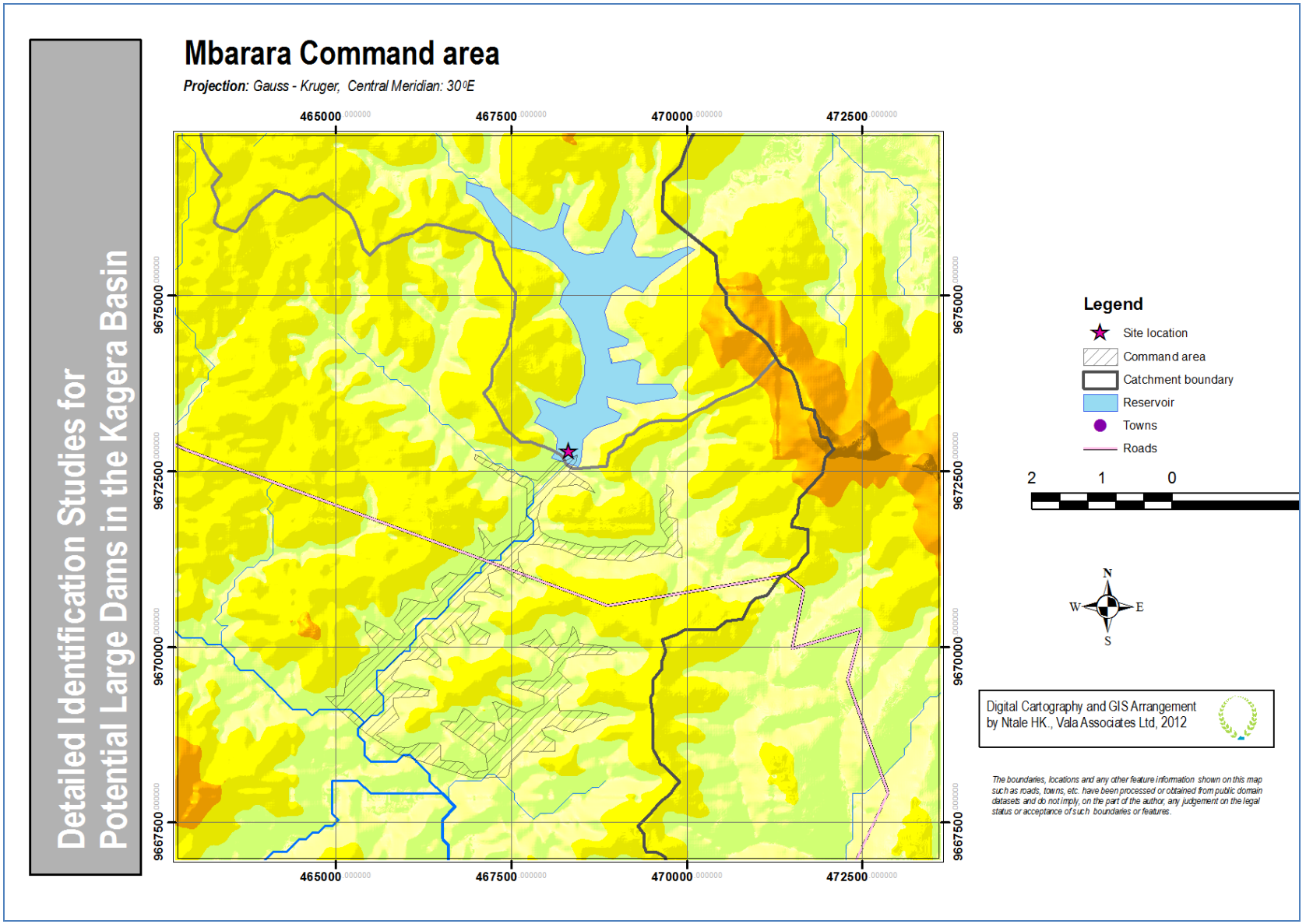

Figure 4.5-7 Mbarara Command area

4.5.8 Project costs

The estimated costs for the Mbarara project total to 10.9 million US dollars as broken down in Table 4.5-9 below.

Table 4.5-9 Estimated Mbarara Project costs

MBARARA DAM PROJECT CONSTRUCTION COSTS					
No	**Item**	**Units**	**Quantity**	**Rate (USD)**	**Amount (USD)**
1.0	**PREPARATORY WORKS**				
	Mobilisation and demobilisation	Lumpsum	1	800000	800000
	Permanent access	km	3.5	100000	350000
	Temporary access	Lumpsum	1	100000	100000
	River diversion during construction	Lumpsum	1	500000	500000
	Resettlement and compensation	ha	233	2500	582500
	Subtotal				**2332500**
2.0	**MAIN DAM**				
	Excavation, loose	m3	50000	15	750000
	Excavation, rock	m3	13000	22	286000
	Foundation preparation	Lumpsum	1	300000	300000
	Dam earthworks - random fill	m3	120000	15	1800000
	Dam earthworks - impermeable core	m3	80000	20	1600000
	Subtotal				**4736000**
3.0	**SPILLWAY, INTAKE**				
	Excavation, loose	m3	1200	15	18000
	Excavation, rock	m3	4000	22	88000
	Concrete Spillway	m3	5000	200	1000000
	Concrete intake	Lumpsum	1	250000	250000
	Penstocks, 2No @ 6.5 m2 steel	m		1500	0
	Other civil structures	Lumpsum	1	300000	300000
	Subtotal				**1656000**
	TOTAL, CONSTRUCTION COST				**8724500**
	ADMINISTRATION AND ENGINEERING		10%		872450
	CONTINGENCIES		15%		1308675
	CAPITAL COST (WITHOUT VAT)				**10905625**

4.5.9 Anticipated Impacts and Mitigation Measures for the Mbarara Project

4.5.9.1 Positive 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;
- There will improvement in access roads to facilitate transportation of project machinery and equaipment and such facilities will benefit the communities;

- The project will help vulnerable groups such women to earn side income to supplement domestic needs. This is because most of the people farming in the marshland are women;
- The construction of the dam will bring some side developments such as improvement of water supply and access roads amongst others; 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.

4.5.9.2 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 and most important on the women who seem to constitute a large part of the marshland user community;
- The project works will likely impact on water supply facilities since a protected spring is within the vicinity of the the proposed site;
- The project will impact on the communities in terms of loss of roadside crops especially bananas and woodlots;
- 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 concerns 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 4.5-10 as follows:

Table 4.5-10 Key impacts and mitigation measures for the planned the Proposed Mbarara site

Nº.	Project Impact	Mitigation measures
01.	Loss of marshland 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 For the women who are likely to be affected by the loss of the marshland, the project should propose feasible measures to for women to earn income upon uptake of the marshland. Such measures have to be discussed participartorily; Some of the possible measures could

Nº.	Project Impact	Mitigation measures
		include some group revolving fund from which they can borrow at lower interest rates to support start up and improvement of any of their on-going income ventures
02.	Impact on roadside vegetation such as bananas and woodlots.	Where inevitable, there should be compensation for the lost roadside resources.
03.	The dam site will take up a community road that passes through the site connecting the north-south villages.	Alternate route for the community be set up by the project.
04.	Land uptake through construction of the dam and access roads, camp sites, etc	Compensation for land uptake after Resettlement Action Plan (RAP) studies.
05.	Concerns relating to management of cut to spoil materials	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
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.
09.	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.
10.	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.
11.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
12.	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.
13.	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.
14.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
15.	Noise and vibrations	Noise from equipment and the workforce
16.	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

Nº.	Project Impact	Mitigation measures
		To address potential cumulative impacts of the project regarding HIV/AIDS, it is proposed that, the Project works with existing health entities to design measures for delivery HIV/AIDS even after construction of the dam.
17.	Air Quality concerns likely to arise from project works	Dust suppression measures will be instituted to ensure air quality levels are kept appropriate.
18.	Possible increase in crime rate in the areas of the project.	Working together with the police and law enforcement agencies to control crime in the areas.
19.	Impacts on socio-cultural sites	It is proposed that, detailed ESIA looks into the issue of socio-cultural aspects on the site and comes with appropriate measures to address such concerns based on possible finds regarding such aspectsNo

4.6 Upper Ruvubu Dam Site

4.6.1 Physical Environment Profile

4.6.1.1 Location

The site is located on the Upper Ruvubu River at -3° 3' 8.64 (South) and 29° 43' 6.12" (East) near Gahombo Town in Kayonza Province, Burundi (see Plate 4.6-1 below and Figure 4.5-1 above). The main potential uses cited for this development are irrigation, hydropower and water supply. It has an estimated catchment area of 440 km^2 and an average annual inflow of 239Mm^3/year. The site has a potential maximum head of 47 m and is expected to generate 15.9 GWh/year of firm energy.

Plate 4.6-1 Upper Ruvubu Site. Dotted line shows the proposed dam axis.

The area to be inundated by the reservoir is sparsely populated but is mainly used as farm land. The only area with significant population that would be affected is Rukago, though most settlements are on hill tops and the valleys are used for agriculture. The areas that would benefit from extra water for irrigation resulting from the project include Butaganzwa, Muhanga, Mutaho and maybe Gihohazi.

4.6.1.2 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 October 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 on average. The mean annual potential evaporation

is 1107 mm and varies over a narrow range between 72 mm in December and 117 mm in September. The temperature ranges between 17°C in June and 19°C in November.

4.6.1.3 Soils

The soils are part of the wider province soils that are characteristically poor in nutrients as evidenced by state of poor crop stands around the site. The poor soils have driven communities to farm in the marshlands implying the planned development will go a long way to alleviate food situation in the areas. The crop stands of cassava are poor evidence that, the soils are poor to support cultivation.

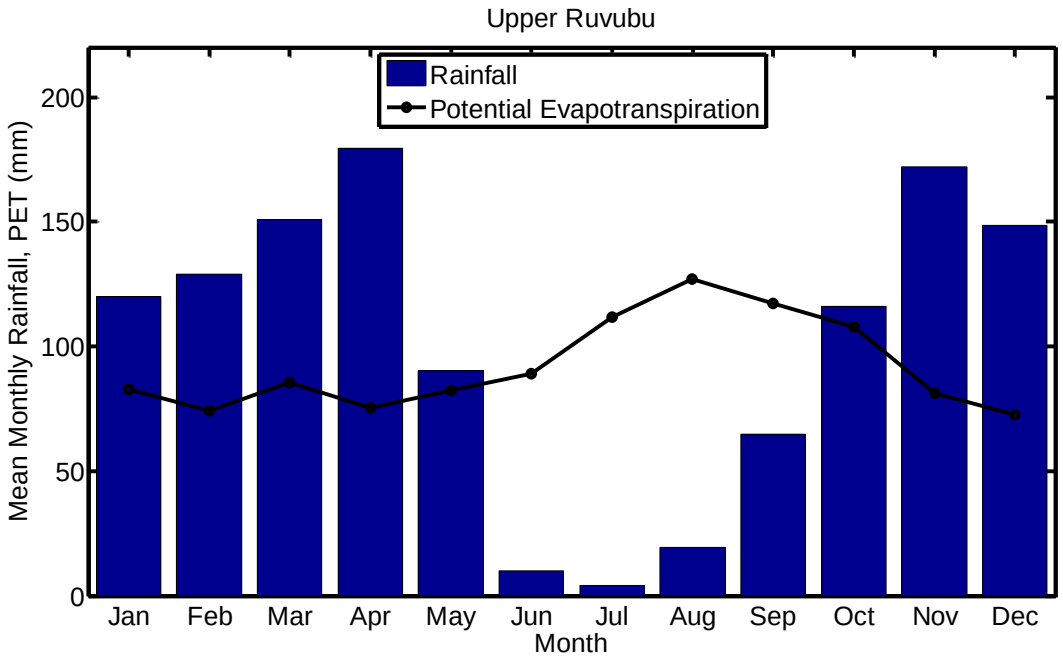

Figure 4.6-1: Upper Ruvubu catchment mean monthly rainfall and potential evaporation

4.6.1.4 Geology, mining and minerals

The results of geological prospecting in the province of Kayanza resulted in the discovery of metallic deposits of gold, cassiterite and non metallic kaolin and feldspath. The existence of mineral deposits in the municipality of Kayanza was discovered at Kabuye (SnO, Sn, Nb, Ta.) The Kayanza Province has a number of quarries and borrow pits sources of construction materials. Just for the municipality of Kayanza, here are 15 sites of clay, 12 sites of stones, 3 sites of sand, 2 sites of gravel and 2 sites of laterite.

4.6.2 Social Economic Profile

4.6.2.1 Demographics and trends

Data on the population of the Kayanza 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 Kayanza is 1.19%. According to the PUP, in 2005 the population of the Kayanza municipality alone was estimated to be 72,613 inhabitants.

This population is spread over an area of 122.36 km^2 (10% of province), where its average density is 593 inhabitants/km^2, higher than the average density of the province (417 inhab/km^2). This density is the highest in the province.

The population distribution by age group and gender shows that:

- Women outnumber men; they represent 52% of population;
- The population of Kayanza is extremely young: 33,470 or 46% of the population are aged under 25;
- The elders over 60 years are 3297 or 4.5% for the Kayanza population;
- The labor force is estimated at 35,846 (49%) and is in charge of 36,767, 51% of the total population of Kayanza.
- This means that a person active must support more than one person, one younger or older.

