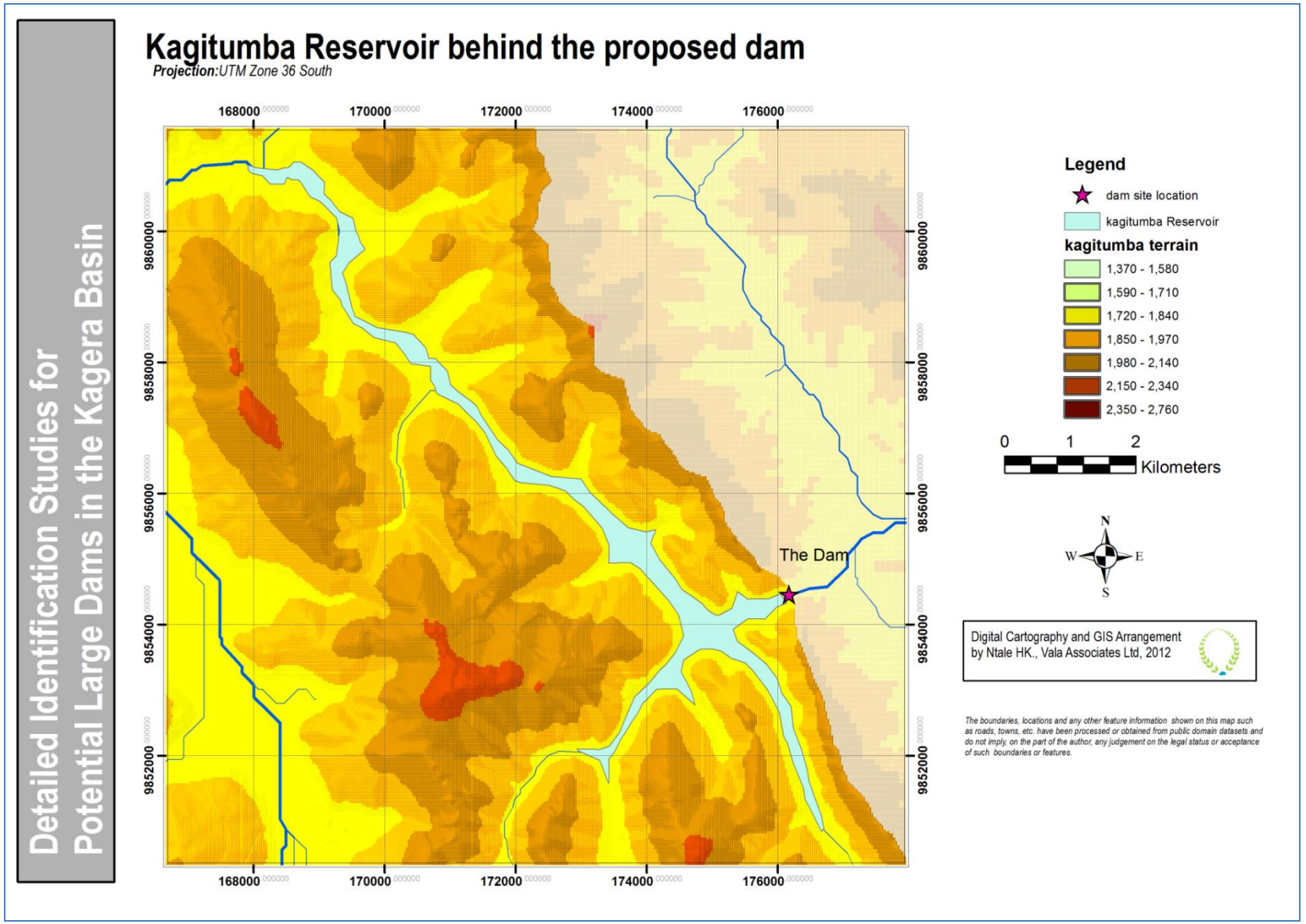


Figure 4.2-13 Kagitumba Maziba Reservoir at 1788m above sea level

4.2.5.6 Sedimentation

Using the approach suggested by Lawrence et al (2004), sedimentation yields for the Kagitumba catchment contributing to the dam site was established to be 492 t/km^2/yr. The dead storage properties of the dam are shown in below:

Table 4.2-4 Kagitumba Sediment Properties

Site Name	Kagitumba
Reservoir Volume (Mm^3)	26.3
Catchment area (km^2)	712
S_Y (t/km^2/yr)	492
Assumed Sediment density (t/m^3)	1.1
Dead Volume (Mm^3)/yr	0.14
Dead storage after 50 years (Mm^3)	6.93
Percentage of Reservoir filled with sediment after 50 years	26%

4.2.5.7 Floods

The annual maximum series model was used for flood frequency analysis. The following approach was used

i). Selection of the maximum 24-hour flows from the measured flow at Nyakizumba gauging station

ii). Selection of the distribution that best fits the data. Lognormal distribution was shown to provide an acceptable fit to the annual maximum data (Figure 4.2-14)

iii). Estimation of the flood magnitudes corresponding to various return periods (Table 4.2-5)

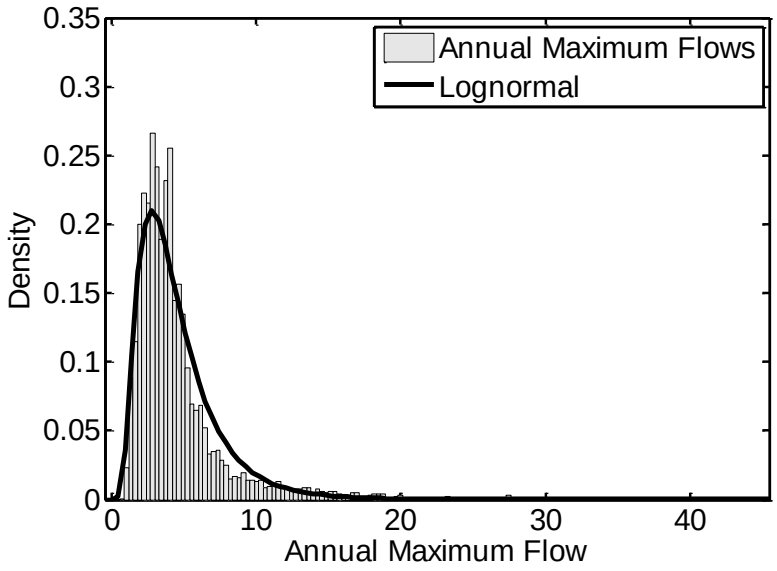


Figure 4.2-14: Lognormal fit to annual maximum data, R. Nyakizumba

Table 4.2-5: Kagitumba flood estimates and associated return periods

Return period, T (years)	Flood magnitude (m^3/s)	Risk of failure for a 50 year design life (%)
50	56.4	63.6
100	64.8	39.5
200	73.6	22.2
500	85.8	9.5
1000	95.5	4.9
2000	105.7	2.5
5000	120.0	1.0
10000	131.4	0.5

4.2.6 Dam Design elements

4.2.6.1 General

Owing to the nature of the river cross-section at the proposed dam site as a U-shaped medium width valley, a concrete dam is proposed. The dam will have a base elevation of 1770 m asl while the crest elevation will be 1790 m asl. The dam crest will be 177 m long. An Ogee type spillway is included within the design to be located on the right side of the dam. The spillway crest elevation will be 1787 m asl while the spillway crest length will be 28 m. Three possible locations of the power stations are considered

- Site 1: this will be located at the dam site for which the maximum available head is 17 m
- Site 2: this will be located 600 m downstream of the dam site. The maximum available head at this site is 57 m
- Site 3: This will be located 9 km downstream of the dam site. The head at this site is 257 m and the site represents considerable advantages in terms of additional power produced. However, the site also represents many challenges concerning the construction of the power head race canal especially since it has to cross at least 3 valleys.

The relative merits and demerits of the 3 power station options should be explored during the feasibility study stage. This study presents only the third option whereby the power station will be located 9 km downstream from the dam site.

4.2.6.2 Dam Type

The dam at Kagitumba has been designed as a concrete gravity dam with a roadway on top and an Ogee spillway section. This preliminary design proposes a downstream slope of 0.8 and an upstream slope of 0.1. The dam foundation will be located firm basement rock assumed to be 5 m below the ground level in the current design.

Table 4.2-6: Kagitumba dam design

Variable			Units	Value
Dam location				**Kagitumba-Maziba**
Dam type				Concrete Gravity
Reservoir base elevation			m asl	1770
Reservoir top elevation			m asl	1788.0
Reservoir depth at above dam base (Hnet)			m	18.0
Free board (Flood control pool + 3% of dam height)	Flood control pool (flood height above spillway crest): 1.5m 3% of dam height (for wave action, etc): 1.5m	2.5	m	2.5
Dam height H			m	20.5
Crest elevation			m asl	1790.5
Spillway crest elevation			m asl	1788.0
Crest length			m	177
Top width (7-12 m depending on dam height)			m	7

4.2.6.3 Diversion works

During the construction of the dam, the river will be diverted by an upstream coffer dam through two tunnels on the left of the bank. The tunnels will be 120 m long and unlined. The tunnels will be circular with a cross-sectional area of 6 m^2 that is needed for safely discharging a 100-year flood of 65 m^3/s without overtopping the cofferdam that shall be raised to an elevation of 1775 m asl. A cofferdam will also be provided upstream from the tunnel outlet to prevent the diverted water from rising into the works area. The cofferdams will be ransom fill embankments with impervious facings. The crest elevation of the upstream cofferdam will be 1775 m asl while that of the downstream cofferdam will be 1774 m asl. After construction, the two cofferdams will be breached. The inboard tunnel will be fitted with a valve and retained as a bottom reservoir outlet while the outboard tunnel will be plugged at the upstream end and used to access the valve chamber for the bottom outlet.

4.2.6.4 Spillway

The spillway will be of the unregulated Ogee type. It will be located on the left side of the dam. The inlet to the spillway will be shared with the power station inlet. Table 4.2-7 shows the main design parameters of the spillway. The spillway will discharge via a flared ski-jump into an existing an existing pond below the dam.

Table 4.2-7: Spillway design parameters, Kagitumba project

Variable	Units	Value

Return period	years	10,000
Spillway crest elevation	m asl	1,787
Design flood	cumecs	132
Discharge coefficient, Cd (assumed)		1.7
Spillway crest length, L	m	28.0
Head on spillway, H	m	2.0
Spillway discharge, Q=Cd*L*H^(3/2)	cumecs	134.6

4.2.6.5 Power station

The power station will be located within the Kahondo gorge, 9 km downstream of the dam site. A canal will be provided for transferring the water from the dam to the hill that overlooks the gorge after which penstock will be used to build pressures required for power production. The canal will share an inlet with the spillway. Further studies will be carried out to identify the route that the head race canal should take which results in minimum head loss. The power station will be a surface concrete structure equipped with 2 turbines each with a rated power of 5.5 MW.

Table 4.2-8: Hydropower estimation, Kagitumba project

Variable	Value	Units
Rated reservoir level	1780	m asl
Canal mean slope	0.5%	
Canal length	8.6	km
Elevation at penstock intake	1737	m asl
Elevation at power station	1530	m asl
Head	207	m
Mean flow	4.5	m^3/s
Rated flow (30% higher than mean)	5.9	
Plant efficiency	90%	
Power	10.7	MW
Energy	102	GWh/year

The proposed hydropower station at the Kagitumba-Maziba site has the potential to produce 102 GWh of energy per year which is enough to supply about 113,000 houses and over 680,000 people.

4.2.6.6 Ancillary works

There is an existing all weather road passing close to the proposed dam site connecting Kabale to parts of Kavu, Rugarama, and Kahondo . The road may require some limited remedial works to be able to provide access for the heavy trucks, construction materials and supplies during dam construction. Parts of this road will be submerged when the reservoir is filled. A new road at a higher elevation will have to be constructed.

For the power station, the nearest road is 300 m away (and over 60 m higher is elevation) and will also require some remedial works for a distance of at least 3 km. To provide

access to the power station site, a gently sloping road will be required. The length of the road will be about 1.2 km.

4.2.6.7 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. Good quality concrete aggregates can partly be obtained from alluvial deposits in the river valley. However, the bulk of the aggregates may be obtained from a quarry opened above the left or right flanks of the river valley. Investigations may reveal that there may be other locations with better material quality and economic haul distances. Random fill for the cofferdams will be obtained from foundation stripping operations.

4.2.7 Irrigation and command area

The Kagitumba site is not suitable for irrigation downstream of the dam. The valley remains relatively narrow for some considerable distance downstream. Besides, it should be recalled that in order to obtain the 240m for power production, the head race will have to travel for approximately nine kilometres downstream to the proposed power house close to the border with Rwanda. From that point on to boarder, only 178 ha can be irrigated (on the Ugandan side) as shown in Table 4.2-9. The command area can support 356 farmers and provide food for about 1780 people. This command area is shown in the attached drawing in Volume II of this report. The annual water demand for irrigation is about 0.9 Mm^3.

Table 4.2-9: Irrigation command area for Kagitumba-Maziba

County	Sub-county	Area (ha)
Ndorwa	Maziba	178.0

4.2.8 Water Supply

The total population that can benefit from water supply from the Kagitumba-Maziba project in 2012 and 2062 was estimated at 46,728 and 225,716 people respectively (Table 4.2-10). The annual water demands are 0.5 Mm^3 and 2.5 Mm^3 for 2012 and 2062, respectively.

Table 4.2-10: Potential water supply beneficiaries for Kagitumba-Maziba

County	Sub-county	Population (2012)	Population (2062)
Ndorwa	Buhara	13,409	64,770
	Kaharo	5,940	28,691
	Kitumba	4,758	22,982
	Kyanamira	11,172	53,963
	Maziba	11,450	55,310
Total (Water supply)		**46,728**	**225,716**

4.2.9 Project costs

The estimated costs for the Kagitumba project total to 32.1 million US dollars as broken down in Table 4.2-11 below.

Table 4.2-11 Kagitumba Dam project costs

No	Item	Units	Quantity	Rate (USD)	Amount (USD)
1.0	**PREPARATORY WORKS**				
	Mobilisation and demobilisation	Lumpsum	1	1200000	1200000
	Permanent access	km	3	100000	300000
	Temporary access	Lumpsum	1	100000	100000
	River diversion during construction	Lumpsum	1	500000	500000
	Resettlement and compensation	ha	370.5	2500	926250
	Subtotal				**3026250**
2.0	**MAIN DAM**				
	Excavation, loose	m3	20000	15	300000
	Excavation, rock	m3	5000	22	110000
	Foundation preparation, grouting, etc	Lumpsum	1	750000	750000
	Concrete works (RCC)	m3	35000	150	5250000
	Subtotal				6410000
3.0	**SPILLWAY, INTAKE, AND PENSTOCKS**				
	Excavation, loose	**m3**	**1200**	**15**	**18000**
	Excavation, rock	m3	6000	25	150000
	Concrete Spillway	m3	6500	200	1300000
	Concrete intake	Lumpsum	1	250000	250000
	Penstocks, 2No @ 1.2 m2 steel	m	1400	1000	1400000
	Other civil structures	Lumpsum	1	300000	300000
	Subtotal				3418000
4.0	**POWER CANAL**				
	Excavation, loose	**m3**	**25318**	**15**	**379770**
	Excavation, rock	m3	6330	25	158250
	Canal lining, 1.8 m2 cross-section	m	8600	400	3440000
	Subtotal				3978020
5.0	**POWER STATION**				
	Excavation, loose	m3	7500	15	112500
	Excavation, rock	**m3**	**7500**	**25**	**187500**
	Reinforced concrete power station	m3	5000	350	1750000
	Other civil works	Lumpsum	1	500000	500000
	Subtotal				2550000
6.0	**MECHANICAL AND ELECTRICAL WORKS**				
	Turbines (2x6MW Francis) and miscellaneous mechanical equipment	**Lumpsum**	**1**	**3000000**	**3000000**
	Generators, transformers and miscellaneous electrical equipment	Lumpsum	1	2000000	2000000

	Gates for intake, outlet	**Lumpsum**	**1**	**1000000**	**1000000**
	Switchyard	Lumpsum	1	300000	300000
	Subtotal				6300000
	TOTAL, CONSTRUCTION COST				25682270
	ADMINISTRATION AND ENGINEERING		0.1		2568227
	CONTINGENCIES		0.15		3852340.5
	CAPITAL COST (WITHOUT VAT)				**32102837.5**

4.2.10 Anticipated Impacts and Mitigation Measures for the Kagitumba Project

4.2.10.1Positive Impacts

The following are some of the anticipated positive impacts of the dam project. They are:

- The dam will facilitate cultivation of crops to be done throughout the year and that will guarantee household income for the communities and also food security;
- Proposed integrated watershed management measures will likely bring about improved environmental management in and around the wider watershed areas of the project;
- Some local can benefit from sale of local construction materials to the project such as sand and other fill materials;
- It is expected that, delivery of social serives will likely improve once electricity is in place. Immuization, eductation and security will likly improve in the areas;
- The electricity to be generated will likely induce other developments in the area in the long run;
- Access rooutes for transportation of equipment and, project machinery will be improved thereby benefitting the locals;
- The dam will lead to production of electricity that will stimulate growth of agro-processing industries which will bring about a number of positive multiplier effects on the communities livelihoods;
- There will be improved supply of water for both domestic and livestock purpose; and
- During construction phase, the communities will get benefits in terms of employment.

4.2.10.2Negative Impacts

At this stage of the study, the preliminary potential impact examination has identified the following impacts:

- Social issues regarding land availability and subsequent compensation aspects will likely be crucial for the success of the project in view of scarse land in the areas of the project;
- There are cultivations close to the river banks. Therefore, to develop irrigation infrastructure (canals, drains, division boxes etc) it will be necessary to reduce the area under cultivation. This will need a participatory approach since the early stages of project implementation to commit the beneficiaries to the project. Also,

the peat extraction company has rights on one area that must be excluded from any development;

- Development of peat marshlands must be undertaken with precautions regarding drainage and water level management to avoid drying of the peat. Such drying is causing risks of ignition, sterilization of top soil and subsidence. It will be essential to ensure that the planned development is not threatening the hydraulic behavior of the whole system;
- The erosion of river banks could be an issue due to the Project since areas around the site are heavily farmed;
- Loss of vegetation through clearances of the sites and access roads;
- Sedimentation transport could be an issue as the annual sedimentation is quite important, leading the site likely exposed to siltation. Thus, it should be taken into consideration during the ESIA as the area is highly cultivated;
- Noise and vibrations from equipment operations as well as air quality concerns;
- Loss of water resources through evaporation will be a minor impact as the net losses due to evaporation could likely be low as compared to annual inflow;
- Due to the change of the hydrology of the River, the aquatic environment as well as the wetlands near the Project area should be taken in consideration during the ESIA;
- Pollution of water sources from loose soils, and agro-chemical residual impacts;
- The water hyacinth plant should be studied in case of presence in the area, especially upstream. However, no presence of hyacinth has been observed during the site mission;
- HIV/AIDS from the workforce and the communities;
-
- Water diseases through establishment of the dam could increase such as malaria, bilharzia should be studied during the ESIA.

One of the tasks of this assignment is preliminary identification of potential environmental and social impacts of the project and proposing mitigation measures. At this point, the consultant has identified some key impacts as well as proposing mitigation measures to address such concerns and have been summarized in Table 4.2-12 as follows:

Table 4.2-12 Key impacts and mitigation measures for the planned Kagitumba-Maziba Dam site

N°.	Project Impact	Mitigation measures
01.	Land uptake through construction of access roads, camp sites, etc	Compensation for land uptake after Resettlement Action Plan (RAP) studies.
02.	Concerns relating to management of cut to spoil materials	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
03.	Loss of marsh and cropland areas due to inundation where rice fields are in place.	Compensation for loss of crop and issuing early notice to farmers to harvest crops. The project will likely disrupt cropping on the marshland and there will be need to put in place measures to ensure sources of livelihoods are not disrupted
04.	Loss of vegetation through clearances of the sites and access roads.	Restrict clearances to work/designated portions or areas. Compensatory planting of trees by the projects.

