type	Clay core zoned earth and rockfill embankment
Maximum height	12,00 meters (from the natural ground level)
Crest length	610,16 meters
Maximum width at NGL	60,00 meters
Slope of upstream face	2.5H:1V
Slope of downstream face	2H:1V
Plan alignment	straight
Dam Crest level	1 268,00 m asl
Full Supply Level	1 266,00 m asl
Maximum water level	1 267,24 m asl
Minimum operational level	1 262 m asl

The cross section of the dam consists of an earth zoning dam type with central core of clay, supported upstream and downstream by filter and drainage system and rockfill random material. Homogeneous earthfill dam was initially recommended by the Consultant, but the client has required the change of the design due to its local experience with such type of dam.

Upstream embankment will be protected with rock to prevent erosion. It is as well advised to protect downstream embankment with grass.

In order to mitigate uncertainty about water seepage and on the basis of available investigations results, the seepage control is improved by a 15m cut-off wall (which projects into the core and bedrock) in the River valley and a horizontal drain downstream.

The main uses of the dam have been defined as follows:

- Irrigation with the designed perimeter covering a geographical area of 600 ha, out of which it is expected a reduction due to the right of way of canals and drains. Thus, the net irrigated area is estimated at 451 ha, with 6 km distance between the dam and the downstream block. Different cropping pattern could be carried out in this area, based on annual crops (maize, rice, beans, potato, and vegetable) as well as perennial crops, mainly forage and fruits such as pineapple, orange, citrus.
- For the water supply, the proposed scheme covers the following wards in Isingiro district: Nyakitunda, Kabingo, Kashumba and Ngarama for the objective of 23 600 households as beneficiaries.
- For the livestock watering, the design has been produced for 151 000 livestock units with 20 water points, each one with a capacity of 7 000 litres.
- Taking into consideration that there is no aquaculture experience in the Project area, this activity could be developed at first as pilot project with 20 fish ponds.

The cost of the dam construction is estimated to 37M US$ as follows. The economic viability of the project is consequently questionable when compared to similar dam costs. The high cost of the dam is mainly due to the 15m cut-off wall.

Bigasha dam	Cost US $
Preliminary works	3 755 439
Dam	30 686 903
Spillway	2 356 417
Bottom Outlet	146 405
Hydro Steel Structure Equipment	82 800
Total	**37 027 964**

The summary of costs for all the projects is 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
Dam	37 030 000		37 030 000
Irrigation	2 433 000	1 586 000	4 019 000
Potable Water Supply	17 535 000		17 535 000
Livestock Water Supply	2 397 000	959 000	3 356 000
Aquaculture	896 000	2 007 000	2 903 000
Sub-total	**60 291 000**	**4 552 000**	**64 843 000**

The benefits includes time saving for fetching water and health benefit (for water supply project), land appreciation, increased income and VAT benefit.

The economic analysis for the multipurpose dam with the objectives of irrigation, water supply, fish ponds and livestock watering give the following results taking into consideration all the benefits as described above:

- EIRR: 20,10 %
- ENPV: US $ 34 622 000
- EBCR: 1,287

However, in case of a scenario with 15% increase in costs and 15% decrease in benefits, the project would not be economically viable.

Irrigation and water supply components are not economically viable if developed alone, but need to be associated with other water use components.

The economic balance of the water use components requires that indirect revenues and collective increased incomes related to project nature and activities (such as appreciation of land, economic growth, employment) are taken into account.

1. INTRODUCTION

1.1. Preamble remarks

Following the inception mission, 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).

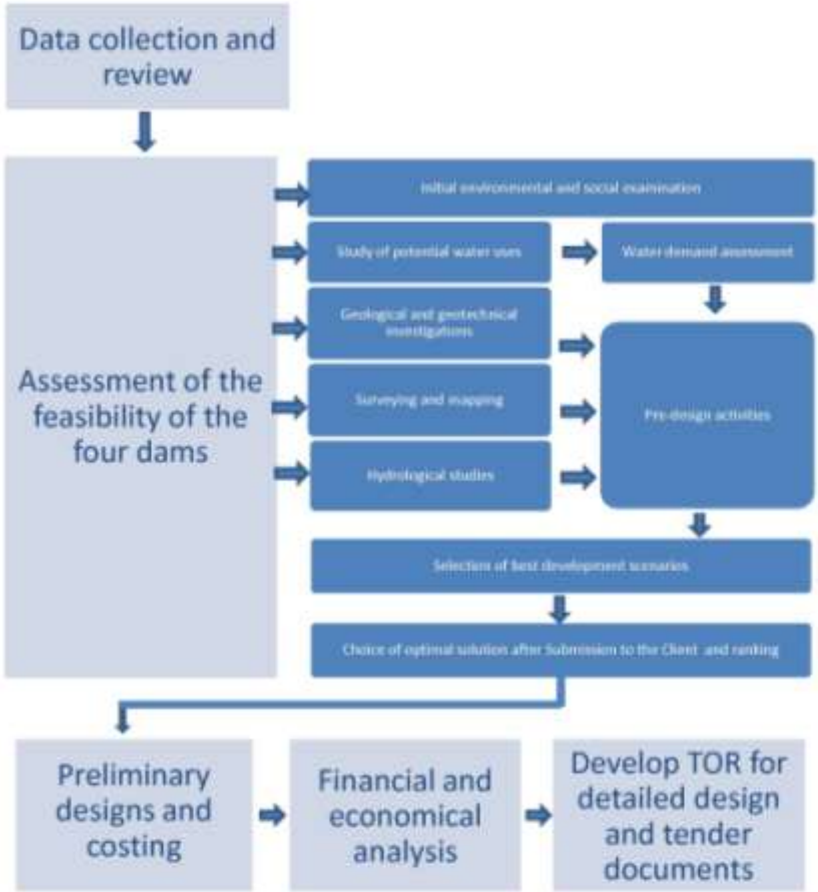
1.3. Study objective

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 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;
  - Design of the 4 selected dams' infrastructure and appurtenances;
  - Detailed technical, financial and economic assessment of the multipurpose dam sites; 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;
- The terms of reference for the detailed designs and tender documents.

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 Uganda were 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.

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.

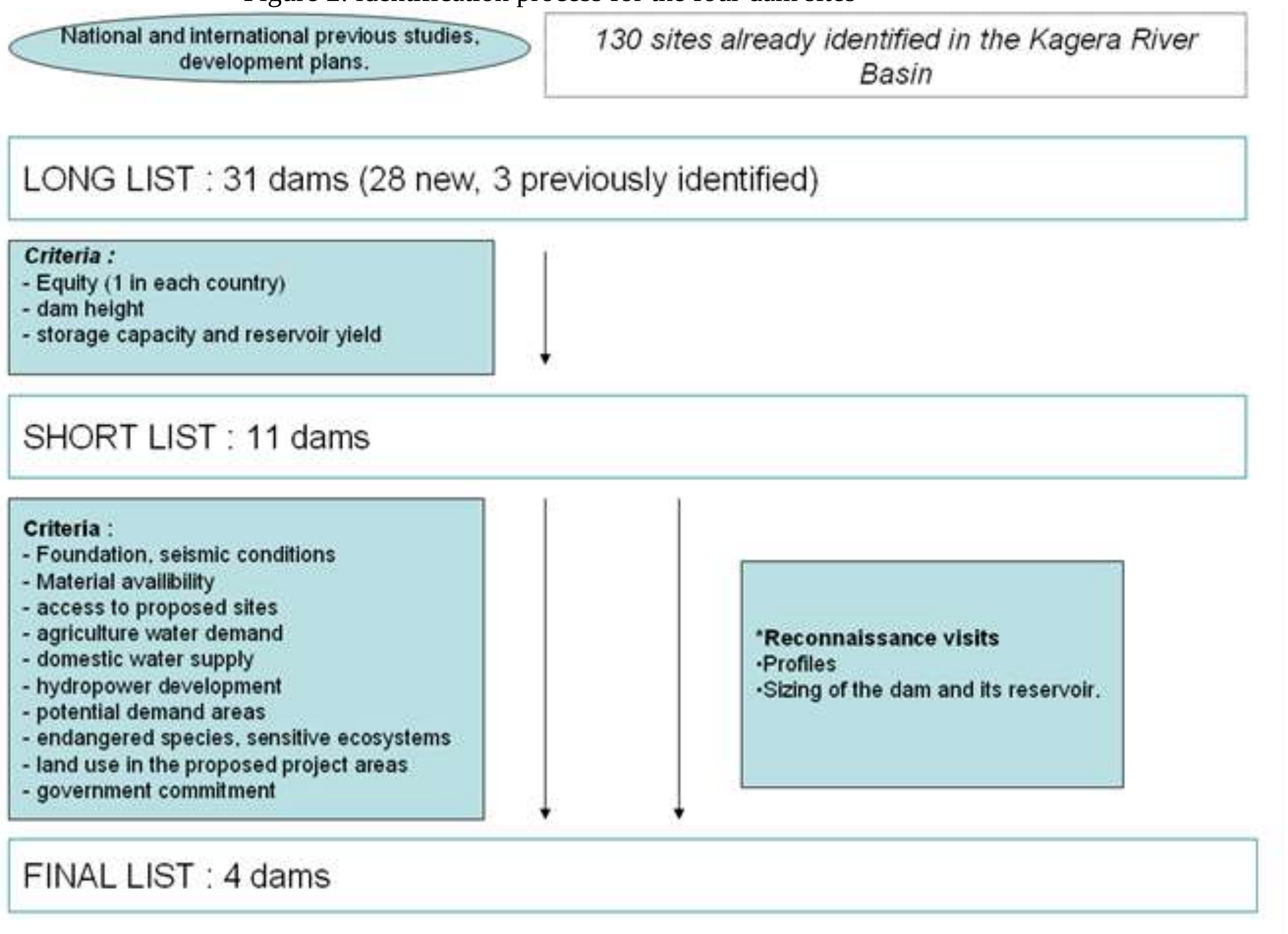
The project objective of the Kagera Trans-boundary Integrated Water Resources Management and Development Project is to establish a sustainable framework for management of water resources of Kagera River Basin, in order to prepare for sustainable development oriented investments that will improve the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

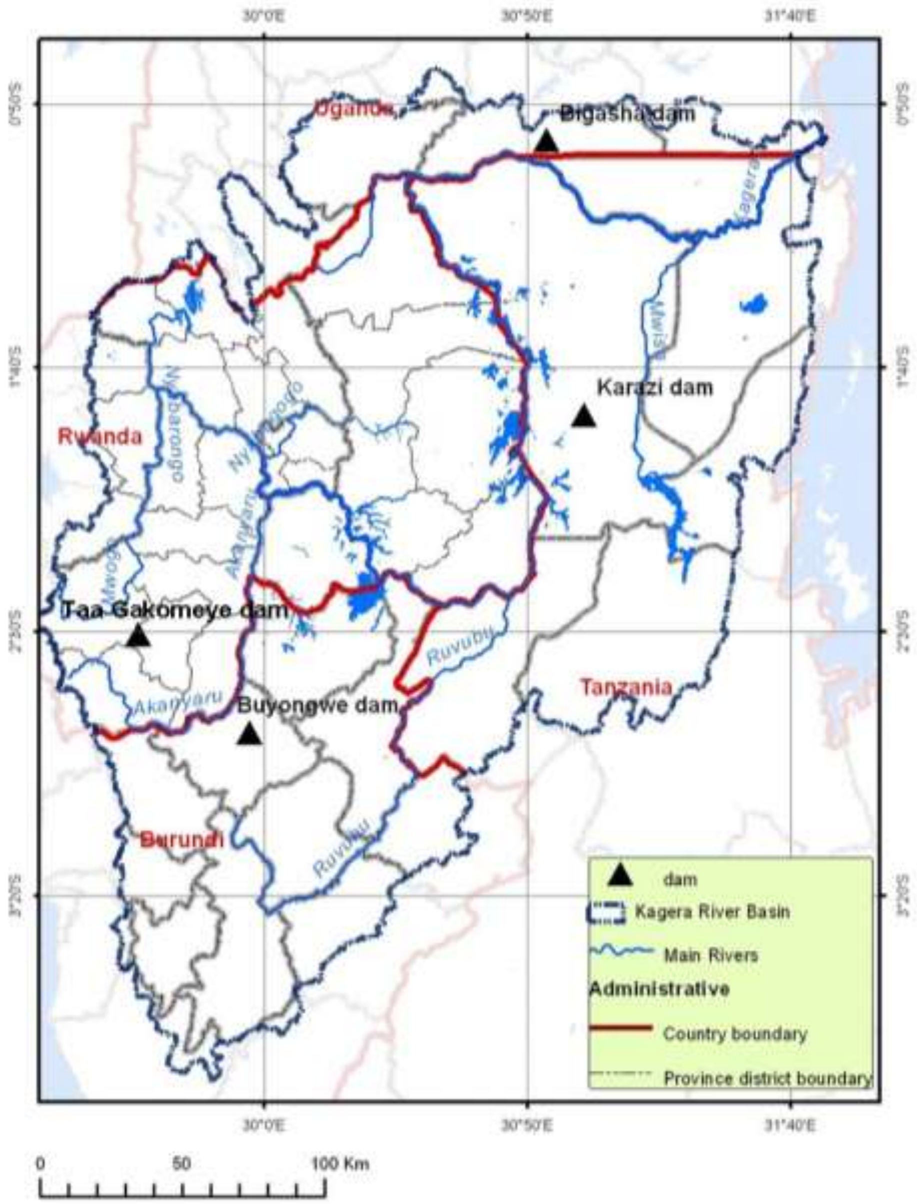


However, the study did not consider environmental and social economic considerations in the identification of the dam sub-projects. Thus, the aim of this present study is the feasibility studies for these four priority multipurpose dam sites, which study will assess the technical, social, economic &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

2.3. Location of the Project

The locations of the sites are shown on the following map within the Kagera River Basin.

Figure 3: location of the four sites of the 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)

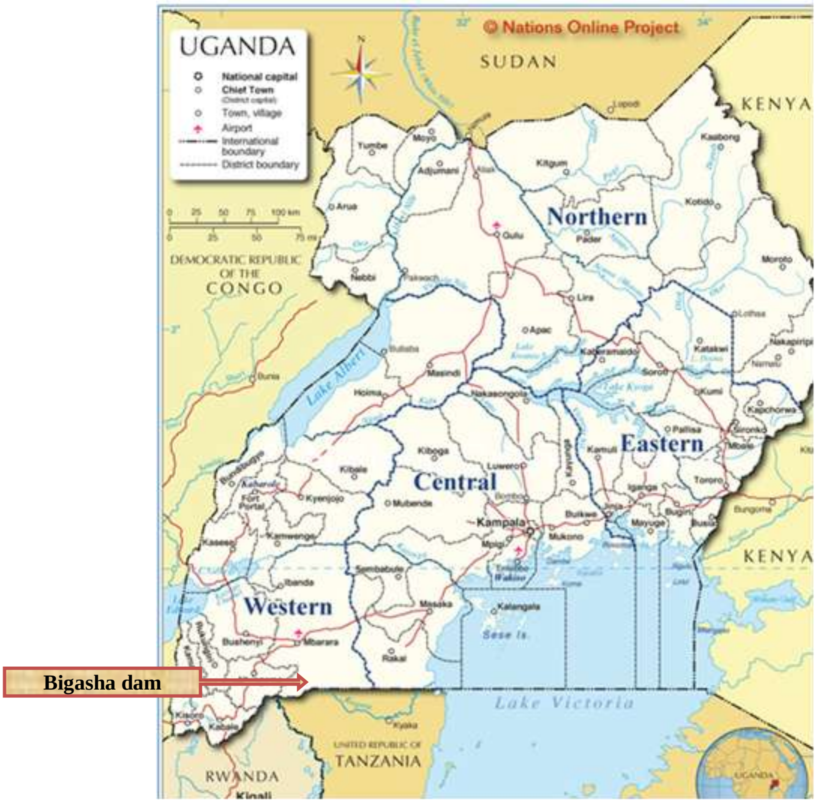
Country	Dam site	Y (DD)	X (DD)	Z (m)
Rwanda	Taba-Gakomeye	-2,50775	29,60169	1659
Burundi	Buyongwe	-2,81669	29,95647	1382
Tanzania	Karazi	-1,82336	31,01526	1324
Uganda	Bigasha	-0,94818	30,89745	1261

2.4. Location of Buyongwe site

Uganda is divided into regions, districts, sub-districts, counties, sub-counties, parishes and villages. The four administrative regions of Uganda are Northern, Eastern, Central (Kingdom of Buganda) and Western. The following map highlights the four regions of Uganda and the location of the Bigasha dam site.

Parallel with the state administration, six traditional Bantu kingdoms have remained, enjoying some degrees of mainly cultural autonomy. The kingdoms are Toro, Ankole, Busoga, Bunyoro, Buganda and Rwenzururu.

Figure 4: Uganda administrative map



Source: NationsOnline Project, http://www.nationsonline.org

The Project is located in Western Region of Uganda, in Isingiro District in Ngarama Sub-county, Bukanga County. The dam site is about 30 km from Isingiro town, the main municipal, administrative and commercial centre in the District, located approximately 35 km by road, southeast of Mbarara, the largest city in the sub-region.

Figure 5: Location of dam site in Isingiro District

The coordinates for the axis of the proposed dam were recorded as follows:

Table 2: Bigasha dam axis coordinates

DAM AXIS COORDINATES					
Bigasha - Uganda					
	30,89597	-0,94423	265852,76	9895563,25	Right
	30,89832	-0,95016	266114,8	9894907,52	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":

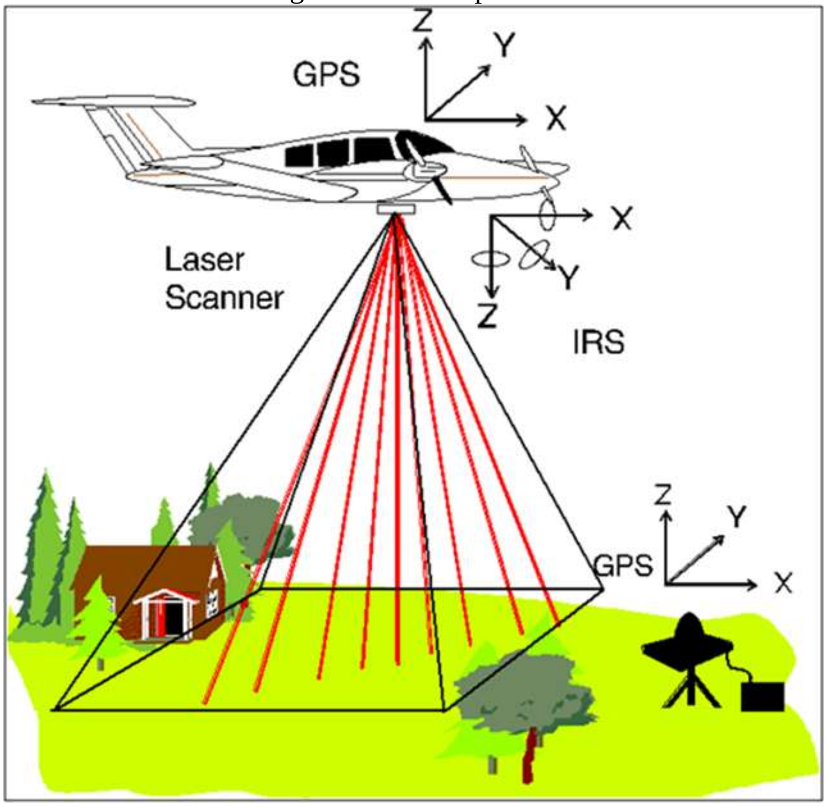
- *Ground* key points are defined in such a way that where a rapid change in elevation occurs, the density of the points is maintained and as such the slope is always well defined. However, where there is relatively little change in elevation the density of the points is reduced because of the fact that 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 Uganda 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.

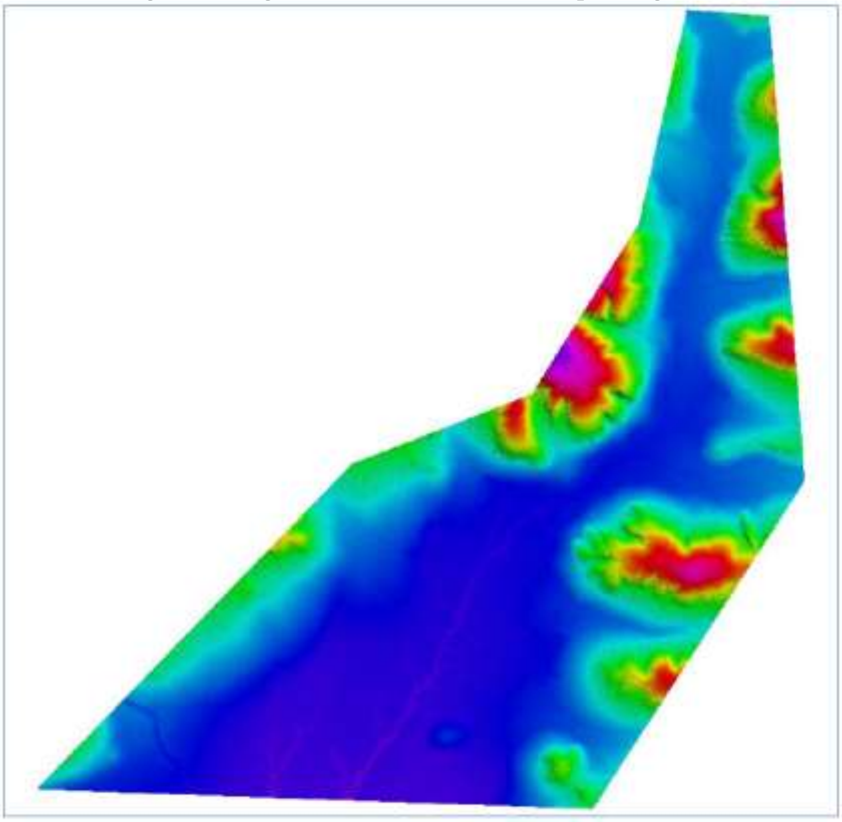
Digital colour images were also taken from the aircraft and rectified to produce colour orthophotos of the project area. The survey was flown at a height of approximately 800m and an image pixel size of 10cm has been produced.

Figure 6: LiDAR process



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

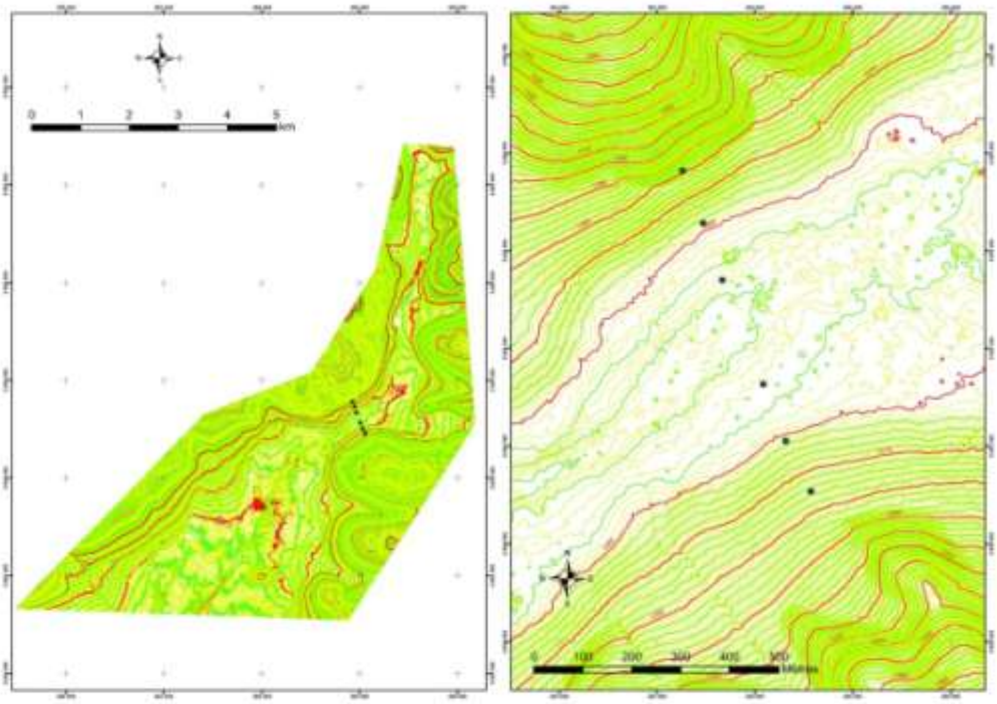
Figure 7: Bigasha site shaded relief map in Uganda



Topographical maps based on the LiDAR data have been produced for the dam site as produced in the Appendix for the same scale.

The data could lead different type of topographical maps such as the following figure about Bigasha dam site. It has been used all along this report.

Figure 8: Topographical map of Bigasha dam site in Uganda



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 and to check surfacial deposits and reveal tectonic-structural patterns.

Geophysical investigations have checked the suitability of the selected site for the construction of the dam and appurtenant structures. The geotechnical investigation campaign gave a factual picture of each 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 methodology was as follows: 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 9: 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 10: Light Dynamic Cone Penetrometer tests used in Uganda

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 each site in order to understand the findings of the entire report. The hydrological report is annexed in the Appendix H.

3.3.2. Monthly discharge computation

For Bigasha dam site, no gauging station was identified in the vicinity of the site, including outside of the Kagera River basin. Because of the lack of direct discharge data, the Consultant computed the monthly discharges at Bigasha in the following manner:

- In a first step, the average monthly discharge at Bigasha has been computed. For this, the Consultant made use of the observed rainfall distribution, and of the catchment loss amounting to 81.9% of the yearly precipitation.
- In a second step, the Consultant assessed the long-term discharge variability of inflows at Bigasha dam site by applying the variability at Rusumo Falls. The monthly discharge record has been obtained over the period 1940-2009 as follow:

$$Q_{m,y}\ Bigasha\ = 12 \times Ratio\ of\ monthly\ runoff_m\ \ Bigasha\ \times \frac{Q_{yr}\ \ Bigasha}{Q_{yr}\ \ Rusumo\ Falls} \times Q_{yr,y}\ \ Rusumo\ Falls$$

where for each month *m* of the year *y*, $Q_{yr},_{m,y}$ (Rusumo Falls) is the mean yearly discharge of year *y* at Rusumo Falls.

Results are discussed in the section dedicated to the inflows analysis.

3.3.3. 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 catchment of Taba-Gakomeye dam site is ungauged and 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 H), Taba-Gakomeye and Buyongwe dam sites are 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 Taba-Gakomeye and Buyongwe dam sites.

3.3.4. Methodology for the optimization of the reservoir capacity

3.3.4.1. 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.

3.3.4.2. 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 each 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

<u>Irrigation water requirement:</u>

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. Crop water requirement 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 = ΣCrop Area ×[CWR − Effective rainfall]

CWR of the paddy crop is estimated as:

CWRrice=[Σ(KcricexETo+ Deep percolation]

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

CWRother crops=Σ(Kcother crops xETo

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

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
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

Water requirement for livestock:

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).

Water demand forecasting for livestock:

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 report.

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 10000 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: 3000 to 5000 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 persons/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 consultant has used the population density 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. The methodology is the same as described in chapter 3.3.4 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 each 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 percent 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 percent is recommended as a base flow to sustain good survival conditions for most aquatic life forms and general recreation (fair and degrading habitat). Sixty percent 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 the four Kagera dam sites are characterized with poor or minimum habitats, an environmental flow of 10% of the MAF have been retained for a permanent River. Furthermore, such a criterion is also applied in France for new schemes.

For a temporary River, it is recommended to take into account ecological information.

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 11: 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 K 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 each of the four schemes. Conclusions have been based on the impact assessment for each project and the justification of fatal flaws or critical impacts, if any, for the concerned project(s).

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 interim reports, which has changed the design of the project. Thus, this chapter will present 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 Bigasha site area

4.2.1. Context

The topographical survey was undertaken on the 2nd March 2012 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.

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 SMCA120203 and SMCA120204. The values of these surveyed points are as follows:

Coordinate system: ITRF08 Geographic

Name	Longitude	Latitude	Ellipsoidal Height (m)	Orthometric Height (m)
SMCA120203	-0 58 42.8122	30 50 32.0238	1270.82	1283.24
SMCA120204	-0 56 42.0836	30 53 56.2629	1245.68	1258.27

Coordinate system: ITRF08 UTM36 South

Name	Easting	Northing	Ellipsoidal Height (m)	Orthometric Height (m)
SMCA120203	259 871.76	9 891 762.48	1270.82	1283.24
SMCA120204	266 185.92	9 895 475.71	1245.68	1258.27

The map 07 in the Appendix E has been defined based on the aerial survey. The reservoir has been drawn at FWL for a 12m dam.