Table 4.6-1 Distribution and Population Density by Municipality

Municipality	Total population	Surface area in km^2	Density inhab/km^2)
Butanganzwa	48660	103.38	471
Gahombo	34585	80.64	429
Gatara	55011	103.96	529
Kabarore	50371	200.12	252
Kayanza	72613	122.36	593
Matongo	63213	167.80	377
Muhanga	60362	128.90	468
Muruta	51239	147.08	348
Rango	78021	179	436
Total Kayanza Province	**514,075**	**1233.24**	**417**

(Source: PUP 2003-2010 Projections, Kayanza Municipality).

In 2005, the population of Kayanza municipality was estimated to 72,613. The prospects for the year 2012 indicate that the population will reach 77,054, an increase of 6% between 2005 and 2012.

4.6.2.2 Agriculture and Livestock

In the Kayanza Province and Kayanza 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), 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: banana, cassava, potato sweet potatoes, beans and corn. On the relative production of major food crops, the only municipality of Kayanza produced in 5 years, an average production of 60,654 tons of food, being 8% of food products during the same period in the province the production was 761,632 tons. The only cash 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

Kayanza is provided by OCIBU which makes available to growers pesticides and fertilizers in the form of seasonal loans.

The farming practiced in Kayanza is of traditional type and constituted of cattle, goats, sheep, pigs and poultry. The animals in the hills of Kayanza 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.

4.6.2.3 Communication

Regarding the mobile phones, the Province of Kayanza is covered by networks of ONAMOB, Telecel, Africell and Spacetel. Faxes were reduced in number; they are functioning except occasionally when there is a shortage of power. In the province of Kayanza, there is a post office with more than 1 thousand customers, and an estimated number of 2000 landlines.

4.6.2.4 Housing

Most of the population of the Kayanza Province live in houses which are of ironsheet roof, local tiles and some in grass thatched houses. In the communities around the site there os no electricity and the source of energy is largely woodfuel. The housing improvement has always been characterized by:

- The types of roofs. Among the roofs encountered, there is a predominance of homes thatched. Another part of the houses is covered with corrugated iron sheets and tiles.
- The types of pavement. Houses whose floor is clay predominant. Very few homes are made of durable materials and semi-durable for which the pavement is local or cement tiles. From the above, we may conclude very few people are building durable houses, modern-looking with well maintained toilets.

4.6.2.5 Water and sanitation

The province has non functional and functional water supply facilities. The municipality of Kayanza on its own has 31 fountains. While the standards for optimal water supply are for a water point for 500 meters or two water points per square kilometer, the assessment has revealed there is one water point for 1.79km2, which is not satisfactory. Thus, the number of households per water point is 66. All these facilities are inadequate to serve the total population of Kayanza province. It should also be noted that the distribution of these facilities through the hills is uneven. The public should be sensitized to the regular maintenance and repair of water supply infrastructure.

The Province of Kayanza like other provinces, has the same sanitary and health problems such as insufficient equipment in health facilities; poor staffing and lack of medicines. The health situation presents a clinical picture characterized by the following persistent diseases: malaria; ARI in children under 5 years; diarrhea; bacillary dysentery, and malnutrition

4.6.3 Previous studies

While carrying out the current assignment, 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.

4.6.4 Alternative developments

The Upper Ruvubu dam development offers two options for the location of the dam axis.

- Option 1: Is at the narrowest point in the valley (Figure 4.6-2) where the valley width is in the order of 100 m. The problem with this option is that maximum elevation on the right bank is only 1611 m asl and this would restrict the amount of water that can be stored in the reservoir
- Option 2: This is located about 200 m upstream from Option 1. This would provide no restrictions on the reservoir size but the width of the river valley at the site is about 220 m.
- Option 2 is considered better as it offers more flexibility concerning the development of the site. Therefore, this study concentrated on Option 2 for the location of the dam axis.

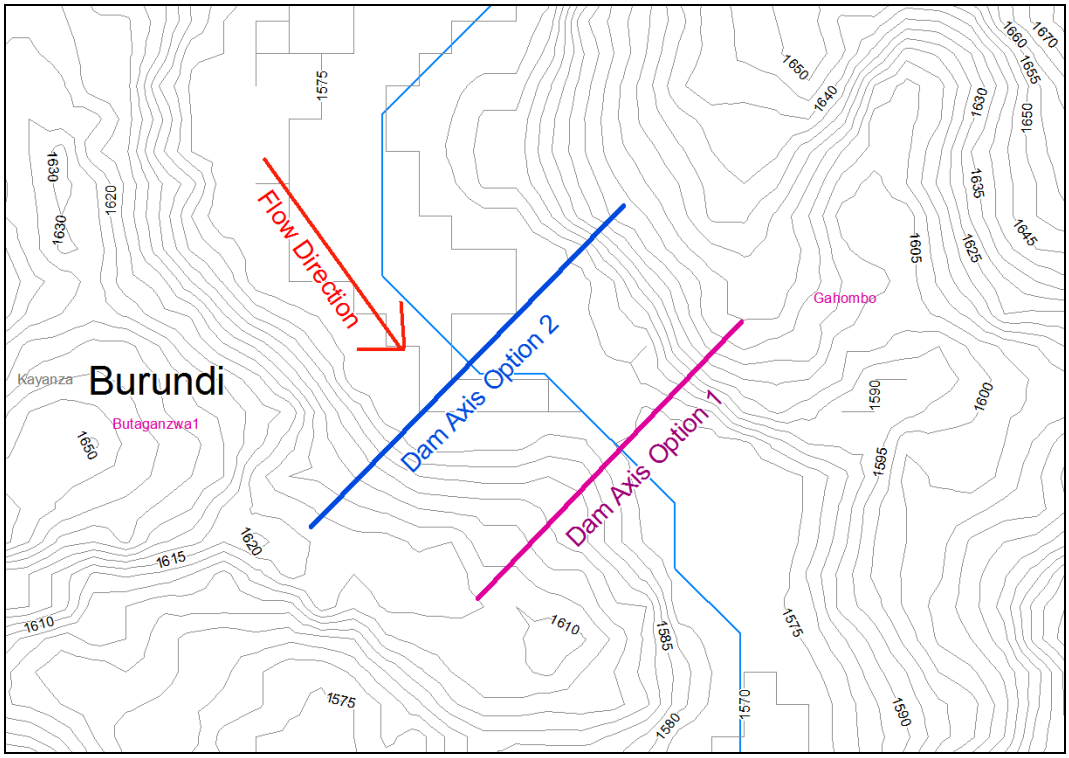

Figure 4.6-2 Upper Ruvubu Dam Axis Options

4.6.5 Hydrology

4.6.5.1 The catchment

The catchment upstream of the proposed Upper Ruvubu dam site has an area of 440 km^2 and wholly contained within Kayanza Province in Burundi. The catchment has a length of 27 km and an average width of about 26 km (Figure 4.5-1). The catchment slope averages

27% though it can be higher than 80% especially in the highlands to the west and south. The catchment elevation ranges between 1575 m asl at the dam site to a maximum 2578 m asl while the mean is 1865 m asl.

The river section at the dam site is fed by 4 tributaries, 2 of which drain the eastern part of the basin while the other two drain the northern part. From the confluence of the tributaries, the river flows for 5 km in a southern direction to the dam site. The river continues in the southern direction 1.3 km before making a 90^{o} to flow eastwards. The average channel slope upstream of the dam site is about 0.2% while the slope downstream is about 0.4%.

The topography of the dam site is shown in (Figure 4.5-1). The elevation of the riverbed at the dam site is about 1575 m asl. The river valley is generally flat and is 230 m wide. The left flank of the river rises at a slope of 40% while the right flank rises at a slope of 28%.

4.6.5.2 Runoff

Using flow data for 4 years from the Ruvubu Burasira gauging station (Station number 21070), a hydrological model for the flow at the outlet at the dam site was constructed. The modeling results showed that daily flow at the dam site ranged between 3.1 m^3/s on 18-September-1975 and 58.0 m^3/s on 16-February-1990 and averaged 7.6 m3/s (Figure 4.6-3). The mean flow has an exceedance probability of 32% while the median flow is 6.4 m^3/s.

The mean monthly total flows vary between 28.4 Million m^3 (Mm^3) in May and 13.6 Mm^3 in August (Figure 4.6-4). A secondary peak flow of 21.2 Mm^3 occurs in November. The total annual flow averages about 239 Mm^3.

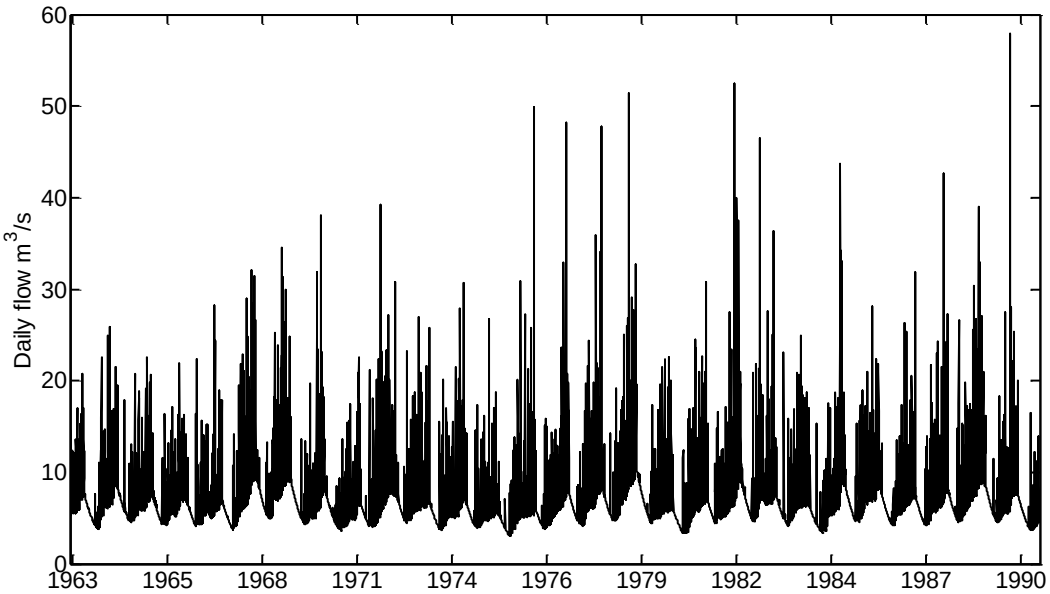

Figure 4.6-3: Daily flow variation, Upper Ruvubu River

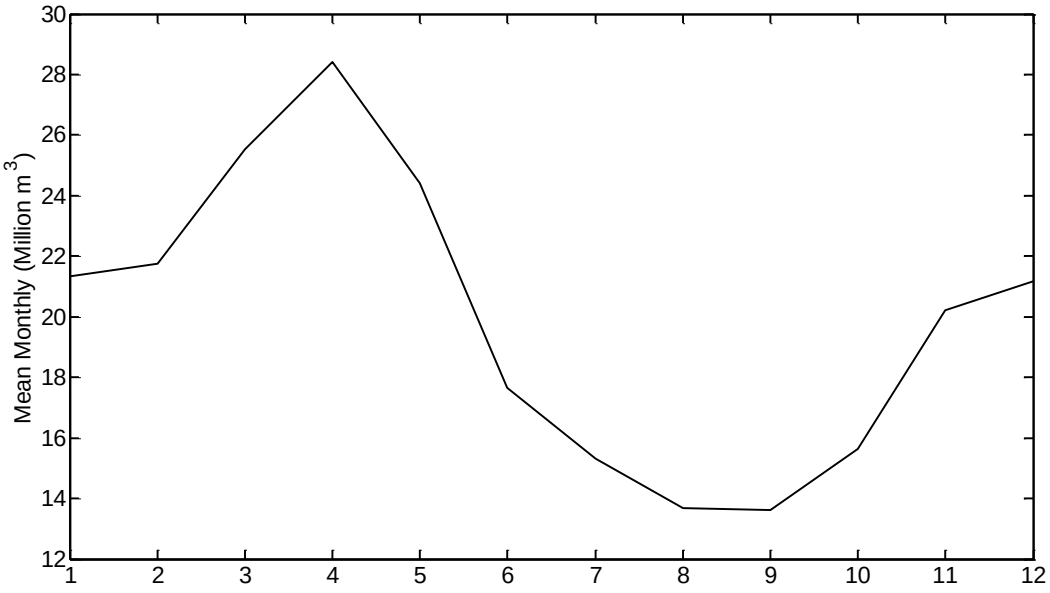

Figure 4.6-4: Mean monthly flow variation, Upper Ruvubu River

4.6.5.3 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 4.6-5 and Figure 4.6-6 respectively. Figure 4.6-5 shows that the inundation area increases sharply with elevation up to an elevation of 1625 m asl. After this, the curve is flatter meaning that small increases in elevation result in large increases in inundated area and maybe unviable. From this point of view, therefore, the maximum viable elevation to which the reservoir can be raised is about 1625 m asl. The KIRBMDS report gives a maximum elevation of the Upper Ruvubu reservoir as 1617 m asl. Setting the required reservoir volume can be based on the required storage to offset the deficit between inflow and outflow during the driest months. Dry months in the area range between 3 and 4 months during which river flows can drop to as low as 30-40% of the mean flow. A total of three months storage was set as the minimum that should be met by the reservoir by the Upper Ruvubu reservoir. Taking dead storage into consideration, a reservoir elevation of 1617 m asl would be sufficient to meet this requirement at the proposed dam site. Detailed socioeconomic assessments at the feasibility and detailed design stages will be necessary to assess the relative costs of different possible reservoir maximum elevations in terms of displacement of people and inundation of agricultural lands.