Nº.	Project Impact	Mitigation measures
05.	Conflicts in water use due to a multiplicity of users (power generation, water supply and irrigations needs including local domestic uses). Some sections of the river have a number of dams and the planned ones will add to such existing dams along the same river system there by putting stress on water supply process.	Put in place site-based sectoral committees to handle equitable and rational use of water in the project. There is need to plan the development of this dam sites while ensuring that the needs of other users are taken care of.
07.	Impacts on water quality through upgrading of existing facilities and where communities draw water for their needs	Provide alternate site rather than disrupt this existing and functioning facility already in place.
08.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
09.	Pollution of water sources from loose soils, and agro-chemical residual impacts.	Impacts of water quality from agro-chemicals have to be mitigated through monitoring water quality parameters during the project phases.
10.	Equipment related concerns in terms of oil spillages, used batteries and oil filters as well as used tyres.	Preparing decommissioning plan and site restoration and re-grassing.
11.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
12.	Noise and vibrations	Noise from equipment and the workforce
13.	HIV/AIDS from the workforce and the communities	Contractors to work with HIV/AIDS service providers to sensitize communities on HIV/AIDS.
14.	Air Quality concerns	Furthermore, the project should work out HIV/AIDS mitigation measures with the district leadership and the health department so that there should be an HIV/AIDS programme dedicated to the project. This is important in that, the project will affect social dynamic of the areas, hence there will be induced developments and population influx which all will have impacts on the communities with reference to HIV/AIDS prevalence.
15.	Crime rate possible increase	In all, the detailed ESIA should investigate this issue and propose appropriate mitigation measures.
16.	Impacts on socio-cultural sites	Dust suppression measures will be instituted to ensure air quality levels are kept appropriate.
17.	Impacts on biodiversity areas of high conservation concerns (Important Bird Areas-IBAs, national and central forest reserves etc).	Working together with the police and law enforcement agencies to control crime in the areas.

4.3 Muvumba Dam Site

4.3.1 Physical Environment Profile

4.3.1.1 Location

The coordinates of the proposed dam site are -1° 21' 26.46 (South) and 30° 13' 48.6" (East.) The project area is basically the district of Nyagatare, which forms part of the current Eastern Province of Rwanda. The Eastern Province is bordered to the north by Uganda and to the east by Tanzania and to the south by both Tanzania and Burundi. The other districts within the Eastern Province are Bugesera, Gatsibo, Kayonza, Rwamagana, Kirehe and Kibungo. Nyagatare was originally part of the old Umutara province. The old Umutara province was originally formed from the current Nyagatare, Gatsibo and some parts of Kayonza and Gicumbi.

The Muvumba site is approximately 19km downstream of the Kagitumba site on the same river. Therefore the physical environment profiles of the two projects are relatively similar. The drainage area for the Muvumba site is about 956 km^2 of which 360 km^2 are in Rwanda while 596 km^2 are in Uganda.

The primary purpose of the dam is irrigation while its secondary purpose would be hydropower production.

4.3.1.2 Topography

River Muvumba originates from Southern-western Uganda and North-eastern Rwanda. Two small tributaries, River Kabizi and River Kahondo join River Nyakizumba to form River Muvumba. It enters Rwanda approximately 5km from the point River Kahondo joins it. Approximately 63% of the catchment is located in Uganda and the remainder in Rwanda. The catchment is characterized by hilly terrain, very steep hills in Uganda, rising from 1500 m.a.s.l to 2300 m a.s.l, while in Rwanda the terrain remains hilly but with a lower range, rising from 1370 m a.s.l to 1500 m a.s.l. The surrounding areas of the project is characterized by gently rolling hills although the proposed site is relatively flat with a gentle slope towards Muvumba River, laying at an average of 1290 m a.s.l.

4.3.1.3 Geology

The review of the Geological map of Rwanda shows that there are a number well pronounced faults in the southern part of the Eastern Province, together with a wide range of geological formations. However, the northern part of the Eastern province is largely covered by massive granite of the Basement complex, which is of Pre-cambrian age. River valley are characterized by deposition of Quaternary Sediments; clay, alluvium. The relief of the catchment distinctly changes at the border; intense folding, steep slopes, high hills, narrow V-valleys in Uganda, while the Rwandan side is characterized with hills with milder slopes and wider U valleys. The proposed dam axis is placed across a U–valley, wholly underlain by granite rock as a basement rock, which would provide a sound foundation for the Dam.

4.3.1.4 Climate

The region surrounding the site is characterized by hot and dry weather conditions for most of the year. The Eastern Province, has several meteorological stations which include

- Nyagatare at an altitude of 1450 masl
- Karama at an altitude of 1500 masl.
- Gabiro at an altitude of 1472 masl

Data from the above stations give the following characteristics

Table 4.3-1 Temperature Characteristics near the Muvumba project site

	Average Annual Daily Temp. °C	**Max. Annual Daily Temp. °C**	**Min. Annual Daily Temp. °C**	**Min. Recorded Daily Temp. oC**
Nyagatare	20.5	26.9	14	8.5
Karama	20.8	27.3	14.3	8.7
Gabiro	20.4	26.8	14	8.4

According to the isohyetal map of Rwanda, the average rainfall over Eastern Province ranges between; 900mm to the far East and 1400mm to the Western part of the province. The larger part of the Eastern province experience drier conditions while the Western part is wetter.

The closest meteorological station to the project area, with only three years' data on humidity is Birenga in Kibungo located at Lat. 2° 10', Long. 30° 32' and Altitude 1680 m.asl, giving an average monthly Relative Humidity of 72.8%. The same station has only three years' data on evaporation which give an average annual evaporation of 993.9mm.

The Muvumba watershed receives a mean annual rainfall of 1054 mm. The mean monthly rainfall distribution is bimodal with two rainy seasons. The long rains occur from March to May while the short rains occur between September and November but can sometimes extend to December. The maximum rainfall is received in April and averages 147 mm while maximum rainfall in the short rainy season is received in November and averages 130 mm. July is the driest month, receiving only 21 mm of rainfall. The mean annual potential evaporation is 1016 mm and varies over a narrow range between 95 mm in March and 70 mm in May. The mean monthly temperature ranges between 16°C in July and 19°C in April.

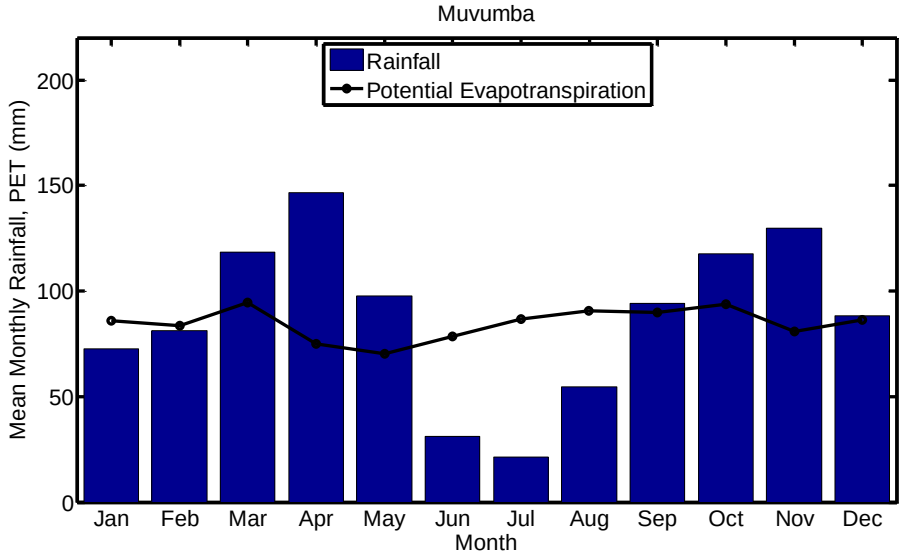


Figure 4.3-1 Muvumba catchment monthly rainfall and potential evaporation variation

4.3.1.5 Soils

The soils are part of wider District are mainly vertisols with a high content of expansive clay. The mineral content of these soils is high but requires modern agricultural techniques for successful cultivation. Throughout the Muvumba valley at the site, there is lot of alluvial deposits mixed with weathered river bed rocks (Plate 4.3-1).

Plate 4.3-1 A section of the Muvumba River 2km upstream of the proposed site

4.3.2 Socio-Economic Environment Profile

4.3.2.1 Population

The total population in the area is 291,452 inhabitants, 51% being women basing on the 2007 census. The average population density in the area stands at 167 inhabitants/km^2

which is by far lower than the national density figure–321 inhabitants/km^2. The most populated sectors are Mimuli and Katabagemu which have 25,651 and 25,250 inhabitants, respectively. A lot of immigration is currently taking place into this area, and rapid increase in population is therefore expected in the future.

4.3.2.2 Housing

The quality of housing is an indicator of the quality of life, the levels of income and the domestic circumstances of the households. In all, the quality of housing falls below the national average, and the household incomes are obviously low, and the ability to pay to sustain services will probably also below. This was quite apparent during the site visit to the area. It would thus appear that the level of service in water supply will be largely by off-site supply or yard taps. In house connections would probably be restricted to the housing with concrete finishes, which is probably about 5-6% of the households. This compares well with rural levels of service in other countries.

4.3.2.3 Land Use

The main land use around the project site is subsistence cultivation where gardens have been opened close to river banks. The crops grown include maize, sorghum which is sold to local beers brewers (*omuramba*). To the north of the site are expanses of *Eucalyptus* and *Grevalia* spp woodlots which are largely for the supply of wood fuel. South of site has plots of bananas and subsistence crops. There is no natural vegetation in the vicinity of the project (no national parks or forest reserves close by the site). There are no animals of conservation concerns in proximity except for Weaver Birds (*Quelea quelea*) which are drawn to the areas because of cereals (maize and sorghum) cultivated in the area.

(a) **(b)**

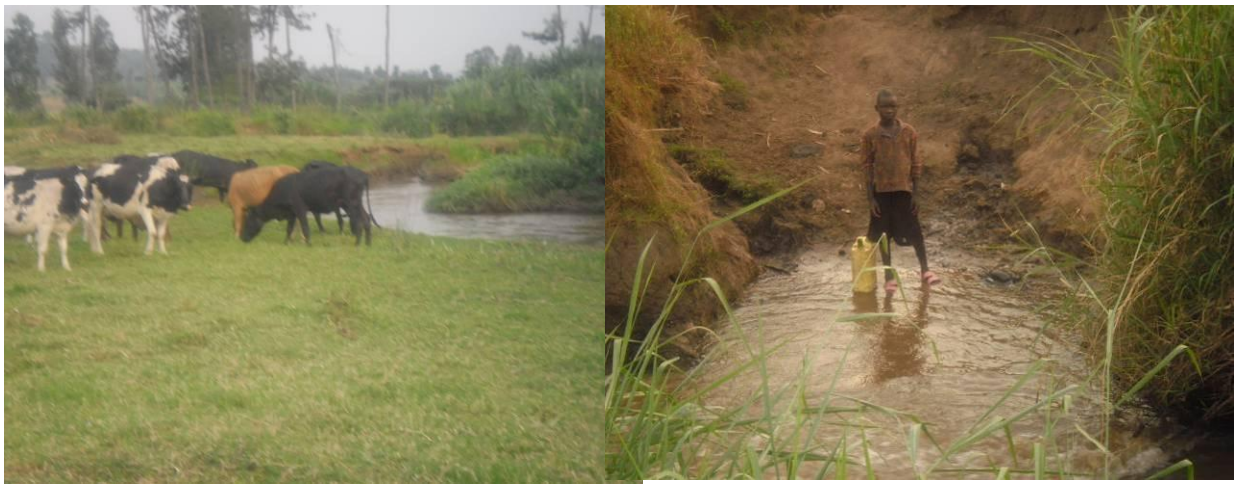
Plate 4.3-2 **(a)** A section of the river towards the project site. Note the nature of state of the vegetation typically overgrazed; and **(b)** Banana cultivation in the project area. Note their good and healthy state an indication of good and fertile soils.

(a) **(b)**

Plate 4.3-3 (a) The area has shortage of wood fuel. Note white arrows pointing at the tree barks collected for cooking purpose; and (b) Part of Eucalyptus/*Gerevalia* plantation forest north of the site

4.3.2.4 Sources of Water

On a general note, the Muvumba River is an important natural resource in the project area as a whole. It was established that some of the area residents draw water directly from the river for domestic use and for watering their livestock. There are about a dozen (12) planned and on-going water related projects along the river at differing stages of development. The quality of water from Muvumba River is presently affected by the nonpoint pollution sources such as agricultural activities along the river valley and from direct watering of livestock.



(a) **(b)**

Plate 4.3-4 (a) Watering of livestock close in the proposed project area; and (b) A young boy collecting water in the R. Muvumba

(a) **(b)**

Plate 4.3-5 (a) Brick making along the banks of R. Muvumba. In the background are fields of maize at harvest stages; and (b) Some of the pits left behind out of brick making activities

4.3.2.5 Tourism

The Akagera National Park covers 1,200km² in eastern Rwanda, against the Tanzanian border. It was founded in 1934 to protect animals and vegetation in three ecoregions: savannah, mountain and swamp. The park is named after the Kagera River which flows along its eastern boundary feeding into several lakes the largest of which is Lake Ihema. The complex system of lakes and linking papyrus swamps makes up over 1/3 of the park and is the largest protected wetland in central Africa. Much of the savannah area of the park was settled in the late 1990s by former refugees returning after the end of the Rwandan Civil War. Due to land shortages, in 1997 the western boundary was regazetted and much of the land allocated as farms to returning refugees. The park was reduced in size from over 2,500km² to its current size. Although much of the best savannah grazing land is now outside the park boundaries, what remains of Akagera is some of the most diverse and scenic landscape in Africa.

In 2009 the Rwanda Development Board (RDB) and the African Parks Network entered into a 20 year renewable agreement for the joint management of Akagera. The Akagera Management Company was formed in 2010 as the joint management body for Akagera National Park. Over the next 5 years a US$10 million expenditure is planned for Akagera including the construction of a 120km western boundary fence and the reintroduction of lion and black rhino. With reference to the planned Muvumba multi-purpose dam, the Park is more than 10km east of the project hence; there will be no impact on it by the project.

4.3.2.6 Economic activities

It can be seen that the majority of the population are engaged in farming, and this is not too different from the rest of the country. Relative to the rest of the country, the leading activity in the area is livestock rearing, especially cattle. In the year 2004 there were a total of 1,466,573 No cows in the country and over 20% of these were in the then Umutara province, making this province the second biggest cattle rearing area in the country, next to the then Byumba province. It is government policy to raise the quality of the livestock

through cross breeding and insemination, and at the same time to reduce the numbers to drop stocking rates. The target set in the "Rwanda Development Indicators" is to reduce the numbers to 400,000 No cows of improved breed for the whole country.

Crop farming in the project area appears to be for subsistence only. For the year 2002, thetotal crop production in Rwanda was about seven million tones. The then Umutara province contributed the second lowest amount (5% of total production) after Gikongoro. The government target set in the "Rwanda Development Indicators" is to increase crop production by 5% per annum through better farming methods and the use of fertilizers.

4.3.3 Previous studies

While carrying out the Muvumba assessment, the following related studies were reviewed

- Development of Kagera Integrated River Basin Management and Development Strategy (KIRBMDS) by SWECO international carried out on behalf of NELSAP. The primary objective of the consultancy is to develop an integrated river basin management and development strategy for the Kagera basin.
- Nyagatare Water Resources Assessment Project by M&E Associates in association with Real Contractors S.a.r.l on behalf of Government of Rwanda. The objective of the study was to carry out a prefeasibility study on the development of storage for various water uses along River Muvumba/ Kagitumba.

4.3.4 Hydrology

4.3.4.1 The catchment

The catchment area of the basin upstream of the dam site is 956 km^2 and is shared between Uganda and Rwanda. The Muvumba catchments is 214km^2 more than the Kagitumba catchment. The topography of the dam site is shown in Figure 4.2-1 above. The elevation of the riverbed at the dam site is about 1700 m asl. The river valley cross-section is bowl-shaped.

The catchment has a length of 85 km and an average width of about 13 km (Figure 3.2-1). The mean catchment slope is about 27.4% but the steepest slopes may be higher than 80%. The catchment elevation ranges between 1375 m asl at the dam site to over 2400 m asl while the mean is 1934 m a.s.l.

4.3.4.2 Runoff

Flow at the proposed dam was estimated using records at the Nyakizumba site 17 km upstream in Uganda and using a catchment area adjustment to transfer the flows. Results show that between years 1956 and 1999, the daily flow at the dam site ranged between 1.1 m^3/s on 15-July-1999 and 59 m^3/s on 14-May-1979 and averaged 6.3 m3/s (Figure 4.3-2). The mean flow has an exceedance probability of 63% while the median flow is 5.1 m^3/s.

The mean monthly total flows vary between 10 Million m^3 (Mm^3) in August and 34 Mm^3 in May (Figure 4.3-3). A secondary peak flow of 18 Mm^3 occurs in November. The total annual flow averages about 198 Mm^3.

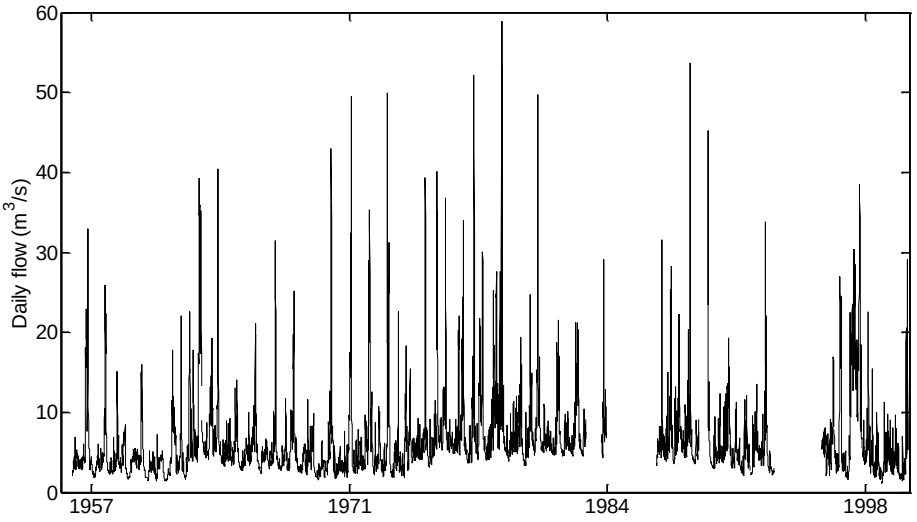


Figure 4.3-2: Daily flow variation

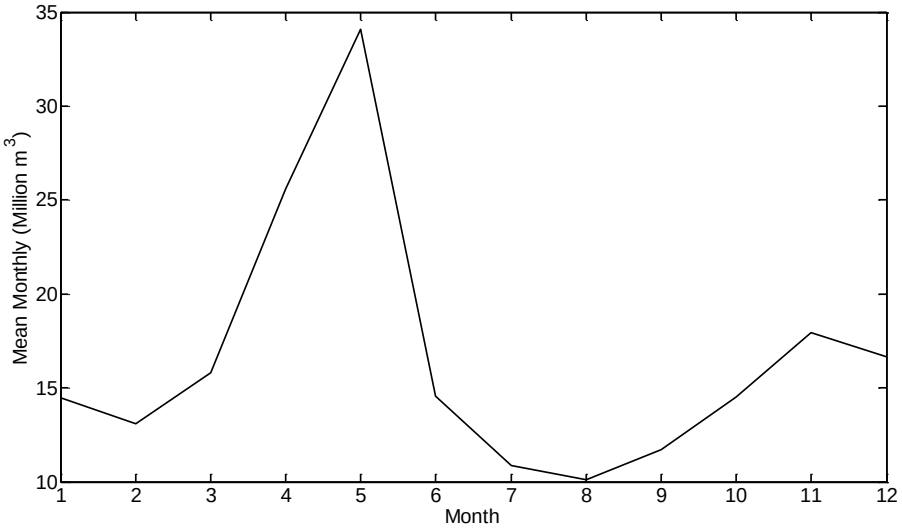


Figure 4.3-3 Mean monthly flow variation

4.3.4.3 Reservoir

Using a 30m digital elevation model (DEM) of the area, reservoir elevation-area and elevation-volume curves were prepared and are shown in Figure 4.3-4 and Figure 4.3-5 respectively. The figures show that the inundation area and volume of reservoir increases steadily with elevation up to an elevation of 1420 m asl. After computation of the available runoff at the site, and also taking into consideration of the site geometry, it was decided to fix the top reservoir level to 1415m asl.