4.2.3. Main characteristics for Bigasha reservoir

Based on these above results, the characteristics of the reservoir dam have been defined using the new topographical data issued by LiDAR survey as summarized in the following table and have been compared to the ToRs data.

The reservoir has been drawn according to the dam height in the Appendix E.

Table 5: Bigasha dam characteristics

BIGASHA	*ToR*	*Final dam design*
Dam height (m)	*9,5*	**12,00**
Storage capacity at FWL (Mm^3)	*18,97*	**6,41**
Dam crest Length (m)	*470*	**610,16**
Reservoir Width maximum(Km)		**1,14 at MWL**
Reservoir Length maximum (Km)	*2,80*	**2,37 at MWL**
Full Supply Level (m)		**+10** (1266m asl)
Maximum Water Level (m)		**+11,25** (1267,25m)
Reservoir surface area at FWL (km^2)		**1,45**
Reservoir surface area at MWL (km$^{2)}$		**1,64**
Contributing catchment area (km^2)		**101**
Catchment sediment yield (Tons/km^2/yr)	*1 608*	**637**

4.3. Geophysical and Geotechnical Investigations

Following the site missions and the LiDAR survey, the feasibility of Bigasha dam at the proposed axis seemed to be questionable:

- No flowing water has been seen by the local people during the rainy season at the dam axis site;
- During the geotechnical investigations within the rainy season, no water has been found;
- On the aerial survey area, no water has been found at the vicinity of the dam axis.

The object of this chapter is a geological analysis of the findings in order to explain the absence of River flow at the dam axis.

4.3.1. Geomorphological description

The site identified for Bigasha dam is located in the south-western part of Uganda, near the border with Tanzania. It is located in the lower part of the Kagera River basin, also called the West Victoria Lake region.

The valley is around 500 m wide at the dam site, but is rapidly widening since, 6 km downstream of the dam site, it merges with the valley of a tributary river coming down from the hills of Ngarama village and flowing in a NW-SE direction. There, the valley stretches over a width of 4 to 5 km.

The valley fits into a hilly landscape, culminating at 1 600 to 1 700 m. The valley lies within alluvial-colluvial deposits forming a slightly undulated valley bottom. Sandy or loamy-sandy texture appears at the surface.

Bigasha River is non-perennial, and thus flows only during rainy seasons. In fact there is no pronounced River bed, but rather several little channels across the valley in the upper section. The River bed appears dry intermittently; downstream, the River bed is well established, and consists in a V-shape 6 to 8 m deep from the surrounding plain.

4.3.2. Geological description

Uganda lies within the African plate, a portion of continental crust that extends through much of eastern and central Africa and has been modified by subsequent geological events such as high-grade metamorphism along mobile belts, the deposition of several layers of sedimentary cover, granitic and other intrusions, and the development of rift faulting. Precambrian rocks underlie two-thirds of Uganda.

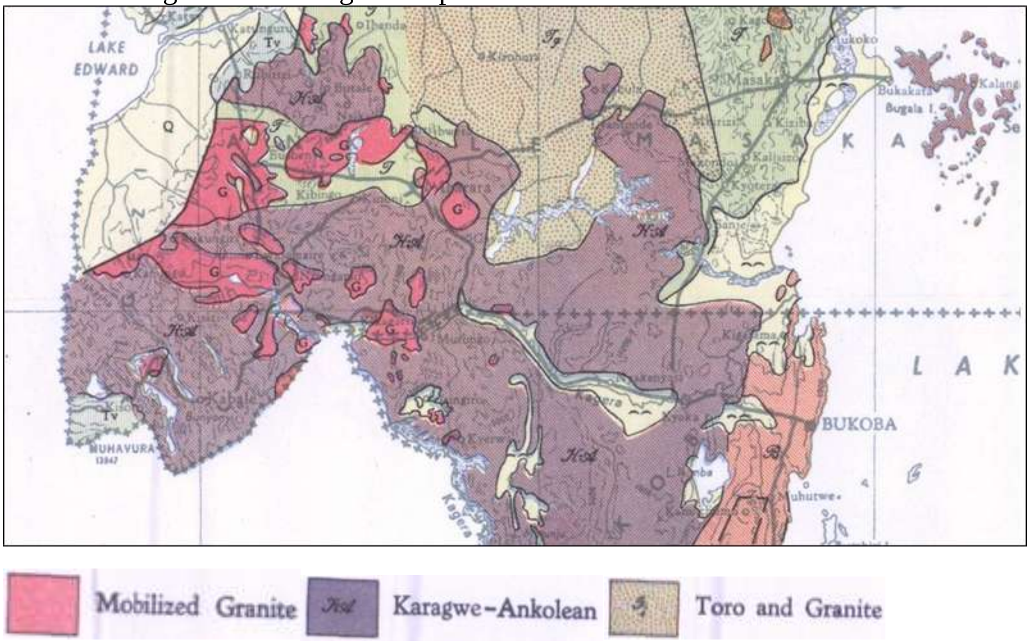
Three major Proterozoic belts underlie central and western Uganda:

- the Paleoproterozoic Buganda-Toro metasediments;
- the Mesoproterozoic Karagwe-Ankolean (Kibaran) Belt, in the southwest of the country;
- the Neoproterozoic Pan-African rocks (Gabert 1984), which includes the Bunyoro Series with tillites and argillites (Bjorlykke 1973), and the undeformed shallow water sediments of the Bukoban Supergroup.

The Karagwe-Ankolean system lies within the Mesoproterozoic Kibaran Fold Belt that extends southwest, from Uganda into the Democratic Republic of the Congo and Zambia. Younger than the Buganda-Toro system, its sedimentary features reflect shallow-water deposition with argillites, shales and sandstones in a uniform succession.

At the base of the system, metacalcareous rocks generally occur. Metamorphism is less developed and the argillaceous terms of the series, mildly metamorphosed to phyllites, argillites and low grade sericitic schists, while the arenaceous formations have been changed to quartzites. The rocks are deformed along north-south axes with circular intrusives of porphyritic granites lying at the cores of the anticlines. Resistant quartzite ridges surround the granite intrusives.

Figure 12: Geological map of East Africa - 1:2 000 000 -1952



The dam site lies within the Mesoproterozoic Karagwe-Ankolean system mobile belt with rocks of various ages and grades of metamorphism.

At the dam site, rock is not outcropping, except on the top of the right bank where it has been possible to find an outcrop of cemented sandstone (as verified during the mission on site for the geophysics investigations on January 2012).

On the two banks, the bedrock is covered by a soil horizon, composed of lateritic clay and lateritic sandy gravel. At the bottom of the valley, a lightly swampy river plain, there is sandy clay to clayey sand.

Soils within the valley are commonly ferrasols with a characteristic red-brown colour.

From the pits executed on site, there is evidence that the water table level is at a shallow depth or near the surface (about 2 m in the pits that have been dug). This is also confirmed from the many pits being dug on the river plane to allow extraction of water from the unconfined aquifer.

Figure 13: Geotechnical investigations on the 1st of April 2012 at Bigasha dam site (during the main rainy season)

4.3.3. Geophysical and geotechnical investigations

The following geophysical and geotechnical investigations have been performed in order to assess the suitability of the dam site and the suitability/availability of the quarrying materials:

- Electrical resistivity tests using 2D Imaging along dam axis (715 meters long);
- 7 auger holes (A1 to A7) at a maximum depth of 2m;
- 4 test pits near A4, A5, A6 and A7 (at 2m depth);
- 4 light cone penetration tests;
- 4 undisturbed samples from test pits;
- 18 disturbed samples from test pits and auger holes;
- Laboratory testing: non-disturbed and disturbed samples have been collected to carry out following tests: particle size, specific gravity, Atterberg limits, permeability and oedometric tests.

Figure 14: location of existing and proposed investigations

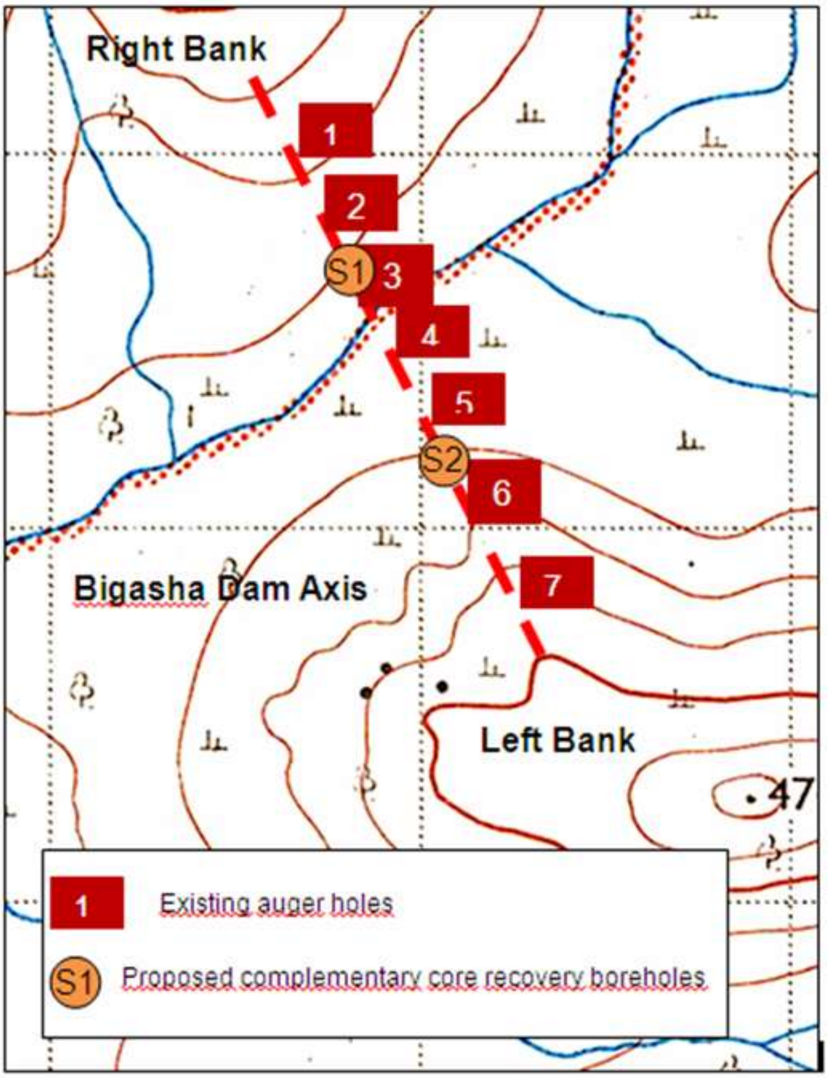


Table 6: List of existing investigations

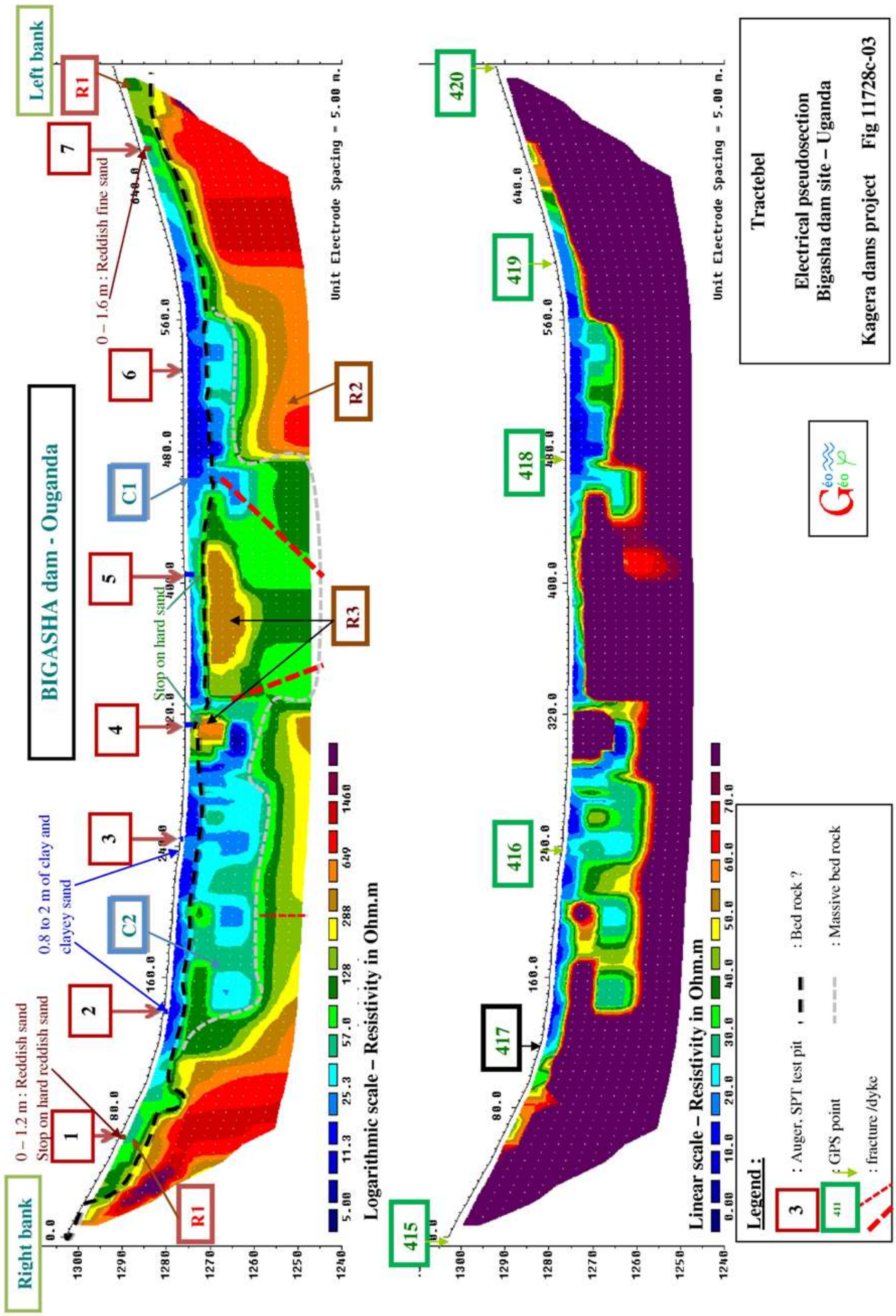
Auger	Depth (m)	Distance from top of right bank (m)	Lithology	Tests
1	1,2	70	Reddish sand	Water content, Sieve, Atterberg lim., oed.,
2	0,8	140	clay and sandy clay	Water content,sieve, Atterberg lim.,
3	0,6	240	clay and sandy clay	Water content,sieve, Atterberg lim., oed.,
4	1,8	310	Clayey sand	Water content,Sieve, Atterberg lim., oed.,
5	2,0	405	Clayey fine sand	-
6	1,6	525	Reddish fine sand	-
7	1,6	655	Reddish fine sand	Atterberg limits

The granulometry of the 4 samples is composed of 45% of sand (particle size >0,075mm, the gravel fraction – size >2mm- is less than 2%) and 55% of silt and clay (particle size < 0,075mm) so that the samples can be defined sandy clays; the plasticity index is very low (less than 5%) and the liquid limit is of 18%.

The SPT values, from 0,6 to 1,7m depth, has an average of 19 so that the soil can be considered to be stiff with a relative density of 50% and an estimated friction angle of 32-34°(Schmertmann, 1978).

The results about geophysical survey carried out on Bigasha project dam site gave the following figure. The appendix I includes all the results of the investigations.

Figure 15: Electrical pseudosection of Bigasha dam axis

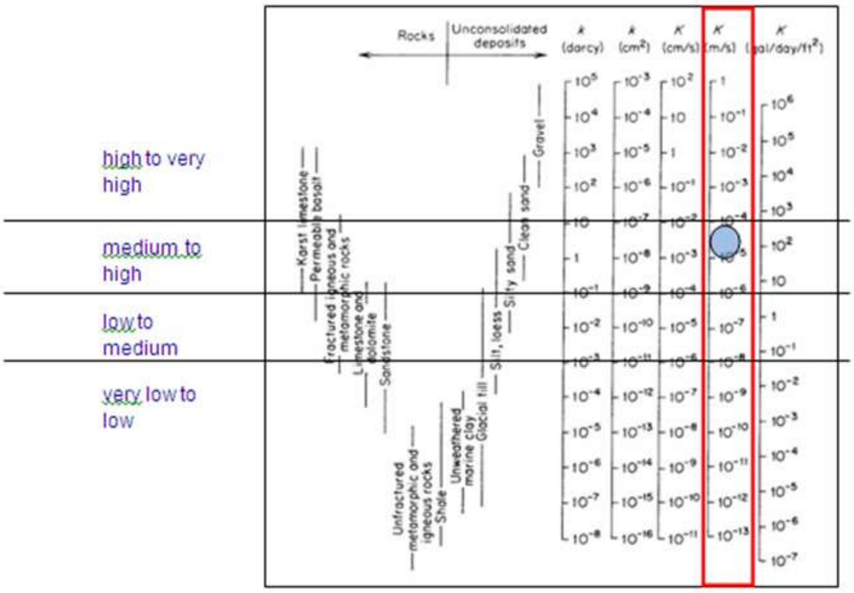


4.3.4. Geophysical weathering and permeability conditions of the bedrock

Groundwater in rock formations generally occurs in the weathered and fractured bedrock. The weathered rock may have a good transmissivity and storage capacity to provide some yield; generally, however, the better aquifers are found in the contact zone between the overburden and the fresh rock. Ultimately, the higher yielding aquifers can be expected in the fractured bedrock. Large and deep, fractured aquifers may be recharged through an interconnected system of fractured zones. The recharge of shallow aquifers, found in the overburden or in the fractured upper part of the bedrock is generally dependent on the size of the catchment area and the lithological character of the overburden.

The permeability determined in the 3 pits executed near the auger holes A1, A3 and A4, at depths of 0,8 to 1,6 m from the surface, is comprised between 4*10-5 and 6*10-5 m/s, thus it can be considered to be in the range of medium to high permeability.

Figure 16: Hydraulic conductivity ranges and results of permeability tests

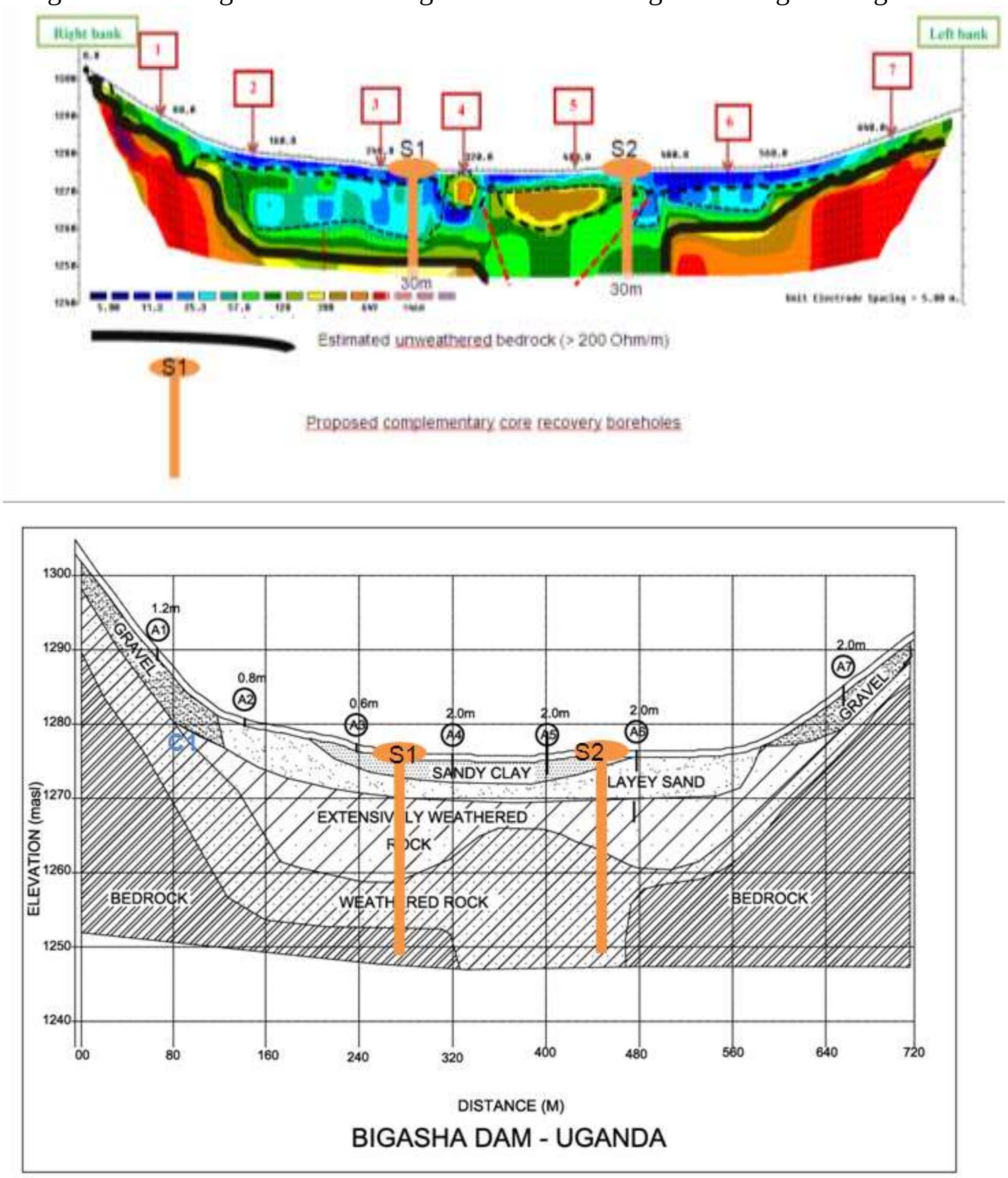


The geological/geotechnical investigations at the dam site only allowed a partial reconstruction of the geology and of the hydrogeological characteristics of the bedrock at the dam axis: these tests only investigate a very limited and superficial portion of the area where the dam is being proposed.

The discontinuous nature of the Bigasha River and the permeability of the bedrock along the dam axis need to be further investigated.

In particular, the geophysics shows in the central part of the dam axis, on a length of about 200m, a decreasing profile of resistivity, that can be explained with the presence of a highly weathered/highly jointed bedrock at a depth to 25-30 m (which is maximal investigation depth achieved with the geophysics at the site).

Figure 17: Geological section along dam axis according to existing investigations



The synthesis of the investigations shows the following stratigraphic setting:

Bottom of the River:

- 0 to 5m of clayey sand to sandy clay;
- 5 to 20-25m: highly weathered to weathered rock (that should be constituted by variously cemented sandstones or siltstones), with resistivities until 300 Ohm*m;
- From 20 to 25m: In the central part of the valley a less weathered to unweathered block of sandstones is probably to be expected as a possible uplifted compartment. The massive rock, at more than 500 Ohm*m is expected at more than 25-30m of depth.

Right and left bank:

- 0 to 5m: reddish sand, which corresponds to lateritic soils;
- 5 to 10m of weathered rock;
- From 10m: unweathered rock.

The bedrock along the proposed Bigasha dam axis is most probably composed of a sequence of argillites/shales and sandstones and is thus expected to have higher permeabilities in correspondence to the sandstones layers and lower permeability in the argillites or shales levels.

The discontinuous nature of the Bigasha River is most probably to be attributed to variations of the top of the bedrock and to lateral variations of the weathered horizon of the bedrock that may explain local changes of the permeability.

The permeability of the sandstone is mainly due to the jointing of the bedrock and to the chemical/solution weathering of the rock mass followed by the removal of loosening sand grains by flowing underground water (process of 'arenisation'); this could be interpreted as "pseudokarst" or "endokarst". Possible features triggering pseudo karst conditions are the chemical and mineralogical composition of the bedrock (apparently sandstone is outcropping on the top of the right bank but further determinations of rock outcrops are required).

There is no major evidence of karstic morphological features (i.e. dolines) in the area of the dam axis, but this will have to be further determined with a geomorphological/geological mapping of the site.

The following complementary activities/investigations could be performed during the detailed design for the Bigasha dam site:

- Determination of main rock lithologies at dam site (to evaluate the risk of pseudokarstic conditions within the bedrock) → preliminary geomorphological/geological mapping of the proposed dam area (at least 3 km upstream of the dam axis and 2 km downstream) and rock sampling around the dam axis area for petrographic determinations and/or thin sections to define mineralogy;
- Determination about the depth of the weathered bedrock along dam axis (to complete and calibrate geoelectrical panels) → execution of 2 core recovery boreholes at 30m depth, along the dam axis with piezometer installation and undisturbed sampling;
- Determination of permeability within the bedrock → water tests every 5m (falling head tests in the unconsolidated deposits and Lugeon tests in the bedrock) inside the 2 boreholes;
- Estimation of hydrodynamic parameters within the weathered part of the bedrock → tracing tests from the river to the boreholes and/or the existing pits.

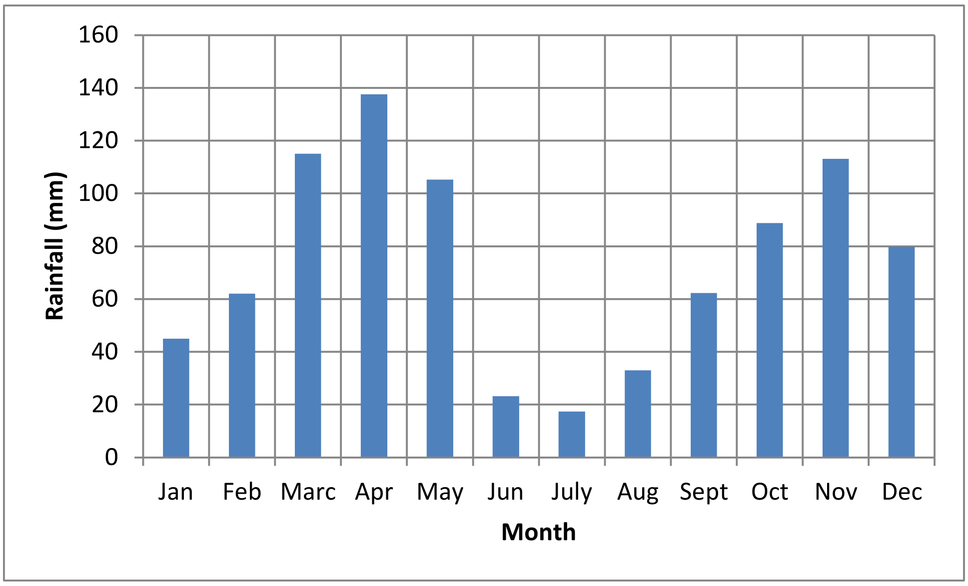
4.4. Hydrological results for Bigasha dam site

4.4.1. Context

Bigasha dam site is located at about 1 250 m above sea level, on Bigasha River, which is a seasonal river. The site is located in the lower part of the Kagera River basin also called the West Victoria Lake region. This zone is characterized by moderate relief and more arid conditions.

Catchment area is 111 km² and altitude is in the range 1 725 – 1 233 m above sea level. Average annual rainfall is about 843 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 (see the following figure).