The proposed reservoir elevation will inundate 681 ha of land and will have a total volume of 110 million cubic meters of water. It would require resettlement of over 3,000 people (Table 4.6-2). The reservoir fetch will be 8.5 km along the main river while the fetch along the tributaries will average about 1.5 km (Figure 4.6-7). The average width of the reservoir will be about 450 m.

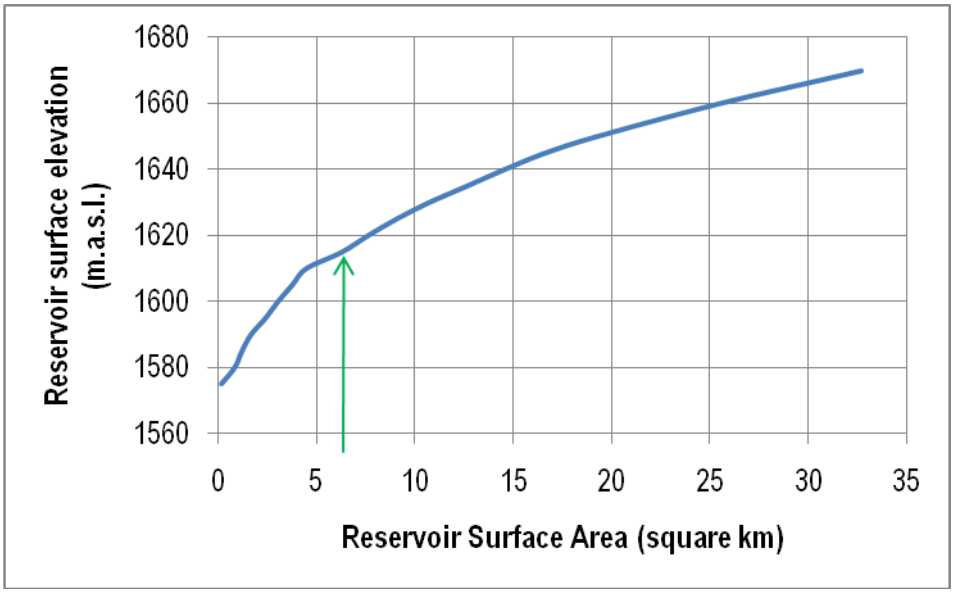

Figure 4.6-5: Upper Ruvubu reservoir surface elevation versus reservoir surface area

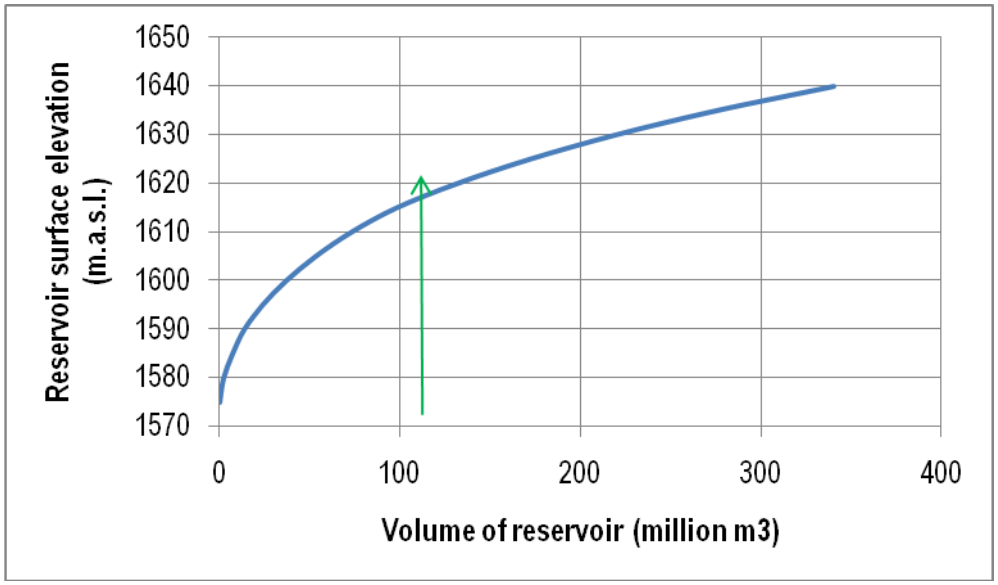

Figure 4.6-6: Upper Ruvubu reservoir surface elevation versus reservoir volume

Table 4.6-2: Land area to be inundated by the reservoir and potentially affected population

Province	Commune	Land Area (km²)	Population
Kayanza	Butaganzwa1	0.5	228
	Gahombo	2.6	1,285
	Gatara	3.7	1,814
Total		**6.8**	**3,327**

4.6.5.4 Reservoir evaporation

Being an open water body, the reservoir evaporation rates would be expected to be close to the potential evapotranspiration rates. Table 4.6-3 shows the daily and monthly

potential evaporation rates estimated from data at 3 meteorological stations located close to the Upper Ruvubu dam site.

Table 4.6-3: Daily and monthly potential evaporation rates

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

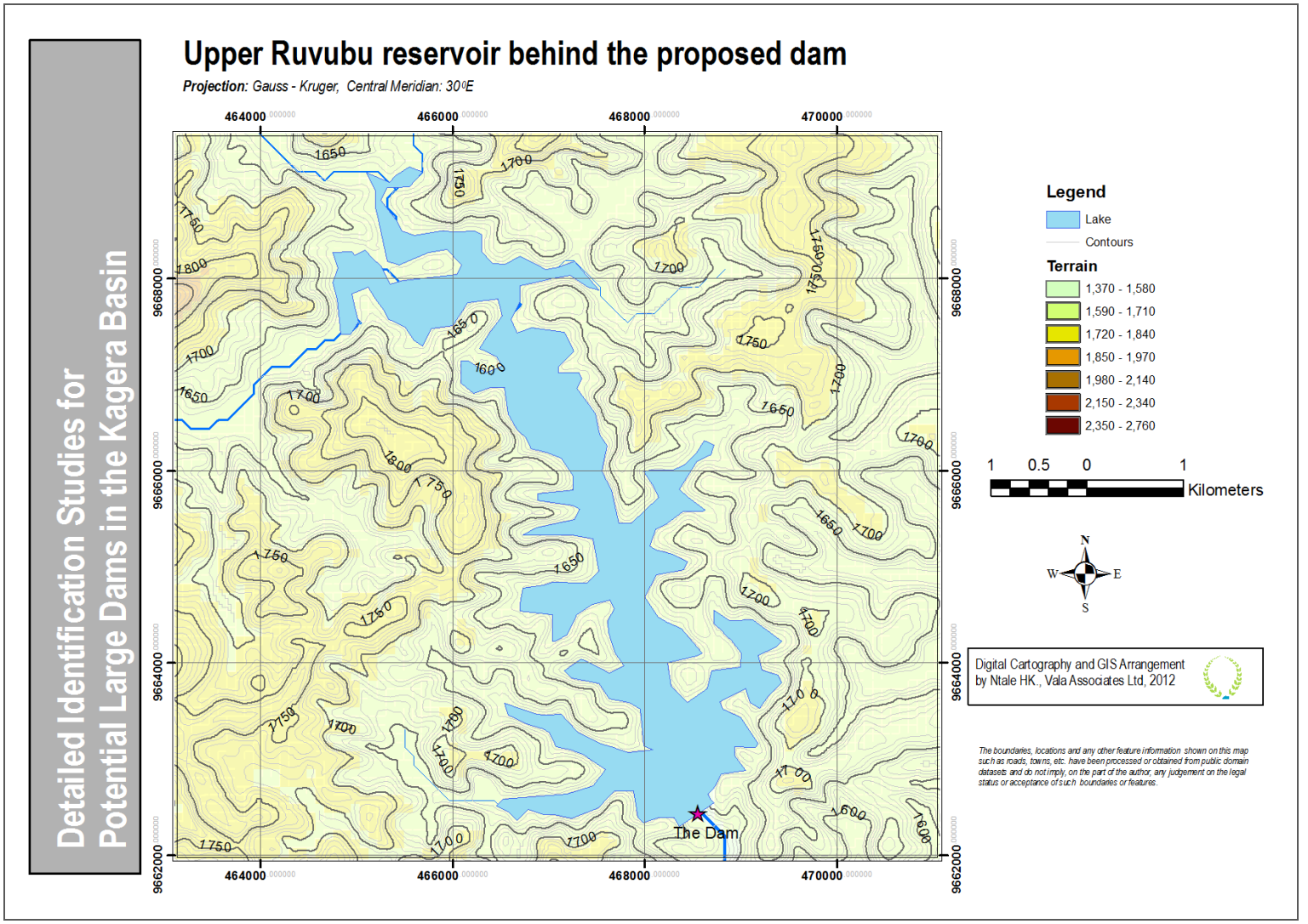

Figure 4.6-7: Upper Ruvubu Reservoir

4.6.5.5 Floods

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

(i) Selection of the annual maximum 24-hour flows from the measured flow
(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 4.6-4)

Table 4.6-4: Upper Ruvubu flood estimates and associated return periods

Return period, T (years)	Flood magnitude (m3/s)	Risk of failure for a 50 year design life (%)
50	67.0	63.6
100	75.4	39.5
200	84.5	22.2
500	97.4	9.5
1000	108.1	4.9
2000	119.6	2.5
5000	136.1	1.0
10000	149.7	0.5

4.6.5.6 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 1,743 t/km^2/yr. The River is very silty all year round (Plate 4.6-2). The dead storage properties of the dam are shown in Table 4.6-5 below:

Table 4.6-5 Upper Ruvubu Sediment Properties

Site Name	Upper Ruvubu
Reservoir Volume (Mm^3)	110
Catchment area (km^2)	440
SY (t/km^2/yr)	1,743
Assumed Sediment density (t/m^3)	1.1
Dead Volume (Mm^3)/yr	0.30
Dead storage after 50 years (Mm^3)	15.17
Percentage of Reservoir filled with sediment after 50 years	14%

Plate 4.6-2 The silty waters of Upper Ruvubu at the dam site.

4.6.6 Irrigation command area

The irrigation command area for the Upper Ruvubu reservoirs totals some 8137 ha. The irrigable land is located in the provinces shown in Table 4.6-6. The irrigable belt has an average width of 1.5 km and a length of 25 km (see Figure 4.3-7 below). The command area can support 16,275 farmers and provide food for about 81,374 people. The annual water demand for irrigation is about 41 Mm^3.

Table 4.6-6: Irrigation command areas for Upper Ruvubu

Province	Commune	Area (Ha)
Ngozi	Ruhororo	822
Gitega	Mutaho	2,139
Kayanza	Butaganzwa1	612
	Gahombo	134
	Muhanga	3,941
	Rango	490
Total		**8,137**

4.6.7 Water Supply

The total population that can benefit from water supply from the Upper Ruvubu project in 2012 and 2062 was estimated at 154,613 and 585,824 people respectively (Table 4.6-7). The annual water demands are 1.7 Mm^3 and 6.4 Mm^3 for 2012 and 2062, respectively.

Table 4.6-7: Potential water supply beneficiaries for Upper Ruvubu

Province	Commune	Population (2012)	Population (2062)
Ngozi	Ruhororo	3,778	14,315
Ngozi	Ngozi	4,370	16,558
Gitega	Mutaho	19,647	74,442
Kayanza	Butaganzwa1	21,694	82,199
	Gahombo	17,006	64,434
	Gatara	13,122	49,719
	Muhanga	49,556	187,765
	Rango	25,440	96,393
Total (water supply)		**154,613**	**585,824**

4.6.8 Dam Design Elements

4.6.8.1 General

The dam at Upper Ruvubu site has been designed as an embankment dam owing to the nature of the valley cross-section at the site and availability of potential construction materials. The dam will have a base elevation of 1575 m asl. The dam crest will be 480 m long. A chute spillway on the left of the dam is proposed.

4.6.8.2 Dam

The dam at Upper Ruvubu has been designed as an earth-fill embankment dam with a roadway on top. This preliminary design proposes a downstream slope of 2:1 and an upstream slope of 2:1. The dam foundation will be located on firm basement rock assumed to be 10 m below the ground level. The rest of the dam properties are given in Table 4.6-8 below.