A reservoir elevation of 1415 m asl will inundate 706 ha of land and will have a total volume of 109 million cubic meters of water. The reservoir fetch will be 4 km along the main river while the average width of the reservoir will be about 1.2km.

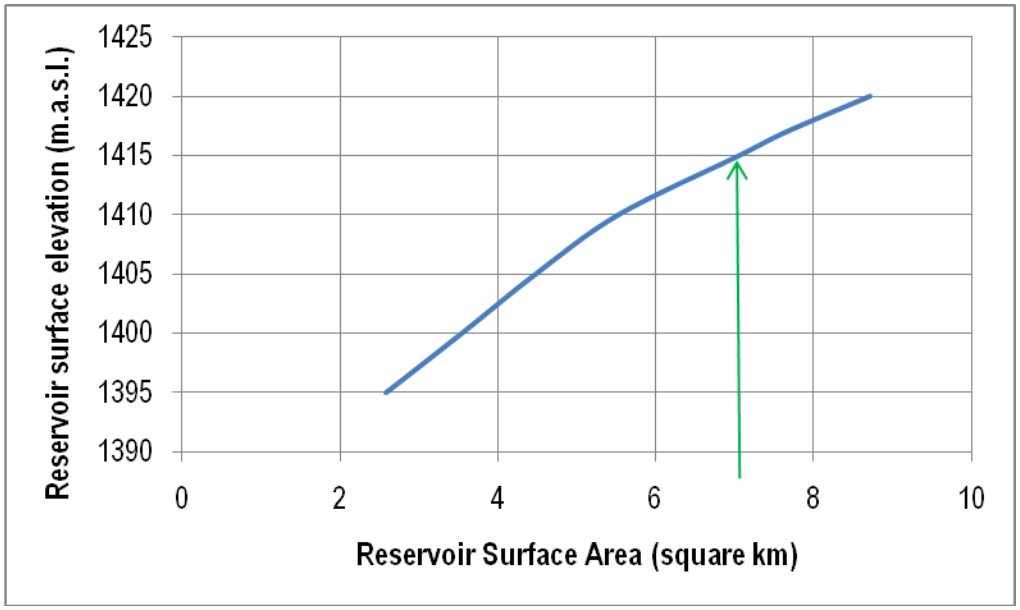


Figure 4.3-4: Plot of reservoir surface elevation versus reservoir surface area, Muvumba project

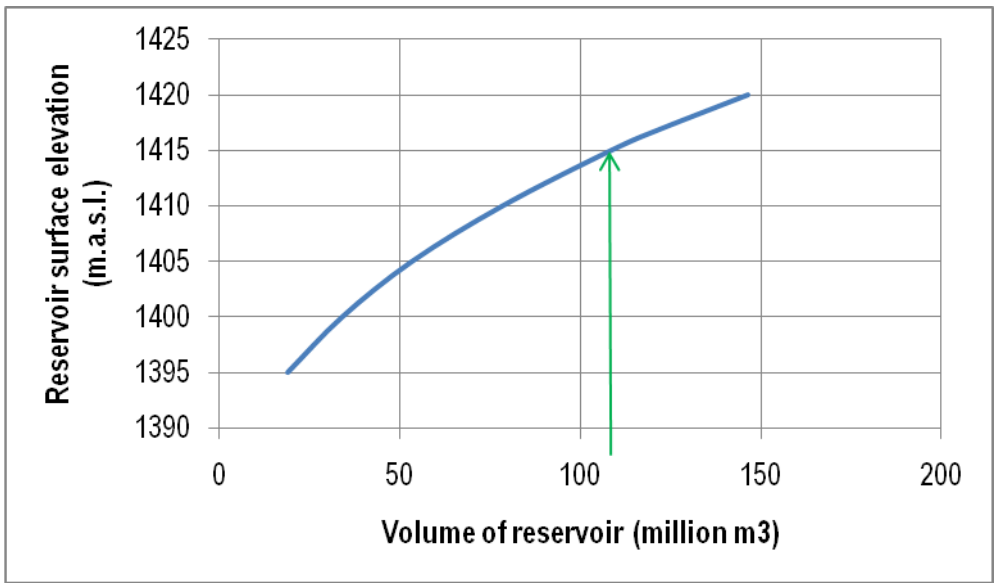


Figure 4.3-5: Plot of reservoir surface elevation versus reservoir volume, Muvumba project

A total area of 7 km^2 would be inundated by the Muvumba reservoir, in the Muvumba Commune requiring the resettlement of about 1,435 people

4.3.4.4 Reservoir evaporation

Being an open water body, the reservoir evaporation rates would be expected to be close to the potential evapotranspiration rates. Table 4.1-2 shows the daily and monthly potential evaporation rates estimated from data at 2 meteorological stations located close to the Muvumba dam site.

Table 4.3-2 Daily and monthly potential evaporation rates

Month	Daily Evaporation (mm)	Monthly Evaporation (mm)
Jan	2.8	86
Feb	3.0	83
Mar	3.0	95
Apr	2.5	75
May	2.3	70
Jun	2.6	79
Jul	2.8	87
Aug	2.9	91
Sep	3.0	90
Oct	3.0	94
Nov	2.7	81
Dec	2.8	86
Annual	2.8	1016

4.3.4.5 Sedimentation

Using the approach suggested by Lawrence et al (2004), sedimentation yields for the Muvumba catchment contributing to the dam site was established to be 448 t/km^2/yr. The dead storage properties of the dam are shown in Table 4.3-3 below:

Table 4.3-3 Muvumba Sediment Properties

Site Name	Muvumba
Reservoir Volume (Mm^3)	108.7
Catchment area (km^2)	956
S_Y (t/km^2/yr)	448
Assumed Sediment density (t/m^3)	1.1
Dead Volume (Mm^3)/yr	0.17
Dead storage after 50 years (Mm^3)	8.48
Percentage of Reservoir filled with sediment after 50 years	8%

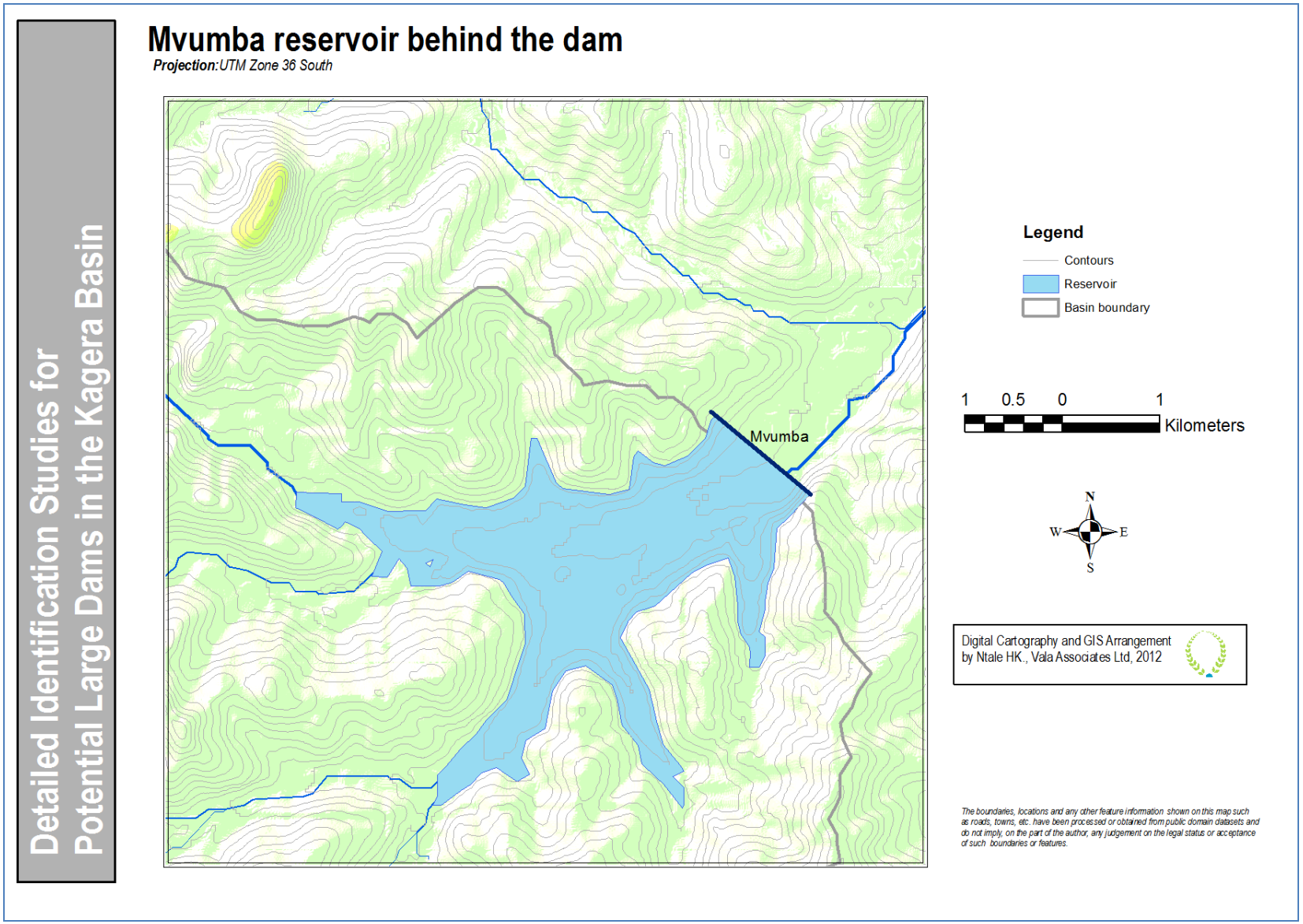


Figure 4.3-6 Muvumba Reservoir at 1415m above sea level

4.3.4.6 Floods

The annual maximum series model was used for flood frequency analysis. The following approach was used

(i) Selection of the maximum 24-hour flows from the measured flow at Muvumba gauging station

(ii) Selection of the distribution that best fits the data. Lognormal distribution was shown to provide an acceptable fit to the annual maximum data

(iii) Estimation of the flood magnitudes corresponding to various return periods (Table 4.2-5)

Table 4.3-4: Muvumba flood estimates and associated return periods

Return period, T (years)	Flood magnitude (m3/s)	Risk of failure for a 50 year design life (%)
50	75.8	63.6
100	87.0	39.5
200	98.8	22.2
500	115.2	9.5
1000	128.3	4.9
2000	142.0	2.5
5000	161.2	1.0
10000	176.5	0.5

4.3.5 Dam Design elements

4.3.5.1 Dam Type

The dam at Muvumba has been designed as an earth fill dam with a roadway on top and an Ogee spillway section. The dam foundation will be located firm basement rock assumed to be 5 m below the ground level in the current design.

Table 4.3-5: Muvumba dam design

Variable	Units	Value
Dam location		**Muvumba-**
Dam type		Earth fill
Reservoir base elevation	m asl	1375
Reservoir top elevation	m asl	1415
Reservoir depth at above dam base (H_{net})	m	40

Free board (Flood control pool + 3% of dam height)	Flood control pool (flood height above spillway crest): 1.5m 3% of dam height (for wave action, etc): 1.5m	3.0	m	3
Dam height H			m	43
Crest elevation			m asl	1418
Spillway crest elevation			m asl	1415
Crest length			m	1300
Top width (7-12 m depending on dam height)			m	10

4.3.5.2 Spillway

The spillway will be of the unregulated Ogee type. It will be located on the left side of the dam. The inlet to the spillway will be shared with the power station inlet. Table 4.2-7 shows the main design parameters of the spillway. The spillway will discharge via a flared ski-jump into an existing an existing pond below the dam.

Table 4.3-6: Spillway design parameters, Muvumba project

Variable	**Units**	**Value**	**Check**	
			Criteria	**Value**
Spillway type	Unregulated Ogee			
Return period	Years	10,000		
Reservoir maximum elevation	m asl	1,415.0		
Design flood	Cumecs	177		
Discharge coefficient, C_d (assumed)		1.7		
Spillway crest length, L	M	30.0		
Head on spillway, H	M	2.5		
Spillway discharge, Q=Cd*L*H^(3/2)	Cumecs	201.6	>= design flood	Ok
Spillway crest elevation	m asl	1,415.0		

4.3.5.3 Power station

With a head of 40m, it is possible to harness hydropower at the site, while at the same time irrigating the downstream basins. The power station will be a surface concrete structure equipped with 2 turbines each with a rated power of 1.5 MW.

Table 4.3-7: Hydropower estimation, Muvumba project

Variable	**Value**	**Units**
Rated reservoir level	1415	m asl
Tailwater level	1375	
Head	40	m
Mean flow	6.3	m3/s

Rated flow (30% higher than mean)	8.2	m3/s
Plant efficiency	90%	
Power	2.9	MW
Energy	25.3	GWh/year
Turbine type	Francis	
Number of turbines	2	
Flow for each turbine	4.1	

The proposed 25 GWh hydropower station at the Muvumba site has the potential to produce to supply about 28 000 houses and over 170,000 people.

4.3.5.4 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. Good quality concrete aggregates can partly be obtained from alluvial deposits in the river valley. However, the bulk of the aggregates may be obtained from a quarry opened above the left or right flanks of the river valley. Investigations may reveal that there may be other locations with better material quality and economic haul distances.

Random fill for the cofferdams will be obtained from foundation stripping operations.

4.3.6 Irrigation and command area

The Muvumba site is very suitable for irrigation immediately downstream of the dam. There is intensive mixed farming in the Muvumba valley. Availability of water all year around would enable the valley residents to engage in more profitable agriculture. Figure 4.3-7 below shows the potential command area (2198 ha) located in Byumba Province (Table 4.3-8). which can be directly irrigated using the Muvumba reservoir waters. The command area can support 4,396 farmers and provide food for about 21,980 people. The annual water demand for irrigation (in the 2198 ha) is about 11 Mm^3. The Reservoir can irrigate an additional 10,000 ha downstream of the Muvumba river.

Table 4.3-8: Irrigation command area for Muvumba

Province	Commune	Area (ha)
Byumba	Muvumba	2,198
Total Area		**2,198**

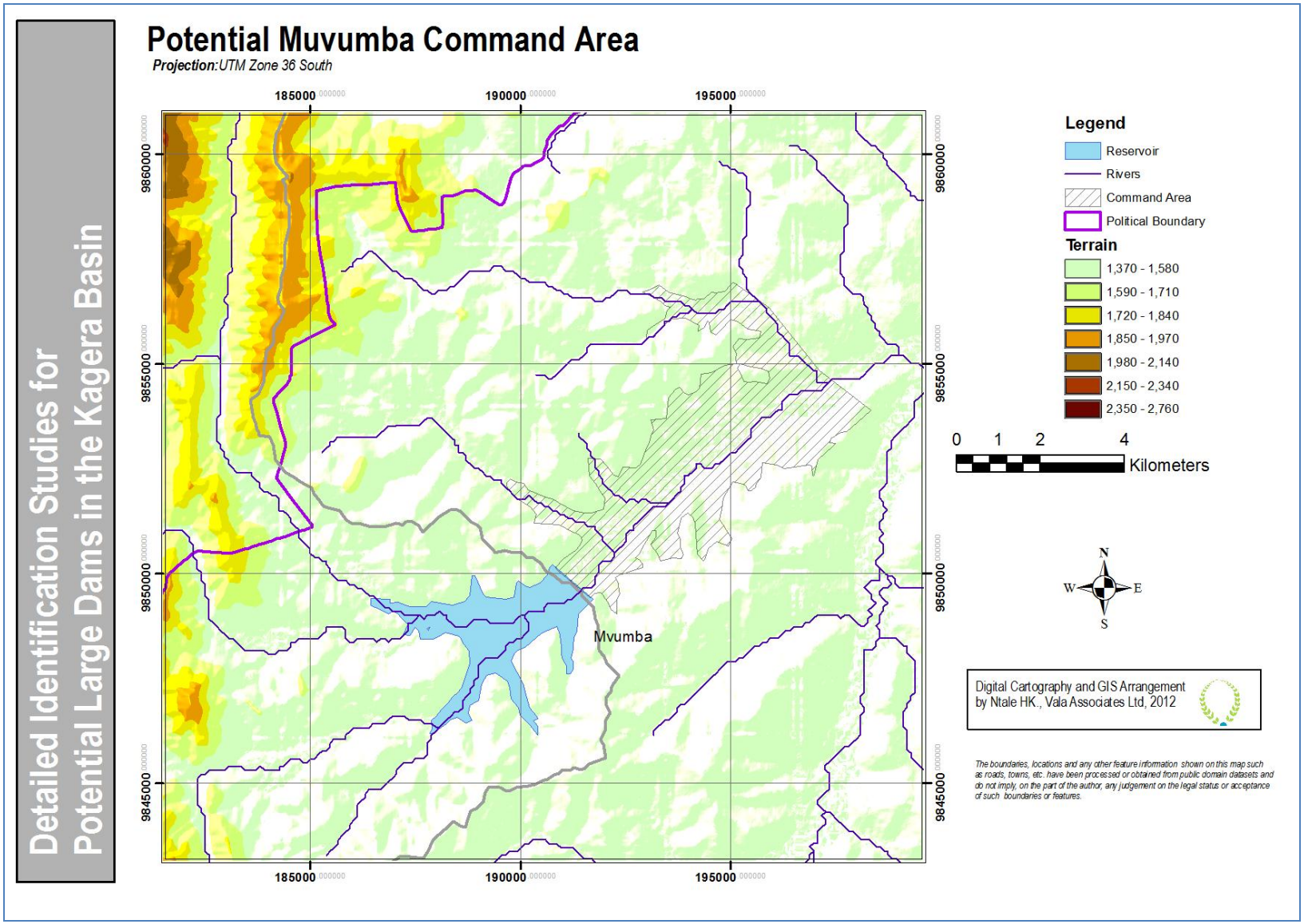


Figure 4.3-7 Muvumba Command area

4.3.6.1 Water Supply

The total population that can benefit from water supply from the Muvumba project in 2012 and 2062 was estimated at 29,788 and 118,494 people, respectively (Table 4.3-9). The annual water demands are 0.3 Mm^3 and 1.3 Mm^3 for 2012 and 2062, respectively.

Table 4.3-9: Potential water supply beneficiaries for Muvumba

Province	Commune	Population (2012)	Population (2062)
Byumba	Muvumba	29,565	117,606
	Ngarama	223	888
Total (Water supply)		**29,788**	**118,494**

4.3.7 Project costs

The estimated costs for the Muvumba project total to 103.3 million US dollars as broken down in Table 4.3-10 below.