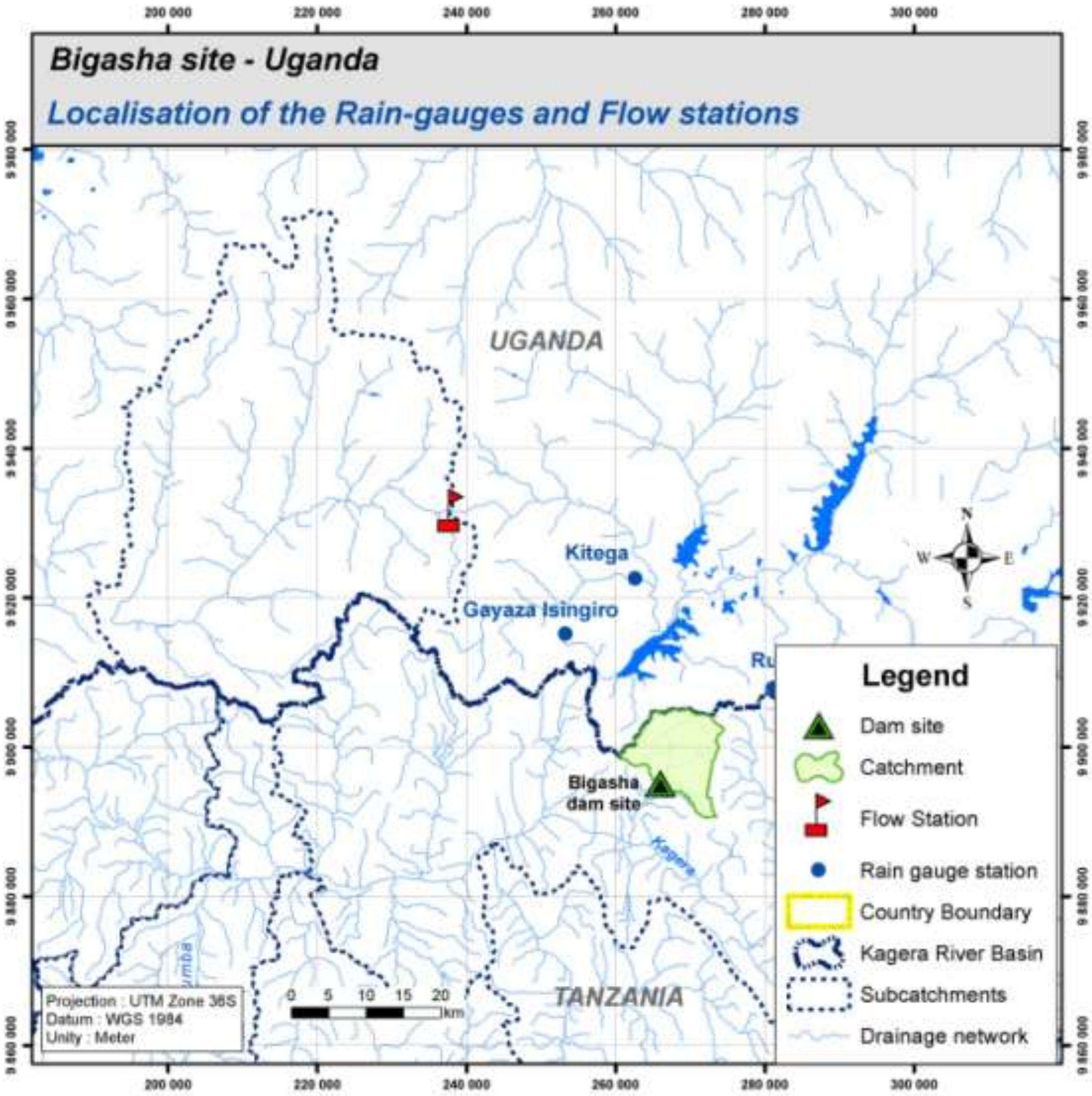
Figure 18: Monthly rainfall at Gayaza meteorological station near Bigasha site



4.4.2. Data

Rainfall information has been collected from the AQUALIUM database provided by the Client. Rainfall stations are Gayaza, Kitega and Rugaga stations, all located in the close vicinity of the catchment (Figure 19). Hydrological information for Bigasha dam site has been collected. Discharge data exist for Ruizi River at Mbarara Water Works (2 070 km² [AQUALIUM]) for the period 1954-2011. This gauging station is located in Uganda, outside the Kagera River basin but provide relevant regional hydrological information about runoff coefficient. But hydrological regime of Ruizi River is very different from the one at Bigasha since Ruizi River is a permanent river without dry periods with no flows.

Figure 19: Localisation of rain gauges and gauging stations for Bigasha dam site



4.4.3. Inflows

For Bigasha dam site, there is no gauged site that could be used as a reference. As a consequence, inflows at dam site are estimated at a monthly time step by applying the following formula:

$$Q_{m,y}\ \ Bigasha\ = 12 \times Ratio\ of\ monthly\ runoff_m\ \ Bigasha\ \times \frac{Q_{yr}\ \ Bigasha}{Q_{yr}\ \ Rusumo\ Falls} \times Q_{yr,y}\ \ Rusumo\ Falls$$

where for each month *m* of the year *y*, ratio of monthly runoff *m* is taken in the Table 7, Qyr (Bigasha) is equal to 0,40 m^3/s (deducted from water balance considerations with runoff coefficient equal to 0,136 (Ruizi River at Mbarara gauging station)) and Qyr,m,y (Rusumo Falls) is the mean yearly discharge of year *y* at Rusumo Falls.

Monthly inflows at Bigasha dam site are corrected in order to take into account the impact of Kagongo dam located in the upper part of the catchment.

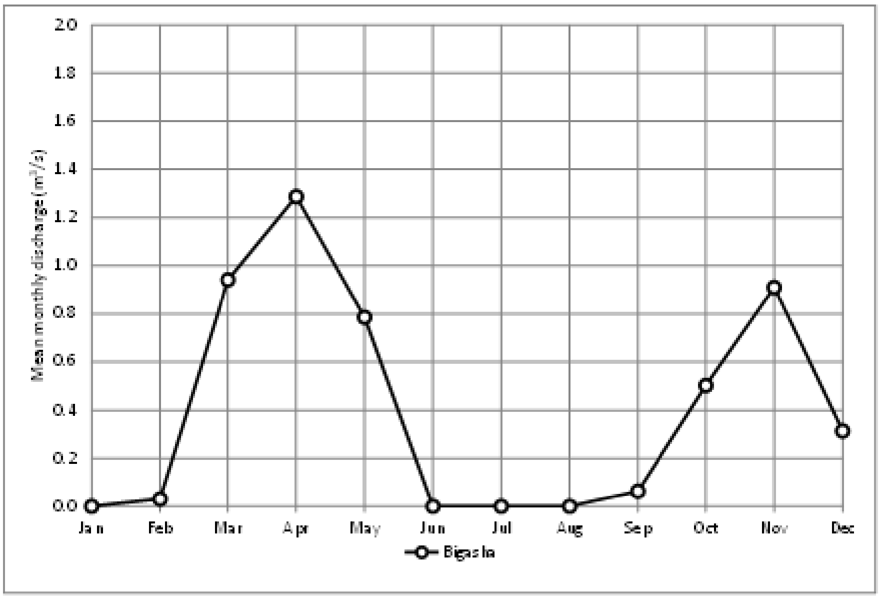
Kagongo's catchment is about 10 km², so 10% of the total area of Bigasha catchment. The water stored in Kagongo reservoir is transferred to neighbour's catchments for water uses. That is to say that the runoff here does not contribute to the runoff at Bigasha dam site. As a consequence monthly inflows at Bigasha are multiplicated by 0.9 to take into account the water losses due to Kagongo dam.

Table 7: Monthly Distribution of rainfall and runoff at Bigasha dam site

Month	Rainfall	Loss	Runoff	Ratio of monthly runoff
	(mm)	(mm)	(mm)	%
January	43	43	0	0.000
February	59	58	1	0.006
March	110	80	30	0.195
April	131	90	41	0.266
May	101	76	25	0.162
June	22	22	0	0.000
July	17	17	0	0.000
August	32	32	0	0.000
September	60	58	2	0.013
Octber	85	69	16	0.104
November	108	79	29	0.188
December	76	66	10	0.065
Year	844	690	154	100%

Mean monthly inflows are presented in the following figure. Two peaks corresponding to rainy seasons can be observed in April and in November. The seasonal pattern is quite pronounced due to more arid conditions and dry periods without flows in January and between June and August.

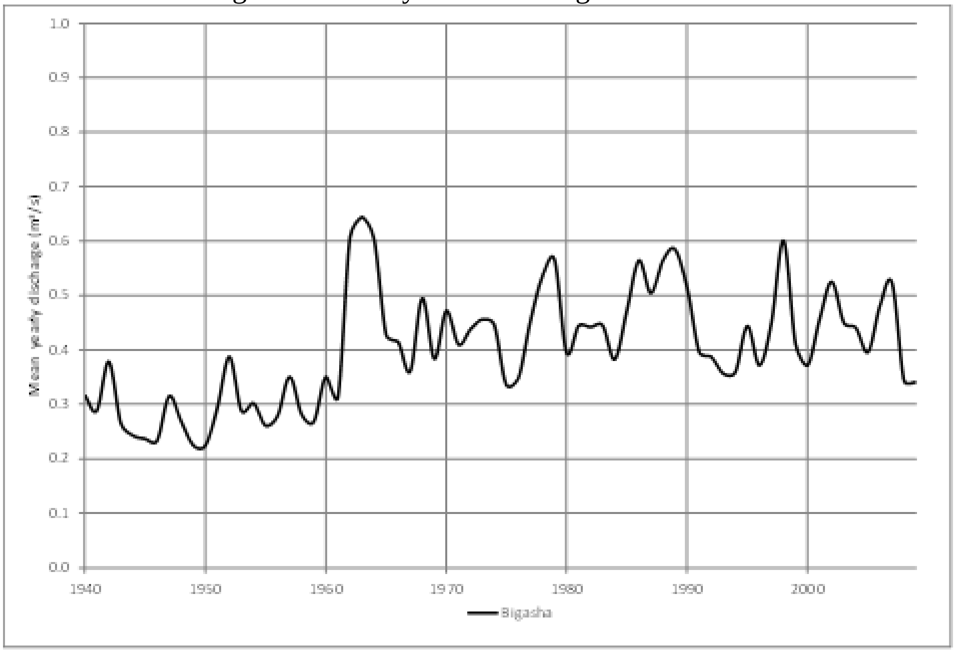
Figure 20: Mean monthly inflows at Bigasha dam site for the 1940-2009 period



Yearly inflows at Bigasha dam site are presented in the following figure. 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 = 0,26 m^3/s) and a post-1960 period with a high runoff level (mean discharge = 0,40 m^3/s).

Annual variability is rather high. Maximum mean yearly discharge (0,64 m^3/s in 1963) represents a +60% increase of the mean discharge (0,36 m^3/s), and minimum mean yearly discharge (0,22 m^3/s in 1950) a -45% decrease of the mean discharge.

Figure 21: Yearly inflows at Bigasha dam site

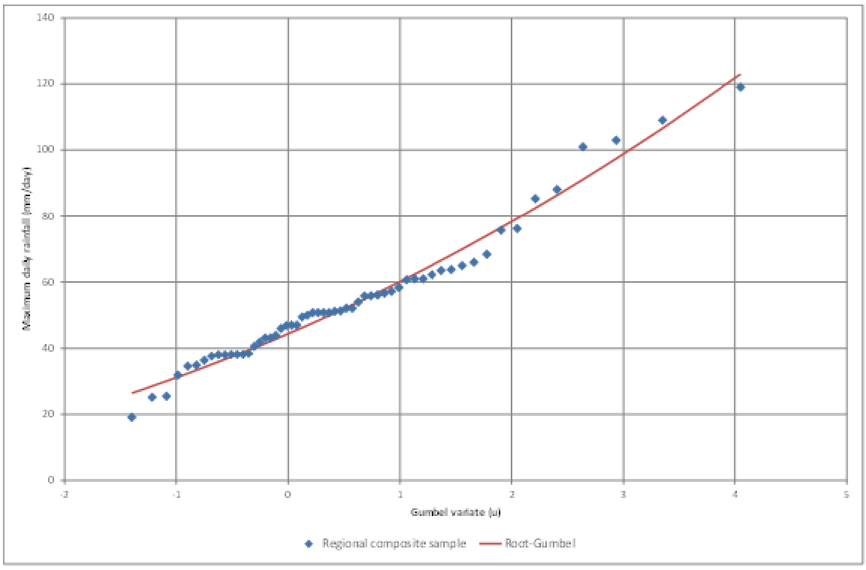


4.4.4. Floods

4.4.4.1. MAXIMUM DAILY RAINFALL

For Bigasha dam site, daily rainfall records at 4 rainfall stations located in Uganda and Tanzania are processed. The station year method is applied to establish one regional composite sample of maximum daily rainfall. The sample has a size of 57 station-years. A root-Gumbel distribution is convenient to describe this sample (see the following figure).

Figure 22: Bigasha 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. 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 8: 24-hour rainfall over Bigasha catchment for different return periods

T	**Pdmx(T)**	**P24(T)**	**P24-Bigasha**
(year)	**(mm/day)**	**(mm)**	**(mm)**
2	50	56	47
5	69	78	65
10	83	94	79
20	98	111	93
50	119	135	113
100	137	154	130
200	155	175	147
500	181	204	172
1 000	202	228	192
2 000	224	253	212
5 000	255	288	242
10 000	280	316	265
PMP	398	450	377

4.4.4.2. 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 H. The calculated Francou-Rodier's indexes for peak discharge are in the range 2,10 (return period T=20 years) – 4.47 (PMF).

Table 9: Bigasha dam site - Flood hydrographs

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)	18	34	51	154	343	486
Mean daily discharge (Q24) (m3/s)	10	18	27	69	128	190
Qp/Q24	1.83	1.82	1.89	2.22	2.68	2.57
K(Qp)	2.10	2.54	2.84	3.64	4.22	4.47

4.4.5. 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 Bigasha 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 Bigasha catchment in order to estimate the sediment yields. Eventually, the sedimentation rate of the reservoir is assessed by applying Brune's approach. We should keep in mind that 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.

With a storage capacity of about 9,6 Mm^3, the ratio of storage capacity to mean annual inflows is high (95%). As a consequence, the annual sedimentation rate is quite insignificant (0,6%) and the site is likely not exposed to siltation.

Table 10: Bigasha - 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 sediment ation rate
	(km^2)	(mm)	(mm)	(t/km^2/year)	(m3/year)	(m)	Mm3	Mm3	-		
Bigasha	111	843	102	637	62 580	14	9.6	10	0.94	98%	0.6%

4.5. Water uses and water demand for Bigasha

4.5.1. Context

This chapter 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.

4.5.2. Irrigation

4.5.2.1. INSTITUTIONAL CONTEXT

The Ministry of Agriculture, Animal Industries and Fisheries is in charge of the policy formulation for water use for irrigation, livestock, aquaculture and other agro-based activities.

The National development plan 2010, coving the fiscal period 2010/2011 to 2014/2015, highlights the irrigation as the third of the eight priorities gazetted in this plan.

4.5.2.2. WATER USES FOR IRRIGATION

a) Literacy context

In the *Draft National Irrigation plan*, development scenarios are carried out with the development of irrigation area in Isingiro district.

The Agriculture of the Nile Basin overview report identifies various practices sites in Uganda with three water harvesting sites identified in Isingiro district.

b) Field context based on the field mission carried out in February 2012

No irrigation perimeters have been developed until now in Isingiro district. One scheme is currently being designed. It is designed as a surface irrigation scheme for rice cultivation.

Another private scheme is currently operated by an individual farmer near Isingiro. This scheme use pumping to supply a water tower, then a pressurized system to convey water to plots. On plot, a hose fills watering cans, used for irrigation of fruits and vegetables.

<u>The Bigasha valley:</u>

Bigasha is a River which flows following a northeast-southwest direction at the extreme South of Uganda. It crosses the border between Uganda and Tanzania just some kilometres before merging into the Kagera River.

Bigasha River is non-perennial, and thus flows only during rainy seasons. In fact there is no pronounced River bed, but rather several little channels across the valley in the upper section. Downstream, the River bed is well established, and consists in a V-shape 6 to 8 m deep from the surrounding plain.

The valley is around 500 m wide at the level of the dam site, but is rapidly widening because, 6 km downstream of the dam site, it merges with the valley of another River coming down from the hills of Ngarama village and flowing in a northwest-southeast direction (see the map on the Figure 28 and the picture on the Figure 27). There, the valley stretches over 4 to 5 km.

The valley fits into a landscape of hills culminating at 1600 to 1700 m and with strong slopes.

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

There is a marked transition between the flat valley and its sides. Slopes bear red ferrallitic soils and are more and more cultivated, down to the valley (see Figure 27).

Banana is the main cash crop and brings wealth to this area. Beans, maize, Irish potatoes and sweet potatoes are grown during the two rainy seasons, i.e. from March to May and from September to December.

The valley is built with alluvial-colluvial deposits forming a slightly undulated valley bottom. Sandy or loamy-sandy texture appears at the surface (see Figure 26).

Figure 23 : Bigasha valley, upstream of the dam site

Figure 24 : Bigasha valley, downstream of the dam site

Figure 25 : Bigasha valley, 1.1 km downstream of the dam site

Figure 26 : Bigasha valley, 3.7 km downstream of the dam site

Figure 27 : Bigasha valley, 6.2 km downstream of the dam site

The valley is not cultivated. A vegetation of grasslands with savannah bushes is grazed by cattle. This natural pasture is of poor quality. The land of the valley is owned by the cattle keepers, but these latter have reduced the number of cattle and are starting growing crops.

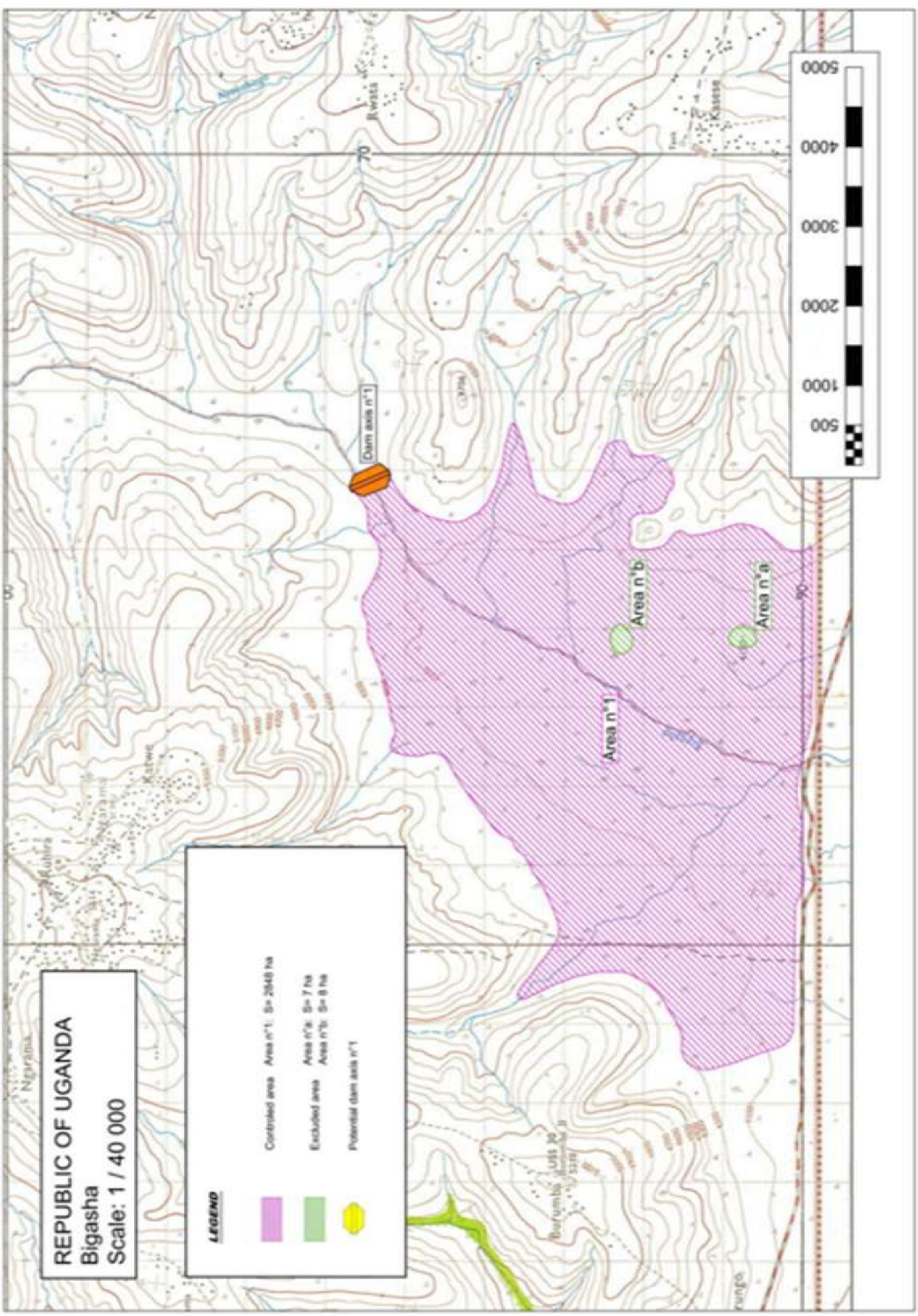
4.5.2.3. IRRIGATION POTENTIAL ASSESSMENT

Land availability:
A large potential command area is suitable to supply and to increase the local food production thanks to surface irrigation.

The rough extent of the controlled area initially found was about 2 800 ha (based on the 1/40 000 available map at the time of the field mission), out of which river beds and housing should be excluded as well as some fenced pastures. The controlled area would spread as far as the border between Uganda and Tanzania. However, after LiDAR and high resolution aerial photograph exploited, it is expected not to have more than 800 to 1 300 ha irrigable, depending on the development alternative.

The valley is used at present for cattle grazing, drinking and some fish farming. The preservation of these existing activities will have to be considered while developing irrigation. Two main alternatives may be envisaged: (i) exclude part of the valley from any development or (ii) promote fodder cropping in irrigated areas so that cattle could be fed and the project is consistent with national livestock strategy which consists in shifting from extensive to intensive by reducing the number of cattle and increasing the productivity.

Figure 28: Bigasha potential irrigation area



Topographical data analysis

There is a serious gap between documents (1/40 000 map) used during the field mission and the up to date data (LIDAR contour lines on orthophotographs): the controlled and net irrigable areas specified above should be reduced to take into account the definitive elevations.

Furthermore, LiDAR survey did not cover the whole valley due to flight restrictions at the border area between Uganda and Tanzania: therefore 3 to 5 kilometers are missing downstream of the valley, on one of the most suitable area for irrigation development. This missing area should then be completed by the 1/40 000 map that shows differences with LIDAR survey on the upstream area. Thus, a land survey should be compulsory to complete the topographical data with a reasonable accuracy during the detailed design of the project.

Table 11: Evolution of controlled area during the project

	First estimate based on 1/40 000° map	Second estimate based on LiDAR survey	Reduction (%)
Minimum area	800 ha	312,5 ha	61%
Maximum area	1 300 ha	600 ha	54%

Switching from low accuracy 1/40 000° 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) due to several factors:

- Some troughs in the area are not included on the 1/40 000° map, but could clearly appear following the LiDAR survey. These areas are not suitable for irrigation, as it is prone to erosion. Moreover, it is recommended not to develop areas close to these troughs- in order to use them for erosion control activities (reforestation, land modelling, terracing, etc.)
- Elevations lines have not exactly the same shape leading to narrow the area controlled by the dam (Minimum water level of 1 262m). Thus the main canal begins with a bed level set at 1 261 m and 0,95 m water height in the canal and most elevated spots of controlled area are about 1 m down the level of water in the main canal.

Even though this drop in the area is usual, the value is high at that stage, because others reductions could 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 drainage system, some high or low spots, access, etc.

Potential crops and cropping pattern:

Local opinion expressed by the chairman of Isingiro district, whom had been met on 23rd of February 2012, is to mainly dedicate the irrigation perimeter for fruits. Farmers have the skills to grow fruit trees (see Figure 29 and Figure 30), but have no experience in irrigation. However, they will accept it to overcome the dry season.

The agriculture officer of Isingiro district also pointed out the interest of developing forage crops and vegetables.

In fact, as the irrigation perimeter shall be closed to cattle roaming, keeping free only the customary migration corridors, it is proposed to dedicate a part of the irrigated area to forage crops in compensation to replace the poor natural grasslands.

Regarding vegetables, which are high value crops, their best growing season will be the dry season during which prices are higher.

Among the other annual crops, the most important ones are beans, maize, Irish potatoes and sweet potatoes.

Thus, as a large command area can be developed, it makes sense to plan on growing all this kind of crops, i.e. a part of the perimeter dedicated to perennial crops, either fruit trees or forage crops, and another part to annual crops, stressing on vegetables during the dry season.

It is not envisaged to grow rice for several reasons : soils seem to have medium or coarse texture, people aren't use to grow rice, and, as land for irrigation isn't too much limited, the same amount of water will increase the value of a larger area in the case of no rice. Due to the heavy water consumption of rice, the command area should be reduced if this crop would be grown.

Figure 29 : Fruit farm in the vicinity of Isingiro, banana, mango and pineapple

Figure 30 : Fruit farm in the vicinity of Isingiro, banana, orange and pineapple

A lot of crops can already be grown and, while introducing irrigation, thus by securing the crops cycle and allowing dry season cropping; more kind of crops could be envisaged.

A double season cropping is used on the hillside, the first one from March until June and the second one from September until January. The introduction of irrigation will allow three crops a year as most of the annual regional crops have a growing cycle between 90 and 120 days.

At this stage of the study, the main common crops are chosen in order to calculate crop water requirements: these are maize, beans, Irish potatoes and vegetables. Several vegetables may be grown, cabbage, tomato, onion, carrot, eggplant, pumpkin, which have more or less the same length of cycle. Thus, it is possible to compute specifications which will allow growing any of them. A rotation will be introduced at the plot level among all these crops, for example maize/vegetable/beans.

A part of the perimeter will be dedicated to high productive forage crops, such as elephant grass, desmodium or alfalfa.

Another part will be dedicated to fruit production. Pineapple, citrus or orange trees and mango trees seem to be the most appropriate ones. As banana is already hugely grown on the hillside and as it is a big water consumer, it is not recommended to introduce it in the valley.

It is expected to reach a yield of 2.5 t/ha for maize, 1.6 t/ha for beans and soybeans, 15.0 t/ha for potatoes, and from 2 to 6.0 t/ha for vegetables, depending on the crop which will be grown, and from 10 to 15 dry matter t/ha for the forage crops.

These are reasonable yield figures which may be expected in Africa. They may be improved if better associated cultural techniques, so as extension and capacity building services are provided.

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 Mbarara in Uganda (altitude 1413 m, latitude -0.61°, longitude 30.65°) (see Figure 32). The total annual rainfall reaches 946 mm and the effective rainfall (Pe) reaches 798 mm after correction using the FAO method.

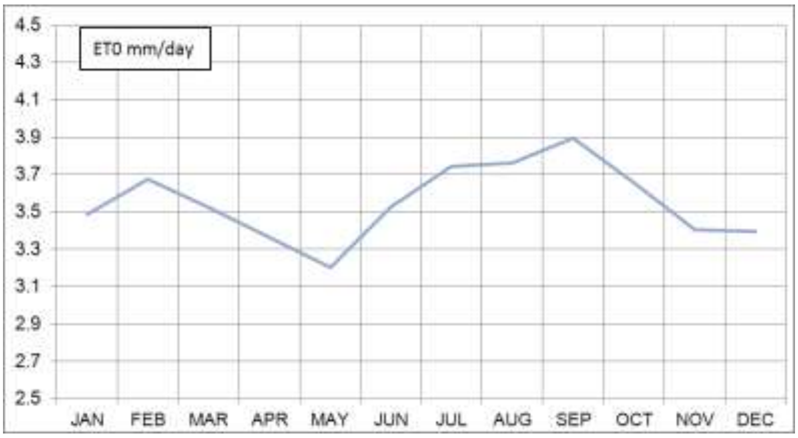
The meteorological year is usually divided into four periods: a short dry season in January-February, the long wet season from March until May, the dry season from June until September and a short wet season from October until December. The chart (Figure 32) shows this distribution, with a long dry season until October, with a short wet season mostly in November and a short dry season mostly in January.

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

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

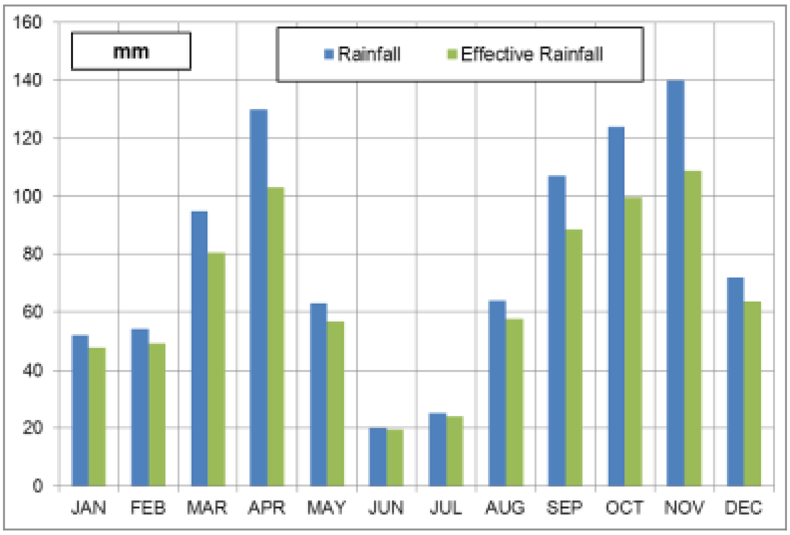
I = kc Eto – Pe where kc is the crop coefficient
I = 0 if Pe of the considered decade > kc Eto

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



(source: Climwat FAO)

Figure 32 : Rainfall and effective rainfall at Mbarara, Uganda



(source: Climwat FAO)

For each possible crop, the Table 12 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 12: Expected yields and water requirements for the crops

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
Maize 1	1st Sep	150	2.5	1 000	0.2
Maize 2	1st Feb	150	2.5	1 500	0.3
Maize 3	1st May	150	2.5	2 600	0.4
Beans 1	1st Sep	120	1.6	400	0.2
Beans 2	1st Feb	120	1.6	600	0.2
Beans 3	1st May	120	1.6	2 300	0.4
Potatoes 1	1st Sep	130	15.0	900	0.2
Potatoes 2	1st Feb	130	15.0	1 200	0.3
Potatoes 3	1st May	130	15.0	2 700	0.4
Vegetables	1st Jun	120	2 to 6	2 300	0.3
Pineapple	perennial	360	20 - 40	800	0.1
Orange/Citrus	perennial	360	5 - 15	2 100	0.2
Banana	perennial	360	15 - 25	6 300	0.4
Forage crops	perennial	360	10 to 15 DM *	5 100	0.3

DM dry matter

Volume of irrigation water:

Regarding annual crops, the irrigation water requirements are more dependent on the seasons than on the kind of crop.