Table 4.6-8: Upper Ruvubu dam design

Variable	Units	Value	Check	
			Criteria	Value
Dam location		Upper Ruvubu		
Dam type		Earthfill Dam		
Reservoir base elevation		1,575		
Reservoir top elevation		1,617		
Reservoir depth at above dam base (Hnet)	m	42.0		
Free board (Flood control pool + 3% of dam height)				

	Flood control pool (flood height above spillway crest)	m	1.5		
	3% of dam height (for wave action, etc)	m	2.0		
	Freeboard on dam	m	3.5		
Dam height H		m	45.5		
Dam crest elevation		m asl	1,622		
Spillway crest elevation		m asl	1,617		
Crest length		m	480.0		
Base length		m	212.0		
Top width (7-12 m depending on dam height)		m	10.0	Allows for road on top	
Upstream slope N:1			2.0		
Downstream slope N:1			2.0		
Bottom width		m	197.5		
Impervious core	Top width	m	4.0	>=3.5 m	
	U/S slope N:1		0.6		
	D/S slope N:1		0.5		
	Core depth (1 m below crest level)	m	45.9	Protection of core	
	Base width	m	54.5	Min width 0.4*H=	18.7
Cutoff (compacted backfill trench)	Bottom width (contact with core)	m	54.5		
	Depth of pervious foundation material	m	10.0	assumed	
	U/S slope N:1		1.0		
	D/S slope N:1		1.0		
	bottom width (contact with impervious layer)	m	34.5		

4.6.8.3 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 300 m long and unlined. The tunnels will be circular with a cross-sectional area of 8 m^2 that is needed for safely discharging a 100-year flood of 76 m^3/s without overtopping the cofferdam that shall be raised to an elevation of 1577 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 1577 m asl while that of the downstream cofferdam will be 1576 m asl. The upstream coffer dam will be incorporated in the dam while the downstream cofferdam will be breached after completion of construction. 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.

4.6.8.4 Spillway

A chute spillway is provided for on the left abutment. The spillway crest will be at an elevation of 1617 m and will be uncontrolled. The spillway will be about 80 m long and will

discharge through a ski jump into an existing pond below the dam. Table 4.6-9 shows the main design parameters of the spillway

Table 4.6-9: Spillway design parameters

Variable	Units	Value
Spillway type	Chute, over crest	
Return period	years	10,000
Spillway crest elevation	m asl	1,617
Design flood	cumecs	150
Discharge coefficient, Cd (assumed)		1.7
Spillway crest length, L	m	30.0
Head on spillway, H=(Q/(Cd*L))^(2/3)	m	2.1
Freeboard (40% of head on spillway)	m	0.8
Total height above spillway crest	m	2.9

4.6.8.5 Power station

The power station will be situated on the left abutment inboard from the spillway and will share the entrance with the spillway. The intake structure will consist of submerged reinforced concrete and twin rectangular inlets controlled by two 2.5 by 2.5 m roller gates. The sill of the gates will be at an elevation of 1616 m asl. The intake structure will supply two steel penstocks each about 60 m long and with each with an area of 2 m^2 to convey water from the inlet to the power station on the left toe of the dam. The power station will be a surface concrete structure equipped with two 1.8 MW Kaplan turbines.

shows the maximum rated power and energy from the site.

The proposed hydropower scheme on Upper Ruvubu River has the potential to produce 31 GWh of energy per year which is enough to supply about 35,000 houses and over 209,000 people.

Table 4.6-10 Hydropower estimation

Variable	Value	Units
Rated reservoir level	1617	m asl
Tailwater level	1576	
Head	41	m
Mean flow	7.6	m3/s
Rated flow (30% higher than mean)	9.9	
Plant efficiency	90%	
Power	3.6	MW
Energy	31.3	GW/year

4.6.8.6 Ancillary works

There is an existing dirt road passing very close to the dam site and connecting the area to a nearby Gahombo. The road is about 7.5 km long and would needed to be upgraded to provide access to the site for supplies, construction materials and equipment.

4.6.8.7 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. Impervious materials can be obtained from silt and clayey deposits which are probably available within the river flood plain. 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.

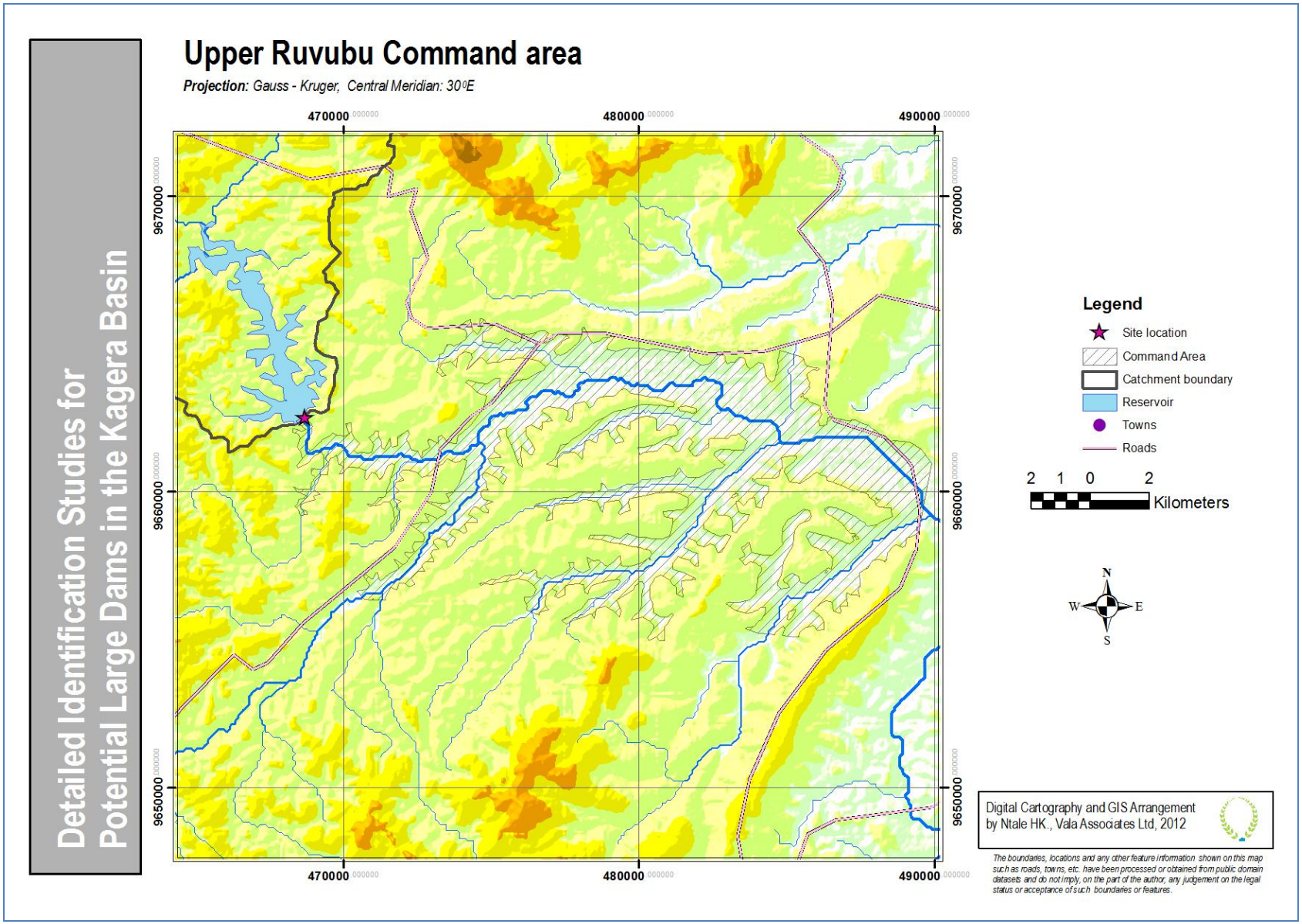

Figure 4.6-8 Upper Ruvubu Command area

4.6.9 Project costs

The estimated costs for the Upper Ruvubu project total to 69.9 million US dollars as broken down in Table 4.6-11 below.

Table 4.6-11 Upper Ruvubu Project costs

UPPER RUVUBU 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	4	100000	400000
	Temporary access	Lumpsum	1	100000	100000
	River diversion during construction	Lumpsum	1	800000	800000
	Resettlement and compensation	ha	679	2500	1697500
	Subtotal				**4197500**
2.0	**MAIN DAM**				
	Excavation, loose	m3	190000	15	2850000
	Excavation, rock	m3	50000	22	1100000
	Foundation preparation	Lumpsum	1	500000	500000
	Dam earthworks - random fill	m3	1100000	15	16500000
	Dam earthworks - impermeable core	m3	750000	20	15000000
	Subtotal				**35950000**
3.0	**SPILLWAY, INTAKE, AND PENSTOCKS**				
	Excavation, loose	m3	5200	15	78000
	Excavation, rock	m3	21000	22	462000
	Concrete Spillway	m3	20000	200	4000000
	Concrete intake	Lumpsum	1	250000	250000
	Penstocks, 2No @ 2 m2 steel	m	300	1500	450000
	Other civil structures	Lumpsum	1	500000	500000
	Subtotal				**5740000**
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	2500000	2500000
	Generators, transformers and miscellaneous electrical equipment	Lumpsum	1	2000000	2000000
	Gates for intake, outlet	Lumpsum	1	1000000	1000000

	Switchyard	Lumpsum	1	300000	300000
	Subtotal				**5800000**
	TOTAL, CONSTRUCTION COST				**55965000**
	ADMINISTRATION AND ENGINEERING		0.1		5596500
	CONTINGENCIES		0.15		8394750
	CAPITAL COST (WITHOUT VAT)				**69956250**

4.6.10 Anticipated Impacts and Mitigation Measures for the Upper Ruvubu Project

4.6.10.1Positive Impacts

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

They are:

- The Dam will provide renewable energy source which will spur the social and economic growth of the province and the country at large;
- 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;
- The project will generate power that will lead to estabalishment of agro-processing facilities in the communities and trading centres which brings about value addition in their produce hence, they will be able to earn better incomes and lead improved lives;
- The development of the marshland will assist women through improved water supply to irrigate their crops;
- The development will likely bring about improvement of access roads to the site thereby benefiting the communities at large;
- 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; 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.

4.6.10.2Negative Impacts

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

- The dam sites 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;
- It important to note that, the project will impact on the women who constitute part of the communities cultivating the marshlands and this will deny them sources of their livelihoods and it is a major impact of this project;
- The dam will take up parts of adjacent woodlots and shambas at the edges of the marshland;
- 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 inTable 4.6-12 as follows:

Table 4.6-12 Key impacts and mitigation measures for the planned Upper Ruvubu site

Nº.	**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 parts of the adjacent woodlots and some nearby shambas.	The affected farmers be compensated for possible crop and woodlots areas that are likely to be taken up by the project and should be after RAP investigations.
03.	The dam site will take up a community road that passes through the site connecting the neighbouring villages.	Alternate route for the community be set up by the project.
04.	Land uptake through construction of the dam and access roads, camp sites, etc	Compensation for land uptake after Resettlement Action Plan (RAP) studies.
05.	Concerns relating to management of cut to spoil materials	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
06.	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 For the women who are likely to be affected by the loss of the marshland, the project should propose feasible measures to for women to earn income upon uptake of the marshland. Such measures have to be discussed participartorily; Some of the possible measures could include some group revolving fund from which they can borrow at lower interest rates to support start up and improvement of any of their on-going income ventures.
07.	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.
08.	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	Put in place site-based sectoral committees to handle equitable and rational use of water in the project.

Nº.	Project Impact	Mitigation measures
	dams and the planned ones will add to such existing dams along the same river system there by putting stress on water supply process.	There is need to plan the development of this dam sites while ensuring that the needs of other users are taken care of.
09.	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.
10.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
11.	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.
12.	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.
13.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
14.	Noise and vibrations	Noise from equipment and the workforce
15.	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.
16.	Air Quality concerns likely to arise from project works	Since the project will attract a number of people who are looking for employment and also induce developments of different modes, such will likely influence the lifestyles of the communities thereby impacting on levels of HIV/AIDS prevalence in the area. Some measures need to be worked with the area leadership and, the health sector and this could be the project contributing towards supporting existing heatlh facilities in the vicinity to assist improve HIV/AIDS services.
17.	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.
18.	Impacts on socio-cultural sites	Working together with the police and law enforcement agencies to control crime in the areas.
19.	Impacts on biodiversity areas of high conservation concerns (Important Bird Areas-IBAs, national and central forest reserves etc).	Though during the IESE study no socio-cultural sites were encountered, it is suggested further ESIA could focus on this aspect and where possible, define measures to address such impacts when they are encountered.

4.7 Ruvyironza Dam Site

4.7.1 Physical Environmental Profile

4.7.1.1 Location

The Ruvyironza site is located in central Burundi on River Ruvyironza about 15 km north of the town of Gitega and about 9 km upstream from the Ruvyironza-Ruvuvu confluence (Figure 4.7-1). The coordinates of the proposed dam site are -3° 19' 38.22"(South) and 29° 55' 52.5" (East.) The catchment area of the basin upstream of the dam site is 1999 km^2 and all of it lies within Burundi. It has a length of 121 km and an average width of about 20 km (Figure 4.7-1). The mean catchment slope is about 13.5% but the steepest slopes may be higher than 85%. The catchment elevation ranges between 1471 m asl at the dam site to 2314 m asl while the mean is 1787 m a.s.l.

The Ruvyironza (or Luvironza) River of Burundi, one of the upper branches of the Kagera River, is regarded as the true and ultimate source of the Nile. It has an estimated catchment area of 1,994 km^2 and an annual average inflow of 703.7 Mm^3/year.

The primary potential use of the project is hydropower with other potential secondary uses of water supply and irrigation. The site has a potential maximum head of 98 m and is expected to generate 113 GWh/year of energy. The principal challenge presented by this site is that if it is constructed, about 4km of the Gitega - Ngozi highway would be flooded by the impounded reservoir and hence that section of the road would have to be relocated around the new lake. The Impounded reservoir would attain a size of 14.96 km^2 at the maximum water level reaching a volume of 372 million cubic meters.