Table 4.3-10 Muvumba Project Costs

No	Item	Units	Quantity	Rate (USD)	Amount (USD)
1.0	**PREPARATORY WORKS**				
	Mobilisation and demobilisation	Lumpsum	1	1200000	1200000
	Permanent access	km	3	100000	300000
	Temporary access	Lumpsum	1	100000	100000
	River diversion during construction	Lumpsum	1	500000	500000
	Resettlement and compensation	ha	706	2500	1765000
	Subtotal				**3865000**
2.0	**MAIN DAM**				
	Excavation, loose	m3	440000	15	6600000
	Excavation, rock	m3	110000	22	2420000
	Foundation preparation	Lumpsum	1	500000	500000
	Dam earthworks - random fill	m3	2100000	15	31500000
	Dam earthworks - impermeable core	m3	1150000	20	23000000
	Subtotal				**64020000**
3.0	**SPILLWAY, INTAKE, AND PENSTOCKS**				
	Excavation, loose	m3	2500	15	37500
	Excavation, rock	m3	9000	22	198000
	Concrete Spillway	m3	39000	200	7800000
	Concrete intake	Lumpsum	1	250000	250000
	Penstocks, 2No @ 1.0 m2 steel	m	100	500	50000
	Other civil structures	Lumpsum	1	300000	300000
	Subtotal				**8635500**
4.0	**POWER STATION**				
	Excavation, loose	m3	4000	15	60000
	Excavation, rock	m3	4000	22	88000

	Reinforced concrete power station	m3	5000	350	1750000
	Other civil works	Lumpsum	1	500000	500000
	Subtotal				**2398000**
5.0	**MECHANICAL AND ELECTRICAL WORKS**				
	Turbines (2x1.5MW Francis) and miscellaneous mechanical equipment	Lumpsum	1	1600000	1600000
	Generators, transformers and miscellaneous electrical equipment	Lumpsum	1	1000000	1000000
	Gates for intake, outlet	Lumpsum	1	800000	800000
	Switchyard	Lumpsum	1	300000	300000
	Subtotal				**3700000**
	TOTAL, CONSTRUCTION COST				**82618500**
	ADMINISTRATION AND ENGINEERING		0.1		8261850
	CONTINGENCIES		0.15		12392775
	CAPITAL COST (WITHOUT VAT)				**103273125**

4.3.8 Anticipated Impacts and Mitigation Measures for the Muvumba Project

4.3.8.1 Positive Impacts

The following are some of the anticipated positive impacts of the dam project. They are:

- It is hoped that, the project will bring about flood control in the areas of downstream of the river;
- The dam will facilitate cultivation of crops to be done throughout the year and that will guarantee household income for the communities and also food security in the project areas;
- Proposed integrated watershed management measures will likely bring about improved environmental management in and around the wider watershed areas of the project;
- Some local can benefit from sale of local construction materials to the project such as sand and other fill materials;
- It is expected that, delivery of social serives will likely improve once electricity is in place. Immuization, eductation and security will likly improve in the areas;
- The electricity to be generated will likely induce other developments in the area in the long run;
- Access rooutes for transportation of equipment and, project machinery will be improved thereby benefitting the locals;
- The plan to have power generation as a component of the project will bring about possible emergence of value addition in the agro-processing and this enable farmers to earn better income and have improved livelihoods;
- The establishment of dam will lead to improved access in terms of roads that will equally be improved to facilitate delivery of construction of the dam facility;
- It is equally anticipated that, the dam will attract development into the area in terms of planned settlements and business outlets; and
- During construction phase, the communities will get benefits in terms of employment and source of income through sale of food items to the workforce.

4.3.8.2 Negative Impacts

At this stage of the study, the preliminary potential impact examination has identified the following impacts:

- The dam works will displace farmers on their marshlands thereby depriving them of their area of livelihood. This is a fundamental impact that can have long term implications in terms of food security. During this IESE, the study team observed poor state of the crops giving impression that, the yields are likely to be poor hence, the heavy reliance of the communities on the marshlands for farming activities;
- Being near a border of Uganda and Rwanda with adjacent communities practising some different economic activities and using water from this river, this is likely to trigger some conflicts with communities over water user rights which if not well addressed right from the planning stage, is likely to brew disharmony in the two countries;
- During the construction of the dam, there is likely to be impacts on the communities in nearby areas especially through the neighboring trading centre during the market days when communities conduct business by the roadside;
- The dam construction will interfere with the community water sources downstream. In addition, social issues regarding land availability and sharing will be crucial for the success of the project;
- The erosion of river banks could be an issue due to the Project since areas around the site are heavily farmed;
- Loss of vegetation through clearances of the sites and access roads;
- Sedimentation transport could be an issue as the annual sedimentation is quite important, leading the site likely exposed to siltation. Thus, it should be taken into consideration during the ESIA as the area is highly cultivated;
- Noise and vibrations from equipment operations as well as air quality concerns;
- Pollution of water sources from loose soils, and agro-chemical residual impacts;
- HIV/AIDS from the workforce and the communities; and
- Water diseases through establishment of the dam could potentially occur and such diseases include malaria amongst others.

One of the tasks of this assignment is preliminary identification of potential environmental and social impacts of the project and proposing mitigation measures. At this point, the consultant has identified some key impacts as well as proposing mitigation measures to address such concerns and have been summarized in Table 4.3-11 as follows:

Table 4.3-11 Key impacts and mitigation measures for the planned the Proposed Muvumba site

N°.	Project Impact	Mitigation measures
01.	Loss of marsh and cropland areas due to inundation where rice fields are in place.	Compensation for loss of crop and issuing early notice to farmers to harvest crops
02.	Impact on the roadside communities likely to be impacted by construction equipment during transportation.	Arrangements should be made to widen access road to the site to easy transportation of equipment.
03.	Land uptake through construction of the dam	Compensation for land uptake after

Nº.	Project Impact	Mitigation measures
	and access roads, camp sites, etc	Resettlement Action Plan (RAP) studies are conducted to establish actual PAPs and details of compensation needed.
04.	Concerns relating to management of excess cut to spoil materials during construction phase of the project.	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
05.	Loss of marsh and cropland areas due to inundation where rice fields are in place.	Compensation for loss of crop and issuing early notice to farmers to harvest crops
06.	Loss of vegetation through clearances of the sites and access roads.	Restrict clearances to work/designated portions or areas. Compensatory planting of trees by the projects.
07.	Potential conflicts in water use due to a multiplicity of users (power generation, water supply and irrigations needs including local domestic uses). Some sections of the river have a number of dams and the planned ones will add to such existing dams along the same river system there by putting stress on water supply process.	Put in place site-based sectoral committees to handle equitable and rational use of water in the project. There is need to plan the development of this dam sites while ensuring that the needs of other users are taken care of.
08.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
09.	Pollution of water sources from loose soils, and agro-chemical residual impacts.	Impacts of water quality from agro-chemicals have to be mitigated through monitoring water quality parameters during the project phases.
10.	Equipment related concerns in terms of oil spillages, used batteries and oil filters as well as used tyres.	Preparing decommissioning plan and site restoration and re-grassing.
11.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
12.	Noise and vibrations	Noise from equipment and the workforce
13.	HIV/AIDS impacts due to influx of people in search of work opportunities in the project.	Contractors to work with HIV/AIDS service providers to sensitize communities on HIV/AIDS.
14.	Air Quality concerns likely to arise from project works	Furthermore, the project should work out HIV/AIDS mitigation measures with the district leadership and the health department so that there should be an HIV/AIDS programme dedicated to the project. This is important in that, the project will affect social dynamic of the areas, hence there will be induced developments and population influx which all will have impacts on the communities with reference to HIV/AIDS prevalence.

Nº.	Project Impact	Mitigation measures
15.	Possible increase in crime rate in the areas of the project.	In all, the detailed ESIA should investigate this issue and propose appropriate mitigation measures.
16.	Impacts on socio-cultural sites	Dust suppression measures will be instituted to ensure air quality levels are kept appropriate.
17.	Impacts on biodiversity areas of high conservation concerns (Important Bird Areas-IBAs, national and central forest reserves etc).	Working together with the police and law enforcement agencies to control crime in the areas.

4.4 Akanyaru Dam Site

4.4.1 Physical Environmental Profile

4.4.1.1 Location

The Kanyaru site is situated at 2° 46' 35.4" South and 29° 49' 10.32" East, at Burundi-Rwanda border on the Kanyaru River (Figure 4.4-1). The site is located in Gisagara District which is one of the 8 Districts that make up the southern province of Rwanda, in Kyimana Village, Mukindo Sector and it borders the Republic of Burundi to the south. The primary potential use of the project is irrigation coupled with hydropower generation. It has an estimated catchment area of 1,832 km^2 and an annual average inflow of 739.2 Mm^3/year. The site has a potential maximum head of 40 m and is expected to generate 42 GWh/year of firm energy. It is noted that, R. Kanyaru's hydrography is also made of dense network of water sources and streams that snake the bottom of valleys inside the District. On rainfall, the average annual rainfall in the area is estimated to be about 800 mm.

The Kanyaru marshland is a vast drowned valley which forms a natural border between Rwanda and Burundi. Its dimensions range from 200 to 3 000 m wide and 70 km long. Its area is estimated at about 200 km². The marshland is characterized by waters highly loaded with suspended matter due to mechanical erosion from river banks, deforestation and environmental degradation of the watersheds.

4.4.1.2 Site description

The Kanyaru dam site occurs in wetlands/fairly marshy areas of the Kanyaru river. The vegetation consists of a variety of marshy habitats and papyrus swamp. Early successional stages are occupied by floating vegetation dominated by *Pistia stratiotes*, *Leersia hexandra* and *Oryza barthii*. Intermediate stages are a mixture of *Typha australis*, *Miscanthidium violaceum*, *Cladium jamaicense* and some papyrus. More complex habitats are occupied by *Typha australis*, *Miscanthidium violaceum*, *Cyperus denudatus*, *C. latifolius* and *Echinochloa pyramidalis.* There are expanses of papyrus, either as pure stands or combined with shrubby vegetation at the close verges of the river banks.

(a) **(b)**

Plate 4.4-1 (a) A section of the Kanyaru River; and (b) Dam axis location indicated by red line

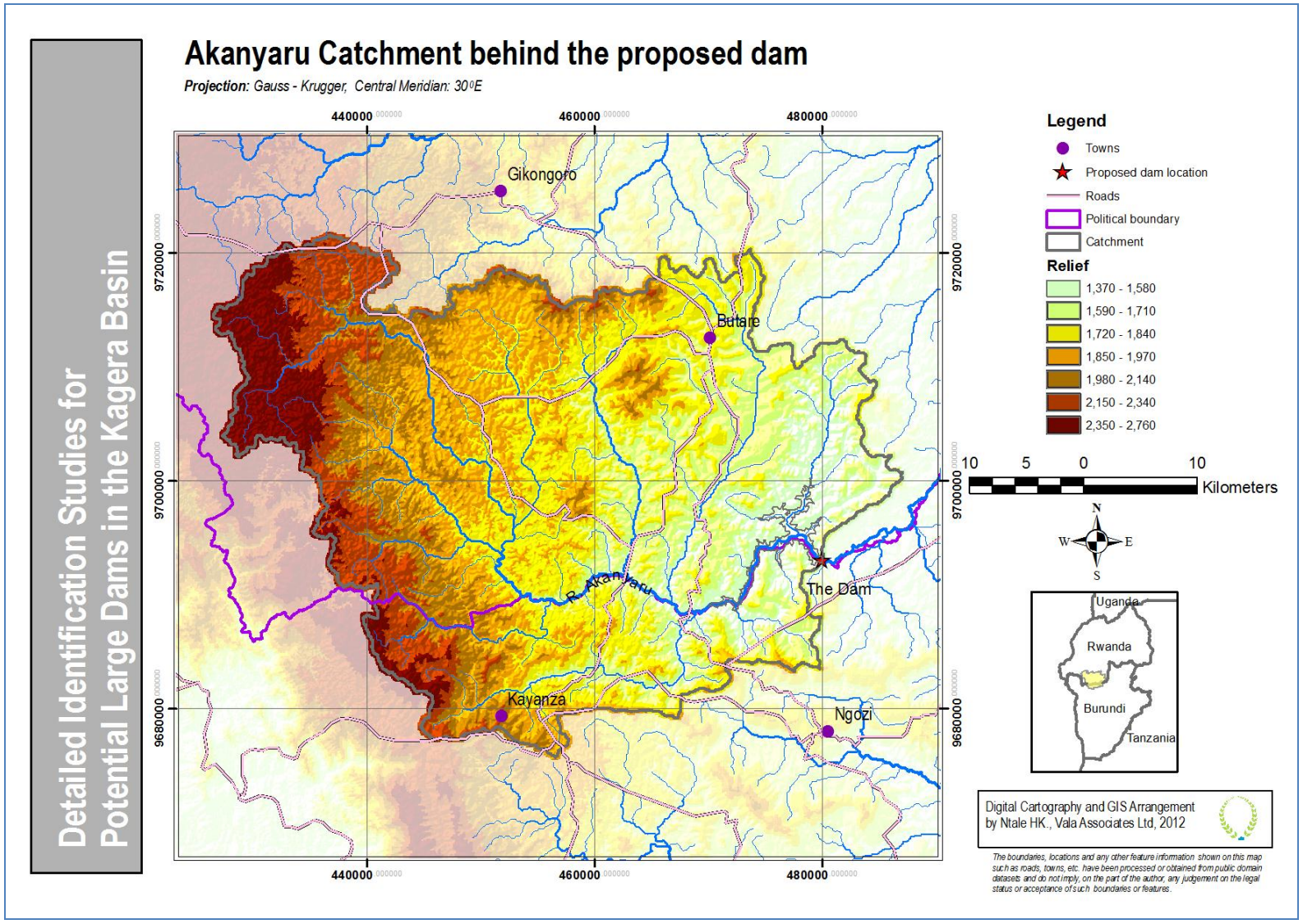


Figure 4.4-1 Kanyaru Catchment contributing to the reservoir

4.4.1.3 Climate

Based on the broader Gisagara District climatic data, the planned dam site has a temperate climate by altitude even if it is geographically located near the Equator (Figure 4.4-2). However, it should be noted that the succession of seasons becomes irregular from year to year which triggers dry spells.

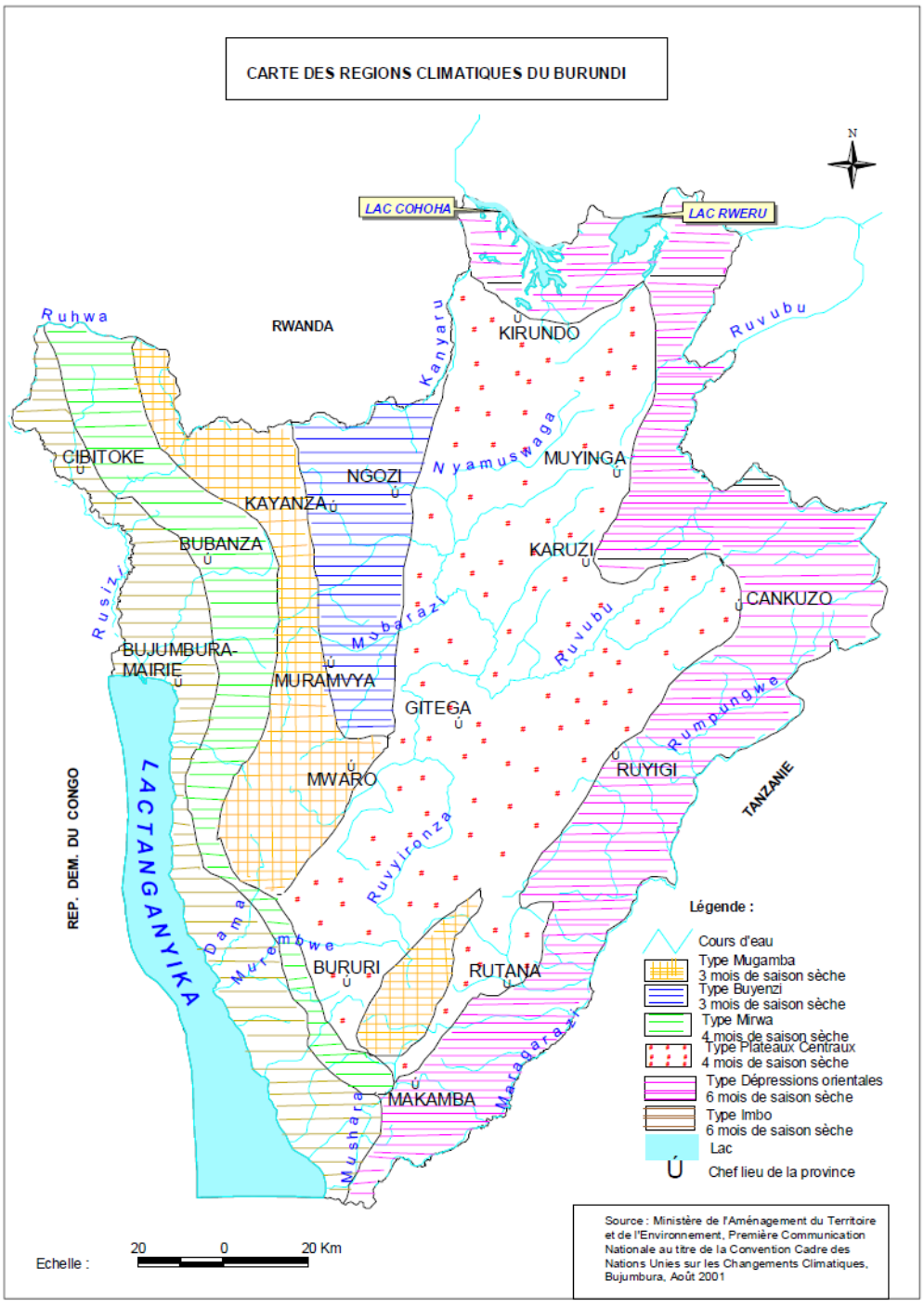


Figure 4.4-2 Climatic Regions of Burundi (Source: NAPA for Burundi, 2005)

Available data indicates that the basin receives a mean annual rainfall of 1152 mm. The mean monthly rainfall distribution is bimodal with two rainy seasons. The long rains occur from March to May while the short rains occur between October to December. The maximum rainfall is received in April and averages 202 mm while maximum rainfall in the short rainy season is received in November and averages 119 mm. July is the driest month, receiving only 6 mm of rainfall on average. The mean annual potential evaporation is 1107 mm and varies over a narrow range between 72 mm in December and 127 mm in August. The average temperatures range between 17°C in June and 19°C in September.

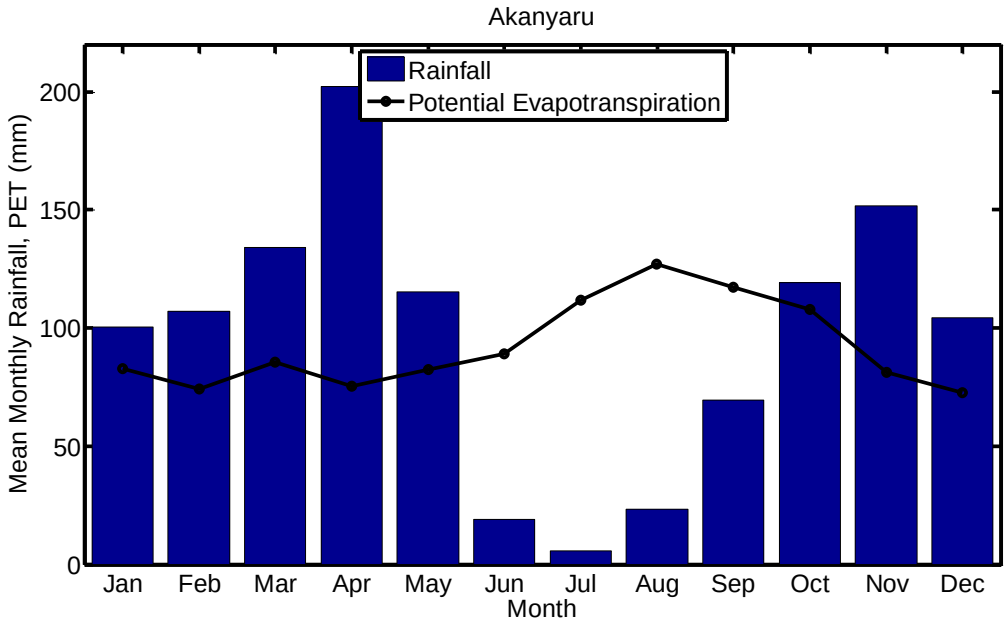


Figure 4.4-3: Akanyaru mean monthly rainfall and potential evaporation variation

4.4.2 Social economic profile

4.4.2.1 Demographics and trends

According to administrative areas, Gisagara currently has 267,161 inhabitants, with a density of 394 inhabitants per km2. It is clear from the table below that the district's population is unevenly distributed; since some sectors are more populated than others. This could be related to internal migration of the population unemployed and willing to look for other income-generating activities that are not agriculture related. Apart from this movement from rural areas to urban areas, there is concentration of population in the areas of Kibilizi, Save, Kigembe, and Nyanza. This is influenced by the presence of infrastructures such as schools, hospitals, communication facilities, water infrastructure, etc.