Irrigation water requirements are low during the rainy seasons which have been called 1 when beginning in September and 2 when beginning in February. The required amount ranges around 1 000 to 1 500 m^3/ha, with a lower value in case of beans.

Irrigation water requirements are markedly higher in the case of every crop grown during the dry season. The required amount ranges around 2 500 m^3/ha.

Nevertheless, even when irrigation requirements are low, it shall be kept in mind that:

- during rainy seasons, irrigation is usually required at the beginning and at the end of the crop cycle, and thus is essential for the success of the cultivation,
- while avoiding the uncertainty of rains, irrigation is compulsory to secure 3 crops a year and thus to implement the agricultural intensification.

Regarding perennial crops, the irrigation water requirements are low in the case of pineapple and remain moderate in the case of orange trees, because the crop coefficients are low. They would be very high in the case of banana which has not been introduced for this reason.

The highest irrigation water requirements belong to forage crops which are growing all year round. They reach up to 5 000 m^3/ha.

Irrigation requirements have been computed with mean rainfall. During drier years, they may be more important.

Base flow (specific flow):

The base flow remains moderate whatever the crop, ranging between 0.2 and 0.4 l/s/ha. Thus, a base flow of 0.4 l/s/ha is sufficient to irrigate every kind of crop.

Cropping pattern:

The cycles of the three season crops may not overlap, provided irrigation is securing an accurate schedule of crops on the perimeter. Thus, after choosing a part of this latter under perennial crops, it is realistic to apply triple cropping on the remaining area.

The recommendation would be to begin with 30% of perennial crops, with 10% for forage crops and 20% for fruits which involve an important initial investment. After a while this proportion could be increased.

Regarding annual crops (see Table 14), many cropping patterns may be thought, but, as the water requirements are roughly in the same range, the simulation was done with one to compute a global need of irrigation water. It is made up of:

- 50% of longer crop cycle in September, half maize and half potatoes, and 20% of beans which have a shorter cycle,
- during the second rainy season, plots with maize and potatoes are grown with beans, and in reverse order for those which began with beans,
- all plots may be grown with vegetables during the dry season.

<u>Project discharge:</u>

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

Table 13: Irrigation duty

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

4.5.2.4. IRRIGATION WATER DEMAND

Assuming a type of cropping pattern with annual and perennial crops, the water used for irrigation have been evaluated for an elementary irrigated area of 100 ha (Table 16). Required amounts of water for different sizes of the scheme may be easily deduced from this table.

Table 14: Total yearly irrigation water consumption for a 100 ha scheme

Growing season	***% of crops* and gross volume of water m^{3} ***							
	annual crops				***perennial crops***			**TOTAL**
	Maize	**Beans**	**Potatoes**	**Vegetables**	**Pineapple**	**Orange Citrus**	**Forage crops**	
Sep/Oct - Jan	*25%*	*20%*	*25%*		*5%*	*15%*	*10%*	*100%*
	25 000	8 000	22 500		500	6 000	12 000	74 000
Feb - May/Jun	*10%*	*50%*	*10%*		*5%*	*15%*	*10%*	*100%*
	15 000	30 000	12 000		0	6 000	13 000	76 000
June - Sept				*70%*	*5%*	*15%*	*10%*	*100%*
				161 000	3 500	21 000	27 000	212 500
TOTAL	40 000	38 000	34 500	161 000	4 000	33 000	52 000	**362 500**

** taking into account the conveyance efficiency*

Assuming an optimized cropping pattern with annual and perennial crops for the proposed scheme, the water used for irrigation has been evaluated as follows.

Table 15: Total yearly irrigation water consumption for the scheme

Crop	Annual irrigation requirement	% in cropping pattern	Gross water consumption for a 451 ha scheme
Pineapple	800	15%	54 120
Orange/Citrus	2 100	25%	236 775
Banana	6 300	30%	852 390
Forage crops	5 100	30%	690 030
Total			1 833 315

4.5.2.5. ENVIRONMENTAL AND SOCIAL ISSUES

The main constraints for the future development of Bigasha area are identified below:

- Land tenure: at present, most of the valley is used by herders for cattle grazing and drinking. Other uses, such as fish farming, do exist within the project area. Beyond the necessary compensation (resettlement, cattle drinking facilities, fish ponds…), two development alternatives could be envisaged. The final option will have to be confirmed by the client with the beneficiaries.
- Social: Participatory approach is compulsory to commit local people to the project and discuss resettlement and land sharing options.
- Transboundary water management: Bigasha River is flowing to Tanzania, downstream the project area. It will be necessary to check that no particular constraint arise from that situation.

4.5.1. Livestock watering

4.5.1.1. FIELD CONTEXT

The community relies mainly on agro-pastoralism. The district has a large number of livestock. To avoid conflict, farming mainly banana are grown in the upper reaches of the hills and low plains are used for pasture and grazing.

Many cattle water points are found in the valley and have water during the wet seasons. During the dry seasons, the livestock move about 30 km to Kagera River, causing conflicts with Tanzanian authorities and loss of many cattle due to diseases got from other met livestock.

4.5.1.2. LIVESTOCK RESOURCES

According to the socio-economic survey in the Isingiro District Council, the present population of livestock is as follows:

- Nyakitunda subcounty : cattle 2 532 and goats 16 892
- Kabingo subcounty: cattle 800 and goats 1 250
- Birere subcounty: cattle 1 200 and goats 8 900
- Ngarama subcounty: cattle 621 and goats 21 300
- Isingiro Town: cattle 1 320 and goats 2 400
- Kaberebere Town: cattle 1 500 and goats 2 500
- Kabuyanda Town: cattle nil and goats 6 210
- Adjacent subcounties: cattle 30 000 and goats 60 000

- Total in project area: cattle 37 973 and goats 119 452
- Total in Isingiro District: cattle 110 442 and goats 202 842

No literature is available on land carrying capacity.

Based on the criteria given for humid area in the methodology 0, the present livestock population is about 151 010 LSU (livestock unit).

4.5.1.3. LIVESTOCK WATER DEMAND

a) Livestock water demand

Water demand calculation is presented below using the design criteria adopted for this assignment as given in the chapter 3.4.1.3. Based on the estimation of livestock population, the present and future livestock water demand is estimated as follows assuming that 40% of the livestock is in the Project area. It is also assumed that by year 2037, the population will increase by 100%

The present and future livestock water demand is estimated as follows:

Table 16: Livestock water demand at Bigasha site

Type	Demand lpd	2012		2037	
		Numbers	m3/day	Numbers	m3/day
Beef Cattle	25	37 973	949	47 466	1 187
Dairy Cattle	40	#	#	#	#
Pigs	10	#	#	#	#
Sheep and Goats	5	119 452	597	149 315	747
Poultry	30 per 100 birds	#	#	#	#
TOTAL m3/d			1 547		1 933
Annual Demand m3/year			0,56 million m^3		0,71 million m^3

 # data not available however a percentage can be included.

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

b) Technical constraints

The location of the water ponds should be taken into consideration as well as the other use of the project. The livestock watering should not be considered as a main use of the dam for economic reasons. However, it could be associated with other uses. Thus, the technical feasibility will be assessed after the choice of the other uses. Technical assessment will then be reviewed at later stager in case of implementing this use.

4.5.2. Aquaculture

4.5.2.1. LEGISLATIVE FRAMEWORK

The Fisheries department of the Ministry of agriculture is in charge of promoting sustainable management of fish and fisheries resources in Uganda.

For the fisheries, the act to be considered is the Fish Act, CAP 197 and the Fish (Beach Management) Rules, 2003.

4.5.2.2. WATER USES FOR AQUACULTURE

According to the Uganda state of environment plan, (EMA Consult, [b]), the application of fish ponds by farmers is uneven throughout the country. The estimation of operational small-scale fishponds is between 10 000 to 20 000 in Uganda. Furthermore, there may be about 10-30% more ponds that are not operational, because of shortage of funds.

Most of the small-scale ponds are operated on the 'low output' principle that means that ponds are stocked after constructions without other inputs in terms of feeds and fertilizers. The production potential for these ponds is approximately 1kg per m^2 per year on a natural basis implying that only 10% of the production is currently realised.

No fish ponds existed due to lack of perennial streams in the area of Project.

4.5.2.3. WATER DEMAND FOR AQUACULTURE

a) Aquaculture water demand estimation

Based on an estimated present population density of about 147 persons/km2, the table below gives two options of ponds, subsistence or commercial fish farming:

	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	147	147	300	300
population	1 847	7 390	3 770	15 082
fish consumption kg @ 1kg/person/year	1 847	7 390	3 770	15 082
Pond Area Ha	0,92	2,46	1,89	5,03
Nrs of ponds	23	6	47	13

Taking into consideration that each pond has an average depth of 1,20m, that the annual evaporation is assumed to be 1300 mm, that soil percolation is assumed to be 1500 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 17: Estimation of water demand for aquaculture for Bigasha site

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	23	0	30	5
Volume	11 085	-	14 400	21 926
10% exchange daily / annually	404 602	-	525 600	800 314
Evaporation 1.3m/ year	12 009	-	15 600	23 754
Seepage 1.5m/year	13 856	-	18 000	27 408
Volume m3/year	441 552	-	573 600	873 402
Total Volume m3/year	0,44 Mm3		1,45 Mm3	

The theoretically estimation of the volume required for fish farming is estimated to 0,44 million m3 for 23 fish ponds without taking into consideration the phases of the implementation.

b) Technical constraints for aquaculture

It should be considered that aquaculture is no practised in the Project area and the scarcity of water. The development of such activity will require including training on the use with the implementation. It should as well require further investigations about the wish of the local population for such development as the social assessment has found a low interest for such activity among the local communities.

4.5.3. Hydropower development

4.5.3.1. LEGISLATIVE FRAMEWORK

The Ministry of Energy and Mineral Development is responsible for formulating and implementing policies, licensing and monitoring energy projects.

Among the agencies and departments under this Ministry, the Rural Electrification Agency is a semi-autonomous agency in charge of the rural electrification.

The main policies relevant for the hydropower development ate as follows:

- The National Energy Policy, 2002
- Renewable energy policy for Uganda 2007
- Vision 2025

4.5.3.2. HYDROPOWER PLANS

According to the Ugandan State Environment [k], major built sites are Nalubale and Kiira, with 180 and 80 MW capacities. Other small operational hydropower stations already exist, among others: Maziba in Kabale, Kuluva in Arua, Kaganda, Mobuku 1 and 2 in Kasese, Kisiizi in Rukungiri.

4.5.3.3. ENERGY USES

The electricity supply is limited to towns (Isingiro, Kaberebere and Kabuyan).

4.5.3.4. HYDROPOWER POTENTIAL ASSESSMENT

The used methodology is the same as described in the chapter 3.4.1.4.

a) Energy production

The results are summarized in the following table:

Table 18: Energy production results for Bigasha site

Name	Full Supply Level (m)	Firm Power (kW)	Mean Power (kW)
BIGASHA	12	33	41

b) 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.

The cost per kWh is estimated equal to 0,15 Euros/kWh.

The benefit after 30 year of exploitation is given in the following table:

Table 19: Benefit of energy selling for Bigasha site

Name	Full Supply Level (m)	Firm Energy (kWh/year)	Benefit after 30 years (Euro)
BIGASHA	12	289 278	449 647

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 the experience of the consultant on similar project, all these cost will not be less than 1,2 millions of Euros.

Thus the site would be not viable economically.

4.5.4. Water supply

4.5.4.1. WATER SUPPLY USES

Communities rely on small springs in the hills and on traditional wells as a source of their water supply. The fetching distances are long to find water as most of the villages are located at the top of the hills.

The safe water coverage in Ngarama sub-county was about 48% in 2010 out of 30% in the District. The water infrastructures in Ngarama sub-county include 16 communal (GFS) taps, 5 springs, 32 boreholes, 30 shallow wells, 4 valley tanks, 114 households water tanks in 2010 [c]. However, in the Project area, there is a shortage of water and the fetching distance could reach sometimes more than 10 km.

4.5.4.2. POTABLE WATER DEMAND

The following table gives the maximum water demand option including Isinjiro town and the three surroundings sub-counties, based on a water demand per capita of 20 litres/person/day (lpd) and on the methodology described in the chapter 3.4.1.2.

Table 20: Estimation of maximum water supply for Bigasha site

Water Supply	Urban	Peri-urban	Rural	2012 Urban	2012 Peri-urban	2012 Rural	2037 Urban	2037 Peri-urban	2037 Rural
Population	levels of services			49 007	17 898	101 421	165 954	37 474	212 352
Communal Water Points / others	30%	60%	80%	14 702	10 739	81 137	49 786	15 180	169 882
Yard Taps	20%	20%	20%	2 940	2 148	16 227	33 191	5 060	42 470
Multiple Taps House Connection	50%	20%	0%	1 470	430	0	82 977	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			368	268	2 028	1 245	380	4 247
Yard Taps	60			176	129	974	1 991	304	2 548
Multiple Taps House Connection	120			176	52	-	9 957	607	0
Sub-Total m3/d				720	449	3 002	13 193	1 290	6 795
Non-domestic 30% m3/d				216	135	901	3 958	387	2 039
Total m3/d				937	584	3 903	17 151	1 677	8 834
30% losses m3/d				281	175	1 171	5 145	503	2 650
Grand Total m3/d				1 217	759	5 073	22 297	2 181	11 484
						7 050 m3/d			35 961 m3/d
Annual demand including Ijinjiro, Kabuyanda & Kaberere tows (m3/year)						2,6 million m3			13,1 million m3
Annual demand including Ijingoro town and the sub-counties of Ngarame, Kashumba and Kikagati (m3/year)						1,5 million m3			7,74 million m3

The maximum water demand option kept for the study will include Isinjiro town and the three surroundings sub-counties, as the primary beneficiaries.

4.5.5. Environmental flow requirement

Following the methodology mentioned in the chapter 3.4.1.6, the environmental flow has been estimated to nil taking into account that the River is seasonal and has not been seen at the dam axis. No environmental impacts have been found to justify taking into consideration an environmental flow at the stage of this study. It is recommended in the detailed design to take into consideration the ecological environment in order to define the most appropriate flow keeping in mind that the Bigasha stream is underground at dam site.

4.5.6. Evaluation of development scenarios

Evaluation of water uses

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

1) potable water supply
2) electricity
3) irrigation
4) livestock watering
5) aquaculture

The below table summarizes the merits and demerits of each water uses based on the above chapters.

Table 21: Evaluation of the water uses scenarios for Bigasha site

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

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

Analysis of findings

The water use review allows estimating the appropriate dam height to deliver the required water demand with an acceptable deficiency. The following table gives the maximum water demand option.

Table 22: Water demand for Bigasha site

Water Use Type	Water demand (m3/year)	
	2012	2037
Water supply demand	1 500 000	7 740 000
Irrigation water demand	723 000	1 833 000
Livestock water demand	560 000	710 000
Aquaculture demand	440 000	1 450 000
Total (m3/year)	**3 223 000**	**11 733 000**
Total (m3/s)	0,10	0,37

For water supply, Isinjiro town and the three surroundings sub-counties as first beneficiaries have been kept.

For irrigation, land tenure could be an issue as most of the valley is used for cattle grazing. The land tenure should be taken into consideration before the development of the irrigation. The water demand has taken into consideration 2 phases for the irrigation development, for a total of 451Ha.

For energy supply, the site would be not viable economically as mentioned in the chapter 4.5.3.4 due to the small discharge capacity. Thus, this water use was excluded from the potential uses to develop.

Bigasha site has two dry seasons with no flows. Storage is therefore necessary for the above use developments.

4.6. Optimization of the reservoir capacity for Bigasha reservoir

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 3.3.4.2) 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.

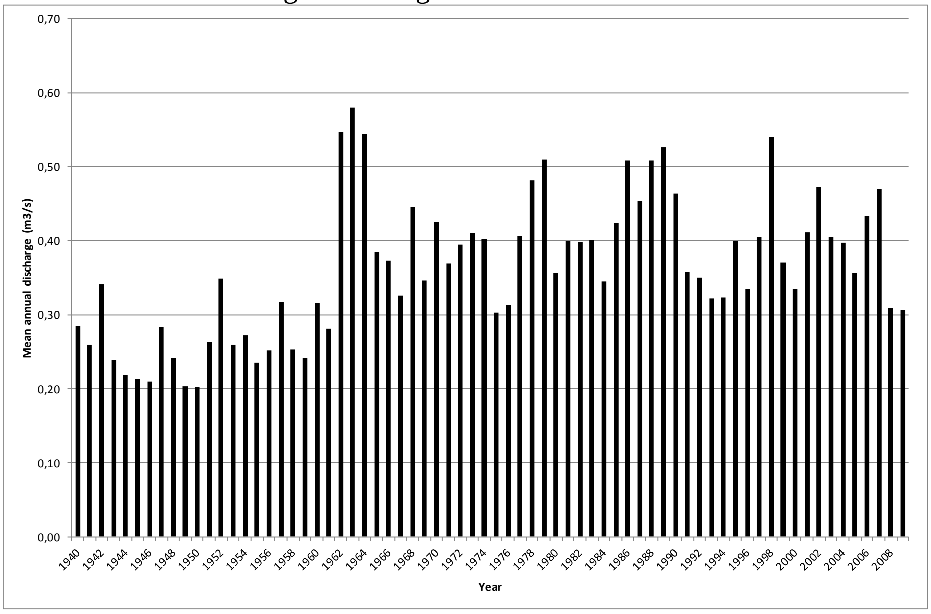
The optimization consists of determining the minimum reservoir capacity which allows an average constant water release with an acceptable deficiency.

4.6.2. Runoff

For Bigasha dam site, no gauging station was identified in the vicinity of the site, including outside of the Kagera River basin. The methodology to assess the inflow at Bigasha dam site is described in the hydrology chapter 4.4.

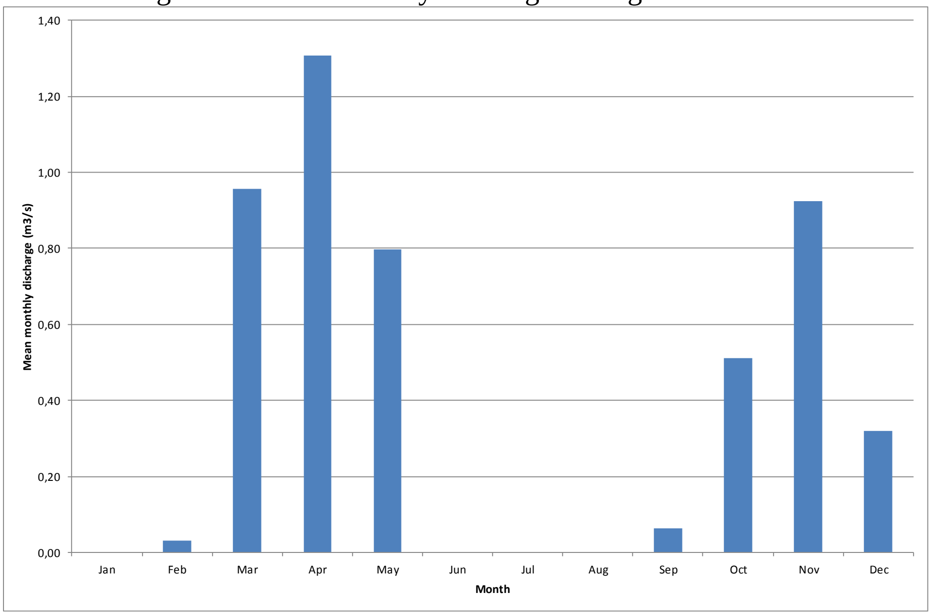
As observed in the region since 1940, the rise in runoff in the early 1960ies appears clearly. Two periods can be distinguished: a pre-1960 period with a moderate runoff level and a post-1960 period with a high runoff level. It has therefore been decided to simulate the reservoir only over the period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

Figure 33: Bigasha Annual Inflows



The annual runoff within the period 1962-2009 is about 0,41 m^3/s, with a quite pronounce seasonal pattern due to arid conditions and dry periods without flows.

Figure 34: Mean monthly discharges at Bigasha dam site



4.6.3. Evaporation

The following table summarize the result of the computed Net Evaporation at the Bigasha dam site. The net losses due to evaporation is about 15,1% of the annual inflow.

Table 23: Estimated evaporation at Bigasha reservoir

	Bigasha	Precipitation		Original evapotranspiration (mm)	Evaporation (mm)	Net Evaporation (mm)	Catchment Area (km²)	Runoff (mm)	Dam Height (m)	Reservoir Surface Area (km²)	Net losses due to evaporation /Inflows
	Altitude (m)	Yearly Amount(mm)	Distribution (%)	based on CRO=	Lower Kagera						
		843		0,181			101	102	14	1,79	15,1%
January		43	5,1%	31	120	89					
February		59	7,0%	43	108	65					
March		110	13,0%	81	117	36					
April		131	15,5%	96	106	10					
May		101	12,0%	74	114	40					
June		22	2,6%	16	124	108					
July		17	2,0%	12	146	134					
August		32	3,8%	23	163	140					
September		60	7,1%	44	136	92					
October		85	10,1%	62	127	65					
November		108	12,8%	79	110	31					
December		76	9,0%	56	117	61					
Total		843	100%		1 488	870					

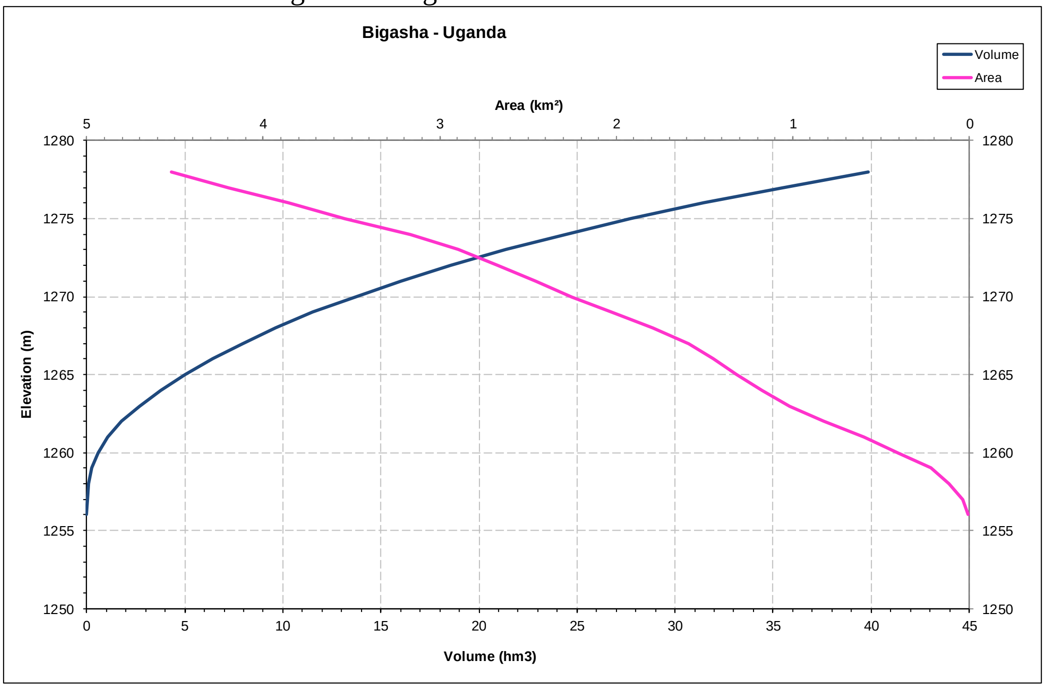
4.6.4. Maximum mean water release

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 0,35 m^3/s (0,41 – 15,1%).

4.6.5. 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 35: Bigasha Reservoir HSV Data



4.6.6. Minimum Operation Level

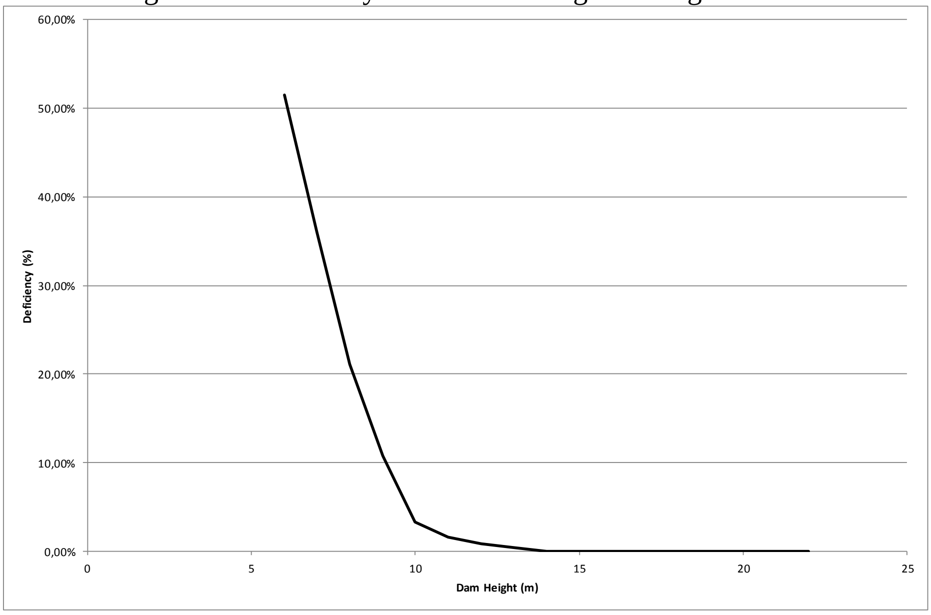
As sediment will be trapped, the reservoir storage capacity will decrease. Therefore, the outlet structure must be set at an elevation above the expected siltation level. Under this level, the water stored will not be used and commonly called as "dead storage".

The annual sedimentation rate at Bigasha site is about 0,062 Mm3 per year. Therefore, the outlet threshold has been set 6m above the minimum ground elevation, giving a dead storage is 1,76 Mm3 representing more than 30 years of sedimentation storage.

4.6.6.1. DEFICIENCY AND GUARANTEED DISCHARGE

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

Figure 36: Deficiency versus Dam Height for Bigasha dam

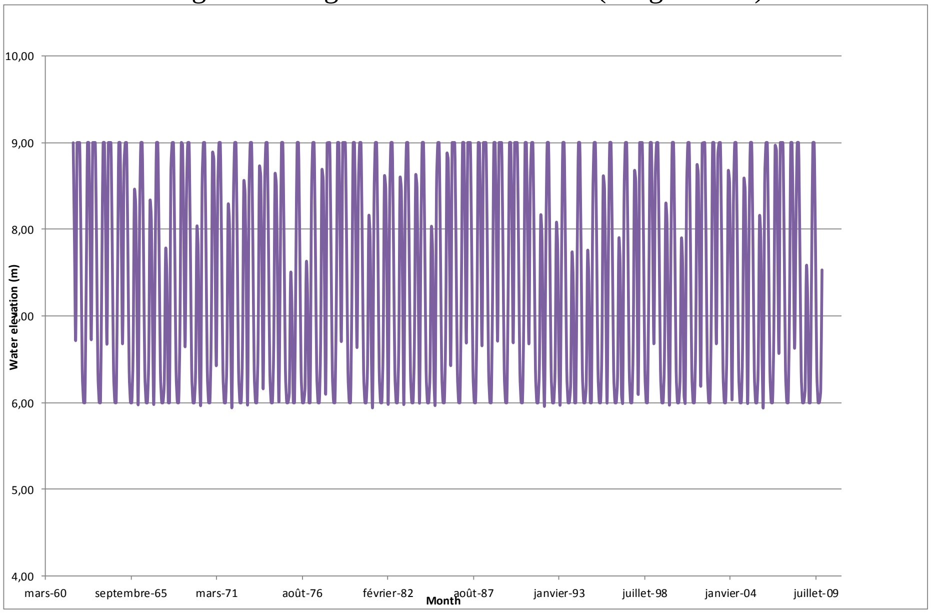


This curve can be divided into three different zones.