4.7.1.2 Topography

The surrounding areas of the project are characterized by gently rolling hills on either side of the R. Ruvyironza. The slopes are cultivated with subsistence crops such as maize and beans. The hills have outcrops of granitic types of rocks which have supported road construction projects. In some

Plate 4.7-1 Cultivation of crops done close to River Ruvyironza banks

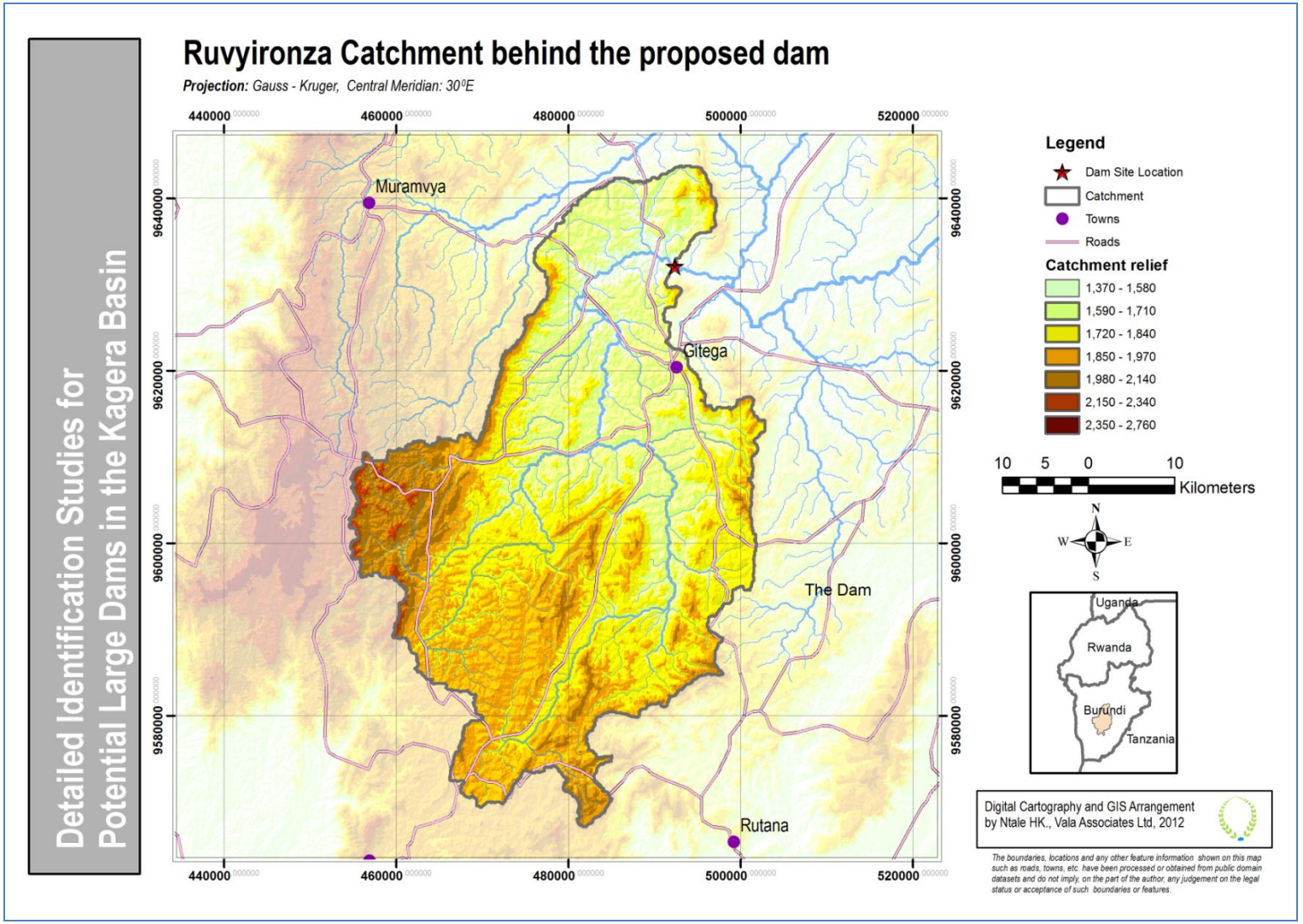

Figure 4.7-1 Ruvyironza Catchment

4.7.1.3 Climate

Elevation is one of the major factors influencing the climate of the area thereby greatly moderating its tropical character. The general high elevation produces relatively cool temperatures, which average only about 70 °F (21 °C) throughout the year in the central plateau area and usually drop to below 60 °F (15 °C) at night.

Available data indicates that the basin receives a mean annual rainfall of 1220 mm. The mean monthly rainfall distribution is bimodal with two rainy seasons(Figure 4.7-2). 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 183 mm while maximum rainfall in the short rainy season is received in November and averages 168 mm. July is the driest month, receiving only 5 mm of rainfall. The mean annual potential evaporation is 1107 mm and varies between 127 mm in March and 73 mm in May.

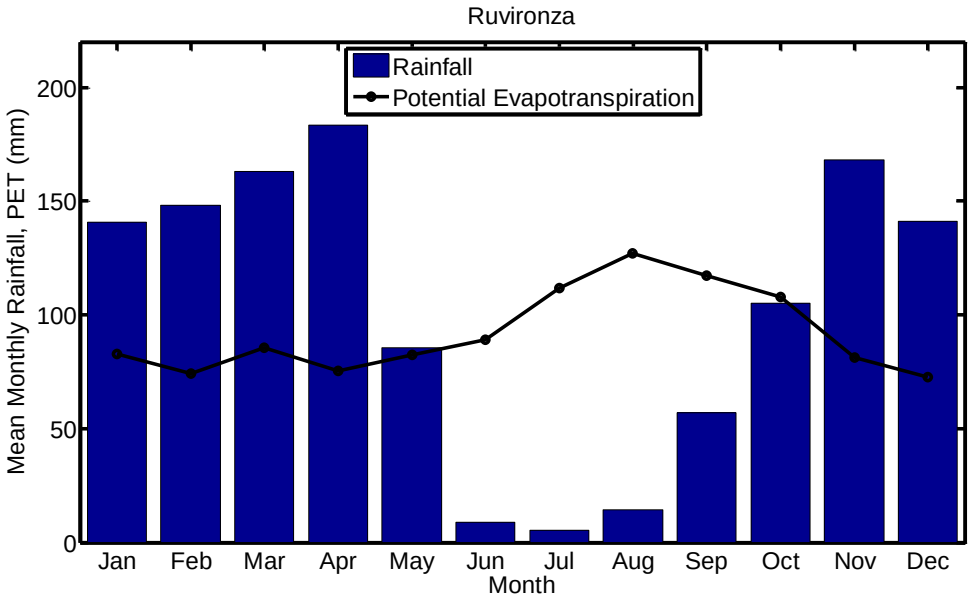

Figure 4.7-2 Ruvyironza catchment mean monthly rainfall and potential evaporation

4.7.1.4 Geology of the Dam site

The bedrock consists chiefly of Phyllites with occasional layers of dolerite and Schist. The sandstone ranges from dense, indurated, sedimentary quartzite to more or less friable, impure sandstone. The quartzite facies are sound and unweathered even at land surface, whereas the sandstones are weathered to depths of 30 m or more, and at least to drainage level.

As the sandstone facies frequently are in contact, the differences between them must reflect their composition rather than the effects of post-depositional tectonic activity. Evidently the orthoquartzites were formed in a stable tectonic environment which favored deep weathering and removal of all weatherable minerals before induration.

The dolerite also exhibits variations in the degree and depth of weathering, but it commonly is sound and relatively unweathered, except where it is fractured or fissured.

Overburden at the dam site consists largely of silty to clayey laterite. The laterite associated with sandstone commonly contains a significant fraction of cobbles and boulders of the parent material.

4.7.1.5 Soils

Light, forest-derived soils predominate, forming a thin layer of humus over lateritic (iron-rich) sub-soils. The best soils are formed from alluvium, but they are confined primarily to the lower portions of larger river valleys. Soil erosion, caused by a combination of steep slopes and frequent rainfall, is a serious problem and creates a major constraint on agriculture; ironically, erosion is further exacerbated by the clearing of land for agricultural an purpose which is undertaken close to the river banks and this leads to siltation of the river bed.

4.7.1.6 Plant and animal life

The natural forest vegetation has almost entirely disappeared from the landscape around the site and what is left is now limited to higher hill tops and are mainly eucalyptus woodlots. On the plateau, wooded savannah is found at higher elevations, giving way to more-open savannah on the lower slopes (Plate 4.7-2). Poaching has dealt a severe blow to the country's wildlife. The elephant population has virtually disappeared, leaving only warthogs and baboons as well as birds. *There is no protected area in the vicinity of site hence, there are no plants and animals of conservation concern in the areas of the project.*

Plate 4.7-2 Part of vegetation set in the areas of Ruvyironza site

4.7.2 Social Economic Profile of the Site

4.7.2.1 *Demographics and trends*

Gitega Province is composed of 9 communes among them the Gitega commune. It has an estimated area of 1978.96 km2 being 7.1% of the total surface area of the country.

The Province of Gitega has a total population of 689,900 inhabitants for which 326,795 are men and 363,105 are women. The population is young as 53 % are under 20 years. It has a population density averaging 349 inhabitants per km2. The population of the commune is mostly composed of youths; the census of the population is showed by the table below.

Population density of Gitega Province

Commune	Total population	Surface area (km²)	Density (inhabit/km²)
Bugendana	104137	283	368
Bukirasazi	34358	87,78	391
Buraza	46191	158,78	291
Giheta	75852	155,56	488
Gishubi	91860	165,44	351
Gitega	123811	315,44	393
Itaba	54793	170	247
Makebuko	61469	151,4	362
Mutaho	63976	222	423
Nyarusange	-	96,36	-
Ryansoro	33453	173,20	193
Total	**689900**	**1978,96**	**349**

4.7.2.1 Settlement patterns

The hilly geography around the site discourages village formation, and traditional family compounds tend to be dispersed rather than concentrated—a key settlement characteristic of the area. This pattern has encouraged isolation rather than community settlement patterns. Civil unrest that began in the early to mid-1990s forced thousands of Hutu to settle in refugee camps spread throughout the countryside and in neighbouring countries and effect of such influx is evident around the site.

4.7.2.2 Agriculture

The practice of cultivation is traditional, labour intensive with a hoe and a predominance of crops association. It was observed that field work is done mostly by women. According to data provided by the "*Direction Provinciale de l'Agriculture er de l'elevage*" (DPAE) of Karuzi, the main food crops by order of importance are: bananas, sweet potatoes, cassava and maize. Banana, sweet potato and cassava are the most daily cultivated in the areas of the planned project (Plate 4.7-3). The only industrial crop is coffee. Agriculture activities are undertaken based on the season of the year. Due to poor soils in most parts of the areas, communities living close to the marshlands have resorted to paddy rice cultivation for domestic and as a source of income for the communities. The cultivation of rice in marshlands is sometimes hindered due to poor rain regimes.

Plate 4.7-3 Field of vegetables on some sections River Ruvyironza

4.7.2.3 Commerce

The different municipalities of Gitega Province have well established markets and some out of standards. The Province has small shops most of them selling food items. The weather conditions and the climate change have decreased the quantity of food available in the province. The livestock commerce is very important and is the most important resource revenue of the province. Traders come from Kayanza, Ngozi, Muyinga, Bujumbura and Rwanda. They buy directly from farmers or from the so called "commissioners" who buy in advance animals and earn profits before delivery.

4.7.2.4 Transport and communication

Movement of people and transport of goods services are provided by road. Means of transport Most common are the transport head, bike, motorcycle and automotive. The most common mode of transport is by motor vehicles, bicycles and motorcycles. There are three categories of roads: - National Roads (RN) - Provincial Roads (PR) - Local roads (LC) Rural roads that facilitate intra-municipalities communication are numerous and most of them in poor conditions. In Gitega municipality, there is an aircraft landing site of dimensions 950m×16m, managed by the government. The facility serves the aircraft Type "small carrier" with a maximum tonnage of 3 tons. These aircrafts belong to United Nations agencies (ICRC, WFP, ONUB). Communication is by telephone through the services of ONATEL (public), Telecel and Africel. The use of internet is beginning to spread and attract a lot of people to its usage in the areas of the project.

4.7.2.5 Energy

Approximately 7km downstream of the proposed site is a private power generation plant which supplies power to Mugera Mission, Mugera Helth Centre, Begenda Community and Mutoyi Hospital. There are others who benefit from the power supplied from this power plant though the output is relatively low (1 MW).

Plate 4.7-4 Diversion works from the Ruvyironza downstream of the proposed site

4.7.2.6 Housing

The province of Gitega was before the 1993 crisis, one of the provinces built as a modern covered with sheets or tiles, especially in the Municipality of Gitega. In that context, craft production of clay based roofing materials has developed so quickly. In Gitega, there is a marked difference between the rural housing and urban habitat.

4.7.2.7 Health

The province has a certain number of hospitals and health centres. The Gitega municipality alone has 13 health centres, one hospital of second reference. The municipality can accommodate approximately 294 patients. The number of pharmacies is not important, one pharmacy of the mutual health and 7 private pharmacies.