The young population dominates as 52% of the population is under 20 years. The structure of the population by sex shows how the district has more women than men, a sex ratio of 84.2 men/100 women. This occurs as a consequence of the 1994 genocide. The majority of women who found themselves head of households live in a precarious situation characterized by a very high vulnerability.

Table 4.4-1 Population of Gisagara District

Sectors	Males	Females	Total	Surface area (km^2)	Density (inhab/ /km^2)
Gikonko	7419	8816	16235	49	331.3
Gishubi	7373	8761	16134	61	264.5
Kansi	8034	9545	17579	42	418.5
Kibilizi	10590	12582	23172	40	579.3
Kigembe	10935	12992	23927	45	531.7
Mamba	11748	13959	25707	80	321.3
Muganza	10470	12441	22911	70	327.3
Mugombwa	8098	9623	17721	50	354.4
Mukindo	10491	12466	22957	50	459.1
Musha	8828	10489	19317	50	386.3
Ndora	8250	9802	18052	61	295.9
Nyanza	8089	9611	17700	39	453.8
Save	11767	13982	25749	41	628.0
Total	122093	145068	267161	678	411.7

(Source: District of Gisagara, Sectors statistics, June 2007)

4.4.2.1 Energy

The primary source of domestic energy in the area is biomass type (wood fuel) as there is electricity grid in the area. Unlike other sites, the Kanyaru area does not have well established woodlots of eucalyptus which would be a good supply of wood fuel. The women are engaged in collection of wood fuel from sources including crop residues. Some few families have indigenous tree stands which are harvested for firewood but at domestic levels.

4.4.2.2 Housing

Like almost all rural areas of Rwanda, the communities close to Kanyaru dam site have simple house facilities which are largely of clay tiles from marshlands. These roofing materials are made locally and subjected to different modes of curing (burning or sun drying). The roofs frames are of eucalyptus poles with reeds as rafters. The walls are a mix ranging from mud and wattle and unbaked bricks. The houses are semi-permanent and have varying ranges of enclosures such live fences with *Euphorbia tiraculii* (Plate 4.4-2).

(a) **(b)**

Plate 4.4-2 (a) A typical House on slate rock outcrop; and (b) Homestead fenced with *Euphorbia tiraculii*

It is recognized that, the region where Kanyaru Multipurpose dam is to be located has suffered serious series of development challenges ranging from rapid population growth, food insecurity, harsh climatic conditions, poor soils, food insecurity amongst others. In view of these, the Kagera RBM Project with the Governments of Rwanda and Burundi are proposing to implement Kanyaru Multipurpose Project.

4.4.2.3 Agriculture and Livestock

The population in the project area practice subsistence cultivation and they grow maize, potatoes and some sunflower. The soils are generally shallow with outcrops of slate rocks and from the state of the crops in the shambas, the harvest is poor and it appears that such harvest indicates that the population is generally food insecure. The region where Kanyaru Multipurpose is located has suffered serious food insecurity for some years now. The region has witnessed chronic famine and the population's standard of living has deteriorated sharply. Due to rapid population growth there is an increasing need for more arable land.

There are plots of coffee up the hills but its performance is poor due to poor soils and erratic rainfall. From the local people, the area has land shortage and the average land holding per house ranges from 0.5-2.0 acres. Along stretches of the Kanyaru River through the project area, the communities have reclaimed it for paddy rice growing with the fields giving the area spectacular view from up the hills. The rice is cultivated on either side of the river by neighboring communities as well from Burundi.

Plate 4.4-3 Part of the Rice fields downstream of the planned dam site

The river section close to the proposed dam site is navigable and there are commercial canoes for transportation of passengers between the two countries though this is reportedly yet at small scale levels which has merited establishment of a border post.

(a) **(b)**

Plate 4.4-4 (a) Harvested beans on rock slate ground; and (b) Poor stand of sunflower crop. Note the patchy/rocky soils in the foreground.

(a) **(b)**

Plate 4.4-5 (a) A mix of yams and coffee. The state of the crop is poor and so is likely to be the harvest. and (b) Children by the roadside at the edge of coffee shamba

4.4.2.4 Employment

Nyanza has a low employment rate of the labour force (57%). This weakness of employment is particularly resulting from atrophy of the secondary sector that includes industries. Indeed, the district has only one class industry SMEs (the dairy Nyabisindu) with no real ability to absorb a qualified labour force non - bloated.

4.4.2.5 Health

Nyanza has 12 health facilities, consisting of health centres and one hospital in the town of Nyanza. The capacity in these health facilities remains a persistent problem faced by patients, since the total number of beds is only 420 beds. All parts of the district are not equipped with health facilities since the Kigoma sector has neither hospital nor health center. The population travels long distances to arrive to the nearest health facility. The problem of lack of medical personnel is acute since for 100,000 inhabitants there are only 15 nurses and three doctors.

The hygiene in all health facilities is not satisfactory. Specifically, water infrastructure is insufficient and inadequate. In terms of latrines, their condition is not only a concern but they are not enough. There is an average 49 latrines in all health facilities.

4.4.2.6 Education

Primary education in Nyanza reveals that the performance is still not reached since the success in national examinations is only 25% for girls and 14.3% for boys. In addition, school dropouts indicate a failure. The number of children in a classroom is 66, does not coincide with the standard desired by the Ministry responsible for education, which is 46. This implies a lack of school infrastructure. Future priorities then consist of the construction of 150 rooms as well as rehabilitation of existing 397. The additional equipment will also be provided.

The district has a total of 20 secondary schools in 9 sectors. Cyabakamyi, Rwabicuma and Nyagisozi sectors don't have Girls' education arises as a major problem in secondary schools. From the core curriculum to graduate school, their enrolment is declining, from 51.5% to 45.3%. In addition, dropouts are accentuated for girls. A further observation is that girls do not grow further in their studies because of the proportion of qualified teachers; we note that most school teachers are male 62.7%. It is therefore essential to promote girls' education. Apart from these challenges, a priority for the future is to make the extension, construction and rehabilitation of school infrastructure and the supply of necessary equipment. Specifically, 100 new buildings should be constructed while 70 areas should be rehabilitated. Improving hygiene in schools is a great need for the dilapidated state of water infrastructure is inadequate and they area barriers to good hygienic conditions.

4.4.2.7 Road infrastructure

The road network is dense Nyanza (380 km), generally in poor condition but passable. It consists mainly of dirt roads. The asphalt road network incorporates the National Kigali Akanyaru axis running through the district and the stretch Bigega-Rwesero only through the town of Nyanza. The dirt roads are in poor condition and require rehabilitation, as well as the adjoining bridges. The following table shows 394km of roads needs rehabilitation.

Table 4.4-2 Nyanza Roads that need rehabilitation

Sector	Principal roads to be rehabilitated	Length (km)	Length (km) by sector
Busoro	Shyira-Burakari	8	
	Kimirama-shyira-Gitovu	22	
	Busoro-Vunga	5	
	Busoro-Murambi	8	
	Total		**43**
Rwabicuma	Nyanza-Rwabicuma-Nyagisozi	13	
	Nyanza- Rwabicuma- Rwaniro	8	
	Mushirarungu- Runga-Rwaniro	10	
	Total		**31**
Ntyazo			
	Ruyenzi-Kibirizi	3	
	Ntyazo-Gikonko	6	
	Bugali-Kibirizi	5	
	Total		**14**
Kibirizi	Nyarubogo- Mututu	10	
	Kibirizi-Mahwa-Busoro	15	
	Kibirizi-Mbuye- Nyagisenyi	3	
	Muyira-Kibirizi-Nytazo	8	
	Kibirizi-Gasagara-Mututu	6	
	Kibirizi-Mpanda-Akanyaru	6	
	Total		**48**
Muyira	Butara-Rusengo	5	
	Nyamiyaga-Kibuzi	8	

Sector	Principal roads to be rehabilitated	Length (km)	Length (km) by sector
	Nyamiyaga –Cyegera	3	
	Buduwi-Kimvuzo	20	
	Total		**36**
Mukingo	Gatagara- Ngwa- Kiruri- Bweramana	7	
	Gatagara- Mpanga	7	
	Mpanga-Nkomero-Cyabakamyi	8	
	Mpanga-Cyerezo- Rwabicuma	5	
	Total		**27**
Busasamana	Nyanza- Gahanda	20	
	Nyanza- Rwabicuma	10	
	Laiterie- Busasamana	5	
	Hôpital- Mpanga	15	
	Kavumu-Gisharara	8	
	Total		**58**
	Grand Sous-Total		**255**

(Source: Nyanza Province Infrastructure Status Report, 2010)

4.4.2.8 Water and sanitation

The people of Nyanza face an acute shortage of drinking water. This problem is due to the inadequacy and poor condition of water infrastructure (water supply and sources). The following table shows the state of supply systems and water sources in the districts.

The network of water supply of Nyanza includes water sources in sufficient quantity (relative to the population served) and quality (only 57% are developed and 61% are to be rehabilitated). Moreover, the average distance traveled by the population is very long (1.5 km on average because it deviates too much from the required standard of 500m in rural areas and 200m in urban areas). The problem of access to drinking water is very pronounced in the District of Nyagisozi, where this distance can reach the average of 2km

Table 4.4-3 Water Sources in the Nyanza Disctrict

Sector	Sources of water in operation	Sources of water non exploited	Sources of water to be Rehabilitated	Average distance to the water point
Busoro	20	34	38	1,5
Rwabicuma	36	31	38	0,8
Ntyazo	26	5	37	1,9
Kibirizi	68	70	97	1,5
Muyira	42	39	43	2
Mukingo	78	31	45	1,6
Busasamana	28	4	27	1,2
Cyabakamyi	15	12	15	0,9
Kigoma	15	13	13	1,7
Nyagisozi	28	26	27	2,2
Total	**356**	**265**	**380**	**1,5**

Source: District of Nyanza, Sector Statistics, June 2007

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Regarding water supply, Nyanza has 21 water supply systems (data available for seven sectors) of which half is in poor condition. The average distance travelled by the population to the water sources is very long because it is an average of 1 km (the required standard is 500 m in rural areas and 200m in urban areas).

4.4.3 Previous studies

While carrying out the Kanyaru assessment, the following related studies were reviewed

- Development of Kagera Integrated River Basin Management and Development Strategy (KIRBMDS) by SWECO international carried out on behalf of NELSAP. The primary objective of the consultancy is to develop an integrated river basin management and development strategy for the Kagera basin.

4.4.4 Hydrology

4.4.4.1 The catchment

The catchment area of the basin upstream of the dam site is 1727 km^2. The topography of the dam catchment and site is shown in Figure 4.4-1 and Figure 4.4-9. The elevation of the riverbed at the dam site is about 1374 m asl. The river valley cross-section is U-shaped.

The catchment has a length of 100 km and an average width of about 17 km (Figure 4.4-1). The mean catchment slope is about 22% but the steepest slopes may be higher than 90%. The catchment elevation ranges between 1374 m asl at the dam site to over 2758 m asl while the mean is 1870m a.s.l.

4.4.4.2 Runoff

Available data between the years 1963 and 1990 showed that daily flow at the dam site ranged between 3 m^3/s on 17-Sep-1967 and 207 m^3/s on 9-May-1979 and averaged 26 m^3/s (Figure 4.4-4). Flow duration curve analysis (Figure 4.4-6) shows that mean flow has an exceedance probability of 59% while the median flow is 24 m^3/s.

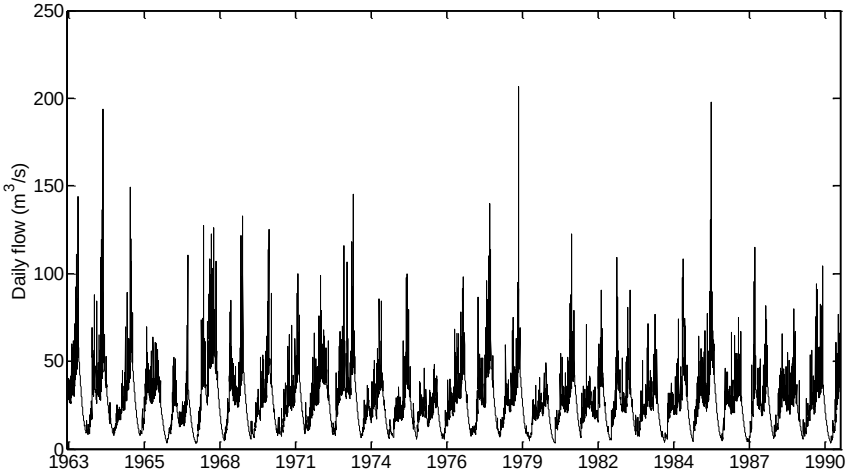


Figure 4.4-4: Daily flow variation, River Kanyaru

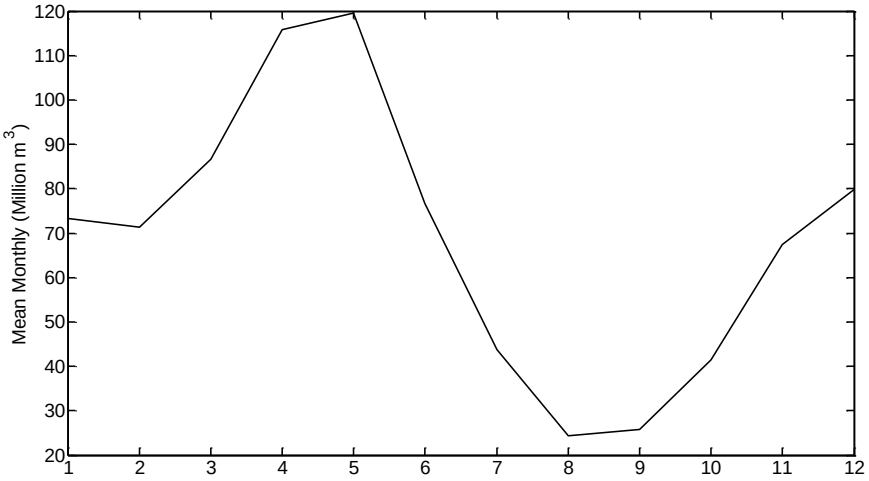


Figure 4.4-5: Mean monthly flow variation, River Kanyaru

The mean monthly total flows vary between 120 Million m^3 (Mm^3) in May and 24 Mm^3 in August (Figure 4.4-5). The total annual flow averages about 826 Mm^3.

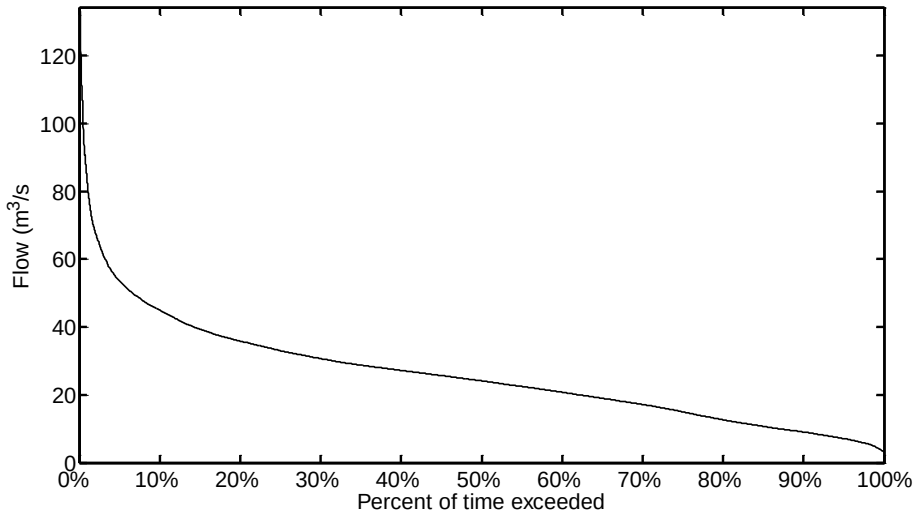


Figure 4.4-6: Flow duration curve, River Kanyaru

4.4.4.3 Reservoir

Using a 30m digital elevation model (DEM) of the area, reservoir elevation-area and elevation-volume curves were prepared and are shown in Figure 4.4-7 and Figure 4.4-8 respectively. The figures show that the inundation area and volume of reservoir increases steadily with elevation up to an elevation of 1435 m asl. After computation of the available runoff at the site, and also taking into consideration of the site geometry, it was decided to fix the top reservoir level to 1412m asl.

A reservoir elevation of 1412 m asl will inundate 1489 ha of land and will have a total volume of 333.9 million cubic meters of water. The reservoir fetch will be 10 km along the main river while the average width of the reservoir will be about 0.8km.

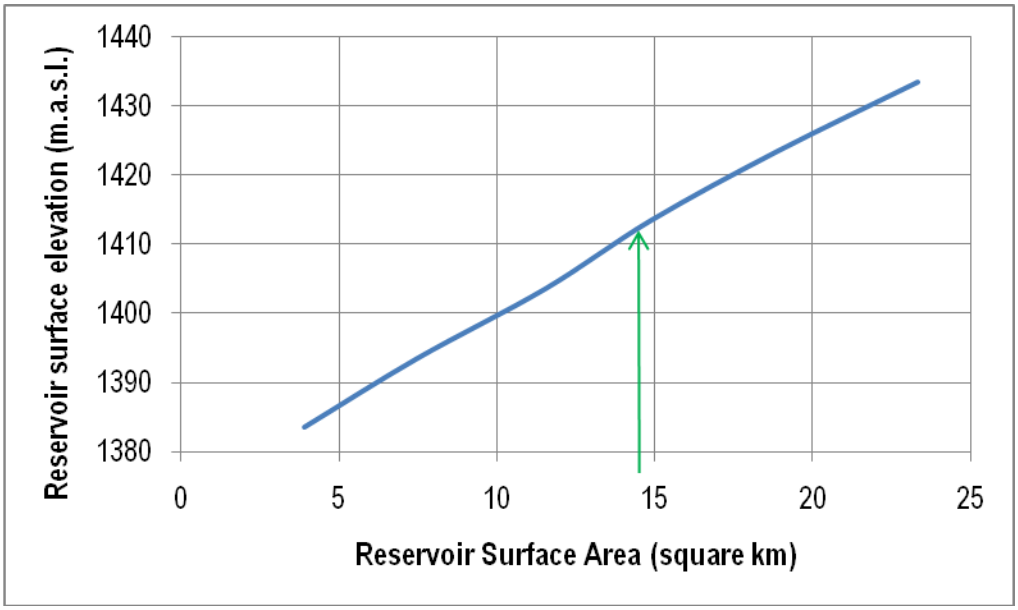


Figure 4.4-7: Plot of reservoir surface elevation versus reservoir surface area, Kanyaru project

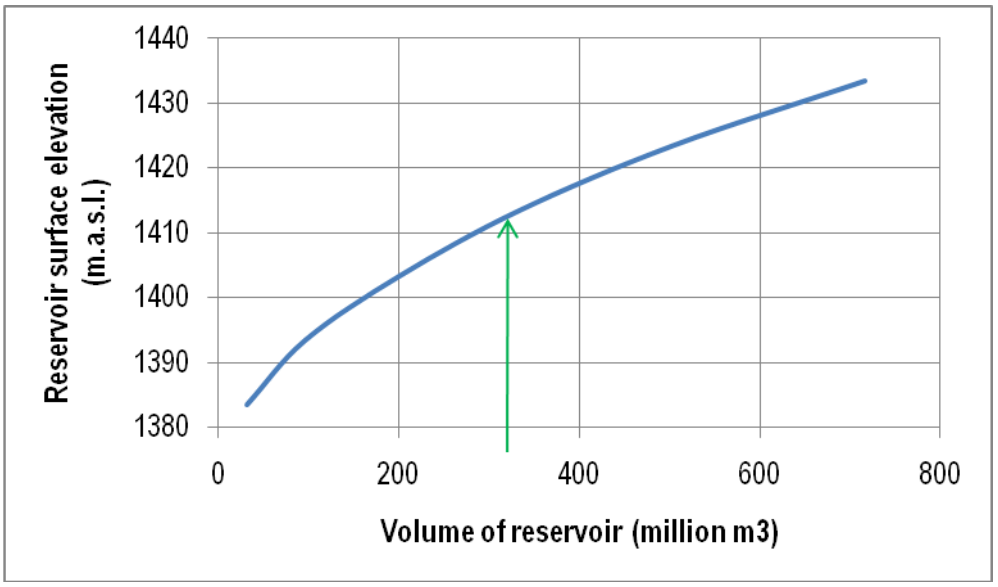


Figure 4.4-8: Plot of reservoir surface elevation versus reservoir volume, Kanyaru project

4.4.4.4 Reservoir inundation

A total area of 19 km2 would be inundated by the Akanyaru reservoir and would result in resettlement of about 8,500 people (Table 4.4-4)

Table 4.4-4: Land area to be inundated by the Akanyaru reservoir and the affected population

Country	Province	Commune	Population density (per km2	Land area (km2)	Population (2012)

Burundi	Ngozi	Busiga	454	1.2	528
		Mwumba	540	6.4	3,433
Rwanda	Butare	Kibayi	376	6.8	2,572
		Kigembe	425	4.1	1,726
		Muganzi	381	0.2	64
		Nyaruhengeri	523	0.3	136
Total (reservoir inundation)				**18.8**	**8,459**

4.4.4.5 Reservoir evaporation

Being an open water body, the reservoir evaporation rates would be expected to be close to the potential evapotranspiration rates. Table 4.2-3 shows the daily and monthly potential evaporation rates estimated from meteorological stations located close to the Kanyaru dam site.