- Zone 1: Below a height of 10m, the curve is rapidly decreasing. The reservoir has a too small capacity to store the water during the wet season and to deliver it constantly during the dry season.

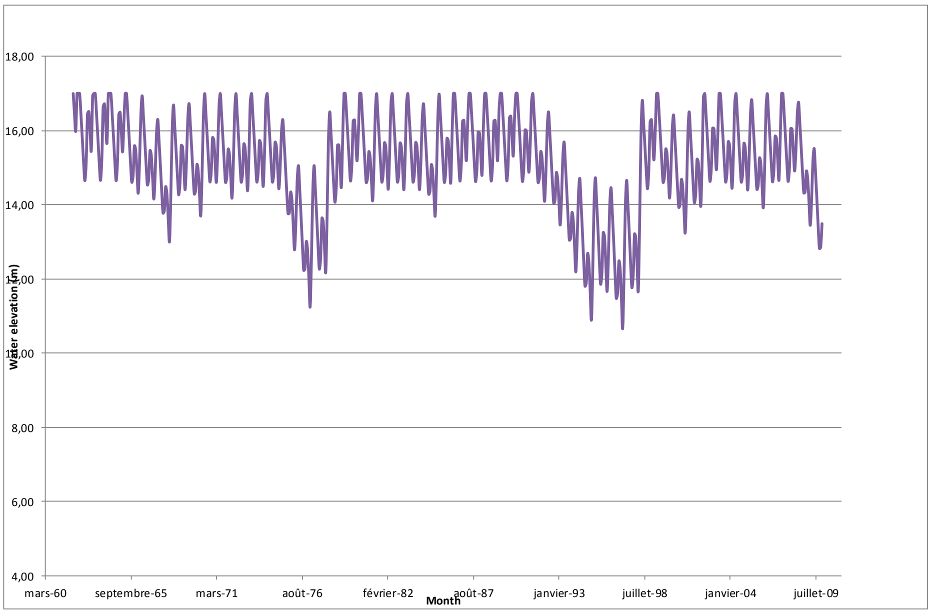
  The following figure shows the water elevation in the reservoir along the simulation period. It can be seen that every single year the reservoir is empty, thus a poor reliability of the reservoir to provide the demand.

Figure 37: Bigasha Water Elevation (Height = 9m)



- Zone 2: Above a height of 14 m, the deficiency is always nil. The reservoir capacity is too important related to the annual inflow. The following figure shows the water elevation in the reservoir along the simulation period, which shows that both the bottom outlet level is never reached and the full supply level is seldom achieved.

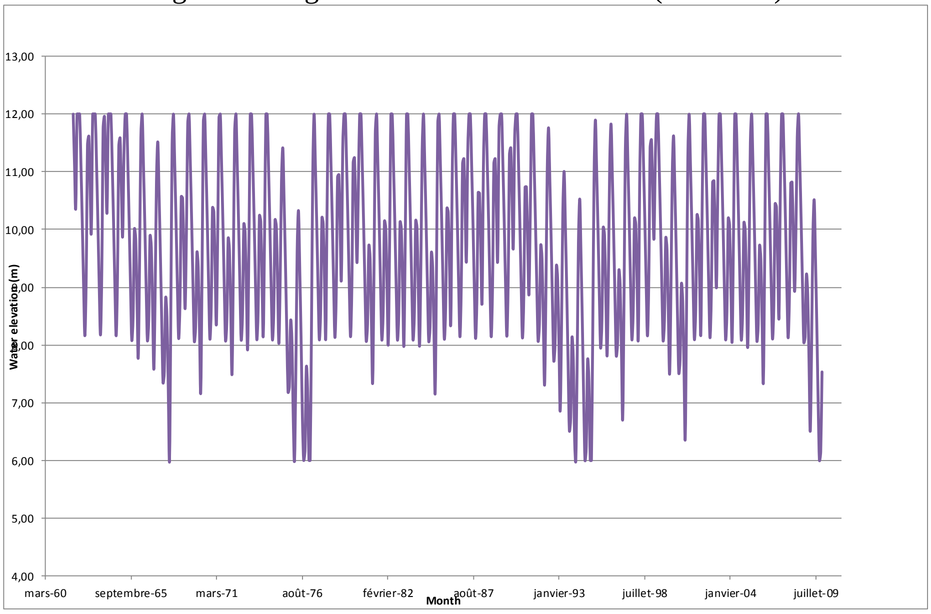
Figure 38: Bigasha Water level simulation (H = 17 m)



- Zone 3: Between a height of 10 and 14m, the deficiency is slightly decreasing. The optimum is within this range of value. As the volume (and therefore the cost) of the dam is increasing rapidly with the square of the height, we recommend to set the full supply level at the bottom range of this zone, that is to say 12 m.

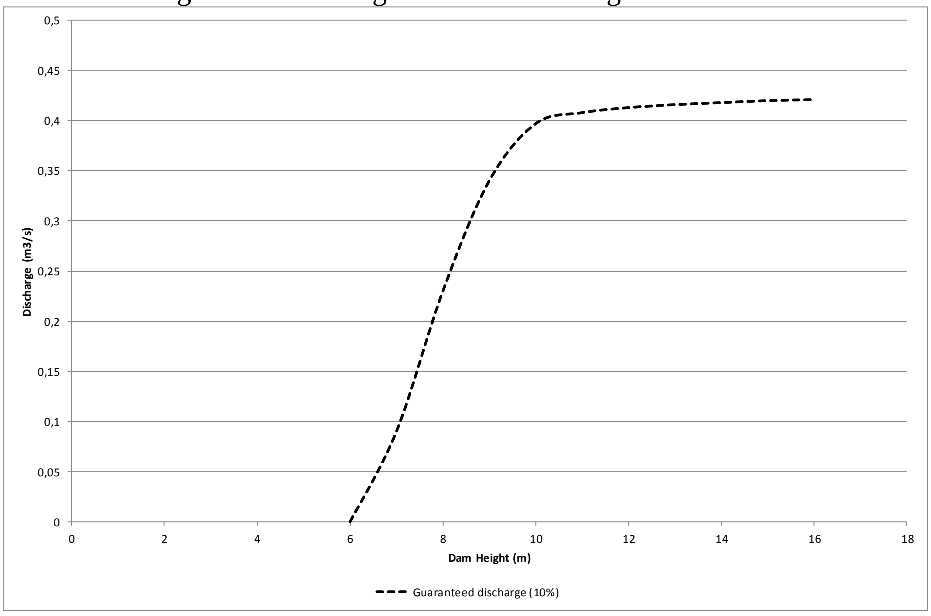
The following figure shows the water elevation in the reservoir along the simulation period, which shows that the reservoir appears quite reliable with only 0,83% of the time when the demand is not entire satisfy and that the reservoir is also quite often full.

Figure 39: Bigasha Water level simulation (H = 12 m)



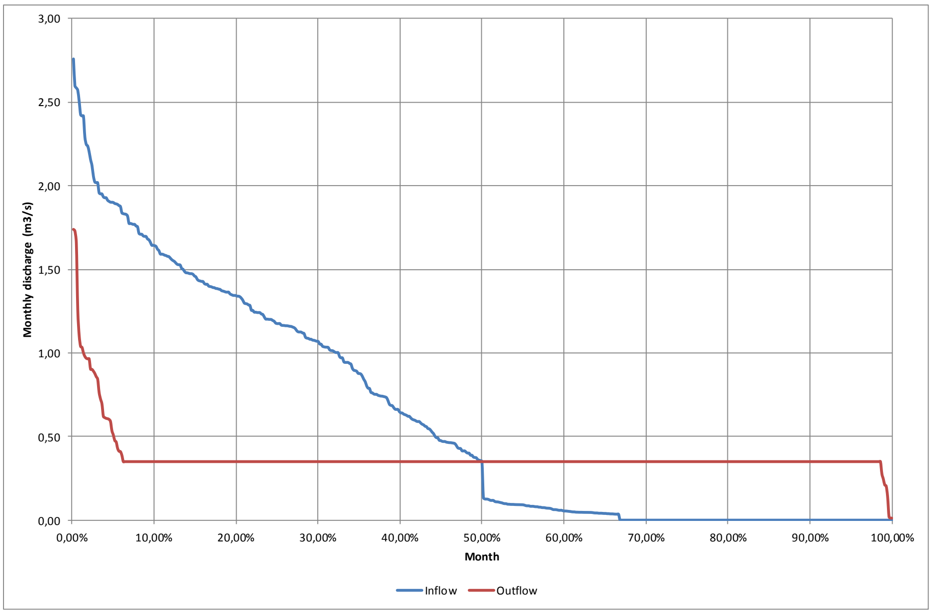
The following table showing the discharge guaranteed 10% of the time versus the dam's height confirms the optimization of a Full Supply Level to 12 meters.

Figure 40: Discharge Guaranteed at Bigasha dam site



With a full supply level set 12 meters above the ground level, the following figure shows the discharge variability without (Inflow) and with the dam (Outflow). The deficiency to provide 0,35 m3/s is 0,83 %.

Figure 41: Discharge variability for Bigasha



5. DETAILED DESIGN AND COSTING FOR BIGASHA DAM

5.1. Introduction

This chapter presents the operational characteristics of the dam. The main characteristic of the dam is as follows:

Table 24: Main characteristics of the dam

BIGASHA	***Final dam design***
Dam height (m)	**12,00**
Storage capacity at FWL (Mm^3)	**6,41**
Dam crest Length (m)	**610,16**
Reservoir Width maximum(Km)	**1,14 at MWL**
Reservoir Length maximum (Km)	**2,37 at MWL**
Full Supply Level (m)	**+10** (1266m asl)
Maximum Water Level (m)	**+11,25** (1267,25m)
Reservoir surface area at FWL (km^2)	**1,45**
Reservoir surface area at MWL (km2)	**1,64**
Contributing catchment area (km^2)	**101**
Catchment sediment yield (Tons/km^2/yr)	**637**

The cross section of the dam consists of an earth zoning dam type with central core of clay, supported upstream and downstream by filter and drainage system and rockfill random material. Homogeneous earthfill dam was initially recommended by the Consultant, but the client has required the change of the design due to its local experience with such type of dam.

The outlets works design is described in Appendix J. The drawings are included in the Appendix E.

5.2. Project area

The Project area is defined as the location and vicinity of the physical project works area, the area to be flooded by the reservoir, and the off-site construction areas. The map 07 in the Appendix D shows the overall project area including:

- The dam axis,
- The reservoir created due to the dam,
- The potential contractor's camp taking into consideration the topographical map (flat area for buildings as well as the access road),
- The access road which is currently a trail from the village, where a road could be reached coming from the other side of the valley,

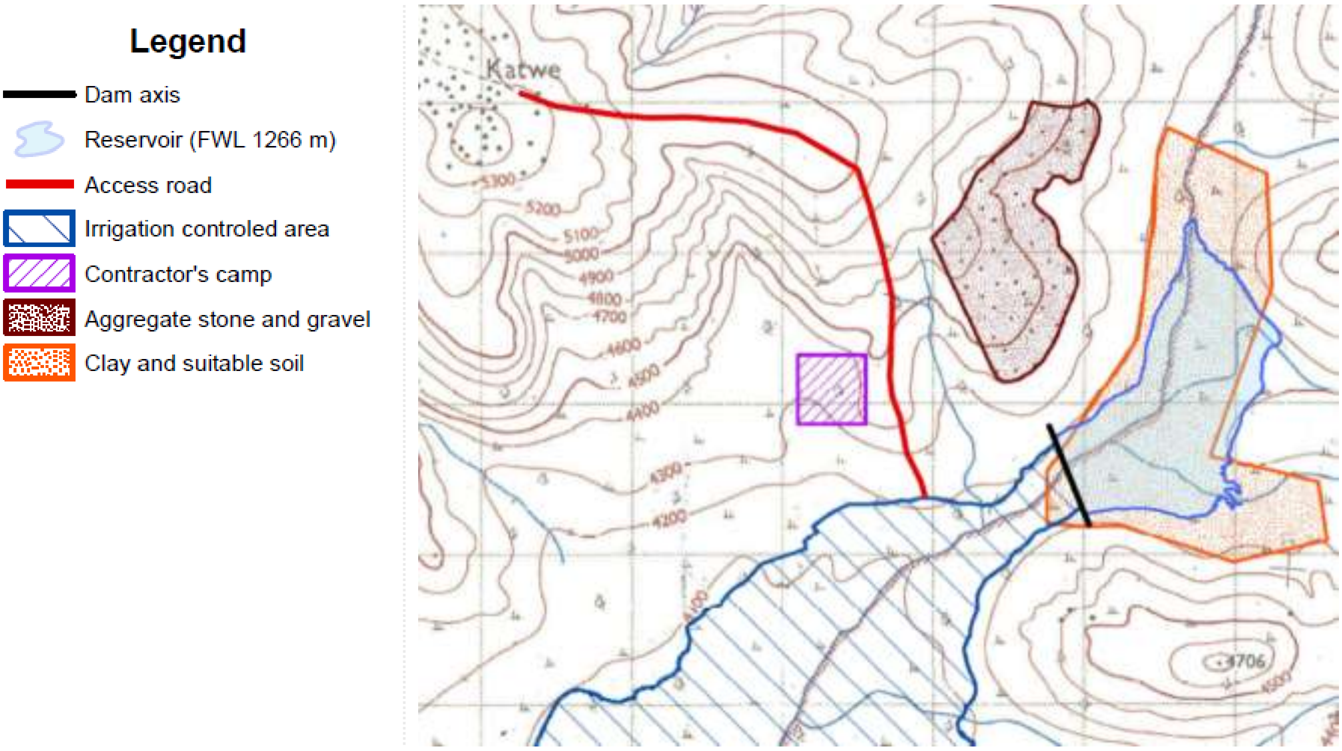
- The extracted material area such as the clay material for the embankment dam from the valley upstream that should be mixed with the gravelly materials from hill sides, as well as a suitable rock face for concrete work that should be identified within a 5 km radius in the nearby hills (northern side) where the contractor could install a crusher for aggregates and sand.
- The potential irrigated area.

5.3. Characteristics of site work

The duration for the site work is estimated to be 7 months.

Size camp is estimated based on 30 containers (20 for personnel and 10 for offices and others), meaning around 700m2. It is located as shown on the following figure and detailed on the map 12 in the Appendix C.

Figure 42: Work site for Bigasha project



The number of workers is estimated to 100 from which it is recommended to hire locally unskilled labour.

Heavy machinery for such dam is estimated to include 2 bulldozers, 2 cement trucks, 2 compactors, 2 hydraulic shovels, 2 wheel loaders, 5 trucks, 1 grader. The equipment would require parking lot estimated to 900m2.

It has been estimated that the waste material could reach 100 000 m^3.

5.4. Components of the dam

The paragraphs hereafter will describe the different components of the dam as well as its characteristics.

5.4.1. Full supply level

The chapter 4.5.6 agglomerates the results of the optimization of the reservoir capacity and the water demand in 2037. A Full Water Supply of 10,0 m is sufficient to provide the water demand with an acceptable deficiency level. According to the topographical map, this corresponds to 1266,0 m asl.

5.4.2. Freeboard and Maximum Water Level

The freeboard is the vertical distance between the crest of the embankment and the reservoir water surface. The Full Supply Level and the dam's crest are respectively set at 1266,0 and 1268,0m, allowing a 2m freeboard.

The minimum freeboard should be provided to prevent overtopping of the embankment by wave action which may coincide with the occurrence of the inflow design floods. The height of the waves generated by winds in a reservoir depends on the wind velocity, the duration of the wind and the fetch.

At Bigasha dam site, with a fetch of about 1,5 km and a wind of 80 km/h, the wave height will be about 0,75 cm.

The maximum water level should therefore not exceed the level 1267,25 m (0,75cm under the dam's crest). The next step is to determine the minimum spillway length respecting this data. The ditto computation is explained in the following chapter.

A small parapet on top of the dam crest will protect against wave ride-up.

5.4.3. Bigasha spillway hydraulic design

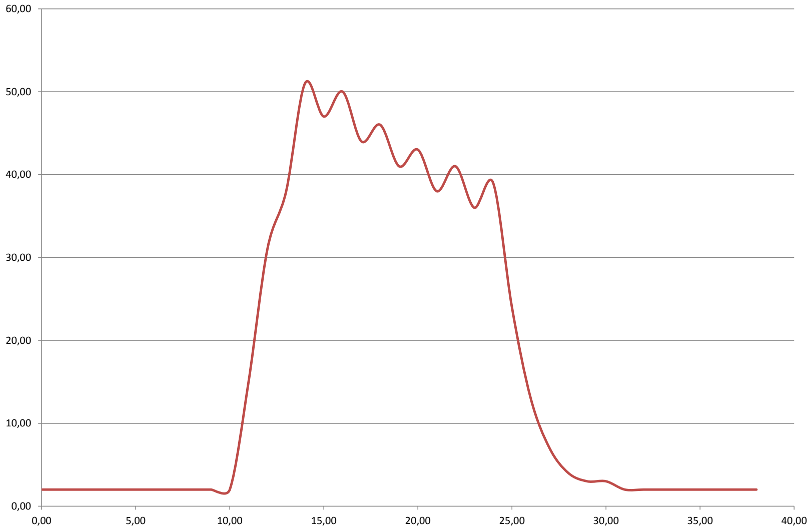
Design Flood

The proposed spillways at the feasibility stage will be a free spillway, located on the bank which presents the better geological condition for its foundation and flow restitution.

The dam has relatively low risk due to the fact that it will be located in a rural area without inhabitants in the river valley. Failure of the dam results in no probable loss of human life and low economic and/or environmental losses. According to the guidelines for dam safety applying in the region, the design flood to be considered is the one with an annual exceeded probability of 1/100.

The corresponding flood hydrographs have been computed in the hydrology study and are given in the flowing chart.

Figure 43: 1/100 Hydrograph flood at Bigasha site



The maximum discharge is 51 m^3/s.

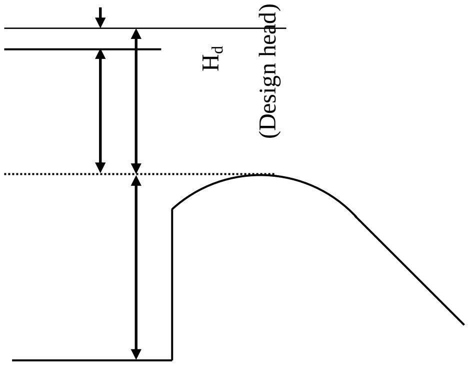
Freeboard and maximum water level

See chapter 5.3.2.

Crest Shape

The crest shape of the ogee approximates to the profile of the lower-nappe falling from a sharp-crested weir. For discharges at design head, the flow glides over the crest with no interference from the boundary surface.

The design head is the maximum head occurring during a 100 year-return period flood, i.e. approximately 1.50 m. with a depth approach equal to 2m, the discharge coefficient will be approximately equal to 2,10.



Flood routing

Discharge coefficient

$$Q = CLH_e^{3/2}$$

The discharge over an ogee crest is given by the equation:

Where:

Q = discharge (m^3/s)
C = variable discharge coefficient (-)
L = effective length of crest (m), and
H_e = head being considered on the crest (m)

The discharge coefficient, C, depends on the following factors:

1. Pier and abutment effects
2. Effect of head difference from design head
3. Approach channel losses

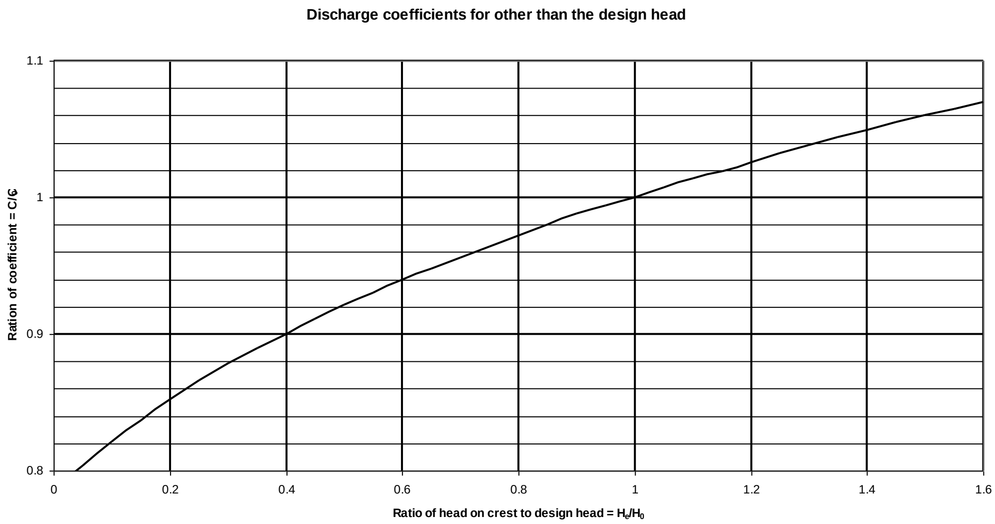
Pier and Abutment Effects

No bridge is foreseen across the spillway crest. Rounded abutments with headwalls placed not more than 45° to direction of flow will provide negligible contraction effect.

Effect of Head difference from design head

The discharge coefficients differ from those defined previously (2.1) when the actual head on the crest varies from that used to determine the crest shape.

The figure below shows the variation of the discharge coefficient.
H_0 = design head



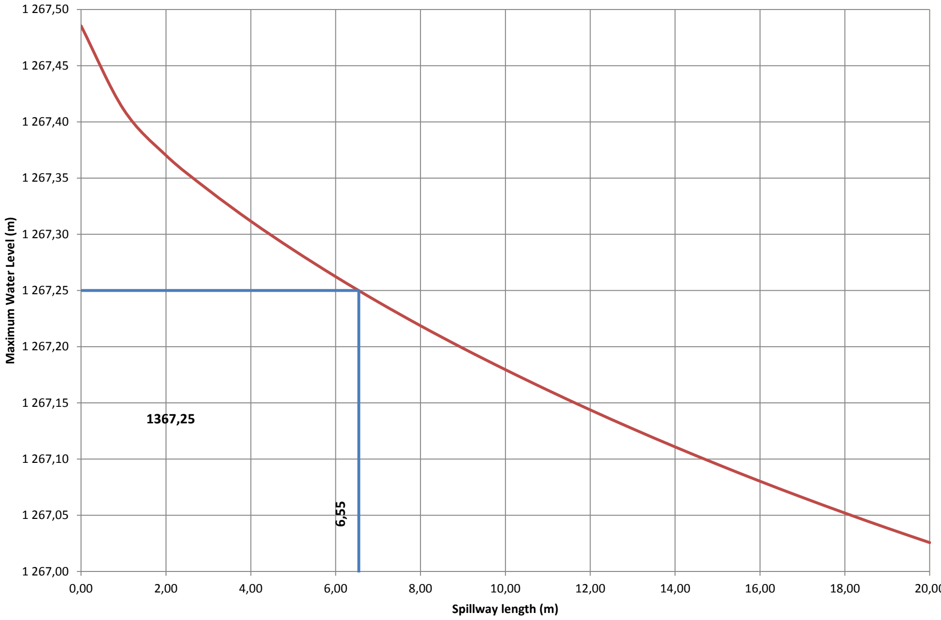
H_e = actual head on the crest

Approach channel losses

The spillway is located against the dam itself. Therefore, the ogee is directly in contact with the reservoir without any approach channel and the corresponding losses can be considered as negligible.

Spillway Length

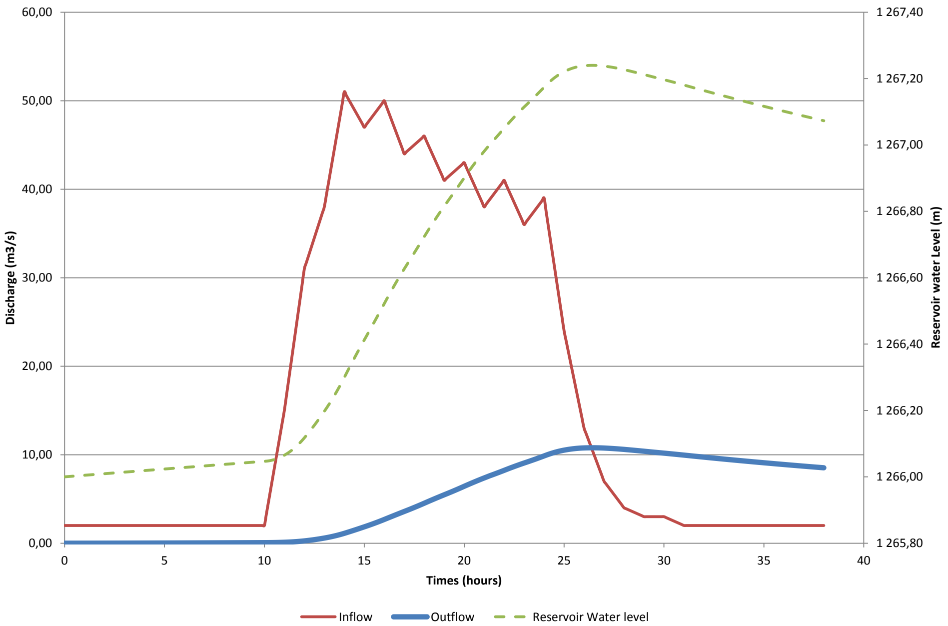
A flood routing computation using Excel software with the above data has been undertaken for several spillway lengths. Results are summarized in the following graph.



On the above chart, the Maximum Water Level of 1267,25 as defined in chapter 2 required a minimum length of the spillway to 6,55 rounded to 7 meters.

<u>Flood routing Result</u>

The flood routing with such length of the spillway is summarized in the following chart.



The maximum water level reached is 1267,24 with a peak outflow discharge of 10,78 m3/s.

5.4.4. Dam Characteristics

With the above results, the main characteristics of the dam is summarised below:

Dam Type	Clay core zoned earth and rockfill embankment
Maximum height	12,00 meters (from the natural ground level)
Crest length	610,16 meters
Maximum width at NGL	60,00 meters
Slope of upstream face	2.5H:1V
Slope of downstream face	2H:1V
Plan alignment	straight
Dam Crest level	1 268,00 m asl
Full Supply Level	1 266,00 m asl
Maximum water level	1 267,24 m asl
Minimum operational level	1 262 m asl

5.4.5. Typical cross section

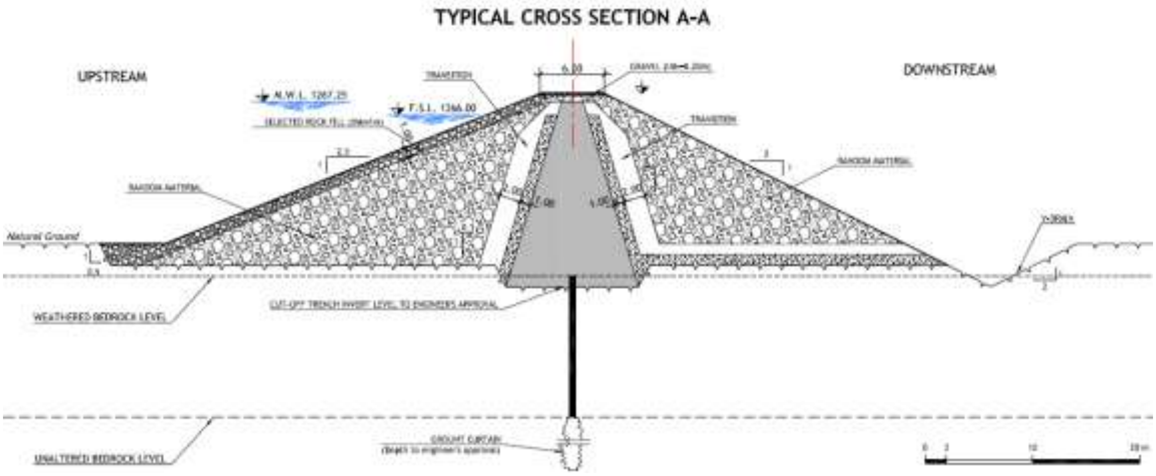
The cross section of the dam consists of an earth zoning dam type with central core of clay, supported upstream and downstream by filter and drainage system and rockfill random material. The transition zone between the core and the shoulders consists of about 1m of a sand filter (close to the clay core) and about 2m transition zone of a granular filter formed of a mixture of crushed rock and natural sand.

The crest width is 6m, the upstream slope is 2.5H:1V, and the downstream slope is 2H:1V.

Upstream embankment will be protected with rock to prevent erosion. It is also advised to protect downstream embankment with grass.

In order to mitigate uncertainty about water seepage and on the basis of available investigations results, the seepage control is improved by a 15m cut-off wall (which projects into the core and bedrock) in the river valley and a horizontal drain downstream.