4.7.2.8 Employment

Agriculture and livestock are practiced by farmers using unpaid and family labor. The movement of young people to Bujumbura and other urban areas and especially Kayanza and Gitega is extremely important cause of the scarcity of land, lack of activities income generation, idleness and very difficult social conditions.

4.7.2.9 Education

In Gitega, as indeed in other municipalities in the province, education is organized by the government, through the Ministry of Education and Culture, the religious organizations, local municipalities and the private sector. We distinguish, preschools and colleges with formal education and schools of business, and Sunday schools called Yagamukama

considered a non formal school. Gitega municipality alone has 36 primary schools, 17 secondary schools and four higher education institutions including one public and three other private. These are: L'Institut Supérieur d'Agriculture (ISA), that trains agronomists, animal scientists technicians and Agriculture Food scientists; Le Grand Séminaire Jean–Paul II; L'Institut Supérieur de Gestion et de Management(I.S.G.M) and L'Institut Supérieur Technique, commercial et Economique (I.S.T.C.E.).

4.7.2.10Cultural sites

One of the cultural sites in the areas of Ruvyironza is Mugera Catholic Mission where Marian Shrine is located. The Marian Shrine of Mugera located in the Archdiocese of Gitega was founded in August 15, 1961 when Burundi was preparing for independence. To avoid Burundi falling into violence, the Catholic bishops wrote, on June 3, 1961, a pastoral letter inviting the faithful to gather on Mount Mugera on August 15 at the Marian shrine, to consecrate the shrine to the Mother of God, Queen of Peace. To date, thousands of faithfuls from all eight dioceses in Burundi make pilgrimage to the shrine and most of them attend the prayer Vigil, during which many receive the sacrament of reconciliation. According to local information in the areas of Ruvyironza, there is belief that, if people take refuge under the protection of Mary, she will offer it through her blessed son, Jesus Christ hence this area being popular. ..

4.7.2.11Water and sanitation

The municipality of Gitega alone has 437 water points, 64 fire hydrants including 42 non-functional, seven tanks owned and managed by the REGIDESO, 3 sheets of aspirations for pumps and finally 1,824 private connections including 24 rural connections. Of the 38 hills, only 24 are supplied with drinking water. Because of the 1993 crisis, water infrastructures are seriously in critical conditions. Those were functional are mostly not operational and some of them were no longer maintained or repaired. Funds for building additional water supplies were suspended. Water supply remains insufficient for the population. It is in this context that some developments partners attempt to intervene. These include the GTZ, IFAD and the AVEDEC. They promised to assist the local administration in the management and rehabilitation of drinking water sources.

4.7.3 Previous studies

The following studies have previously considered some aspects of the Ruvyironza site among others:

- KIRBMD (2010) Main Report: Development of Kagera Integrated River Basin Management and Development Strategy, NBI/NELSAP/KAGERA-TIWRMDP/RFP01/2009, SWECO International.

- Norconsult A.S. and Electrowatt. April 1976. Hydropower potentials of Burundi (including basins outside Kagera river basin) Kagera River Basin Development Phase II. Burundi – Rwanda – United Republic of Tanzania. Sectoral Studies. Technical Report, Volume 3. Report prepared for the United Nations acting as executing agency for UNDP.

4.7.4 Alternative developments

The main available alternatives to developing the water resiurces at the Ruvyironza site are

(v) Construction of a dam and a reservoir at the site (as proposed by KIRBMD, 2010)

(vi) Construction of run-of-the-river hydropower scheme (as proposed by Norconsult, 1976).

The topography at the dam site is conducive as the water passes through a narrow valley before it begins a series of shallow rapids. If dammed it would provide a head of 57m and through use of a diversion canal and a penstock could provide a head of 100m. This would result in a significant amount of power that can be generated. Therefore, the viability of the first alternative of constructing a dam site has been assessed in this study. Hydrology

4.7.5 Hydrology of the site

4.7.5.1 Runoff

Available data, between years 1963 and 1990, the daily flow at the dam site ranged between 3 m^3/s on 4-September-1975 and 341 m^3/s on 22-March-1989 and averaged 25 m^3/s (Figure 4.7-3). The mean flow has an exceedance probability of 62% while the median flow is 20 m^3/s.

The mean monthly total flows vary between 120 Million m^3 (Mm^3) in April and 23 Mm^3 in September (Figure 4.7-4). The total annual flow averages about 788 Mm^3.

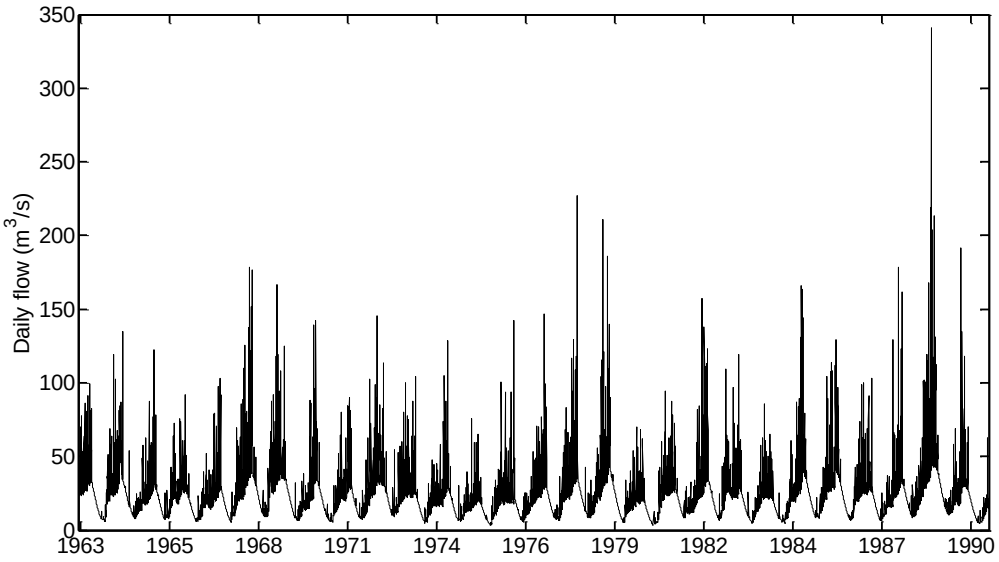

Figure 4.7-3: Ruvyironza Daily flow variation

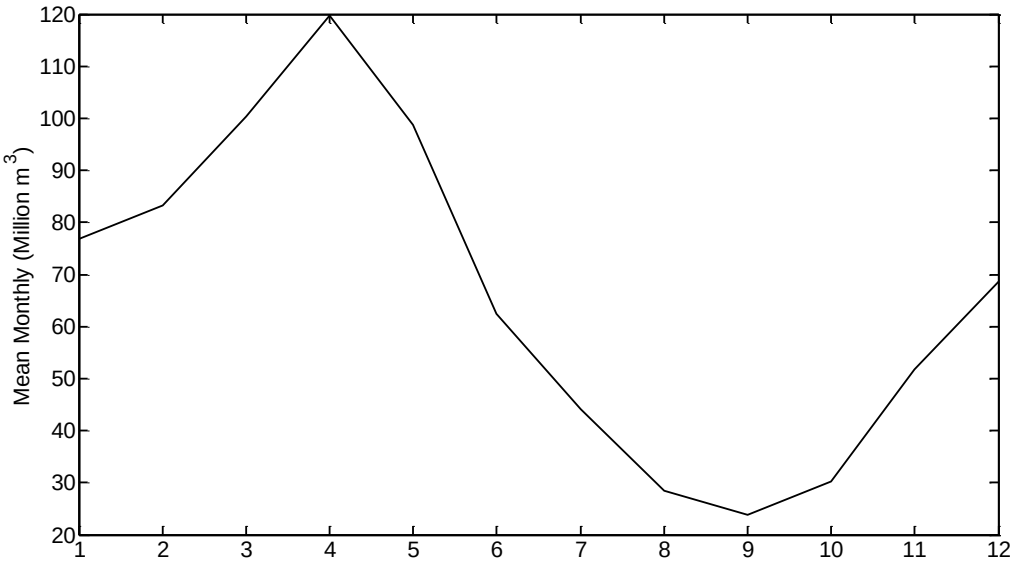

Figure 4.7-4 Ruvyironza Mean monthly flow variation

4.7.5.2 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 4.7-5 and Figure 4.7-6 respectively. Figure 4.7-5 shows that the inundation area increases sharply with elevation up to an elevation of 1529 m asl. After this, the curve is rises gently meaning that small increases in elevation result in large increases in the inundated area and maybe unviable. Setting the required reservoir volume can be based on the required storage to offset the deficit between inflow and outflow during the driest months, among other considerations. Dry months in the area range between 3 and 4 months during which river flows can drop to 20-30% of the mean flow. A total of two months storage was set as the minimum that should be met by the reservoir by the Ruvyironza reservoir. Taking dead storage into consideration, a reservoir elevation of 1528 m asl would be sufficient to meet this requirement at the proposed dam site. Detailed socioeconomic assessments at the feasibility and detailed design stages will be necessary to assess the relative costs of different possible reservoir maximum elevations in terms of displacement of people.

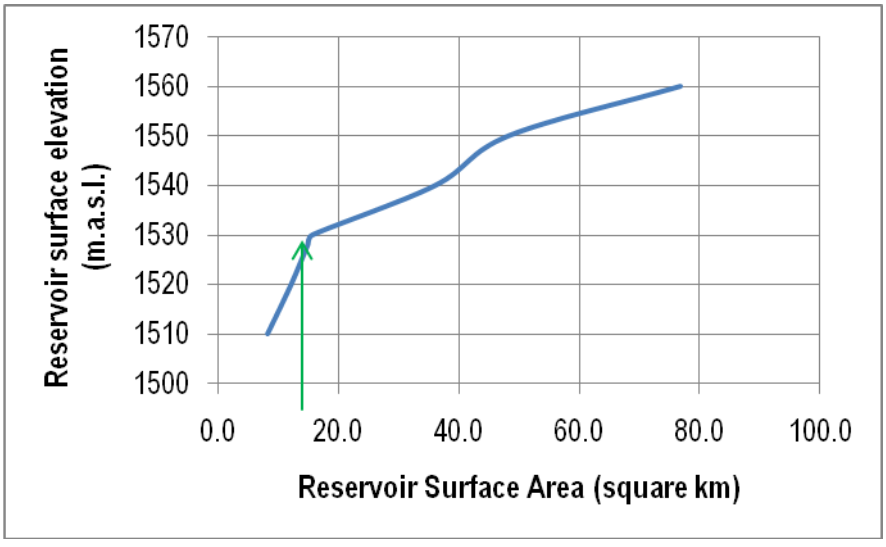

Figure 4.7-5: Plot of Ruvyironza reservoir surface elevation versus reservoir surface area

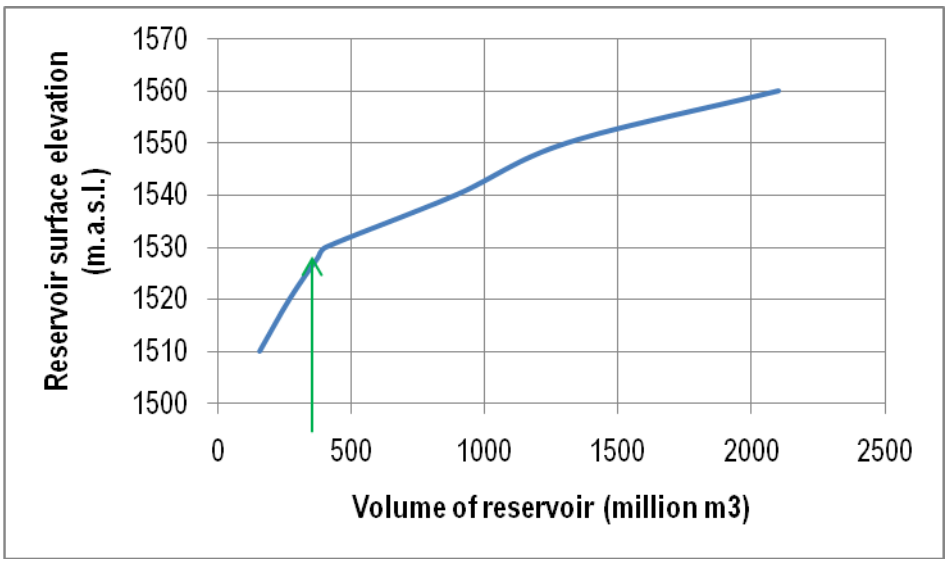

Figure 4.7-6: Plot of Ruvyironza reservoir surface elevation versus reservoir volume

A reservoir elevation of 1528 m asl will inundate 14.96 km^2 of land and will have a total volume of 372.62 million cubic meters of water. The reservoir fetch will be approximately 9 km along the main river and would result in resettlement of over 8,500 people (Table 4.7-1).