Table 4.4-5 Daily and monthly potential evaporation rates, Kanyaru project

Month	Daily Evaporation	Monthly Evaporation (mm)
Jan	2.7	83
Feb	2.7	74
Mar	2.8	86
Apr	2.5	76
May	2.7	82
Jun	3.0	89
Jul	3.6	112
Aug	4.1	127
Sep	3.9	117
Oct	3.5	108
Nov	2.7	81
Dec	2.3	73
Annual	3.0	1107

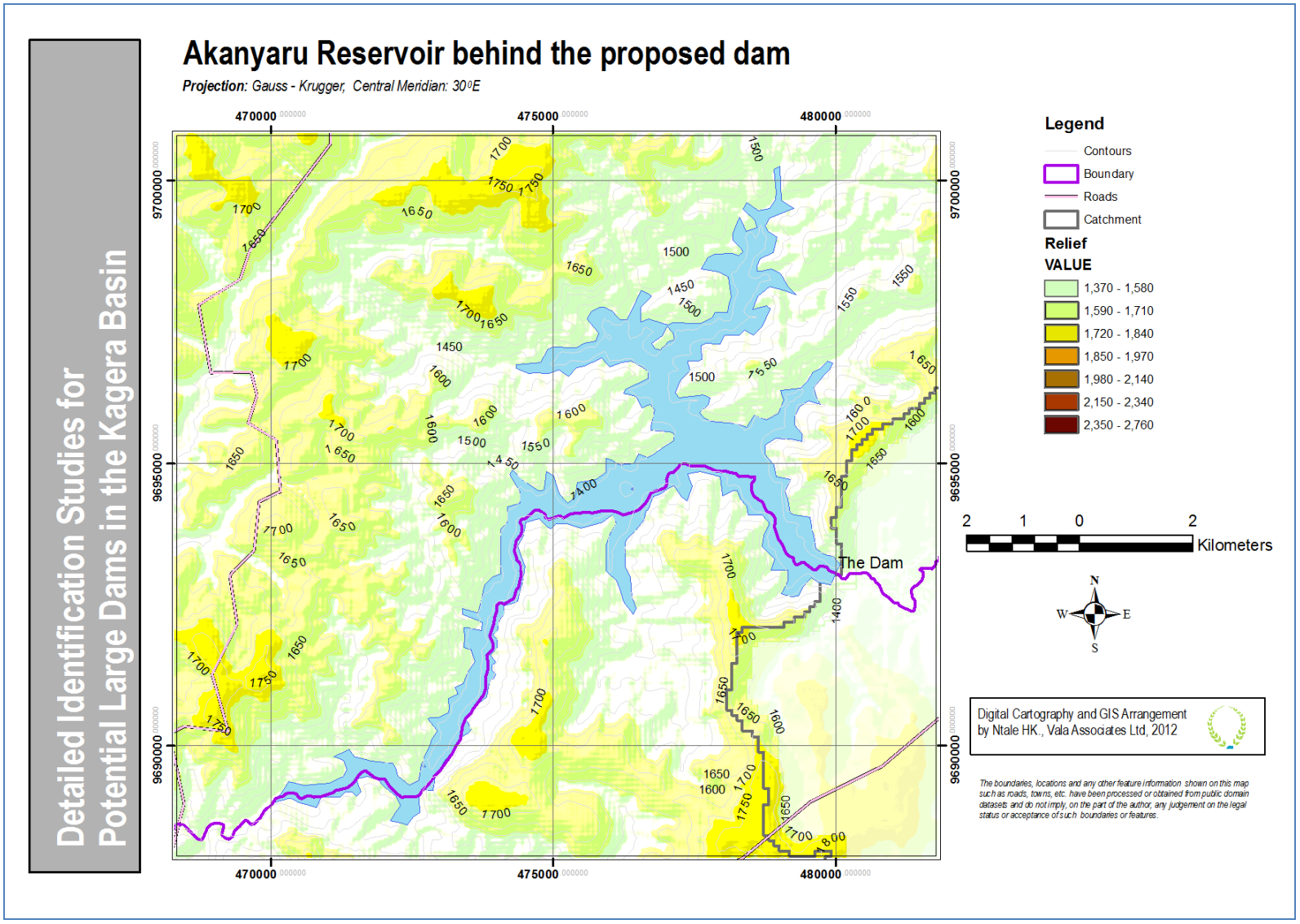


Figure 4.4-9 Kanyaru Reservoir at 1412m above sea level

4.4.4.6 Sedimentation

Using the approach suggested by Lawrence et al (2004), sedimentation yields for the Kanyaru catchment contributing to the dam site was established to be 1,467 t/km^2/yr. The dead storage properties of the dam are shown in Table 4.3-3 below:

Table 4.4-6 Kanyaru Sediment Properties

Site Name	Kanyaru
Reservoir Volume (Mm^3)	333.9
Catchment area (km^2)	1728
S_Y (t/km^2/yr)	1,467
Assumed Sediment density (t/m^3)	1.1
Dead Volume (Mm^3)/yr	0.82
Dead storage after 50 years (Mm^3)	40.96
Percentage of Reservoir filled with sediment after 50 years	12%

4.4.4.7 Floods

The annual maximum series model was used for flood frequency analysis. The following approach was used:

- Selection of the maximum 24-hour flows from the measured flow at Kanyaru gauging station;
- Selection of the distribution that best fits the data. Lognormal distribution was shown to provide an acceptable fit to the annual maximum data (Figure 4.2-14); and
- Estimation of the flood magnitudes corresponding to various return periods (Table 4.2-5).

Table 4.4-7: Akanyaru flood estimates and associated return periods

Return period, T (years)	Flood magnitude (m3/s)	Risk of failure for a 50 year design life (%)
50	225	63.6
100	248	39.5
200	271	22.2
500	302	9.5
1000	325	4.9
2000	349	2.5
5000	381	1.0
10000	406	0.5

4.4.5 Dam Design elements

4.4.5.1 Dam Type

The dam at Kanyaru has been designed as a Rock fill dam with a roadway on top and an Ogee spillway section. The dam foundation will be located firm basement rock assumed to be 5 m below the ground level in the current design.

Table 4.4-8: Kanyaru dam design

Variable			Units	Value
Dam location				Kanyaru
Dam type				Rockfill
Reservoir base elevation			m asl	1363.5
Reservoir top elevation			m asl	1412.0
Reservoir depth at above dam base (Hnet)			m	48.5
Free board (Flood control pool + 3% of dam height)	Flood control pool (flood height above spillway crest): 1.5m 3% of dam height (for wave action, etc): 2m	3.5	m	3.5
Dam height H			m	52.0
Crest elevation			m asl	1415.5
Spillway crest elevation			m asl	1412.0
Crest length			m	513
Top width (7-12 m depending on dam height)			m	9

4.4.5.2 Spillway

The spillway will be of the unregulated Ogee type. It will be located on the left side of the dam. The inlet to the spillway will be shared with the power station inlet. Table 4.2-7 shows the main design parameters of the spillway. The spillway will discharge via a flared ski-jump into an existing an existing pond below the dam.

Table 4.4-9: Spillway design parameters, Kanyaru project

Variable	Units	Value	Check	
			Criteria	Value
Spillway type	Gated Ogee			
Return period	years	10,000		
Reservoir maximum elevation	m asl	1,412		
Design flood	cumecs	406		
Discharge coefficient, Cd (assumed)		1.7		
Spillway crest length, L	m	50.0		

Head on spillway, H	m	3.0		
Spillway discharge, Q=Cd*L*H^(3/2)	cumecs	441.7	>= design flood	Ok
Spillway crest elevation	m asl	1,409.0		

4.4.5.3 Power station

With a head of 40m, it is possible to harness hydropower at the site, while at the same time irrigating the downstream basins. The power station will be a surface concrete structure equipped with 2 turbines each with a rated power of 7.25 MW.

Table 4.4-10: Hydropower estimation, Muvumba project

Variable	Value	Units
Rated reservoir level	1412	m asl
Tailwater level	1363.5	
Head	48.5	m
Mean flow	26	m3/s
Rated flow (30% higher than mean)	33.8	m3/s
Plant efficiency	90%	
Power	14.5	MW
Energy	126.8	GW/year
Turbine type	Kaplan	
Number of turbines	2	
Flow for each turbine	16.9	

The proposed hydropower station at the Akanyaru site has the potential to produce 127 GWh of energy per year which is enough to supply about 141,111 houses and over 846,000 people.

4.4.5.4 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. Good quality concrete aggregates can partly be obtained from alluvial deposits in the river valley. However, the bulk of the aggregates may be obtained from a quarry opened above the left or right flanks of the river valley. Investigations may reveal that there may be other locations with better material quality and economic haul distances. Random fill for the cofferdams will be obtained from foundation stripping operations.

4.4.6 Irrigation and command area

The Kanyaru site is very suitable for irrigation immediately downstream of the dam. There is already intensive farming in the Akanyaru valley. Availability of water all year around would enable the valley residents to engage in more profitable agriculture. Figure 4.3-7 below shows the potential command area (12479 ha) located in the provinces shown in Table 4.4-11. which can be directly irrigated using the Kanyaru reservoir waters. The

command area can support 24,948 farmers and provide food for about 124,740 people. The annual water demand for irrigation is about 62 Mm^3.

Table 4.4-11: Irrigation command area for Akanyaru

Country	Province	Commune	Area (ha)
Burundi	Kirundo	Ntega	2,550
	Ngozi	Marangara	3,735
		Mwumba	230
		Nyamurenza	1,990
Rwanda	Butare	Kibayi	2,274
		Muganzi	1,695
Total irrigable area			**12,474**

4.4.7 Water Supply

The total population that can benefit from water supply from the Akanyaru project in 2012 and 2062 was estimated at 614,202 and 2,340,902 people respectively (Table 4.4-12). The annual water demands are 7 Mm^3 and 26 Mm^3 for 2012 and 2062, respectively.

Table 4.4-12: Potential water supply beneficiaries for Akanyaru

Country	Province	Commune	Population (2012)	Population (2062)
Burundi	Kayanza	Kayanza	77,324	292,979
	Kirundo	Ntega	76,160	288,568
	Ngozi	Busiga	55,994	212,161
		Gashikanwa	50,857	192,696
		Marangara	67,140	254,391
		Mwumba	64,307	243,659
		Ngozi	98,551	373,409
		Nyamurenza	51,332	194,497
Rwanda	Butare	Kibayi	5,501	21,884
		Kigembe	16,757	66,658
		Muganzi	16,758	66,662
		Ndora	16,759	66,666
		Nyaruhengeri	16,760	66,670
Total (Water supply)			**614,202**	**2,340,902**

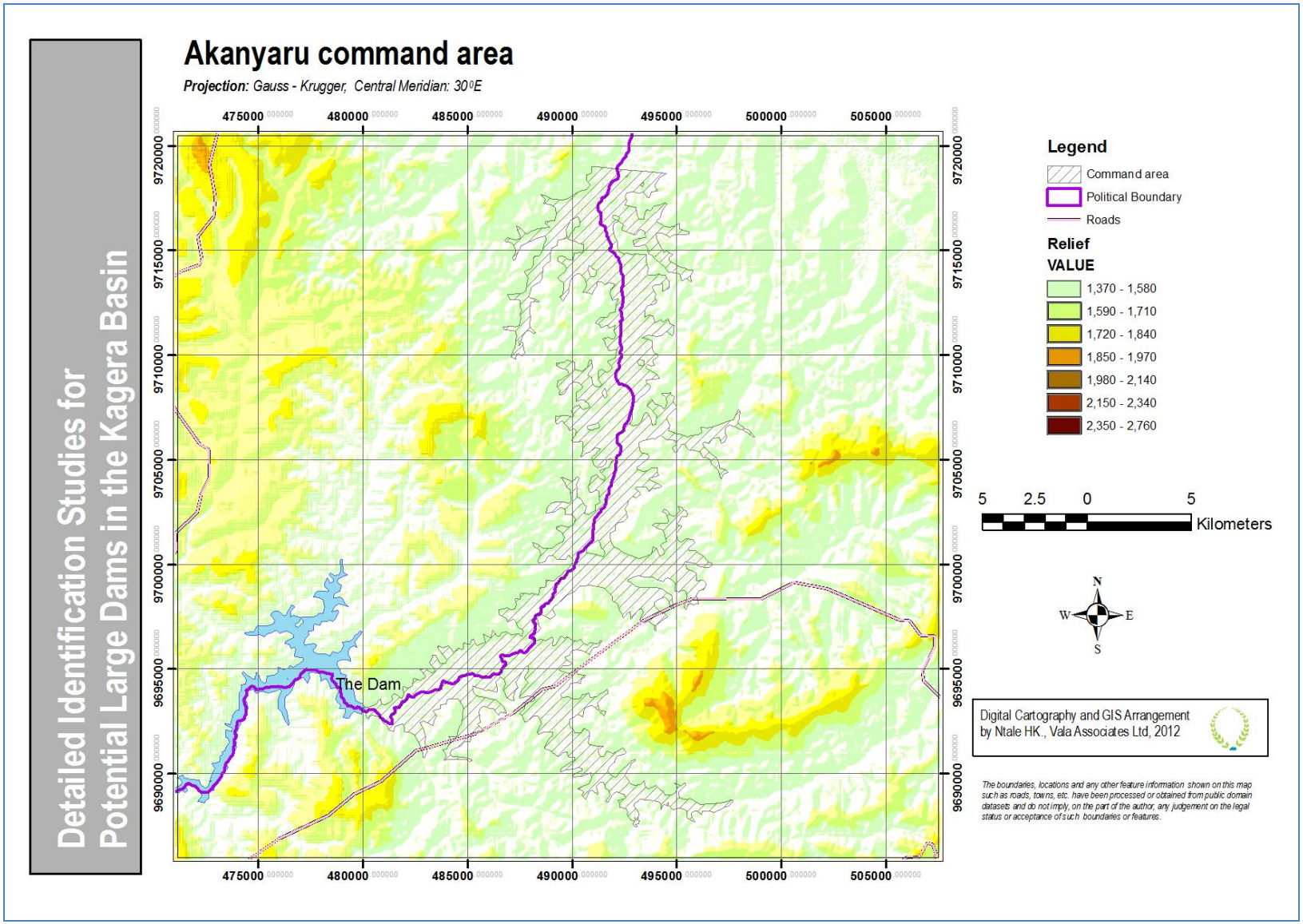


Figure 4.4-10 Kanyaru Command area

4.4.8 Project costs

The estimated costs for the Akanyaru project total to 92 million US dollars as broken down in Table 4.4-13 below. The Project is truly multipourpose with good potential for Hydropower. It has also has vast potential of irrigation command area.

Table 4.4-13 Akanyaru Project Costs

AKANYARU DAM PROJECT CONSTRUCTION COSTS					
No	Item	Units	Quantity	Rate (USD)	Amount (USD)
1.0	**PREPARATORY WORKS**				
	Mobilisation and demobilisation	Lumpsum	1	1200000	1200000
	Permanent access	km	7	100000	700000
	Temporary access	Lumpsum	1	100000	100000
	River diversion during construction	Lumpsum	1	800000	800000
	Resettlement and compensation	ha	1885	2500	4712500
	Subtotal				**7512500**
2.0	**MAIN DAM**				
	Excavation, loose	m3	106000	15	1590000
	Excavation, rock	m3	27000	22	594000
	Foundation preparation	Lumpsum	1	500000	500000
	Dam rock fill	m3	831000	45	37395000
	Dam dry bubble wall	m3	58000	65	3770000
	Dam reinforced concrete lining and cutoff	**m3**	**10000**	**350**	**3500000**
	Subtotal				**47349000**
3.0	SPILLWAY, INTAKE, AND PENSTOCKS				
	Excavation, loose	m3	13000	15	195000
	Excavation, rock	m3	52000	22	1144000
	Concrete Spillway	m3	25000	200	5000000
	Concrete intake	Lumpsum	1	250000	250000
	Penstocks, 2No @ 7 m2 steel	m	170	1500	255000
	Other civil structures	**Lumpsum**	**1**	**500000**	**500000**
	Subtotal				**7344000**
4.0	POWER STATION				
	Excavation, loose	m3	7500	15	112500
	Excavation, rock	m3	7500	22	165000
	Reinforced concrete power station	m3	10000	350	3500000
	Other civil works	**Lumpsum**	**1**	**500000**	**500000**
	Subtotal				4277500
5.0	MECHANICAL AND ELECTRICAL WORKS				
	Turbines (2x6MW Francis) and miscellaneous mechanical equipment	Lumpsum	1	3000000	3000000
	Generators, transformers and miscellaneous electrical equipment	Lumpsum	1	2600000	2600000
	Gates for intake, outlet	Lumpsum	1	1200000	1200000

AKANYARU DAM PROJECT CONSTRUCTION COSTS					
No	Item	Units	Quantity	Rate (USD)	Amount (USD)
	Switchyard	**Lumpsum**	**1**	**300000**	**300000**
	Subtotal				**7100000**
	TOTAL, CONSTRUCTION COST				73583000
	ADMINISTRATION AND ENGINEERING		0.1		7358300
	CONTINGENCIES		**0.15**		**11037450**
	CAPITAL COST (WITHOUT VAT)				**91978750**

4.4.9 Anticipated Impacts and Mitigation Measures for the Akanyaru project

4.4.9.1 Positive Impacts

The following are some of the anticipated positive impacts of the dam project. They are:

- The dam will provide electricity which will facilitate the growth of the economy of the area and improved livelihoods in the communities
- The dam will facilitate cultivation of crops to be done throughout the year and that will guarantee household income for the communities and also food security in Kanyaru areas;
- The Dam will control floods in the areas downstream of the river systems;
- The establishment of dam will lead to improved access in terms of roads that will equally be improved to facilitate delivery of construction of the dam facility;
- Women will likely benefit from smallscale trading especially preparation and sale of food to the workers on the project;
- The project will bring about community developments such as agro-processing facilities whoch likely be established once electricity will be generated in the facility;
- There will likely be induced benefits accruing from the facility such set up of restaurants and accommodation facilities for the workforce;
- It is equally anticipated that, the dam will attract development into the area in terms of planned settlements and business outlets; and
- During construction phase, the communities will get benefits in terms of employment and source of income through sale of food items to the workforce.