Figure 44: Typical cross section of the dam



Feasibility stability analysis has been undertaken on the highest cross section of the dam using characteristics of material obtained from the site investigation. The STB 2010 software using simplified Bishop's Methods has been used. The analysis output is presented in the Geophysical and Geotechnical Report (see Appendix I). In the same way, seepage analysis and settlement are available in the foresaid report. All results are satisfactory.

5.4.6. Foundation design

The dam footprint will be stripped of all grass, trees, excessively plastic soil and any deleterious material. Thereafter a cut-off wall will be constructed to an average depth of 15 m.

A special geological phenomenon occurs in the region where the dam's axis is placed. Some kilometres upstream the axis, the water flow goes underground and all superficial water disappears by infiltration. Low discharges, deep unweathered bedrock and the large bed of the channel contribute to explain this phenomenon.

The solution proposed is to create an obstacle able to stop the groundwater flow and force the water to come up to the surface. According to the geophysical essays, the results of the augers executed in the dam's axis and the field visit made by the technical personal, it is estimated that the cut-off wall should measures 15 m depth in average. This cut-off wall will also lengthen the seepage path, avoiding problems caused by piping events.

The position of the cut-off wall should be object of a particular study in the following phase of the project. Likewise the specific kind of cut-off wall can be optimised.

Control holes shall be drilled to depths up to 18m and water tests shall be executed to check on effectiveness of the cut-off wall.

Shotcrete, dental concrete and slush grout will be applied where necessary.

5.4.7. Instrumentation

Instrumentation on the dam will be in the form of settlement studs, which will be positioned along the downstream edge of the embankment crest at 50m intervals.

There will be a V-drain running along the downstream toe of the dam. Seepage water accumulating in the drain will be measured by 3 V-notches. Two will be in the toe drain while the third will be in the exit channel leading to a suitable discharge point.

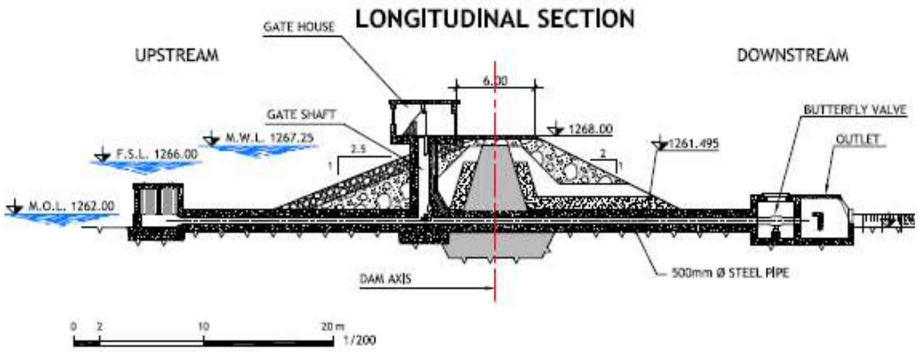
5.4.8. Outlet Works

Description

The outlet works at each dam will comprise:

- Intake trash screen
- Upstream pressure conduit
- Gate shaft and gate house
- Downstream pressure conduit
- Stilling basin

Figure 45: Longitudinal section for the outlet structure



Intake and trash screen

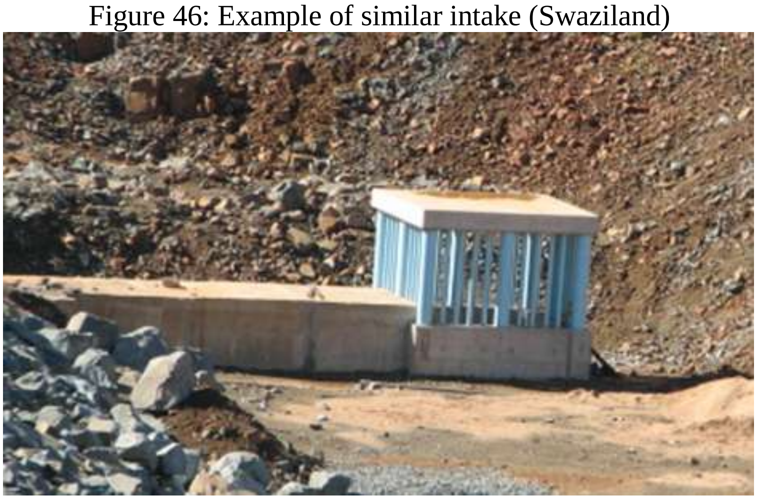
The bottom of the intake and trash screen will be at the Minimum Operation Level (MOL) of the reservoir. The axis of the pressure conduit will be 0,50 m below the MOL. The intake is 2,80 m square in plan with the trash racks axes positioned on a 3,30 m square.

The trash screen consists of 2,0 m long 110 mm outside diameter PVC pipes filled with reinforced concrete placed at 292 mm centres. There are eight 300mm-diameter reinforced concrete columns supporting the concrete bulkhead which will be on top of the trash rack pipes. A bay of removable trash rack pipes is provided to facilitate entry into the intake should the need arise. These removable racks will be provided with lifting lugs to facilitate removal from their position.

The clear spacing between the trash rack pipes will be 182mm and there will be 40 of these spaces giving net area of flow of 14,56 m2. The velocity through the trash screen will be 0,2 m/s. Assuming a 50% clogging of the trash screen, the velocity through it for the peak discharge would be 0,4 m/s, quite below the limiting velocities between 0,9 m/s and 1,22 m/s (Ref. Advanced Dam Engineering).

The velocity inside the intake will be about 0,5 m/s.

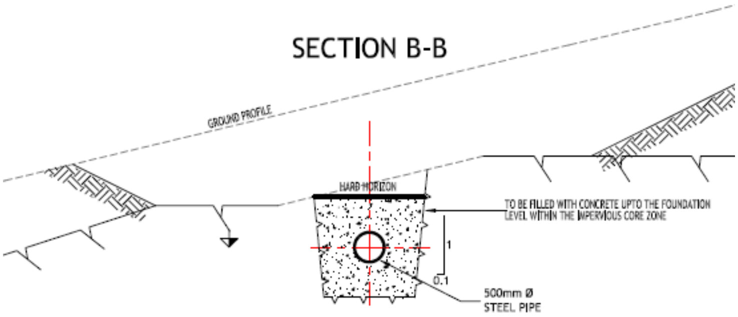
Figure 46: Example of similar intake (Swaziland)



Upstream conduit

The upstream conduit consists of a steel pipe encased in reinforced concrete, founded on rock throughout. The upstream end will be slightly flared to reduce entry losses. The conduit will discharge water into the gate shaft positioned 6,0m upstream of the dam axis.

Figure 47: Illustrative upstream conduit cross-section



Gate shaft and gate house

The gate shaft will be 3m by 2m with 600mm thick reinforced concrete walls. The service gate to close the downstream conduit will be lowered through the gate shaft.

The service gate house will be on top of the gate shaft with a floor level equal to the settled crest level of the embankment. The gate house will be 5m in diameter and 2,5m high with a 200 mm thick reinforced concrete roof. The gate house walls will be 300 mm thick. The gate house will contain the steel service gate which will be suspended at the floor level from a winch system and two supports.

Figure 48: Illustrative gate chamber details

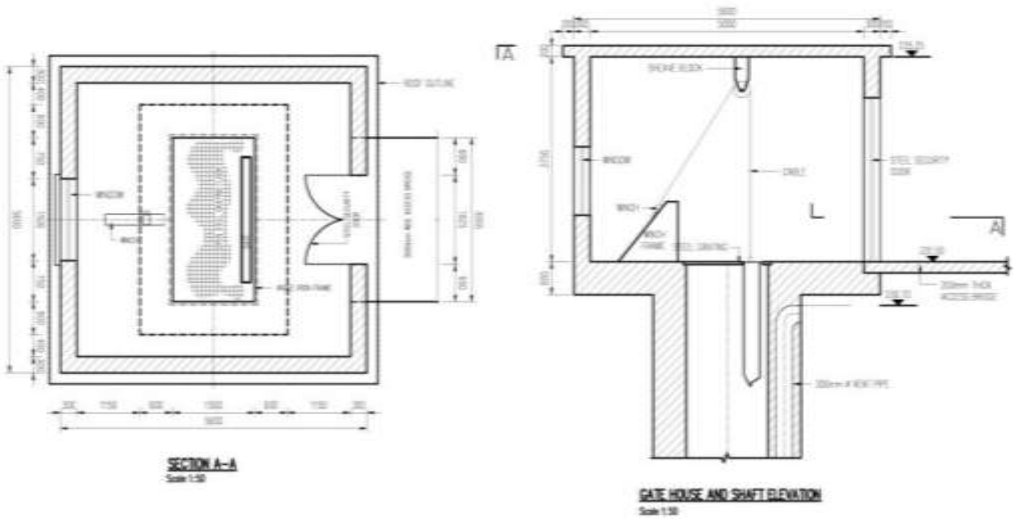
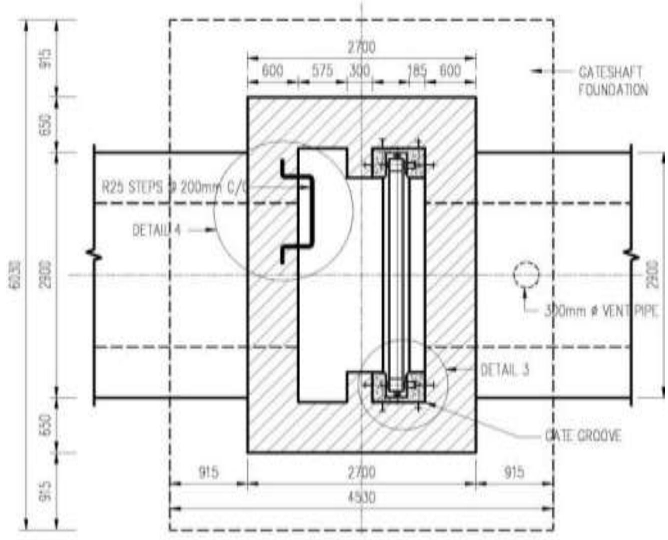


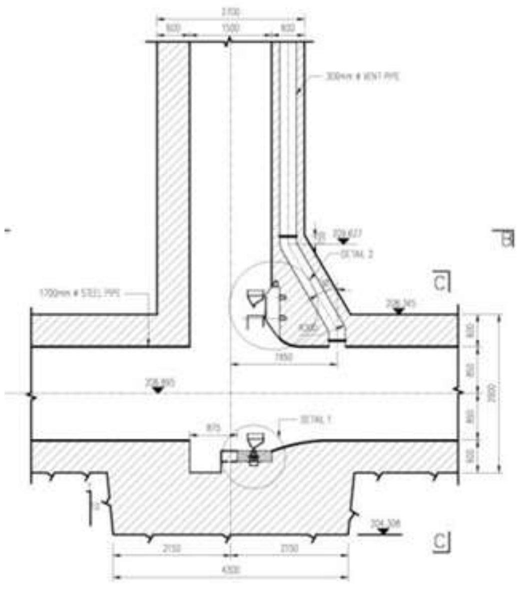
Figure 49: Illustrative gate shaft details



Downstream pressure conduit

The downstream pressure conduit starts at the gate shaft. The upstream end will be bellmouthed to provide good entry conditions. There will be a striker plate below the bellmouth where the gate will rest when lowered down. The gate will be on-seating, i.e. kept in place by the water pressure.

Figure 50: Illustrative bottom of the gate shaft

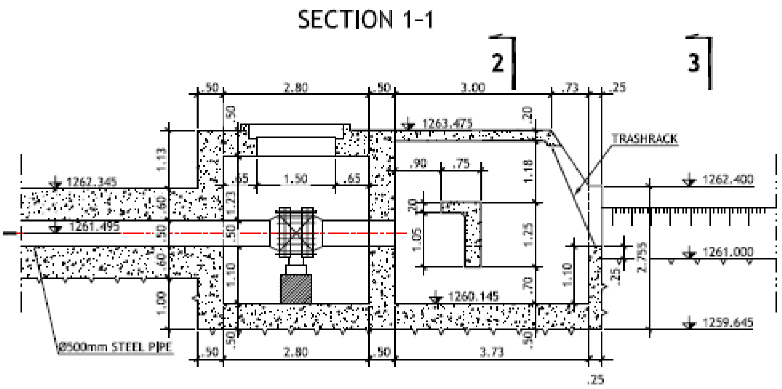


The pressure conduit will be encased in 600 mm thick reinforced concrete which will be cast in a purpose made trench, excavated into hard rock.

Valve chamber and restitution structure

Water discharge will pass through a butterfly valve, which will be used to control water flow and can also be used in case of failure of the wheel gate. Then, the pipe will discharge into a stilling basin where the water jet will hit a baffle wall. This way, the energy will be dissipated in the stilling basin before its restitution to downstream. Trash racks will be placed at the far end of the stilling basin in order to achieve the dissipation and to protect the structure against human aggression.

Figure 51: Valve chamber and restitution structure



Computation

The outlet works is able to supply the full water demand, estimated to be 0,50m3/s in 2037, until the reservoir level 1262,40 m. In appendix J, the discharge of the bottom outlet versus the pipe diameter has been computed. A pipe diameter of 500mm is required to fulfil the requirement.

5.4.9. Bigasha Spillway civil works

Location and general layout

The spillway for Bigasha Reservoir will be located in the right side of the dam where geological conditions offer better condition. The spillway will be orientated in line with the dam, discharging downstream of the toe of the dam into the river.

Spillway components

The spillway consists of the following:

- Spillway ogee
- Spillway chute
- Stilling basin
- Return Channel

Ogee spillway

Shape

The spillway overflow sill has been designed as an ogee spillway 7,0 meters long. The ogee profile provides a hydraulically efficient control structure with a high coefficient of discharge where the upper curve of the ogee conforms closely to the profile of the lower nappe of a ventilated sheet of water falling from an ogee-type weir. For discharge at the designed head, the flow glides over the crest with no interference from the boundary surface and attains near-maximum discharge efficiency.

The ogee shape terminates when the downstream face slope (0,8h:1V) formed by the tangent to the ogee profile intersects the vertical upstream face of the ogee at maximum water level 1 266,0 m.

Ogee concrete sill

The ogee concrete sill for both the main and auxiliary spillways will be a plain mass concrete (CVC) structure of 20/64 concrete grade. The structure will have skin reinforcement in the form of wire mesh on its periphery to prevent thermal cracking.

Stability

The ogee structure will be subjected to water loads (static and dynamic). Although the foundation will be consolidation grouted and a grout curtain provided to prevent seepage, it is assumed that these measures might still not fully preclude seepage water through the foundation and therefore uplift pressures are possible at the varying water levels.

Calculation at the PMF loading case may show that anchor bars are necessary for the actual ogee structure to counter uplift pressure, and anchor bars are necessary on the sloping face to counter sliding.

A system of drains is to be incorporated to ensure that all seepage water is evacuated from below the ogee. The drainage system consists of 150mm diameter half round perforated PVC pipe, laid at 1m centres across the entire length of the ogee in the upstream-downstream direction. Water flows into these drains is discharged into the river.

Grouting

Consolidation grouting will be carried out in the spillway foundation over the whole area to be covered by the ogee structure in order to stabilise the rock which may have become disturbed during excavation. Consolidation grouting will be at 3m staggered centres to a depth of 3m.

Curtain grouting will be undertaken in primary and secondary holes spaced at 12m and tertiary holes at 6m centres, in stage not exceeding 6m length. Grout holes will be drilled vertically on a single line along the ogee spillway axis.

Concrete basin

A concrete basin has been designed at the toe of the ogee structure in order to protect the foundation from the energy gained by the water after flowing over the control section. The concrete slab is about 50 meters long. Then the water will flow up to the river within an excavated trench.

Return channel

After passed throw the stilling basin, flow reach the open channel and flows over the bedrock layer until attaint the riverbed. Laterals walls measuring between 2,00m and 2,50m should be constructed all along the channel to protect excavation banks. No bedrock surface treatment is expected, except in some special cases to be defined.

5.5. Dam safety monitoring and management system

Bigasha is less than 12m, categorized them in the lowest category of dams. Accordingly, only simplified studies shall be conducted with general layout drawings of the dam and outlet works. Moreover, this dam has relatively low risk due to the fact that it is located in a rural area without inhabitants in the River valley. Failure of the dam results in no probable loss of human life and low economic and/or environmental losses.

According to the guidelines for dam safety from the World Bank, the monitoring procedures and instrumentation have been designed to confirm that the structure is performing in accordance with the design.

In this case, sudden changes in seepage, abnormal settlement patterns and slope movements will be the symptoms of deterioration in the embankment and/or foundation. Instrumentation has been then chosen so as to be able to determine whether these foresaid changes are occurring.

1. The settlement studs positioned along the downstream edge of the embankment crest at 50m intervals will permit the settlements patterns follow-up.

2. The V-drain running along the downstream toe of the dam will allow to follow-up the seepage trough the dam body and its foundation.

3. Inspection routine of the completed dam and associated structure (spillway and bottom outlet) on a weekly basis must be implemented during the operation live. During this inspection, damage or abnormal situations will be recorded.

5.6. Bigasha Dam cost estimation

The costs presented hereafter are the average of several prices applied in works done in different African countries. It was privileged to consider projects which present similar geographical conditions.

As the quantities are small for this type of work, the cost of provision for machinery may represent a significant portion of the total cost and is not included in this analysis.

A summary of costs is present in the following table.

Table 25: Cost of Bigasha dam

	Cost US $
Preliminary works	3 755 439
Dam	30 686 903
Spillway	2 356 417
Bottom Outlet	146 405
Hydro Steel Structure Equipment	82 800
Total	**37 027 964**

The costs are high due to the required concrete grout wall across the valley.

The bill of quantities for the dam is described as follows:

Table 26: Bill of quantities for Bigasha dam

Désignation des prix	Unit	Quantity	Unit Price	Total Cost
General Items				**3,755,439**
Site Installation	LS	5.0%		1,663,626
Demolition of site installation	LS	2.5%		831,813
Access road (10 km) maintenance	km month	240	5,250.0	1,260,000
Dam				**30,686,903**
Clearing and grubbing	m^2	35,475	0.2	7,095
Excavation in loose material	m^3	74,493	7.0	521,448
Excavation in rippable material	m^3	25,710	45.0	1,156,950
Backfill homegeneous material (sandy clay)	m^3	254,625	10.0	2,546,250
Backfill Transition/Filter	m^3	74,875	100.0	7,487,500
Rip Rap	m^3	79,375	162.0	12,858,750
Drilling and grouting	ml	10,000	180.0	1,800,000
Class 20/38 mass concrete	m^3	271	485.0	131,605
Formwork	m^2	2,111	16.0	33,768
Reinforcement	T	2.7	3,000.0	8,141
Monitoring	0.50%			132,758
Miscellaneous	15%			4,002,639
Spillway				**2,356,417**
Excavation in loose material	m^3	1,575	7	11,025
Excavation in rock	m^3	525	85	44,625
Class 20/38 mass concrete	m^3	3,797	485	1,841,559
Formwork	m^2	1,284	16	20,544
Extra cost for the formworks with single curvature of radius < 5m	m^2	42	25	1,050
Finishing	m^2	112	12	1,344
Reinforcement	T	38	3,000	113,911
Anchor bolt	ml	1	15,000	15,000
Miscellaneous	15%			307,359
Bottom outlet				**146,405**
Trench in rock material	m^3	50	85.0	4,250
Class 20/38 mass concrete	m^3	130	485.0	63,044
Class 30/38 concrete for reinforced concrete	m^3	75	585.0	44,131
Formwork	m^2	608	16.0	9,721
Reinforcement	T	2.1	3,000.0	6,163
Miscellaneous	15%			19,096
HSS Equipment				**82,800**
Steel Pipe diameter 500 mm	ml	40	300.0	12,000
Fixed roller gate 1m x 1m	U	1	60,000.0	60,000
Miscellaneous	15%			10,800
			TOTAL	**37,027,964**

6. DESCRIPTION OF DETAILED DESIGN SCHEMES FOR BIGASHA

6.1. Introduction

The development schemes follow the decision taken by the country for the use of the dam. It is recommended that Water User Association(s) should be formed to manage the project water resources, and to serve as a tool for conflict management and other related matters.

6.2. Irrigation scheme

6.2.1. Design standards

- **Irrigation duty**

As shown in the chapter about water demand (chapter 4.5.2.2), the first estimation of the irrigation duty gave a value of 1,4 l/s for maize / fodder / vegetables based cropping pattern. This estimation has been calculating using the following assumptions:

- Cropping pattern as defined in the chapter about the water demand (Chapter 4.5.2.3)
- Irrigation time: 12 hours a day
- Overall efficiency (canals + on plot): 60%

Despite the new data, this value of 1,4 l/s will be kept for the feasibility design.

- **Canals**

Main canals

General arrangement / longitudinal slope
Main canal is designed for an irrigation duty of 1,4 l/s/ha, taking into account all losses and irrigation needs of selected crops. Due to the very flat area, the canal should be built with a minimum longitudinal slope of 1/1000. This might be challenging for construction (only 50 cm difference in elevation for 500 m length), but compulsory to actually control most of the area.

Construction materials
Main canals should be built with selected materials, with some minimum requirements in terms of plasticity index and water tightness.

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 should get the following features:

- Side slopes 1/1
- Crest width : 1 m upstream, 1 m downstream for upstream sections, 0,5 m for both banks for downstream sections

In fill
While building in fill (ie. across a trough), main canal should get the following features:

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

Secondary 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 follows the natural transverse slope of the marshland (1/1000 to 3/1000), except if water speed is too high. In that case, drop structures should be built. Secondary canals are designed to supply tertiary canals with a minimum 20 cm elevation difference in the worst case.

Construction materials
The secondary canals should be built using materials locally extracted, especially from drains, to minimize transport and increase production. Thus, maintenance requirements and infiltration rate might 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 are similar.

- Side slopes 1/1
- Crest width : 0,5 m both banks

Tertiary canals

General arrangement / longitudinal slope
Tertiary canal are mainly built parallel to the general direction of the river. The longitudinal slope follows the natural long slope of the marshland (1/1000 to 2/1000), except if water speed is too high. In that case, drop structures should 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
Tertiary canals should be built using materials locally extracted, especially from drains, to minimize transport and increase production. Thus, maintenance requirements and infiltration rate might 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 are similar.

- Side slopes 1/1
- Crest width : 0,5 m both banks

- **Crossing structures**

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

Siphons
Siphons are used to cross major lateral troughs, where the construction cost for a canal is expensive due to its height above natural ground. 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.

Elevated flumes
These structures are used to cross troughs or drain, as a cost effective alternative to culverts. They are made in circular (if precast) or rectangular sections, made of reinforced concrete and supported by piles. Typical long and cross sections are given in typical drawing in the appendix.

- **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 is describing 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

6.2.2. Layout of the scheme

- **Main features of the perimeter**

The designed perimeter is covering a geographical area of 600 ha, out of which the bulk area is about 480 ha. It is expected a reduction of 6 % 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. The net irrigated area is estimated at 451 ha with 178 ha nets on the left bank and 273 ha on the right bank.

The perimeter is spreading on a 6 km distance between the dam and the downstream block. It is divided in 3 sectors, two on right bank separated by a trough and comprising 13 secondary canals, and one on right bank.

- **Main canals**

Main canal has a length of 5,1 km and a total discharge (at the intake) of 0,43 m^3/s, allowing the irrigation of 280 ha net, split in 13 blocks. One siphon and 3 culverts or elevated flumes should be necessary to cross main lateral troughs.

- **Secondary canals**

As the perimeter is quite narrow, the length of secondary canals is short. Secondary canals are perpendicular to the general direction of the valley. There number is estimated to be 13, ranging from a length of 283 m up to 2 120 m.

- **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. Typical arrangement of a block is given in the appendix

- **Drainage system**

A secondary and tertiary drainage system is collecting water, coming from the plots as well as the tributaries. It will directly discharge into troughs or in the river bed through chute structures.

6.2.3. Cost estimate

Cost estimates have been estimated taking into account the remoteness of the area. It was expected that costs were superior to what it could be found in other areas due to the difficult access, the difficulty to hire qualified manpower, difficulties to supply materials on site, distance of transport for equipment. The proposed BOQ has been estimated as follows.

Table 27: Costs of irrigation scheme

Items	Unit	Total Quantity	Unit Price US $	Total Cost
Preliminary and general items (15% of total cost)				
Miscellaneous	15%	1	524 238	524 238
Sub total				**524 238**
Canals & drains (main - primary - secondary)				
Clearing and grubbing area of works	m^2	170 000	0,18	30 600
Common excavation in canal and form compacted embankments (OPM 95%)	m^3	39 000	15,0	585 000
Formwork rough face	m^2	4 000	14,0	56 000
Class C25/C30 concrete for reinforced concrete - supply and placement	m^3	360	405	145 800
Reinforcement	T	29	2 700	78 300
Stone masonry for small structures	m^3	0	135	0
Concrete culverts DN 300	ml	0	124	0
Concrete culverts DN 800	ml	0	170	0
Miscellaneous	10%	1	89 570	89 570
Sub total				**985 270**
Tertiary development				
Form tertiary canals and drains	m^3	28 000	9	252 000
Land levelling +/- 10 cm without topspoil removing	ha	451	4 500	2 029 500
Land levelling +/- 10 cm with topspoil removing	ha	0	13 500	0
Miscellaneous	10%	1	228 150	228 150
Sub total				**2 509 650**
			Total	**4 019 158**

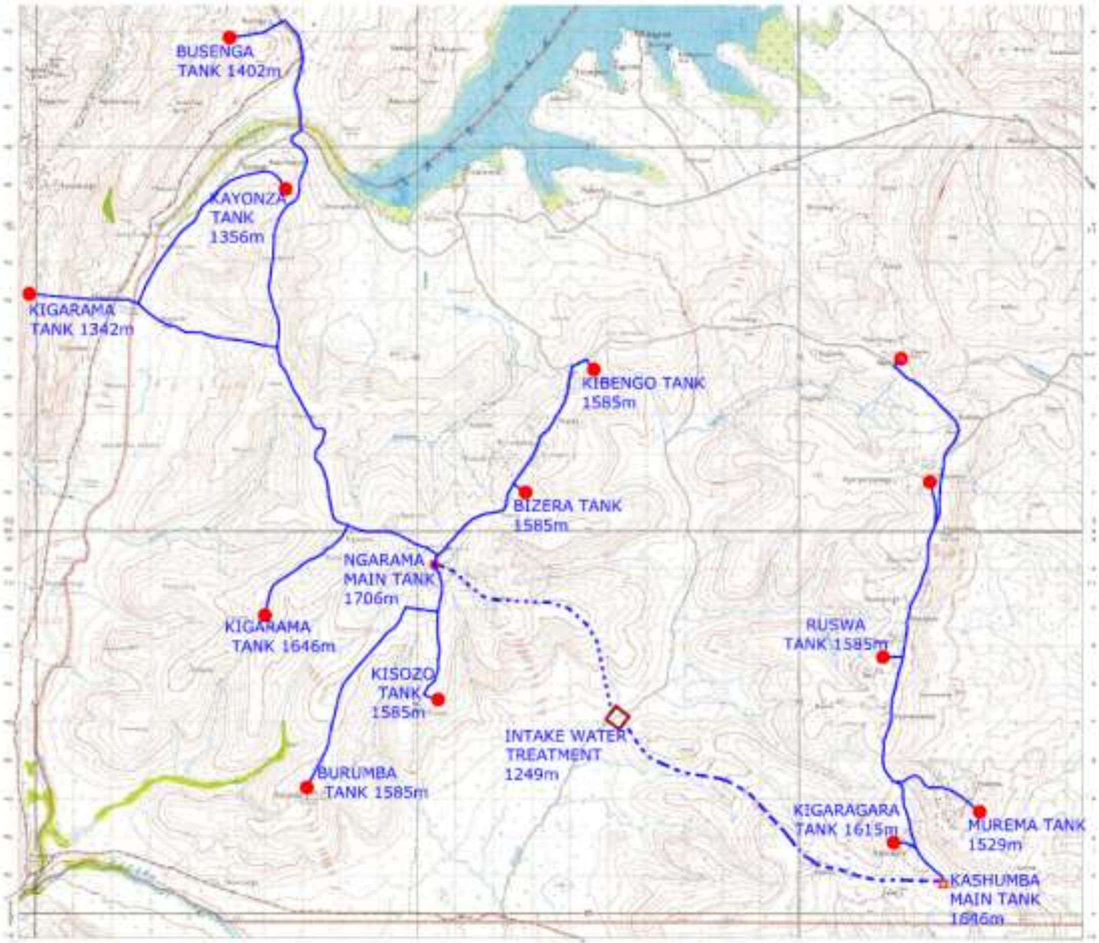
The average cost per hectare is estimated at 9 000 $, which is a relatively low value. This is mainly due to the design of the perimeter which allows short main canals and therefore reduces the ratio length of canals / irrigated area.