Table 4.7-1: Land area to be inundated by the Ruvironza reservoir and the affected population

Province	Commune	Land area (km2)	Population (2012)
Gitega	Bugendana	5.75	2,935
	Giheta	9.32	5,645
Total (reservoir inundation)		**15.1**	**8,579**

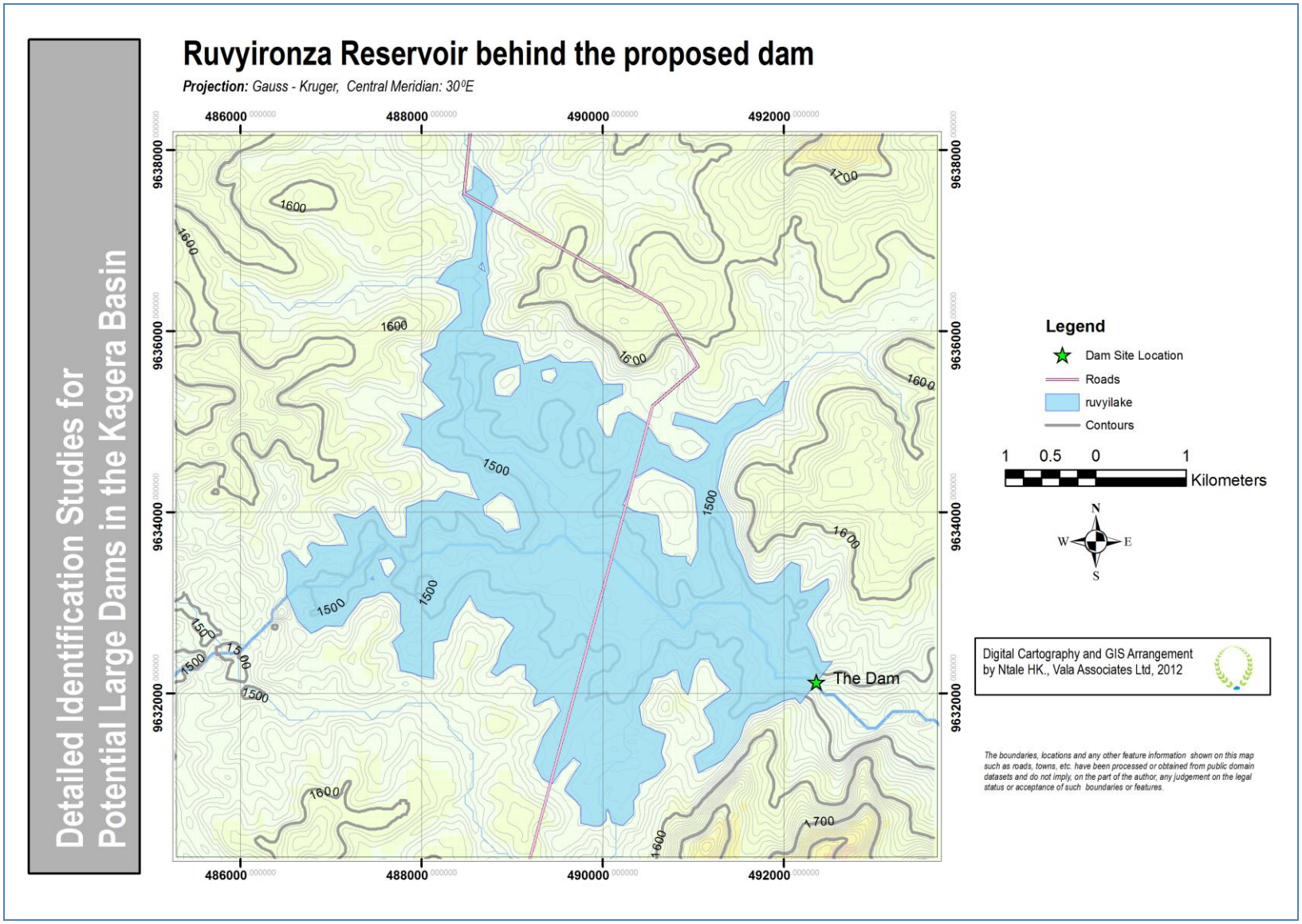

Figure 4.7-7 Ruvyironza Reservoir at 1527m above sea level

4.7.5.3 Reservoir evaporation

Being an open water body, the reservoir evaporation rates would be expected to be close to the potential evapotranspiration rates. Table 4.7-2 shows the daily and monthly potential evaporation rates estimated from data at 2 meteorological stations located close to the Ruvyironza dam site.

Table 4.7-2 Ruvyironza Daily and monthly potential evaporation rates

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

Using the approach suggested by Lawrence et al (2004), sedimentation yields for the Ruvyironza catchment contributing to the dam site was established to be 1063 t/km^2/yr. The dead storage properties of the dam are shown in Table 4.3-3 below:

Table 4.7-3 Ruvyironza Sediment Properties

Site Name	Ruvyironza
Reservoir Volume (Mm^3)	372.2
Catchment area (km^2)	1999
SY (t/km^2/yr)	1,063
Assumed Sediment density (t/m^3)	1.1
Dead Volume (Mm^3)/yr	0.84
Dead storage after 50 years (Mm^3)	42.06
Percentage of Reservoir filled with sediment after 50 years	11%

4.7.5.4 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 Nyakizumba 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
- Estimation of the flood magnitudes corresponding to various return periods (Table 4.7-4)

Table 4.7-4: Ruvyironza flood estimates and associated return periods

Return period, T (years)	Flood magnitude (m3/s)	Risk of failure for a 50 year design life (%)
50	299	63.6
100	343	39.5
200	391	22.2
500	462	9.5
1000	521	4.9
2000	587	2.5
5000	683	1.0
10000	764	0.5

4.7.6 Irrigation and command area

The Ruvyironza site is not very suitable for irrigation immediately downstream of the dam. The downstream valley is generally narrow with relatively steep slopes. **However,** the released waters can be used to irrigate 14674 ha located in the provinces shown in Table 4.7-5 further downstream after the confluence with River Ruvuvu. The command area has to begin after the tailrace of the proposed power house (See Figure 4.7-8). The command area can support 29,348 farmers and provide food for about 146,739 people. The annual water demand for irrigation is about 74 Mm^3.

Table 4.7-5: Irrigation command area for Ruvironza

Province	Commune	Area (ha)
Cankuzo	Cankuzo	1,661
Gitega	Bugendana	42
	Giheta	104
	Gitega	627
Karuzi	Mutumba	3,249
	Nyabikere	1,600
	Shombo	1,403
Muyinga	Mwakiro	1,484
Ruyigi	Butezi	3,492
	Bweru	1,012
Total		**14,674**

4.7.7 Water Supply

The total population that can benefit from water supply from the Ruvironza project in 2012 and 2062 was estimated at 264,531and 1,002,303 people respectively (Table 4.7-6). The annual water demands are 3 Mm^3 and 11 Mm^3 for 2012 and 2062, respectively.

Table 4.7-6: Potential water supply beneficiaries for Ruvironza

Province	Commune	Population (2012)	Population (2062)
Cankuzo	Cankuzo	6,868	26,021
	Kigamba	238	902
Gitega	Bugendana	36,630	138,790
	Giheta	58,023	219,848
	Gitega	42,920	162,622
Karuzi	Mutumba	23,333	88,407
	Nyabikere	14,973	56,734
	Shombo	16,430	62,252
Muyinga	Mwakiro	11,030	41,791
Ruyigi	Butaganzwa2	349	1,323
	Butezi	44,419	168,303
	Bweru	9,320	35,312
Total (Water supply)		**264,531**	**1,002,303**

4.7.8 Dam Design elements

4.7.8.1 General

Owing to the nature of the river cross-section at the proposed dam site as v-shaped medium width valley, an earth dam is proposed. The dam will have a base elevation of 1470 m asl while the crest elevation will be 1531 m asl. The dam crest will be 626m 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 1528 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 56.8 m
- Site 2: this will be located 4km downstream of the dam site just before the intake to the currently existing power dam located at the end of Ruvyironza just before it joins River Ruvuvu. The maximum available head at this site is 100 m

The relative merits and demerits of the 2 power station options should be explored during the feasibility study stage. This study presents only the second option whereby the power station will be located 4 km downstream from the dam site.

4.7.8.2 Dam Type

The dam at Ruvyironza has been designed as a Composite Earth Fill dam with a roadway on top and an Ogee spillway section. The dam properties are presented in Table 4.7-4 below.

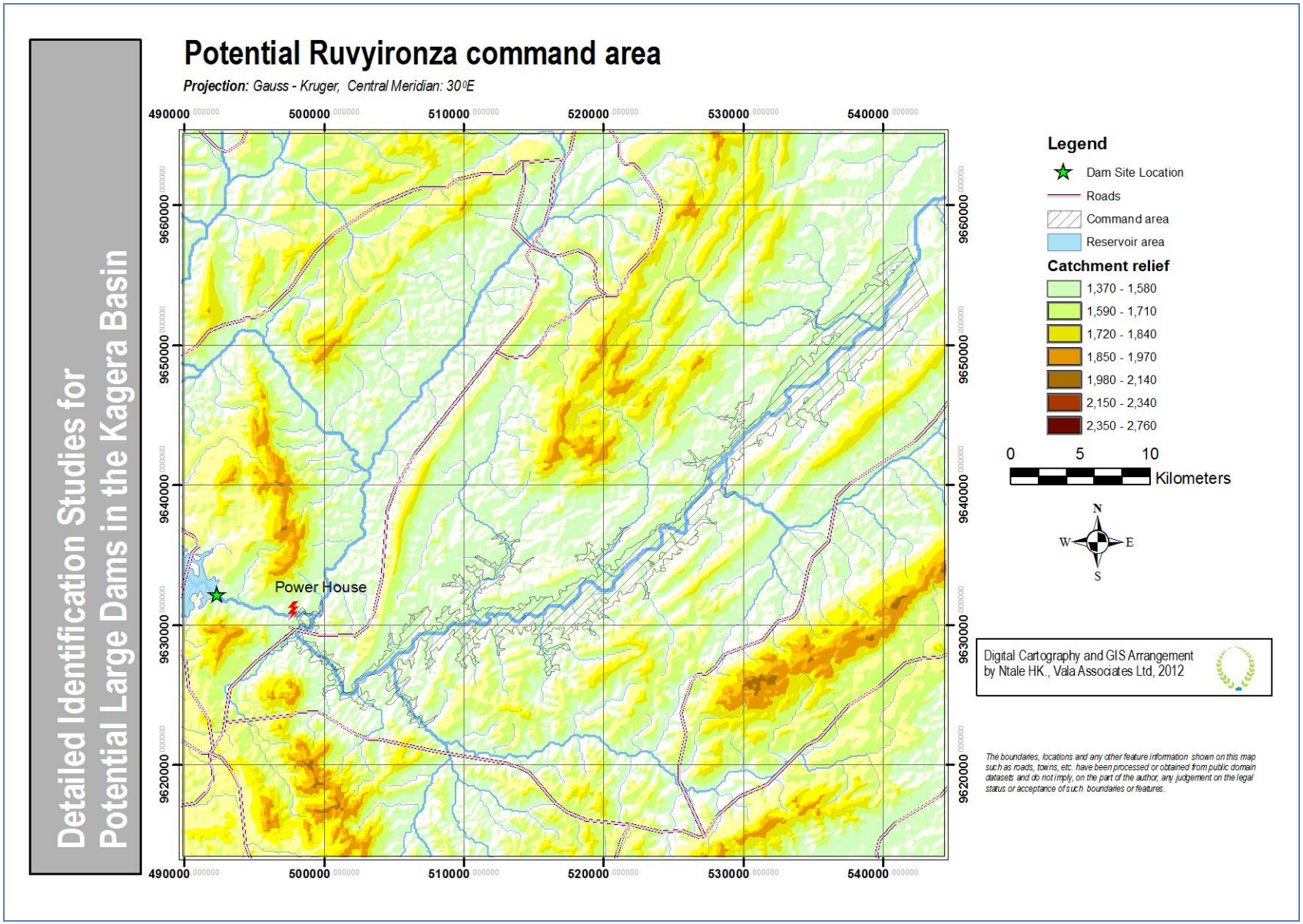

Figure 4.7-8 Ruvyironza Command area

Table 4.7-7: Ruvyironza dam design

Dam location				Ruvyironza
Dam type				Composite Earth Fill
Reservoir base elevation			m asl	1470.6
Reservoir top elevation			m asl	1526.0
Reservoir depth at above dam base (Hnet)			m	55.4
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	Total Free board	m	3.5
Dam height H			m	58.9
Crest elevation			m asl	1529.5
Spillway crest elevation			m asl	1526.0
Crest length			m	626
Top width (7-12 m depending on dam height)			m	10

4.7.8.3 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 4.7-8 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 4.7-8: Ruvyironza Spillway design parameters

Variable	Units	Value
Return period	years	10,000
Spillway crest elevation	m asl	1,528
Design flood	cumecs	
Discharge coefficient, Cd (assumed)		
Spillway crest length, L	m	
Head on spillway, H	m	
Spillway discharge, Q=Cd*L*H^(3/2)	cumecs	
Length of downstream stilling apron		

4.7.8.4 Power station

The power station will be located 4 km downstream of the dam site. A canal will be provided for transferring the water from the dam to adjacent 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 canal in order to establish the route 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 4.7-9: Ruvyironza Hydropower estimation

Variable	Value	Units
Rated reservoir level	1526	m asl
Tailwater level	1471	
Head	96	m
Mean flow	25	m^3/s
Rated flow (30% higher than mean)	32.5	m^3/s
Plant efficiency	90%	
Power	27.5	MW
Energy	241.3	GW/year

The proposed hydropower station at the Ruvironza site has the potential to produce 241 GWh of energy per year which is enough to supply about 268,000 houses and over 1.6 million people.