4.4.9.2 Negative Impacts

At this stage of the study, the preliminary potential impact examination has identified the following impacts:

- The dam works will likely displace farmers on their marshlands thereby depriving them of their area of livelihood. This is a fundamental impact that can have long term implications in terms of food security. During this IESE, the study team observed poor state of the crops giving impression that, the yields are likely to be poor hence, the heavy reliance of the communities on the marshlands for farming activities;

- It is noted that, the dam will be shared between Rwanda and Burundi and each of these countries rely on the River for irrigation and livestock. If the place is dammed, it will likely bring about some conflicts in terms of grazing and water supply for livestock and farming purpose in the communities;
- During the construction of the dam, there is likely to be impacts on the communities in nearby areas especially through the neighbouring trading centre during the market days when communities conduct business by the roadside;
- The dam construction will interfere with the community water sources downstream. In addition, social issues regarding land availability and sharing will be crucial for the success of the project;
- The erosion of river banks could be an issue due to the Project since areas around the site are heavily farmed; and
- Loss of vegetation through clearances of the sites and access roads;
- Sedimentation transport could be an issue as the annual sedimentation is quite important, leading the site likely exposed to siltation. Thus, it should be taken into consideration during the ESIA as the area is highly cultivated;
- Noise and vibrations from equipment operations as well as air quality concerns;
- Pollution of water sources from loose soils, and agro-chemical residual impacts;
- HIV/AIDS issues among the workforce and the communities; and
- Water diseases through establishment of the dam could potentially occur and such diseases include malaria amongst others.

One of the tasks of this assignment is preliminary identification of potential environmental and social impacts of the project and proposing mitigation measures. At this point, the consultant has identified some key impacts as well as proposing mitigation measures to address such concerns and have been summarized in Table 5.1 as follows:

Key impacts and mitigation measures for the planned the Proposed Kanyaru Dam site

Nº.	Project Impact	Mitigation measures
01.	Loss of marsh and cropland areas due to inundation where rice fields are in place. The marshlands are cropped by a cross-section of communities including farmers. In addition, women are involved in farming and as a vulnerable group, they are likely to very much impacted by loss of the marshland.	Compensation for loss of crop and issuing early notice to farmers to harvest crops.
02.	Impact on the roadside communities likely to be impacted by construction equipment during transportation.	Arrangements should be made to widen access road to the site to easy transportation of equipment.
03.	Land uptake through construction of the dam and access roads, camp sites, etc	Compensation for land uptake after Resettlement Action Plan (RAP) studies.
04.	Concerns relating to management of excess cut to spoil materials during construction phase of the project.	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
05.	Loss of marsh and cropland areas due to inundation where rice fields are in place.	Compensation for loss of crop and issuing early notice to farmers to harvest crops

No.	Project Impact	Mitigation measures
06.	Loss of vegetation through clearances of the sites and access roads.	Restrict clearances to work/designated portions or areas. Compensatory planting of trees by the projects.
07.	Potential conflicts in water use due to a multiplicity of users (power generation, water supply and irrigations needs including local domestic uses). Some sections of the river have a number of dams and the planned ones will add to such existing dams along the same river system there by putting stress on water supply process. In addition, being transboundary project, cross-border water issues are likely to arise amongst the communities.	Put in place site-based sectoral committees to handle equitable and rational use of water in the project. There is need to plan the development of this dam sites while ensuring that the needs of other users are taken care of. It is proposed that the detailed ESIA assess this impact further and proposes appropriate measures to address this concern in a participatory manner
08.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
09.	Pollution of water sources from loose soils, and agro-chemical residual impacts.	Impacts of water quality from agro-chemicals have to be mitigated through monitoring water quality parameters during the project phases.
10.	Equipment related concerns in terms of oil spillages, used batteries and oil filters as well as used tyres.	Preparing decommissioning plan and site restoration and re-grassing.
11.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
12.	Noise and vibrations	Noise from equipment and the workforce
13.	HIV/AIDS impacts due to influx of people in search of work opportunities in the project.	Contractors to work with HIV/AIDS service providers to sensitize communities on HIV/AIDS.
14.	Air Quality concerns likely to arise from project works	In addition, HIV/AIDS concerns needs to addressed in a fairly wider sectoral perspective involving the health sector in the area through which, the project could give some support to the nearby existing health facilities so that, they can handle after effects of the construction phase of the project.
15.	Possible increase in crime rate in the areas of the project.	Dust suppression measures will be instituted to ensure air quality levels are kept appropriate.
16.	Impacts on socio-cultural sites	Working together with the police and law enforcement agencies to control

No.	Project Impact	Mitigation measures
		crime in the areas.
17.	Impacts on biodiversity areas of high conservation concerns (Important Bird Areas-IBAs, national and central forest reserves etc).	No immediate noted during the IESE study, it should be further assessed in detailed ESIA.

4.5 Mbarara Dam Site

4.5.1 Physical Environmental Profile

4.5.1.1 Location

The site is situated at Latitude 2° 57' 34.26''S and Longitude 29° 42' 54.24''E, in Burundi on the Mbarara River in the district of Gahambo, Kinyonga village, Ngozi province (Figure 4.5-1 and Plate 4.5-1 below). It has an estimated catchment area of 31 km^2 and potential reservoir capacity of 9.5 Mm^3. The site has a potential maximum head of 17 m. The site is located in a valley surrounded by three blocks of hills on its east, west and north frontiers. The primary potential use of the project is irrigation. Hydropower production at this site is not viable; besides there is a much better hydropower site 4.5km downstream on the same river.

The marshland has been reclaimed for cultivation of sweet potatoes, maize and some sections have tobacco and these crops are all for domestic consumption. The site had originally been developed by the Catholic Relief Services (CRS) through construction of irrigation channels and a protected well. The project also constructed a facility for washing clothes by the communities. From the consultations, when project support ended in 2008, the communities were unable to maintain the channels and to date; a number of them are malfunctioning. **There are no protected areas in the vicinity of the site.**

Plate 4.5-1 Mbarara Dam site, viewed from upstream. The dotted line shows the proposed dam axis.

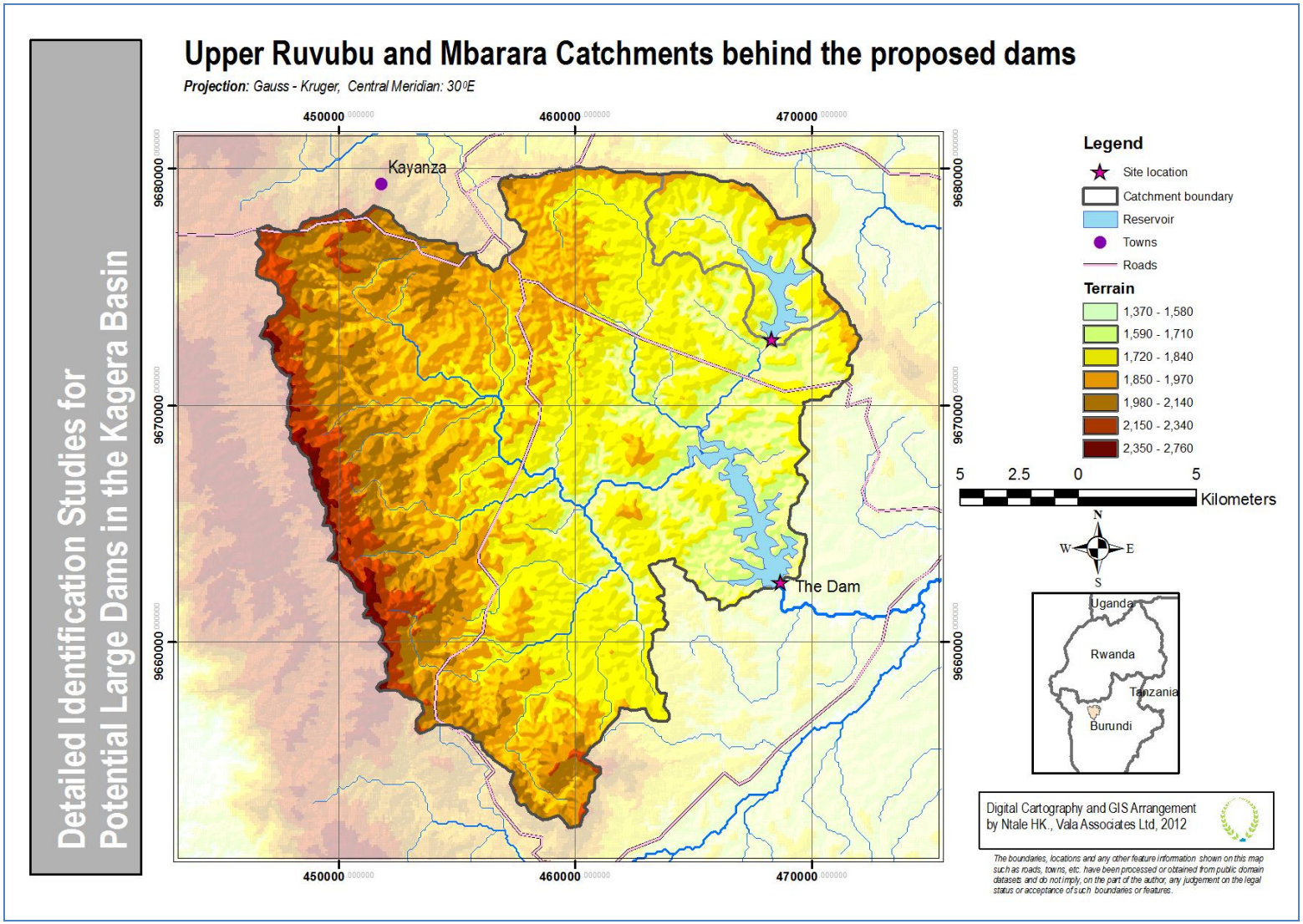


Figure 4.5-1 Mbarara and Upper Ruvubu Catchments (The Mbarara sub catchment is in the right top corner)

Plate 4.5-2 Part of irrigation infrastructure constructed by CRS.

(a) **(b)**

Plate 4.5-3 (a) Cultivation in some sections of Mbarara marshland (b) Fields of sweet potatoes on the marshland

4.5.1.2 Vegetation

The vegetation is largely of agro-based type and comprises woodlots of eucalyptus, bananas and coffee. The woodlots are mainly for supply of construction materials and wood fuel. The communities also cultivate beans and cassava though the harvests seem poor; a sign that the soils are less productive. ***The vegetation in the area is not rare, endangered or threatened; hence implementation of the project will have minimal impacts on the areas.***

Plate 4.5-4 Woodlots in the background and in the foreground a woman returns with fuel wood on the head.

4.5.1.3 Climate

Available data indicates that the basin receives a mean annual rainfall of 1204 mm. The mean monthly rainfall distribution is bimodal with two rainy seasons. The long rains occur from March to May while the short rains occur between September and November but can sometimes extend to December. The maximum rainfall is received in April and averages 179 mm while maximum rainfall in the short rainy season is received in November and averages 172 mm. July is the driest month, receiving only 4 mm of rainfall. The mean annual potential evaporation is 1107 mm and varies over a narrow range between 127 mm in August and 73 mm in December. The mean monthly temperature ranges between 17.5°C in June and 20°C in September.

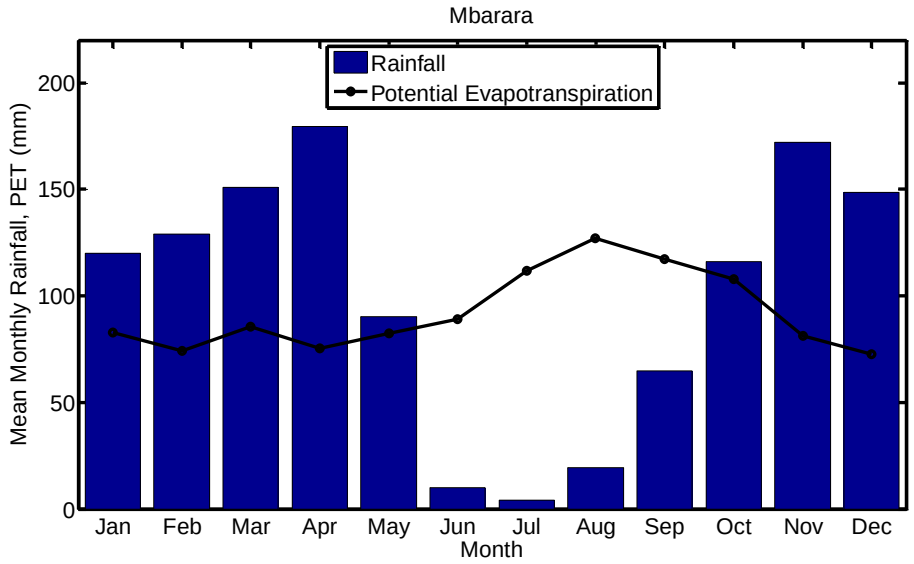


Figure 4.5-2 Mbarara catchment mean monthly rainfall and potential evaporation

4.5.2 Social Environment Profile

4.5.2.1 Demographics and trends

Data on the population of the Ngozi take into consideration the 2003-2010 population projections made by the Planning Unit of the Population (PUP) based on natural growth rates specific to each Province considered constant during the period 1990-2010. The rate of population growth in the province of Ngozi is 0.0292. According to the PUP, in 2005 the population of the Ngozi municipality alone was estimated to 107,613 inhabitants. This population is spread over an area of 184.46 km2 (10% of province), where its average density is 593 inhabitants / km 2, higher than the average density of the province (475 /km^2). This density is the highest in the province.

Table 4.5-1 Distribution and Population Density by Municipality

Municipality	Total population	Surface area in square meters	Density/km2
Busiga	72.828	121.32	600
Gashikanwa	59.798	142,78	419
Kirenga	95.854	243,43	394
Mrangara	73358	182,29	402
Mwumba	77628	128,70	603
Ngozi	107416	184,46	582
Nyamurenza	63078	96,98	650
Ruhororo	72429	154,10	470
Tangara	78049	219,80	355
Total Province	700.438	1.473,86	475

Source: Mininter/UPP 2006)

The population distribution by age group and gender " shows that:

- Women outnumber men; they represent 51% of population;
- The population of Ngozi is extremely young: 67,679,470 or 63% of the population are aged under 25;
- The elders over 60 years are 6015 or 5.6% for the Ngozi population; and
- The labor force is estimated at 53,988 (50.2%) and is in charge of 53,428 being 49.8% of the total population of Ngozi. This means that a person active must support more than one person, one younger or older.

In 2005, the population of Kayanza municipality was estimated to 107.416. The prospects for the year 2010 indicate that the population will reach 127,000, an increase of 18.2% between 2005 and 2010. The population of the Ngozi municipality observed a high growth rate. All things being equal, this extremely rapid growth will have a negative impact on the economy of Ngozi.

4.5.2.2 Housing

The area has semi-permanent house structures which comprise units with locally made tiles and the walls are of mud and wattle. There are no permanent house structures except for public institutions such as schools. The homesteads are surrounded by crops such as bananas and woodlots. Some structures are from banana leaves which constitute roofs.

(a) **(b)**

Plate 4.5-5 (a) A typical house in the areas of the project (b) Homestead surrounded by bananas and woodlots

4.5.2.3 Agriculture and Livestock

In the Ngozi Province and Ngozi municipality, all agricultural activities are practiced by farmers using non improved traditional methods characterized by the sowing on small areas, an average of less than 50 acres per household, use simple tools (hoe), and deficiency in chronological inputs and improved by the use of a mainly family labor. The result yields generally low and a production that generates little revenue. Speculations are grouped into agricultural crops, industrial, vegetables and fruit.

According to data provided by the "*Direction Provinciale de l'Agriculture er de l'elevage" (DPAE)* of Kayanza, the main food crops by order of importance are: cassava, sweet potatoes, bananas, beans, maize, rice and potatoes. Other food crops are also harvested, but at a lower level. These are peanut, soybean, etc

The only industrial crop found in the surrounding of the site is coffee. It is an important source of cash income for most households. The framing of Coffee Growers of Ngozi is provided by OCIBU which makes available to growers pesticides and fertilizers in the form of seasonal loans.

The farming practiced in Ngozi is of traditional type and constituted of cattle, goats, sheep, pigs and poultry. The animals in the hills of Ngozi are predominantly of the breed Local "Ankole" for cattle. No sheep from improved breeding. These animals rarely benefit from basic health care and a dietary supplement. Some cultivated lands of "*Tripsacum laxum*" or "*Penissetum"* can be seen at different areas and are planned to be used especially during the dry season.

The communities in the area are engaged in subsistence cultivation of food crops such as maize, beans, coffee, bananas and sweet potatoes (Plate 4.5-6). From the reconnaissance visits, the soils in the area appear poor implying harvests are poor which has made many

of the people to farm in the marshland. The planned development of the marshland will help the communities to improve food security.

Plate 4.5-6 Garden with beans. Note the poor lateritic soils.

4.5.2.4 Energy

The municipality of Ngozi is supplied with electricity through the central of Rwegura through the power line Kayanza-Ngozi for 1530 connections. The power line is served by DGHR through the power lines Burenge-Mivo for 45 connections, Mivo-Mubuga for 34 connections and Mubuga-Mureke for 11 connections.

Other sources of energy are generators and solar panels. It is important to note that, wood and oil remains the main source of energy for most of the population of the project areas and the province at large.

Plate 4.5-7 Stacks of wood fuel for sale

4.5.2.5 Transport

In the municipality and province of Ngozi, there are two types of transport: - The road transport by vehicles and bicycles; - The transport carriage.

Road transport is the most practiced. The province is crossed by different national roads among them the roads namely NR6 and RN8. It also opened up by rural roads and provincial roads most of which are in poor condition due to inadequate maintenance and soil transported by erosion. Most vehicles and motorcycles are concentrated in the urban center of Ngozi.

The priority should be to maintain the following roads:

Ngozi-Ruhororo, Ngozi-Kanyaru Bas, Ngozi-Busiga and Ngozi-Kanyaru bridged with respective relays: Nyakijima, Akagoma, Nyakagezi, Vyerwa, Kanyaru Rugori, and Rukeco Nkaka.

4.5.2.6 Communication

In the province and municipality of Ngozi, there is a post office, private and public landlines. The area is also covered by 4 mobile telephone networks that are ONAMOB, Telecel, Africell, and Spacetel.

4.5.2.7 Water and sanitation

The communities do not have piped water sources and the only sources of water are marshlands including the Mbarara marshland. With reference to the planned site, the communities previously benefitted from water supply intervention by Catholic Relief Services (CRS) which constructed a protected spring for the communities alongside a

trough for washing clothes. The protected spring serves an estimated 80-100 homestead in the area based on local area residents. This shows the area is water stressed.

(a) **(b)**

Plate 4.5-8 (a) A protected well south edge of Mbarara marshland (b) Community members washing clothes around the protected well

While the standards for optimal water supply are for a water point for 500 meters or two water points per square kilometre, the assessment has revealed there is one water point for 0.12km^2, which is not satisfactory. And unfortunately most of the water points are concentrated in the town of Ngozi. Thus, the number of households per water point is 14. All these facilities are inadequate to serve the total population of Ngozi province. It should also be noted that the distribution of these facilities through the province and municipalities is uneven. The public should be sensitized to the regular maintenance and repair of water supply infrastructure.