6.3. Water supply scheme

6.3.1. 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. Details designs should be carried out at later stage during the detailed design.

Figure 52: Water supply scheme



6.3.2. Design of the water supply

The proposed scheme covers the following wards in Isingiro district: Nyakitunda, Kabingo, Kashumba and Ngarama.

The project comprises the following items all implemented in one Phase:

- Intake at the Dam of capacity 0.289 m3/s Phase I
- Water treatment plant of total capacity 25,000 m3/d in Phase I

- Low lift pumps – 0.289 m3/s, 4 pumps (each Q – 0.095 m3/s, H – 15m and Power 22 Kw – 3 duty and 1 standby). Phase I – 4 nrs,
- High lift pumps following two stations (the static heads are too high, each station will a have a set of booster pumps along the transmission mains)
  - Kashumba Pump Stations (for Kigaragara, Murema, Ruswa, Kashumba and Nyamiyaga areas) – (0.055 m3/s capacity) at water level 1249 masl and a booster station at 1448 masl – each to have 3 pumps (each Q – 0.028 m3/s, H – 212m and Power 90 Kw – 2 duty and 1 standby).
  - Ngarama Isingiro Pump Stations (for Ngarama, Burumba, Bizera, Kigarama, Kayonza and Busenga areas) – (0.23 m3/s capacity) at water level 1249 masl and two booster stations at 1400 masl and at 1552 masl, each to have 4 pumps (each Q – 0.077 m3/s, H – 155m and Power 180 Kw – 3 duty and 1 standby).
- Transmission mains – three sets as follows :
  - Kashumba Transmission Main - 300 mm and length 10.5 km to Kashumba Main Tank 1646 masl - 55 l/s
  - Ngarama Transmission Main - 600 mm of length 8.0 km to Ngarama Main Tank 1706 masl – 230 l/s
- Main Storage tank – 5 tanks r.c concrete tanks (Kashumba 1,000 m3, Ngrama 4,000 m3, Isingiro (Kigarama) 1,000 m3, Busenga 1,000 m3 and Kayonza 850 m3)
- Distribution - Gravity mains from main tanks to village tanks

Pipe diameter (mm)	Length (m)
100	0
150	22,600
175	0
200	33,000
225	0
250	5,800
300	5,500
350	5,500
400	2,500
450	0
500	200
Total	75,100

- Villages storage tanks will be elevated masonry tanks comprising as follows
  - 350 m3: 5
  - 500 m3: 5
- Secondary & tertiary mains:

Pipe diameter (mm)	Length (km)
50 PE	171
75	114
90	114
150	57
Total	456

- Meters and communal kiosks
  - Zonal meter – 16 nrs

    - Domestic meters – 1250 nrs
    - Communal kiosks – 1140 nrs
- Electrical Transmission
    - transmission cable – 15.2 km
    - sub-station with transformers – 1 sets

As the project is small, it could be implemented in one phase. It should be noticed that this project would need to provide energy.

6.3.3. Cost estimate for the water supply scheme

The investment costs for water supply have been evaluated as US$ 43 663 000 as shown in the following table and detailed in the Appendix M.

Table 28: Water supply costs

	Components of water supply	**KASHUMBA**	**NGARAMA KABINGO ISINGIRO**	**TOTAL (US$)**
A	Water Treatment	1,116,000	4,464,000	5,580,000
B	Pumping Stations	820,800	590,400	1,411,200
C	Transmission Mains	2,614,500	3,792,000	6,406,500
D	Storage Tanks	1,740,000	3,399,250	5,139,250
E	Gravity Transfer Mains	1,913,400	6,062,300	7,975,700
F	Secondary & Tertiary Distribution Mains	2,508,000	10,488,000	12,996,000
G	Meters and Communal Kiosks	662,500	2,741,000	3,403,500
H	Power to WTW and PS	367,650	383,483	751,133
	TOTAL	**11,742,850**	**31,920,433**	**43,663,283**

6.4. Livestock water points

6.4.1. Design for the livestock water points

The main irrigation canals could have outlets in the opposite side (away from irrigation) for livestock water points in the form of cattle troughs, located where space in the valley is available. About 20 such locations have been identified as shown on the maps in the Appendix G.

The design has been produced for the 151 000 livestock units. Each water point will have a capacity of 7 000 litres. Access road is included for each trough as well as compacted gravel land around the trough to protect against erosion by cattle movement. Each trough has one side with short heights for smaller animals such as goats and the other side for cattle. The trough has a concrete apron to maintain good hygienic and sanitary condition. A PVC pipe supplies water from the main canal into the trough.

The manure collected at the water troughs is stockpiled for feeding the fish, as both the fish ponds are in close vicinity.

6.4.2. Cost estimate for the livestock water points

20 livestock watering points could be installed in the first phase and 8 more in a second phase. Each trough costs about US$ 120 000 as described in the Appendix M. The total costs is about US$ 3 355 000 as described in the following table.

Table 29: Costs for livestock watering project

SUMMARY	Description	Quantity	Unit	US $ Rates	Total Amount US $
Phase 1	Watering Points	20	Sets	119,828	2,396,560
Phase 2	Watering Points	8	Sets	119,828	958,624
TOTAL					**3,355,184**

6.5. Fish farming

6.5.1. Design for fish farming

The communities do not have experience with fish ponds and therefore pilot projects will be necessary with a pilot in phase 1, followed by Phase 2 that will cover the whole valley.

The numbers of the required ponds are calculated based on population density which is about 147 people by km^2 and could increase to 300 people by km^2 in year 2037. The following table gives two options of ponds, subsistence or commercial fish farming.

Table 30: Estimated number of fish ponds

	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	147	147	300	300
population	1,847	7,390	3,770	15,082
fish consumption kg @ 1kg/person/year	1,847	7,390	3,770	15,082
Pond Area Ha	0.92	2.46	1.89	5.03
Number of ponds	23	6	47	13
Proposed project	20	0	30	5

For the time being, the subsistence fish farms could be installed using community based organizations. In the future to year 2037, commercial fish farming may be promoted with the increase of demand.

The gross area required for the ponds may be 2 to 3 times the net pond area. The main irrigation canals would have outlets in the opposite side (away from irrigation) for filling up the fish ponds. The fish ponds are located in areas without use for irrigation. About 20 locations have been identified as shown on the maps in the Appendix G.

The ponds are made with earthwork of cut which are used to form the dykes. The ponds do not exceed one meter deep. Each subsistence pond is 15m x 30m in plan size while the commercial pond is about 45m x 90m depending on space available. Lime is added at the bottom to neutralize the acidic soils.

The species of fish could be sardine type (dagaa), fillet stripped, tilapia, catfish, Nile perch, and trout. The average fish yields for tilapia could reach 5 – 8 tons/Ha/year while for catfish 15 – 20 tons per Ha and per year. The fish yield is assumed to be 4 tons/Ha/year for small ponds and 8 tons/Ha/year for commercial ponds.

6.5.2. Cost estimate for fish farming

The costs estimate for the fish ponds development has been phased in two phases:

- Year 1 & 2 for 20 small ponds (0.8 Ha) as pilot project
- Year 10 & 11 for 30 small (1.2 Ha) + 5 large commercial ponds (2 Ha)

The estimated cost is about US $ 45 000 for each small pond (0,04 Ha). It is about US$ 133 000 for commercial pond (0,4 Ha) as described in the Appendix M. The total costs is about US$ 2 900 000 as described in the following table.

Table 31: Costs for fish ponds project

Fish Farm	**Rate US $**	**Phase I**		**Phase 2**		**Total**	
SUMMARY		**Qty**	**Amount US $**	**Qty**	**Amount US $**	**Qty**	**Amount US $**
Small Ponds (Number)	44,811	20	896,220	30	1,344,330	50	2,240,550
Commercial Ponds (Number)	132,604	0	0	5	663,020	5	663,020
TOTAL			**896,220**		**2,007,350**		**2,903,570**

7. INITIAL ENVIRONMENTAL AND SOCIAL EXAMINATION FOR BIGASHA DAM

7.1. National legislative and institutional framework

7.1.1. Environment

a) Institutional framework

The institutional framework about environmental issues involves the Minister of Water and Environment. The Directorate of Environmental Affairs is in charge of "environmental policy, regulation, coordination, inspection, supervision and monitoring of the environment and natural resources as well as the restoration of degraded ecosystems and mitigating and adapting to climate change."

The National Environment Management Authority (NEMA) was established by the National Environmental Act, 1995, Cap 153 (Article 4). This Authority is responsible for "the regulatory functions and activities that focus on compliance and enforcement of the existing legal and institutional frameworks on environmental management in Uganda".

b) Legislative context in Uganda

Uganda designed several policies dealing with environmental issues. The following Acts and policies are highly relevant for the current project:

- The National Environment Management Policy, 1994 aims at promoting sustainable economic and social development. It highlights the EIA process as a tool to achieve such goal.
- The Local Governments Act, Cap. 243: According to the "Local Governments Act, Cap. 243", the local governments are responsible for the protection of the environment at the district level. Therefore, the Isingiro district government shall be consulted during the project's development.

c) Regulations regarding environmental impact studies in Uganda

The Fourth Part of the National Environment Act, cap 153, 1995, regulates for which project an EIA is mandatory.

The Environmental Impact Assessment Regulations, Statutory Instrument 153-1, 1998 provide more detailed procedures and guidelines to carry out EIA.

d) International environmental treaties signed or ratified by Uganda

The following Conventions were ratified by Uganda: Protocol Agreement on Conservation of Common Natural Resources (1982), Convention on Biological Diversity, Convention on International Trade in Endangered species, RAMSAR Convention on wetlands of international importance, Convention on the Conservation of Migratory Species of Wild Animas (1979), The United Nations Framework Convention on Climate Change (1992), Convention on the Protection and Use of Trans-boundary Watercourses and International Lakes (1992).

7.1.2. Water management

a) Institutional framework in Uganda

The institutional framework about water management issues involves the Minister of Water and Environment, which is composed of three directorates: the Directorate of Water Development, the Directorate of Water Resources Management and the Directorate of Environmental Affairs.

To be noticed that the Ministry of Tourism, Trade and Industry covers water use and management of industries, commerce, wildlife and tourism.

The Water Policy Committee is the body in charge of advising the Government on all water policy issues in Uganda.

b) Legislative context in Uganda

The main laws, policies and regulations concerning water resources management in Uganda are the following:

- The Water Act, cap 152, 1997 establishes the various authorities in charge of water resources and restricts water uses. The Part II ("Water resources") provides legislation concerning the grant of water permits. The Water Resources Regulations, statutory instrument 152-1, 1998 provides procedures for implementing the provisions of the Water Act. It namely details how to apply for a water permit.
- The Rivers Act, cap 357 lists the rivers where it is necessary to apply for a dredging license.
- The National Water Policy, 1999 states that the development of water for energy production shall be subjected to an EIA in accordance with procedures established by NEMA and approved by the Authority in consultation with the lead agencies.

7.1.3. Land tenure management

a) Institutional context in Uganda

The Ministry of lands, housing and urban development is in charge of the land management. Under this Ministry, the Directorate of Land Management is the main relevant stakeholder for the Project.

b) Legislative context in Uganda

The Constitution of the Republic of Uganda, 1995, is the supreme law of this country. The Chapter 15 details in particular the land tenure legislation. As for compensation mechanism, the Constitution of Uganda requires that if a person's property is compulsorily acquired, that person must receive prompt payment "of fair and adequate compensation prior to taking possession" of the property.

The Land Act, Cap 227 1998, amended in 2010, provides for the ownership and management of land and for the compulsory acquisition of land for public purpose which is taken to include use of land to provide water and sanitation facilities. It provides the rule for land disputes.

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

7.2.1. Physical environment

The country is located on the East African plateau. It averages about 1 100 metres above sea level, and this slopes very steadily downwards to the Sudanese Plain to the north.

a) Geology

Uganda lies within the African plate, which is a continental crust that contains Archaean cratons. The general geological map shows Precambrian basement complex, especially sandstones, silstones, shales, quartzites, conglomerate, phyllites and meta-sediments.

At the dam site, the rocks are not outcropping, except on the left bank, where there is veining with cemented sandstones. On the two banks, the soil is made with lateritic clay and sandy gravels. In the valley, the clay is lightly swampy, with possible pit.

Soils within the valley are commonly ferrasols with a characteristic red-brown colour. The presence of ferrasols restricts the possibility of agricultural development.

b) Climate

Although generally equatorial, the climate is not uniform in the country as the altitude modifies the climate. Southern Uganda is wetter with rain generally spread throughout the year.

The *Five years District management plan 2011/12-2015/16* [c] describes the climate as equatorial climate receiving an average rainfall of 1 200mm and with temperatures between 17 and 30°C. However, according to the previous study [a], the site lies in a relatively dry zone with only 715 mm of average rainfall annually.

c) Hydrology

Bigasha dam site is located on Bigasha River, which is a seasonal river. The site is located in the lower part of the Kagera River basin also called the West Victoria Lake region.

d) Ground water

According to Dr. Mkhandi S.H. [a], most of the monitoring wells in the Kagera sub-catchment in Uganda utilize existing boreholes rather than purpose drilled boreholes. There are two monitoring wells within the Kagera River Basin including one at Isingiro closed to the Project area. Its groundwater monitoring station is equipped with a water level logger.

The assessment of the status of water quality in Uganda in Dr. Mkhandi S.H. report [a] indicated that the common ground water quality problems in the sub-catchment were high levels of iron, high mineral content, high acidity or alkalinity, salty or objectionable taste and aggressive character.

e) Water quality

According to Dr. Mkhandi S.H. report [a], due to the small size of the catchment of Kagera Basin on the Ugandan side (2% of the total land area of Uganda) and due to the high operation and maintenance costs associated with monitoring networks, the government of Uganda has not established water quality monitoring stations in the sub-basin. His assessment of the status of water quality indicated that the common surface water quality problems in the sub-catchment were strong objectionable colour, high turbidity, high suspended solids concentration, high levels of faecal bacteria, high content of humic substances, frequent algal blooms, high concentrations of plant nutrients (N, P and Si), moderate Biological Oxygen Demand and highly organic sediments, mainly due to land degradation, poor domestic sanitation, poor solid waste disposal, the presence of ferralsol soils which is acidic.

It is recommended to carry out a water quality survey on the Bigasha River in Uganda during the ESIA as water quality determination is an important element towards an understanding of River ecosystem health.

7.2.2. Biological environment

a) Fauna and flora

The Isingiro District vegetation is characterized by thorny bushes and trees, grassland savannah, scattered swamps and valleys, and bare hill with stone deposits.

The Lake Nakivali is located in the northern part of the Project area. However, there is not links between this lake and the catchment of the Bigasha River (see map in Appendix B4).

b) Protected area

The Minziro Forest Reserve (25,000 ha, established in 1974), is a semi– swamp area that shares border with Tanzania in the Kagera River Basin and a home to rare species, including the mangabay monkeys. It is located more than 70 km downstream from the Project area and on an affluent of the Kagera River.

In the Ugandan side of the Kager River Basin, the important biodiversity hot spot include the Mgahinga Gorilla National Park and Sango Bay Forest Reserve:

- The Mgahinga National Park is important for the endemic species of mountainous gorilla (Gorilla gorilla berengei). It is located about 150 km from the Project area.

- The Sango Bay seasonal swamp forest ecosystem contains biodiversity of global significance with endemic species of fish, dragon flies and numerous butterflies. The closest protected area is the Malabigambo Forest as a part of the Sango Bay area (see the map in Appendix A2), which is a Ramsar wetlands. The Sango Bay area is the main protected area downstream the Kagera River and downstream from the four dam sites. It is located about 80 km from Bigasha dam site. The Sango Bay - Musambwa Islands - Kagera Wetland System is unique as it is located in the transition between the East and West African vegetation zones making this area a unique complex of natural wetland and swamp forest. Sango Bay contains the biggest tract of swamp forest in Uganda.

7.2.3. Socio-economic context

a) Characteristics of the population

The 2002 census does not include Isingiro district as it is a newly created district within Mbarara district. According to the *Five years District management plan 2011/12-2015/16* [c], the Isingiro District has approximately 81 680 households population with an average household size of 4,8 persons. The District population was projected at 408 400 people in 2011. The growth rate is estimated at 3,2% per year.

However, the Project area is mainly inhabited with only some isolated farms.

The spoken languages are Lunyakole, Lukiga, Luganda and Kinrwanda.

b) Social environment

<u>Health</u>
There are 62 health centres in the District.

The prevalence rate of malaria is 25%, the one of HIV/aids is 3% in the Isingiro District [c].

<u>Education</u>
Ngarama sub-county had 26 permanent classrooms for primary school out of 477 in the District, 18 for secondary school out of 160 in the District in 2011. The literacy rate is 64% [c]

<u>Land tenure</u>
Land is customary ownership, mailo, leashold or freehold.

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

c) Economic activities

According to the *Five years District management plan 2011/12-2015/16* [c], the main economic activities in the Isingiro District are the crops and livestock (cattle) products. However, incomes from agricultural related activities are characterized by fluctuations due to the weather.

The Ngarama sub-county is mainly dominated by crops farmers with banana, bean and maize productions. The project area includes only banana plantations and cattle keepers.

The road infrastructure is not developed without tarmac road in the District.

7.3. Preliminary identification and assessment of potential impacts

At this stage of the study, the preliminary potential impact examination has identified the following impacts for a 12m high dam:

- About physical environment:
  - The net losses due to evaporation is about 10,7% of the annual inflow. Thus, loss of water resources through evaporation will be an issue for the Project.
- About biological environment:
  - The protected area, the Sango Bay area, found downstream the Kagera River might be impacted by the change of the hydrology with the 4 dam projects upstream. With the total quantity of water contribution for this project compared to the Kagera River catchment, it is unlikely due to the small quantity of water retains by the Project compared to the Kagera River catchment. However, it should be studied during the ESIA.
  - Malabigambo Forest is unlikely to be impacted by the Project as it lies at around 80 kilometres.
  - The reservoir will flood a large vegetation area, estimated to be 145Ha at FWL.
- About socio-economic environment:
  - No village should be resettled due to this Project as the majority of the people lives at the top of the hills.
    However, the map MA07 in Appendix D shows that:
    - 1 building will be flooded at MWL = 1267,25m;
    - Around 10 ha of plantations, maybe banana plantations, will be flooded;
    - Around 100 ha of land for cattle grazing will be flooded. Land tenure of this grazing area should be studied in detail during the ESIA.
  - No major infrastructure and cultural heritage site should be impacted by the Project;
  - Water diseases should be studied with the presence of the reservoir.

7.4. Elements of an environmental and social management plan

As the project do not lead as a major resettlement as defined by the World Bank (OP4.12), this project will not lead to carry out a full resettlement management plan as defined by the Operational Policy of the World Bank.

However, the environmental and social management plan should mainly take into account the following measures:

- Deforestation program for using the wood before impounding;
- Reforestation and erosion-prevention programme;
- The materials to build the dam within the identified areas (see map 12 in the Appendix C) should avoid the agricultural land as well buildings;

- Measures to compensate the loss of the grazing area, such as findings new area, or developing fodder cropping as suggested in the irrigation scheme;
- Compensation for the loss of plantations ;
- Health and safety measures such as protection again malaria.

8. ECONOMIC AND FINANCIAL ANALYSIS

8.1. Introduction

Following the findings in the chapters 5 and 6 as well as the appendix M, the economic analysis has been carried out for each component of the project, as different institutional departments are involved.

This economic analysis presents hereafter only the main water uses components of the project, meaning irrigation and water supply developments.

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 (O&M) Costs. The benefits includes time saving for fetching water and health benefit (for water supply project), land appreciation, increased income and VAT benefit.

8.2. 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 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 may be 2 to 3 times more but would be distorting the sale prices.

Each category of capital costs and operating and maintenance (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 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 not 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 – in rural areas the market wage rate is lower than the lowest government scale U8 wage UShs 118,615/- per month or UShs 5,390/- per day. The statutory minimum wage is dated 1984 and very low. The agriculture flower sector for example paid UShs 1,800 to 2,000/- day or monthly UShs 56,000/- in 2008. The present bargain casual rate is UShs 3,800/- or US $1.65/day. The market rate in rural areas is assumed to be lower. The shadow wage factor = 0.7 is adopted
- Skilled Labour - 1.00
- Transfer Costs (taxes) - 0.00

For the project, therefore the composite conversion factors used will be:

- Capital Costs: 0.9
- O & M Costs: 0.84

8.3. Dam costs

8.3.1. Investments costs

The costs of dam and appurtenant structure have been estimated according to unit price method, derived from similar projects.

The dam cost is estimated to US$ 37 030 000 as seen in the chapter 5.6.

O&M costs are estimated to 2,89% of initial investment, meaning US$ 1 070 000.

The ESIA has provided the costs for the environmental and social management plan (ESMP) as US$ 300 000 and for the resettlement action plan (RAP) as US$ 1 537 900, meaning a total of US$ 1 837 900 to add to the total cost of the project.

8.3.2. Conversion Factors – Financial to Economic Costs

The economic costs as found in the following table are obtained from financial capital costs and O & M costs of the project by multiplying with the conversion factors discussed above.

Financial Costs			**Economic costs**		
Capital Cost US $	Annual O &M Costs US $	ESMP & RAP costs US$	Capital Costs US $ CF 0.9	Annual O & M Costs US $ CF 0.84	ESMP & RAP costs US$ CF 0.84
37 030 000	1 070 000	1 837 900	33 327 000	898 800	1 543 836

8.4. Costs & benefits for irrigation development

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

8.4.1. 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

With the dam, the irrigation concerns 451 Ha, and the associated costs are evaluated to US $ 4 019 000 as follows. We suggest developing each bank in different phases: at first, the right side with 273Ha following by the left side with 178 ha.

Stage 1 **Net 273 Ha**	**Stage 2** **Net 178 Ha**	**Total** **Net 451 Ha**
US$ 2 433 000	US$ 1 586 000	US$ 4 019 000

8.4.2. Operational & 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 have been estimated to 2,9% of initial investment as detailed in the Appendix M, meaning US$ 117 000.

8.4.3. Conversion Factors – Financial to Economic Costs

The economic costs as found in the following table are obtained from financial capital costs and O & M costs of the project by multiplying with the conversion factors discussed above.

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 0.84
Phase 1	2 433 000	71 000	2 189 700	59 640
Phase 2	1 586 000	46 000	1 427 400	38 640
Total	4 019 000	117 000	3 617 100	98 280

8.4.4. Benefits

8.4.4.1. CROPS

The valley is not used for cultivation. Cultivation is limited to the hill sides. The proposed cropping patterns include maize, beans, Irish potatoes, vegetables, fruits (pineapples and citrus), and possibly forage with the following benefits.

Crop	Output Value Producer Price US $/ton	Irrigated Crops		
		Input costs		Net Benefit US$/ton
		% of price	US$/ton	
Potatoes	210	50%	105	105
Maize	300	30%	90	210
Beans	434	30%	130	304
Vegetables	375	30%	113	262
Fruits	870	30%	260	610

The following yield was taken into account with irrigation.

Yield (tons/year)					
Maize	Beans	Potatoes	Vegetables	Fruits	Forage
2,50	1,60	15,00	4,00	20,00	12,50

The net benefit is the difference between the "with" and "without" project benefits. It is estimated that farmers' annual revenue could increase from US $ 2 640 000 in phase 1 to US $ 4 061 000 in the phase 2 in mainly due to higher yield per acreage.

8.4.4.2. LAND APPRECIATION

The irrigation project will result in increased yield and therefore appreciate in value. The present average valley land market price is assumed to be US$ 1 000/Ha. With irrigation development, it is assumed an increase of land value from 4 000 to 5 000 US$/Ha, meaning:

- In Phase 1: 273 Ha x $3 500 = US $ 955 500
- In Phase 2: 178 Ha x $3 500 = US $ 623 000

A total of US $ 1 578 500 as one-time benefit is estimated.

8.4.4.3. 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. It is estimated a total benefit of US$ 1 363 000/year assuming that 20% of the unemployed people in the area will acquire job from the economic growth, and assuming a current wage about UShs 1 900/day (US $ 0,83/day) in the agriculture sector and rural areas.

8.4.4.4. 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	2 433 000	71 000	486 600	14 200
Phase 2	1 586 000	46 000	317 200	9 200
Total	4 019 000	117 000	803 800	23 400

8.4.4.5. 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 to HHs 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	2 433 000	71 000	43 794	1 278
Phase 2	1 586 000	46 000	28 548	828
Total	4 019 000	117 000	72 342	2 106

8.4.4.6. SUMMARY OF ALL BENEFITS

The total economic benefits are summarized in table below:

Benefit Type	US $ / year	US $ once
Irrigation Increased Yield		
Phase 1	2,640,000	
Phase 2	4,061,000	
Land Appreciation		
Phase 1		955,500
Phase 2		623,000
Increased Income – Economic Growth		
Phase 1	825,000	
Phase 2	1,363,000	
Project Construction Activities		
Phase 1	14,200	486,600
Phase 2	9,200	317,200
VAT remain in district		
Phase I	1,278	43,794
Phase 2	828	28,548
TOTAL Benefits		
Phase 1	3,480,478	1,485,894
Phase 2	5,434,028	968,748
Conversion Factor	0.874	0.874
Economic Benefits		
Phase 1	3,042,000	1,299,000
Phase 2	4,748,000	847,000

8.5. Costs & benefits for water supply

8.5.1. Investments Costs

The investment costs for water supply have been evaluated as US $ 43 663 000

8.5.2. O & M Costs

These costs have been estimated according to the review of financial performances of similar project in the region (Tanzanie, 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	
US $ 17,535,000	19%	US $ 3,331,650

8.5.3. Conversion Factors – Financial to Economic Costs

The conversion factors described in the Appendix M have been determined as follows:

- Capital Costs:0,963
- O & M Costs:0,874

PHASE	Financial Costs		Economic costs	
	Capital Cost US $	Annual O &M Costs US $	Capital Costs US $ CF 0.963	Annual O & M Costs US $ CF 0.874
Phase 1	43,663,283	7,776,116	42,047,742	6,796,325
Phase 2	-	7,776,116	0	6,796,325
Total	43,663,283	7,776,116	**42,047,742**	**6,796,325**

8.5.4. Benefits

The benefits accrued from a water supply projects are simply that people obtain an improved, healthy and secure living environment without being displaced. Water supply projects have been proved to be effective entry point for poverty alleviation.

Experience has shown in similar water supply and sanitation projects are associated with social and economic benefits that are particularly high, are significant in fall in infant mortality rates, fall in crime rates in other countries, and regularization of land tenure results significant private investments.

Benefits include:

- community empowerment resulting from participatory approach and forming community based organizations – enabling the community to identify, organize and manage future projects, thus enhancing future development and reducing risks and generally resulting in economic growth
- improved water supply connection to those who do not have presently
- reduced fetching distance and therefore time saving. After the implementation of the water supply project, the domestic water points will be closer within 200m walking distance, and the fetching time is estimated to be about 10 min
- improved power supply to those who do have at present
- improved environmental condition and standard of living
- improved health conditions, reduction in diseases and savings in health bills
- increased investments and economic development activities, improved livelihood
- increased land and property values
- employment during construction period

About 23 600 households are expected to benefit from the project (in the future 2037 58 200 households).

The present statistics show rural household incomes are assumed to be about $110 per month (UShs 252,000/HH/month).

8.5.4.1. 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 and are considered where they are significant.

It is assumed more than 70% 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 assumed as about 2,5 km for every 20 litres bucket, estimated as 97,5mn. If the government recommended wage US$ 1,65/day, the gained productive time value is estimated to 480 US$ by household yearly.

8.5.4.2. HEALTH BENEFITS

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

<u>Health Bills</u>

It is assumed that 10% of monthly income (making it US $ 11/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 water supply is estimated to reduce by 30% the medical expenses, than the annual saving per household could be estimated to US $ 39,6.

<u>Productive time</u>

It is assumed that 30% of the households reported to have a person sick every two weeks. The yearly lost productive time could then be estimated to 36 person day by household of lost productive time.

If the water supply project improves health by 30%, the lost time would be reduced by 30% which could be estimated to save yearly US$ 17,8 by household.

8.5.4.3. 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 30% coverage. The new proposed water supply project will therefore have non-incremental supply of 30% and incremental supply of 70%. The existing water supply is presently subsidized either free or with very low payments. In economic analysis, economic price of water has to be taken into account even if it is subsidized. In this analysis, 100% of the project supply is considered as incremental and at a price Willingness to Pay which with sensitization is at the Affordability or Ability to Pay being 4% of disposable income.

Estimating that 4% of the household monthly income of US$110 could be used for water supply and that a household uses 25 litre per day, each household is estimated to pay US$ 1,17/m3, meaning an annual benefit of US$ 52,8 by household.

8.5.4.4. APPRECIATION OF LAND VALUES

Water supply projects could increase land values benefiting land owners and thus house values. It has been estimated that about 25% of the properties which are located near water points and along the pipe lines could increase in value incrementally by 25% after the water supply project is implemented.

It is assumed that the present land values is $\$0,2/m^2$ and that each household plot or premise is assumed to be 1 800 m2.

The net increase in land value per household is then estimated to reach US$ 22,5.

8.5.4.5. INCREASED INCOME DUE TO ECONOMIC GROWTH

The enhanced economic growth due to water supply project might create more jobs or opportunities in business.

It is estimated that about 30% of the population being working age are unemployed meaning 1,5 persons per household, and that about 10% of the unemployed could get a job from the economic growth due to the project. The annual benefits due to the economic growth could then be estimated to US$ 90,3 by household.

8.5.4.6. INCREASED INCOME DUE TO PROJECT CONSTRUCTION ACTIVITIES

The construction 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. The benefits would be estimated as follows.

PHASE	Financial Costs		Financial Benefits to HHs X = 20% x Cost/(23,600 HH)	
	Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
Phase 1	43,663,283	7,776,116	$370/HH	$65.9/HH/year
Phase 2	-	7,776,116		$65.9/HH/year
Total	43,663,283	7,776,116	$370/HH	$65.9/HH/year

8.5.4.7. VAT BENEFIT

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

PHASE	Financial Costs		Financial Benefits to HHs X = 10% x 18% x Cost/(23,600 HH)	
	Capital Cost US $	Annual O &M Costs US $	Capital Cost US $ one time	Annual O &M Costs US $
Phase 1	43,663,283	7,776,116	$33.3/HH	$5.9/HH/year
Phase 2	-	7,776,116		$5.9/HH/year
Total	43,663,283	7,776,116	$33.3/HH	$5.9/HH/year

8.5.4.8. SUMMARY OF ALL BENEFITS

The total economic benefits are estimated to US$ 15,5 million annually and US$ 8,8 million upon completion of the project as detailed in the following table.

Benefit Type	US $ / HH/year	US $ /HH once	Total Benefits for 23,600 HHs
Fetching Distance Saving	480		US $ 11,328,000 / year
Health Improved	57.4		US $ 1,354,640 / year
Sales of Water Annual increase 3.3%	52.8		US $ 1,246,080 / year phased annual increase by 3.68% to $ 3,072,960 / year in year 2037 annual increase $ 73,075
Land Appreciation		22.5	US $ 531,000 once
Increased Income – Economic Growth	90.3		US $ 2,131,080 / year phased
Project Construction Activities	65.9	370	US $ 1,555,240 / year and US $ 8,732,000 once
VAT remain in district	5.9	33.3	US $ 139,240 / year and US $ 785,880 once
TOTAL Benefits	**752.3**	**425.8**	US $ 17,754,280 / year and US $ 10,048,880 once and annual increase $73,075
Conversion Factor	0.874	0.874	
Economic Benefits	**657.5**	**372.1**	US $ 15,517,241 / year and US $ 8,782,721 once and annual increase $63,868

8.6. Economic analysis

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,
- the Economic Net Present Value (ENPV) that has to be positive for a viable project, and,
- the Economic Benefit to Cost Ratio (EBCR) that has to be greater than unity 1.

The economic analysis has been carried out for different scenarios, as follows:
Scenario A: Irrigation + water supply + fish ponds + livestock watering
Scenario B: Irrigation + water supply
Scenario C: Irrigation only
Scenario D: Water supply only

8.6.1. Economic analysis for implementation of irrigation + water supply + fish ponds + livestock watering

The economic analysis for the multipurpose dam with the objectives of irrigation, water supply, fish ponds and livestock watering give the following results:

- EIRR: 20,10 %
- ENPV: US $ 34 622 000
- EBCR: 1,287

In addition, four sensitivity analyses were 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%

Scenario	EIRR	ENPV (US $)	EBCR
Scenario A	20,1%	34 622 000	1,287
I: + 15% Increase in Costs	15,4%	16 548 000	1,119
II: – 15% Decrease in Benefits	14,7%	11 355 000	1,094
III: 15% Increase in Costs and 15% Decrease in Benefits	10,6%	-6 719 000	0,952

8.6.2. Economic analysis for implementation of irrigation + water supply

The economic analysis for the multipurpose dam with the objectives of irrigation and water supply only give the following results:

- EIRR: 18,8 %
- ENPV: US $ 27 484 000
- EBCR: 1,237

In addition, four sensitivity analyses were 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%

Scenario	EIRR	ENPV (US $)	EBCR
Scenario B	18,8%	27 484 000	1,237
I: + 15% Increase in Costs	14,2%	10 115 500	1,076
II: – 15% Decrease in Benefits	13,5%	5 993 000	1,052
III : 15% Increase in Costs and 15% Decrease in Benefits	9,4%	-11 376 000	0,915

8.6.3. Economic analysis for implementation of irrigation only

The economic analysis for the dam with the objectives of irrigation only gives the following results:

- EIRR: 9,9 %
- ENPV: - US $ 4 115 000
- EBCR: 0,893

In addition, four sensitivity analyses were 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%

Scenario	EIRR	ENPV (US $)	EBCR
Scenario C	9,9%	-4 115 000	0,893
I: + 15% Increase in Costs	7,5%	-9 858 000	0,776
II: – 15% Decrease in Benefits	7,2%	-9 241 000	0,759
III : 15% Increase in Costs and 15% Decrease in Benefits	5%	-14 984 000	0,660

If irrigation is only developed, the Bigasha irrigation project could not be economically viable as all the indicators appear negative.

8.6.4. Economic analysis for implementation of water supply only

The economic analysis for the dam with the objectives of water supply only gives the following results:

- EIRR: 12,9 %
- ENPV: US $ 3 033 000
- EBCR: 1,027

In addition, four sensitivity analyses were 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%

Scenario	EIRR	ENPV (US $)	EBCR
Scenario D	12,9%	3 033 000	1,027
I: + 15% Increase in Costs	8,5%	-13 878 000	0,893
II: – 15% Decrease in Benefits	7,8%	-14 833 000	0,873
III : 15% Increase in Costs and 15% Decrease in Benefits	3,8%	-31 244 000	0,759

If water supply is only developed, the Bigasha water supply project could not be economically viable as all the major indicators appear negative.

8.7. Summary of economic analysis

The cost of the dam construction is estimated to 37M US$. The economic viability of the project is consequently questionable when compared to similar dam costs. The high cost of the dam is mainly due to the 15m cut-off wall.

Irrigation and water supply components are not economically viable if developed alone, but need to be associated with other water use components.

The economic balance of the water use components requires that indirect revenues and collective increased incomes related to project nature and activities (such as appreciation of land, economic growth, employment) are taken into account.

The summary of costs for all the projects is 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**
Dam	37 030 000		37 030 000
Irrigation	2 433 000	1 586 000	4 019 000
Potable Water Supply	17 535 000		17 535 000
Livestock Water Supply	2 397 000	959 000	3 356 000
Aquaculture	896 000	2 007 000	2 903 000
Sub-total	**60 291 000**	**4 552 000**	**64 843 000**

9. TERMS OF REFERENCE FOR DETAILED DESIGN OF THE DAM AND TENDER DOCUMENTS

9.1. Description of the Detailed Design phase for dam

The Detailed Design (DD) is the key phase for all projects as it shall put down the base of the construction contract defining technically and financially the works in such details to allow the Contractor fairly and correctly quoting these and then carrying out the job reducing the risk of claims at minimal level.

The discontinuous nature of the Bigasha River and the permeability of the bedrock along the dam axis should be in particular investigated at this stage, as the feasibility of such project is questionable.

The main technical sections of DD are:

- Drawings: in sufficient number for depicting clearly the workings and the overall ways of construction leaving to the Contractor his specific field of choice (equipment, etc.). The Drawings shall be supported by the related supporting calculations. The Detail Design Drawings shall cover the entire range of the project as follows:
- General layout,
- Hydrological and meteorological data,
- Geological available mapping and sections,
- Planview and main sections of each appurtenant working,
- Guidelines for reinforcement,
- Watertightness principles and specific details,
- Grouting and drainage features,
- Civil works stages for hydromechanical equipment,
- Hydromechanical equipment and energy supply,
- Hydroelectric plant (if any),
- Monitoring apparatuses and gear.

In case of an EPC type of contract, the scope being only to outline the Basic features of the project, the number of Drawings may be reduced and more details left to the Contractor's ingenuity.

- Specifications : describing in detail the qualities to be assured and the methods to be respected through the various stages of preparation (procurement of materials, treatment, transport, placing, etc.) for achieving the required result ;
- Programme: a reasonable schedule of the works based on similar projects in comparable conditions.
- Bill of Quantities: a detailed list of the quantities of the Works to be executed corresponding to the items to be priced.

The contractual sections depend upon the intentions of the Client on the type of contract structure:

- Owner's Managed Contract with full production of Construction Drawings and Supervision under Owner's guide (assuming the larger part of risk);
- Engineering, Procurement and Construction Contract leaving the Contractor free in a broader project frame (and assuming the larger share of risks).

The choice between the two options (or any other intermediate) should be decided by the Client in order to adjust the production of the documents to his decision.

9.2. Terms of reference and tender documents

The below text (written in *italic*) is the proposed terms of reference for Bigasha dam:

Consulting Services to Undertake Detailed Design Studies for a Small Multipurpose Dam at Bigasha site in the Kagera River Basin

1. Background

1.1 Introduction

The Nile Basin Initiative (NBI) is a partnership of the riparian states[1]that seeks to develop the Nile River in a cooperative manner, share substantial socio-economic benefits, and promote regional peace and security through its shared vision of "sustainable socio-economic development through the equitable utilization of, and benefit from, the common Nile Basin water resources". NBI's Strategic Action Program is made up of the Shared Vision Program (SVP) and Subsidiary Action Programs (SAPs). The SAPs are mandated to initiate concrete investments and action on the ground in the Eastern Nile (ENSAP) and Nile Equatorial Lakes (NELSAP) sub-basins.

The Kagera River Basin Management Project is one of the three river basin projects implemented under the NELSAP. The objective of the Kagera RBM project 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 in the equatorial zone of Africa between the latitudes of 0°45' and 3°55' South and longitudes of 29°15' and 30°50' East. It has a total area of about 60,000 km2 which is distributed among Burundi (22%), Rwanda (33%), Tanzania (35%) and Uganda (10%). The Kagera River is the principal tributary of Lake Victoria Basin, and as such is commonly considered as the source of the White Nile. Most of the basin lies between elevation 1,200 and 1,600 m.a.m.s.l. and consists largely of woody and grassland savanna. The mountainous areas in the west and northwest, which mark the Nile-Congo Divide, rise to altitudes of more than 2,500 m.a.m.s.l. The Kagera River rises in the western highlands of Burundi and Rwanda. Its main tributaries are the Ruvuvu River, which drains an area of about 12,300 km2 in central and northern Burundi, and the Nyabarongo River, which drains about 16,000 km2 in west central and eastern Rwanda. The Nyabarongo discharges into Lake Rugwero in southeastern Rwanda on the border with Burundi. Below Lake Rugwero the river is known as the Kagera, and it marks the southern border of Rwanda with Burundi and Tanzania to the confluence of the Ruvuvu. At the border of Uganda and Tanzania, Kagera River is joined on the left bank by the Kagitumba River, *which drains 5,200 km2 of northeastern Rwanda and Southern Uganda. The main tributaries in the lower reach are the Mwisa and Ngono Rivers, which drain 2,000 km2 and 3,200 km2 respectively of the Kagera Region in Tanzania on the right bank of the Kagera River.*

During the feasibility study, one studied dam site was Bigasha dam, a project that aims to improve irrigation, livestock and water supply in the region.

1.2 Rationale for the Consultancy

The Kagera basin has a total area of 59,800 km^2 with rainfall less than 1,000 mm over most of the eastern half of the basin, which increases to over 1,800 mm in the western half, where most of the runoff is generated. Although the western half is partially forested, much of the basin has become intensively cultivated resulting in erosion and sediment loading of rivers in the high rainfall areas. The basin is characterized by low productive peasant agriculture, insufficient water for household use and grazing, and endemic poverty. There is continuing land degradation, deforestation and loss of soil fertility and soil erosion caused by population pressure and primitive farming methods. Wetlands are exploited and degraded, and there are unplanned migrations across borders of pastoralists with their cattle, causing friction in the border zones. The dense settlement, along with intensive and improper land management practices in the Kagera River catchments have resulted in heavy pollution loads in tributary rivers. The water quantity and quality available for various uses in the Kagera Basin is gradually dwindling and the water resources situation is already stressful in some parts of the basin.

There is a strong correlation between economic performance and water availability as a result of limited water storage infrastructure. Using the Falkenmark Water Stress Indicator, two of the four Kagera Basin riparian countries, i.e. Rwanda and Burundi, have a per capita water availability of 800 and 500m^3/capita/year respectively; which is far below the recommended threshold value of 1,700m^3/capita/year. The World Water Vision 2000, prepared by the International Water Management Institute (IWMI), classified all the four Kagera Basin Riparian countries as suffering from economic water scarcity. These countries face financial and capacity constraints in meeting their water needs. This situation is expected to get worse as the population increases, as impacts of climate change begin to manifest themselves gradually and as demands of different water use sectors out-match the existing supply. Water related conflicts are on the increase and will pose serious security risks in the catchments if the underlying issues are not adequately addressed. To address these challenges, there is a need to implement structural and non-structural approaches to improve water security through creation of water storage in the basin and promoting water demand management to minimize wastage of the scarce water resources among other solutions.

Agriculture is the economic mainstay of the Kagera river basin employing about 90% of the rural population and contributes about 40% of the GDP of the riparian countries. Despite its high importance in the region, agriculture records very low productivity levels owing to very inefficient traditional agricultural practices and high population pressure on the land. The current trend in developing irrigation is low, although opportunity for increased productivity through irrigation development and intensification is apparent with plains irrigation potential in the lower basin and marshlands irrigation potential in the upper basin catchments (Kagera Monograph, 2008).

There is potential to increase the otherwise very low livestock and aquaculture productivity and investment within the basin. The proposed dam have a potential to avail water for livestock watering, reservoir fisheries development or to avail water to off-reservoir fish ponds, which would improve the livelihood of the beneficiary communities and in some cases lead to adoption of new but economically rewarding activities in the project areas.

The basin has an average potable water coverage of 48% (Kagera Monograph, 2008), which implies that more than half of the population uses unsafe water.

2 Terms of Reference

As downstream work of the feasibility studies, the NELSAP and the Kagera RBM Project are procuring a consultancy to undertake the basic design for multipurpose dam sites. At this stage, a clear definition shall be defined for the different works previewed, including its lay-out design, construction methods and materials implicated in the construction.

It shall be provided every calculation notes using the most advanced methods and plans sufficiently detailed to allow:

- *Establishing an accurate bill of quantity and a good cost estimation;*
- *Writing tender files of civil works and supply of mechanical and electrical equipment.*

Once the Client has chosen the final dam design, the chosen Consultant will carry out the following tasks:

- *Detailed study of civil works;*
- *Determination of the characteristics of equipment;*
- *Study of the access road;*
- *Establishment of the work costs;*
- *Writing technical work specifications;*
- *Development of a construction management plan;*
- *Propose a general management structure;*
- *Preparation of tender dossiers.*

2.1 Geomorphological, geological and geotechnical investigations

Due to the discontinuous nature of the Bigasha River and the permeability of the bedrock along the dam axis, the following complementary activities/investigations should be performed during the detailed design for the Bigasha dam site:

- *Determination of main rock lithologies at dam site (to evaluate the risk of pseudokarstic conditions within the bedrock) → preliminary geomorphological/geological mapping of the proposed dam area (at least 3 km upstream of the dam axis and 2 km downstream) and rock sampling around the dam axis area for petrographic determinations and/or thin sections to define mineralogy;*
- *Determination about the depth of the weathered bedrock along dam axis (to complete and calibrate geoelectrical panels) → execution of 2 core recovery boreholes at 30m depth, along the dam axis with piezometer installation and undisturbed sampling;*
- *Determination of permeability within the bedrock → water tests every 5m (falling head tests in the unconsolidated deposits and Lugeon tests in the bedrock) inside the 2 boreholes;*
- *Estimation of hydrodynamic parameters within the weathered part of the bedrock → tracing tests from the river to the boreholes and/or the existing pits.*

2.2 Detailed study of civil works

The Consultant shall provide all the necessary details on the technical and economical design of the dam and structures attached. These studies will be characterized by descriptive, calculation and checking notes and drawings as well.

These documents shall include:

- *Structural design of embankments, sealing, drainage and foundation grouting;*
- *Calculations of embankments slope stability;*
- *Filters and drains verification notices,*
- *Verification of hydraulic structures design (spillway, adduction system), as well the design of their sealing, drainage and special foundation works if any;*
- *Design of auscultation and monitoring works devices.*

2.3 Determination of the characteristics of the equipment

The basic design of electromechanical equipment shall determine types, specifications, operating principles and assembly and testing planning for all equipment with a sufficient degree of accuracy in a way to allow the preparation of appropriate technical specifications (working condition, main characteristics, construction data, tools and spare parts, etc.) and tender documents.

These facilities will include:

- *A fixe wheel gate;*
- *Hoisting equipment;*
- *Butterfly valve;*
- *Others service equipment, if any;*
- *The necessary spare parts.*

2.4 Study of the access road

The Consultant shall prepare:

- *Layout and longitudinal profile optimization;*
- *Cross section type definition and justification;*
- *Definition and justification of crossing structures (culverts, box culverts, bridges, etc.);*
- *Definition and justification of sewage disposal and drainage;*
- *Study of materials for the road embankment;*
- *Research of quarry for aggregates (for concrete and road layers);*
- *Research of borrow areas of materials for earthworks and concrete;*
- *Laboratory and in situ tests;*
- *Provision of protection layers;*
- *Study of protection and improvement of the environment, especially in woodlands.*

The Consultant will then prepares the technical study of works of the access road, evaluate the estimated cost of work and prepare the tender documents.

2.5 Establishment of the work costs

The Consultant will assess the estimated costs of the project as defined, distinguishing foreign expenditures and expenses in local currency. The assessment of costs will be based on bills of quantities before taking into account uncertainties, specifications relating to certain works conditions and the distance from the site.

2.6 Writing technical work specifications

The Consultant will provide:

- *The security coefficients assumed for the stability studies;*
- *The hypotheses to take into consideration, justifying his choice for the seismic design of structures;*
- *And the standards to which he intends to refer in the design of structures and equipment.*

2.7 Development of a construction management plan

All river diversion phases and work chronogram with key dates will be included in the general report of the project.

The Consultant will propose a general work organization scheme that shall include:

- *General schedule showing the logical construction sequence (including river diversion schemes), highlighting construction and procurement delays, as well as equipment order and installation deadlines;*
- *Procedures for impoundment;*
- *Operating instructions and maintenance works notices, etc.*

2.8 General management structure

The Consultant shall propose a plan with the human resources and equipment to be implemented to ensure the correct operation of the works. It will establish specifications for standard services responsible for the operation of civil engineering, electro-mechanical equipment, social management, etc.

The Consultant shall identify concerned actors and propose a structure for the creation of a Water User Association. This organization should be integrated as a major actor to group manager of the project water resources and also serve as a tool for conflict management and other related matters.

2.9 Reservoir operation plan

The Consultant will prepare an embankment management guidebook, based on hydrological information in its possession, allowing the operator to determine the mode of filling and emptying of the reservoir.

These are the Terms of Reference for the basic design of the Bigasha small dam, where small dams are defined according to the World Bank Environmental and Social Safeguard Policy OP 4.37, i.e. with a height below 15m (but excluding dams between 10m and 15m that are complex).

Documents to be provided:
The Consultant shall prepare 10 copies of the provisional documents, concerning technical specifications for civil works and equipment supply and installation, to be submitted to the Client for approval.

Then proceed to the final edition of 20 copies and a digital reproducible medium (DVD-ROM).

3 Tender Documents

Once the basic design is approved by the Client, the tender documents for the civil works and for the supply and installation of electromechanical equipment should be prepared. The text of the Conditions of Contract universally recognized (and generally adopted by the international Development Banks) is the FIDIC (Federation Internationale Des Ingenieurs Conseils)'s appropriate "book".

The Tender documents shall include a provisional schedule, based on the Consultant experience, framing the aimed duration of the construction Works. Such program shall include key dates (usually related to meteorological constraints or delivery planning of equipment), and be based on reasonable productions of main items (excavations, filling, concrete, etc.).

Tender Documents shall include:
a) Instructions to Bidders

b) Convention
c) Special Papers of Technical Requirements for Civil Works:
- *Description of the structures and work*
- *Provenance, quality, preparation of materials,*
- *Mode works,*
- *Mode of assessment work,*
- *Special clauses.*

d) Special Technical Requirements Specification for equipment
- *Definition and consistency of work*
- *Specification of supplies,*
- *Conditions of contract, controls, fixtures.*

e) Frame price list
f) Estimated retail Framework
g) General Conditions of Contract
- *Bidding work,*
- *Execution of works*
- *Payment of expenses,*
- *Tax,*
- *Payments*
- *Various clauses,*
- *Submission template.*

REFERENCES

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

[b] EMA Consult: the Uganda state of environment, 2006-07

[b] Isingiro District Local Government: Five years District management plan 2011/12-2015/16, prepared by District council, April 2011.

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
C	**UGANDA**
23	2002 Uganda Population and Housing Census by Uganda Bureau of Statisitcs – October 2006
24	Five Year District Development Plan 2011/12 to 2015 / 16 for Isingiro District Local Government – March 2011
25	Isingiro District Nutrition Action Plan – 2011 to 2016 – December 2011
26	Production Sector Development Plan – 2010/2011 to 2012/2013 February 2010 for Isingiro District Local Government
27	The National Development Plan 2010 / 11 to 2014 / 15 for the Government of Uganda - 2010
28	Agriculture Sector Development Strategy and Investment Plan – 2010/11 to 2014/15 – March 2010
29	A Socio-economic and Gender Baseline Survey for the Uganda domestic Biogas Project by Heifer – SNV – HIVOS – 2010
30	A Socio-economic Baseline Survey of Communities Adjacent to Lake Bisina / Opeta and Lake Mburo / Nakivali Wetland System – 2010
31	Uganda Overview – Efficient Water Use for Agricultural Production (EWUAP) Project 2008
32	Poverty Mapping in Uganda Using Socio-economic, Environmental and Satellite Data by PPLPI Features – 2006
33	Revision of the Water for Production Strategy and Investment Plan – Final Report by PEMConsult – 2009
34	Gender and Youth Dimensions in Cross border Trade and Investment in the Nile Basin Countries – Uganda – SDBS – 2008 – NBI
35	National Water Development Report – Uganda prepared for 2nd UN World Water - 2006
36	Environmental and Social Impact Assessment for Proposed Renovation and Equipping of Health Facilities in Uganda – Vol 4 for Western Region by AWE Environmental Engineers - 2010
37	A Review of Agriculture and Health Policies in Uganda with Implications for Dissemination of biofortified Crops – 2007 by Harvest Plus
38	Poverty Eradication Plan PEAP – 2000
39	Plan for the Modernization of Agriculture PMA 2003
40	Efficient Water Use for Agricultural Production (EWUAP) Project, Agricultural Water in the Nile Basin – Uganda Country Overview Annex I – April 2008

41	Socio-economic development and Benefit Sharing Project – The Impact of Regional Power trade on Poor Communities in the Nile Basin Countries – Uganda - 2008
42	The National Fisheries Policy – Ministry of Agriculture, Animal Industry and Fisheries – May 2004
43	A National Water Policy – Uganda 1999
44	The Water Statute 1995
45	Uganda Overview – Efficient Water Use for Agricultural Production (EWUAP) Project 2008
46	Revision of the Water for Production Strategy and Investment Plan – Final Report by PEMConsult – 2009
47	National Water Development Report – Uganda prepared for 2nd UN World Water - 2006
48	The Energy Policy for Uganda of 2002

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 Monograph – 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
C	**UGANDA**
8A	Finding Potential Sites for Small Scale Hydropower in Uganda by Geobiosphere Science Centre 2005
9A	A Socio-economic and Gender Baseline Survey for the Uganda domestic Biogas Project by Heifer – SNV – HIVOS – 2010 pg 28 – 37 – current household energy situation,
10A	The Energy Policy for Uganda of 2002 – pg 23-26, pg 31-34, pg 43-47,

- *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 Monograph – 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
C	**UGANDA**
12B	A National Irrigation Master Plan for Uganda (2010 – 2035) – Draft Report July 2010 Section 2.1, 3.4.2, 4.1, 4.4, 5.2.3 and Annex 1
13B	Annex I – Uganda Country Overview - Efficient Water Use for Agricultural Production (EWUAP) Project, Agriculture Water in the Nile Basin April 2008 – pg 1 to 3 and 9 to 11
14B	Detailed Feasibility Study and Design of One Pilot Scheme for Bulk Water Supply – Mbarara Draft Feasibility Study Report by AAW consultants and BEC Engineers Sept 2007 Chap 5 – Water Demand – Irrigation 5.2
15B	Support to NEPAD – CAADP Implementation for Uganda – Aug 2005 Vol II – Smallholder Irrigation Development and Water Harvesting Vol 1V – Agricultural Marketing Project
16B	Agriculture Sector Development Strategy and Investment Plan – 2010/11 to 2014/15 – March 2010 pg 23 – 26, pg 53- 76 Annex 2 Crops Selection Criteria
17B	National Water Development Report – Uganda prepared for 2nd UN World Water - 2006 Chap 4 Rural WS, Chap 5 Urban WS, Chap 6 Environment, Chap 7 Water & Food (Irrigation, Livestock, Fisheries), Chap 8 - Energy

> *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),
C	**UGANDA**
10C	Support to NEPAD – CAADP Implementation for Uganda – Aug 2005 Vol III – Livestock Development Project
11C	Detailed Feasibility Study and Design of One Pilot Scheme for Bulk Water Supply – Mbarara Draft Feasibility Study Report by AAW consultants and BEC Engineers Sept 2007 Chap 5 – Water Demand – Livestock 5.3
12C	A Socio-economic and Gender Baseline Survey for the Uganda domestic Biogas Project by Heifer – SNV – HIVOS – 2010 pg 28 – 37 – current household energy situation,
13C	National Water Development Report – Uganda prepared for 2nd UN World Water - 2006 Chap 4 Rural WS, Chap 5 Urban WS, Chap 6 Environment, Chap 7 Water & Food (Irrigation, Livestock, Fisheries), Chap 8 - Energy

> *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
C	**UGANDA**
9D	Support to NEPAD – CAADP Implementation for Uganda – Vol VI – Aug 2005 Vol VI - Aquaculture development
10D	National Water Development Report – Uganda prepared for 2nd UN World Water - 2006 Chap 4 Rural WS, Chap 5 Urban WS, Chap 6 Environment, Chap 7 Water & Food (Irrigation, Livestock, Fisheries), Chap 8 - Energy
11D	The National Fisheries Policy – Ministry of Agriculture, Animal Industry and Fisheries – May 2004 Page 36 – Policy Area No. 9 - Aquaculture

> *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
C	**UGANDA**
7E	Detailed Feasibility Study and Design of One Pilot Scheme for Bulk Water Supply – Mbarara Draft Feasibility Study Report by AAW consultants and BEC Engineers Sept 2007 Chap 5 – Water Demand – Potable Water 5.4
8E	National Water Development Report – Uganda prepared for 2nd UN World Water - 2006 Chap 4 Rural WS, Chap 5 Urban WS, Chap 6 Environment, Chap 7 Water & Food (Irrigation, Livestock, Fisheries), Chap 8 - Energy

9E	A National Water Policy – Uganda Ministry of Water, Lands and Environment 1999 Section 5 – Domestic Water Supply, Sec 6 – Water for Agriculture Production, Sec 7 Water – other use,
10E	The Water Statute 1995

> *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
C	**UGANDA**
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13F	Production Sector Development Plan – 2010/2011 to 2012/2013 February 2010 for Isingiro District Local Government pg 6 – 11,
14F	The National Development Plan 2010 / 11 to 2014 / 15 for the Government of Uganda - 2010 Section 5.1 Agriculture, Sec 6.3 – Energy, Sec 6.4 – Water for Production, Sec 7.7 Water & Sanitation,
15F	Revision of the Water for Production – Strategy and Investment Plan – Aug 2009 Uganda pg 31-40,