4.5.3 Previous studies

Ntale (2011) considered some aspects of the Mbarara site in the study report titled “Rapid identification and assessment of potential sites for multipurpose storage reservoirs”, a report prepared for the Kagera River Basin Project.

4.5.4 Hydrology

4.5.4.1 The catchment

The catchment area of the basin upstream of the dam site is 30.69 km^2 and is wholly located in Burundi. The topography of the dam site is shown in Figure 4.5-1 below. The elevation of the riverbed at the dam site is about 1643 m asl. The catchment has a length of 11 km and an average width of about 2.5 km (Figure 4.5-1). The mean catchment slope is about 17.9% but the steepest slopes may be higher than 63%. The catchment elevation ranges between 1643 m asl at the dam site to over 1900 m asl while the mean is 1740 m a.s.l.

4.5.4.2 Runoff

Flow at the proposed dam site is not gauged. However, hydrological modeling using regionalized parameters shows that between years 1963 and 1990, the daily flow at the dam site ranged between 0.1 m^3/s on 8-September-1980 and 2.3 m^3/s on 19-February-1979 and averaged 0.53 m3/s. The mean flow has an exceedance probability of 53% while the median flow is 0.52 m^3/s.

The mean monthly total flows vary between 0.4 Million m^3 (Mm^3) in September and 2.2 Mm^3 in April (Figure 4.3-3). The total annual flow averages about 17 Mm^3.

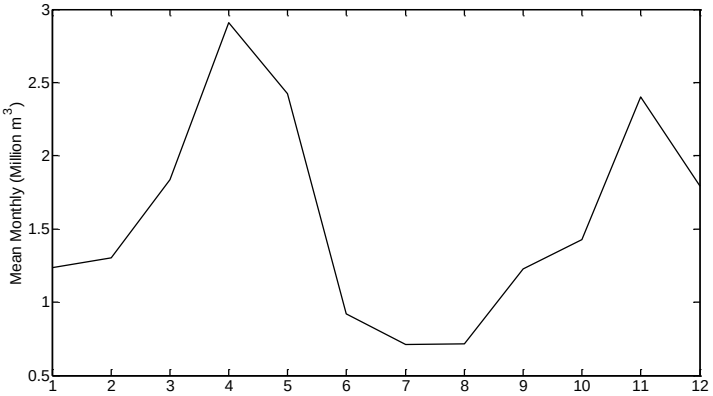


Figure 4.5-3 Mean monthly flow variation

4.5.4.3 Reservoir

Using a 30m digital elevation model (DEM) of the area, reservoir elevation-area and elevation-volume curves were prepared and are shown in Figure 4.2-11 and Figure 4.2-12 respectively. The figures show that the inundation area and volume of reservoir increases steadily with elevation up to an elevation of 1420 m asl. After computation of the available runoff at the site, and also taking into consideration of the site geometry, it was decided to fix the top reservoir level to 1659.5 m asl.

A reservoir elevation of 1659.5 m asl will inundate 157 ha of land and will have a total volume of 9.9 million cubic meters of water. The reservoir fetch will be 4.5 km along the main river while the average width of the reservoir will be about 0.5km.

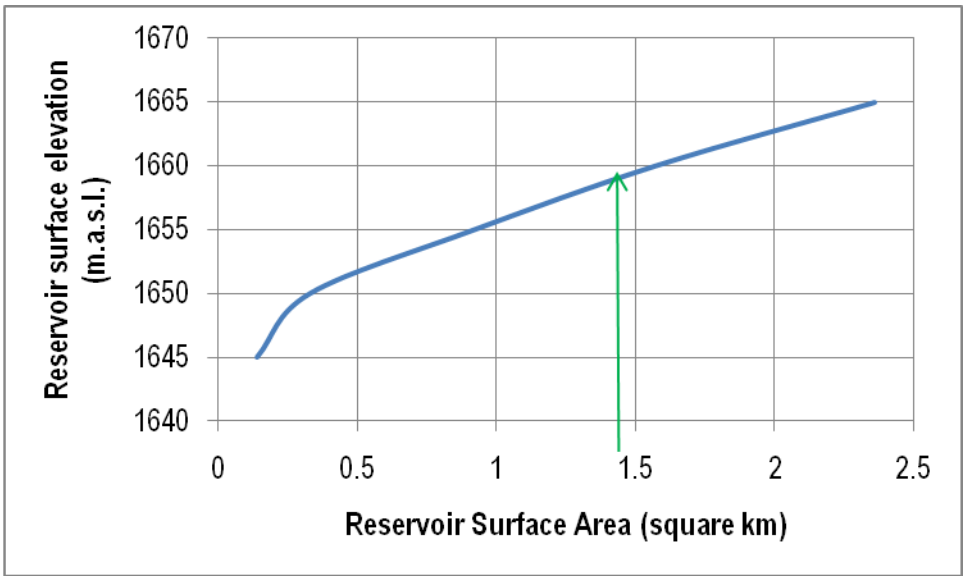


Figure 4.5-4: Plot of reservoir surface elevation versus reservoir surface area, Mbarara project

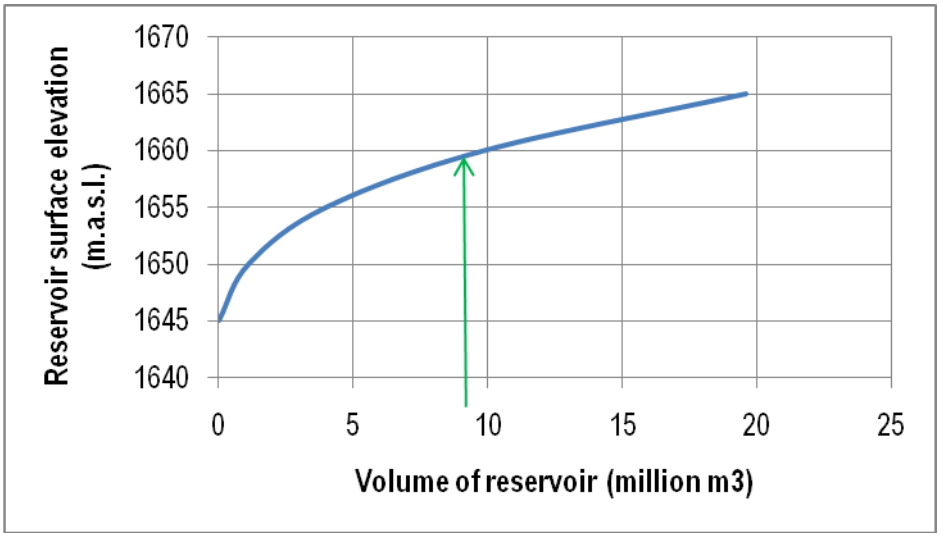


Figure 4.5-5: Plot of reservoir surface elevation versus reservoir volume, Mbarara project

4.5.4.4 Reservoir evaporation

Being an open water body, the reservoir evaporation rates would be expected to be close to the potential evapotranspiration rates. Table 4.1-2 shows the daily and monthly potential evaporation rates estimated from data at 1 meteorological stations located close to the Mbarara dam site.

Table 4.5-2 Daily and monthly potential evaporation rates

Month	Daily Evaporation (mm)	Monthly Evaporation (mm)
Jan	2.7	83
Feb	2.7	74
Mar	2.8	86

Apr	2.5	76
May	2.7	82
Jun	3.0	89
Jul	3.6	112
Aug	4.1	127
Sep	3.9	117
Oct	3.5	108
Nov	2.7	81
Dec	2.3	73
Annual	3.0	1107

4.5.4.5 Sedimentation

Using the approach suggested by Lawrence et al (2004), sedimentation yields for the Mbarara catchment contributing to the dam site was established to be 1,145 t/km^2/yr. The dead storage properties of the dam are shown in Table 4.3-3 below:

Table 4.5-3 Mbarara Sediment Properties

Site Name	**Mbarara**
Reservoir Volume (Mm^3)	9.9
Catchment area (km^2)	31
SY (t/km^2/yr)	1,145
Assumed Sediment density (t/m^3)	1.1
Dead Volume (Mm^3)/yr	0.03
Dead storage after 50 years (Mm^3)	1.61
Percentage of Reservoir filled with sediment after 50 years	16%

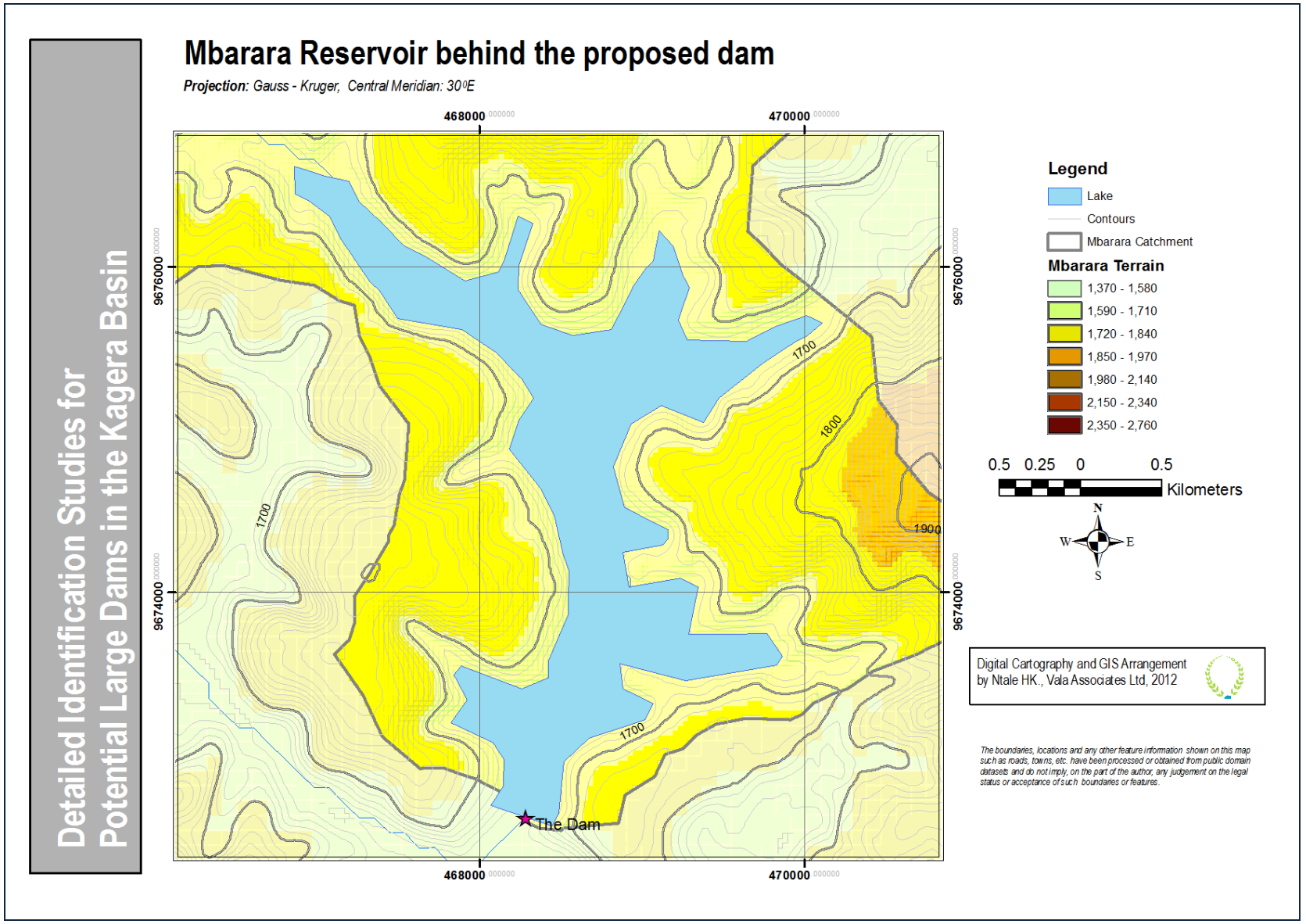


Figure 4.5-6 Mbarara Reservoir at 1659.5m above sea level

4.5.4.6 Floods

The annual maximum series model was used for flood frequency analysis. The following approach was used

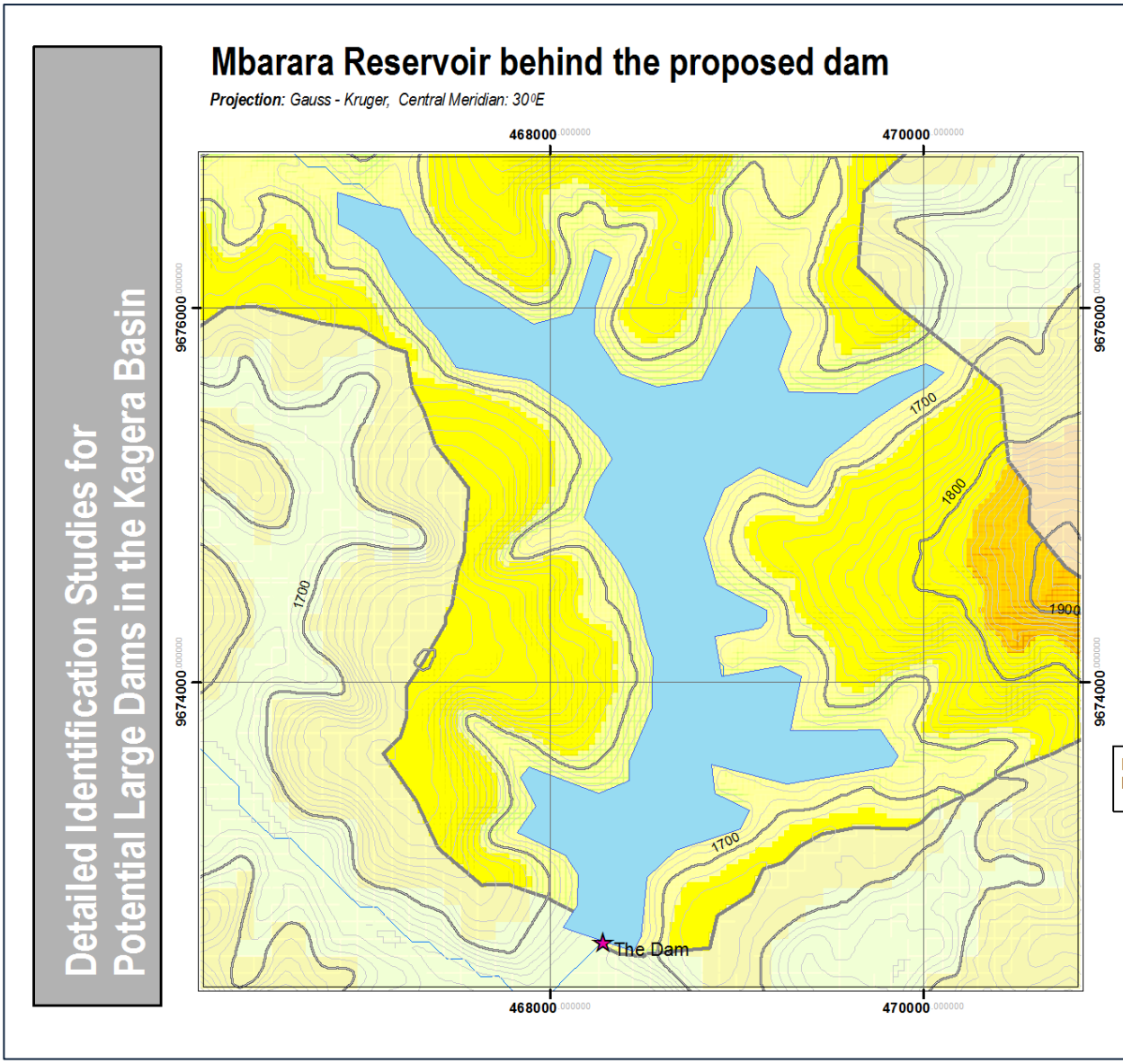
(i) Selection of the maximum 24-hour flows from the measured flow at Mbarara gauging station

(ii) Selection of the distribution that best fits the data. Lognormal distribution was shown to provide an acceptable fit to the annual maximum data

(iii) Estimation of the flood magnitudes corresponding to various return periods (Table 4.2-5)

Table 4.5-4: Mbarara flood estimates and associated return periods

Return period, T (years)	Flood magnitude (m^3/s)	Risk of failure for a 50 year design life (%)
50	2.4	63.6
100	2.6	39.5
200	2.8	22.2
500	3.0	9.5
1000	3.2	4.9
2000	3.3	2.5
5000	3.5	1.0
10000	3.7	0.5



4.5.5 Dam Design elements

4.5.5.1 Dam Type

The dam at Mbarara has been designed as an earth fill dam with a roadway on top and an Ogee spillway section. The dam foundation will be located firm basement rock assumed to be 5 m below the ground level in the current design.

Table 4.5-5: Mbarara dam design

Variable	Units	Value
Dam location		Mbarara
Dam type		Earth Dam
Reservoir base elevation	m asl	1643
Reservoir top elevation	m asl	1659.5
Reservoir depth at above dam base (Hnet)	m	16.5

Free board (Flood control pool + 3% of dam height)	Flood control pool (flood height above spillway crest): 1.5m 3% of dam height (for wave action, etc): 1.0m		m	2.5
Dam height H			m	19.0
Crest elevation			m asl	1662.0
Spillway crest elevation			m asl	1659.5
Crest length			m	350
Top width (7-12 m depending on dam height)			m	7

4.5.5.2 Spillway

The spillway will be of the unregulated Ogee type. It will be located on the left side of the dam. The inlet to the spillway will be shared with the power station inlet. Table 4.2-7 shows the main design parameters of the spillway. The spillway will discharge via a flared ski-jump into an existing an existing pond below the dam.

Table 4.5-6: Spillway design parameters, Mbarara project

Variable	**Units**	**Value**	**Check**	
			Criteria	**Value**
Spillway type	Unregulated Ogee			
Return period	years	10,000		
Reservoir maximum elevation	m asl	1,659.5		
Design flood	cumecs	3.7		
Discharge coefficient, C_d (assumed)		1.7		
Spillway crest length, L	m	5.0		
Head on spillway, H	m	1.0		
Spillway discharge, Q=Cd*L*H^(3/2)	cumecs	8.5	>= design flood	Ok
Spillway crest elevation	m asl	1,659.5		

4.5.5.3 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. Good quality concrete aggregates can partly be obtained from alluvial deposits in the river valley. However, the bulk of the aggregates may be obtained from a quarry opened above the left or right flanks of the river valley. Investigations may reveal that there may be other locations with better material quality and economic haul distances. Random fill for the cofferdams will be obtained from foundation stripping operations.

4.5.6 Irrigation and command area

The Mbarara site is very suitable for irrigation immediately downstream of the dam. There is intensive mixed farming in the Mbarara valley. Availability of water all year around would enable the valley residents to engage in more profitable agriculture. Figure 4.5-7 below

shows the potential command area (490ha) located in the communes shown in Table 4.5-7 which can be directly irrigated using the Mbarara reservoir waters. The command area is limited in extent by the proposed reservoir of the downstream Upper Ruvubu site, otherwise it could extend to 1258 ha. The command area can support 978 farmers and provide food for about 4,889 people. The annual water demand for irrigation is about 2.4 Mm^3.

Table 4.5-7: Irrigation command area for Mbarara

Province	Commune	Area (ha)
Kayanza	Gahombo	325
	Gatara	163
Total		**489**

4.5.7 Water Supply

The total population that can benefit from water supply from the Mbarara project in 2012 and 2062 was estimated at 79,783 and 302,295 people respectively (Table 4.5-8). The annual water demands are 0.9 Mm^3 and 3.3 Mm^3 for 2012 and 2062, respectively.

Table 4.5-8: Potential water supply beneficiaries for Mbarara

Province	Commune	Population (2012)	Population (2062)
Kayanza	Gahombo	20,935	79,324
	Gatara	32,675	123,804
	Kayanza	16,022	60,708
Ngozi	Busiga	10,150	38,459
Total		**79,783**	**302,295**