4.7.8.5 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. From the reconnaissance it was established that there is plenty of good red earth soil within the dam environs which could be used to construct the dam. 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.

4.7.9 Project costs

The estimated costs for the Upper Ruvubu project total to 132.3 million US dollars as broken down in Table 4.7-10 below.

Table 4.7-10 Ruvyironza Project 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
	Relocation of Ngozi-Gitega highway	km	4	1000000	4000000
	Resettlement and compensation	Ha	1506	2500	3765000
	Subtotal				**10565000**
2.0	**MAIN DAM**				
	Excavation, loose	m3	320000	15	4800000
	Excavation, rock	m3	80000	22	1760000
	Foundation preparation	Lumpsum	1	500000	500000
	Dam earthworks - random fill	m3	2600000	15	39000000
	Dam earthworks - impermeable core	m3	1600000	20	32000000
	Subtotal				**78060000**
3.0	**SPILLWAY, INTAKE, AND PENSTOCKS**				
	Excavation, loose	m3	4000	15	60000
	Excavation, rock	m3	15000	22	330000
	Concrete Spillway	m3	31000	200	6200000
	Concrete intake	Lumpsum	1	250000	250000
	Penstocks, 2No @ 6.5 m2 steel	m	200	1500	300000
	Other civil structures	Lumpsum	1	500000	500000
	Subtotal				**7640000**
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	4000000	4000000
	Generators, transformers and miscellaneous electrical equipment	Lumpsum	1	3500000	3500000
	Gates for intake, outlet	Lumpsum	1	1500000	1500000
	Switchyard	Lumpsum	1	300000	300000
	Subtotal				**9300000**
	TOTAL, CONSTRUCTION COST				**109842500**
	ADMINISTRATION AND ENGINEERING		0.1		10984250
	CONTINGENCIES		0.15		16476375
	CAPITAL COST (WITHOUT VAT)				**137303125**

4.7.10 Project Anticipated Impacts and Mitigation Measures

4.7.10.1Positive 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;
- With its planned multi-purpose usage in terms of supply of water and electricity the project will lead to transformation of the areas with developments being stimulated in around the area;
- The project will help vulnerable groups such women to earn side income to supplement domestic needs. This is because most of the people farming in the marshland are women; 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.

4.7.10.2Negative Impacts

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

- One of the key potential adverse impacts of the dam site development will be impacts on the existing small power generation plant downstream that supplies energy to the Mission at Mugera and its institutions;
- The dam works will displace farmers on inn the vicinity of the site thereby depriving them of their area of livelihood. This is a fundamental impact that can have long term implications in terms of food security in the affected households;
- The project will impact on the communities in terms of loss of roadside crops especially bananas and woodlots;
- 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, camp 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 concerns 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 4.7-11 as follows:

Table 4.7-11 Key impacts and mitigation measures for the planned Ruvyironza site

Nº.	**Project Impact**	**Mitigation measures**
01.	Impacts on the power plant downstream that will likely be affected from projects works on the planned project.	The implication of the planned dam have to assessed in the ESIA and feasible measures instituted to avoid disruption of power supply to the

Nº.	Project Impact	Mitigation measures
		beneficiary community such as Mugera mission and its associated institutions.
02.	Loss of adjacent cropland areas due to inundation.	Compensation for loss of crop and issuing early notice to farmers to harvest crops. Feasible measures to ensure food supply for the affected communities and persons are put in place. This could include aspects such as alternate sources of income through some revolving fund for those affected by the project.
03.	Impact on roadside vegetation such as bananas and woodlots.	Where inevitable, there should be compensation for the lost roadside resources.
04.	The dam site will take up a community road that passes through the site connecting the north-south villages.	Alternate route for the community be set up by the project.
05.	Land uptake through construction of the dam and access roads, camp sites, etc	Compensation for land uptake after Resettlement Action Plan (RAP) studies.
06.	Concerns relating to management of cut to spoil materials	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
07.	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.
08.	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.
09.	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.
10.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
11	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.

Nº.	Project Impact	Mitigation measures
12.	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.
13.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
14.	Noise and vibrations	Noise from equipment and the workforce
15.	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. Mugera mission health centre is in place and it is suggested that, the project could link up and partner with such institution and have joined HIV/AIDS interventions to address community and project based concerns in the area.
16.	Air Quality concerns likely to arise from project works	Dust suppression measures will be instituted to ensure air quality levels are kept appropriate.
17.	Possible increase in crime rate in the areas of the project.	Working together with the police and law enforcement agencies to control crime in the areas.
18.	Impacts on socio-cultural sites	This issue should be further investigated during the detailed ESIA once such socio-cultural sites are located, then appropriate measures will be outlined.

4.8 Gashayura Dam Site

4.8.1 Physical Environmental Profile

4.8.1.1 Location

The coordinates of the dam site are 30° 9' 7.8" East and 2° 56' 13.86" South. The 159 km^2 catchment has a length of 25 km and an average width of about 6 km (Figure 4.8-1). Gashayura River crosses Gitaramuka, one of the 7 mucipalities that form Karuzi Province. The site potential reservoir capacity is 19.9 Mm^3. The site has a potential head of 17 m. The main purposes of the dam will be irrigation and water supply. Some hydropower could also be generated. The area to be inundated by the reservoir is sparsely populated but is mainly used as farm land.

The catchment slope averages 15% though it can be higher than 80% especially in the highlands to the west and south. The catchment elevation ranges between 1539 m asl at the dam site to a maximum 1827 m asl while the mean is 1652m asl.

Plate 4.8-1 Gashayura River, just downstream of the proposed dam site

4.8.1.2 Physiography

River Gashayura flows in a south westerly direction to the dam site (Figure 4.8-1). The elevation of the riverbed at the dam site is about 1539 m asl. The river valley is generally flat and about 400 m wide. The elevation of the left flank of the river rises at a slope of 13% before flattening out for a distance of about 90 m at an elevation of 1707 m asl. The right flank elevation rises at a slope of 63% to an elevation of 1697 m asl after which it drops by a 4 m for a distance of 120 m before rising at a slope of 27%.

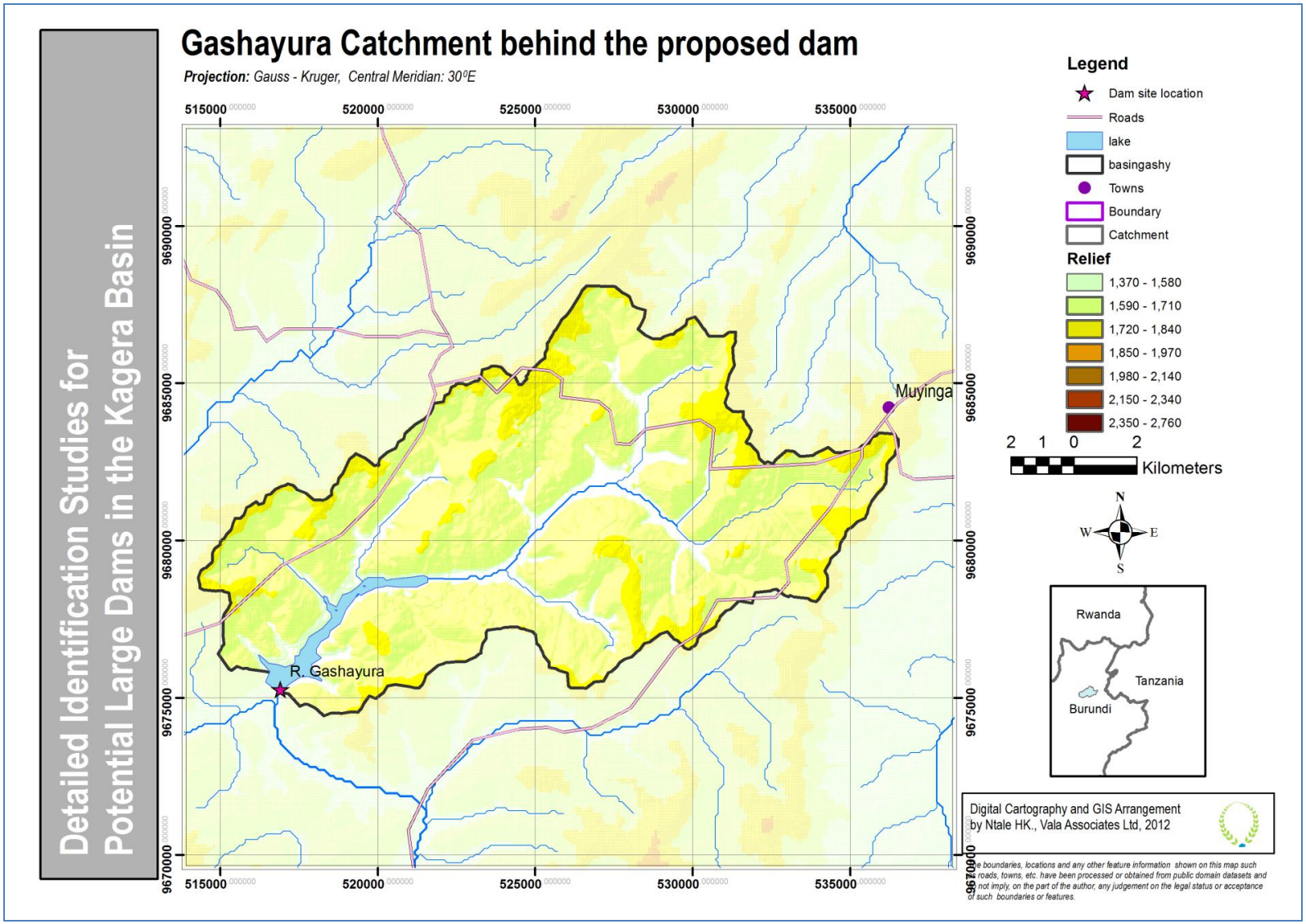

Figure 4.8-1 Gashayura Catchment

4.8.1.3 Climate

Available data indicates that the basin receives a mean annual rainfall of 1217 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 189 mm while maximum rainfall in the short rainy season is received in November and averages 156 mm. July is the driest month, receiving only 7 mm of rainfall on average. The mean annual potential evaporation is 1106 mm and varies over a narrow range between 72 mm in December and 117 mm in September. The average temperatures range between 18°C in June and 20°C in September.

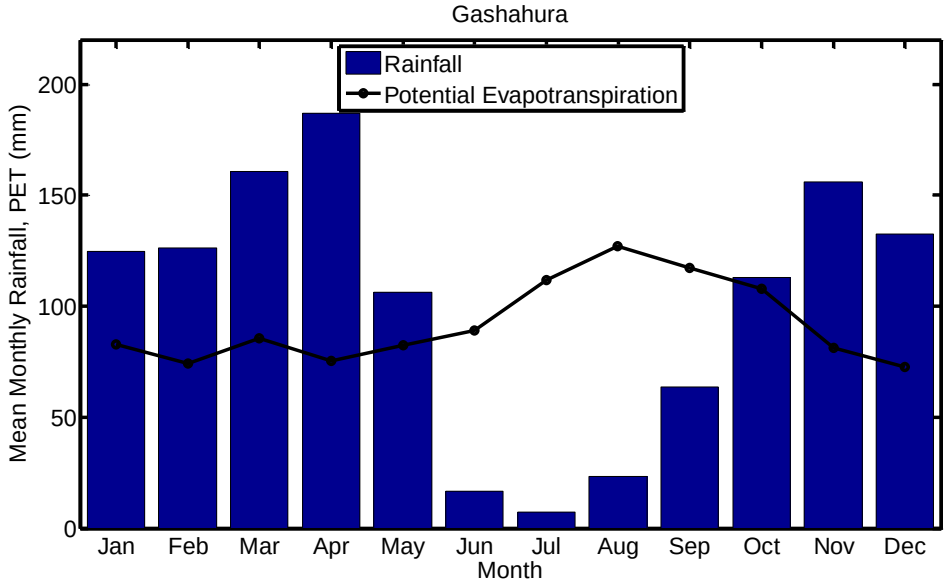

Figure 4.8-2: Gashayura catchment mean monthly rainfall and potential evaporation

4.8.1.4 Geology

The central and eastern parts of the basin are dominated by intrusive rocks. The western part is mainly made up of the Muramba complex that is mainly composed of well banded greenish-grey sandstone shales with granites and other metamorphic minerals in some places. The southern is dominated by the Migogo system which is made of grayish banded shales and sandstones while the lower part may contain homogeneous quartz rocks. Further investigations are necessary to provide stronger understanding of the geology of the area and the dam site in particular. The investigations should focus on the following;

- Geologic structures
- Ancentral stream patterns, ancient structural trends, linements of basement rock,
- Interpretation of concealed subsurface and historic events by use of paleotectonic map series
- Seismic hazard map
- Groundwater flow regimes

- Analysis of the physical and engineering properties of rock units and formations, soils and superficial deposits, tectonic structural patterns, inherent structural deformations, rocksoil weathering and alterations, slope stability and downslope movement,
- geomorphic history; surficial sediments, origin, properties
- Geological phenomena; areal subsidence, downslope movement, weathering rates, sediments filling, seismic history.

4.8.1.5 Soils

The soils are part of the wider province soils that are characteristically poor in nutrients as evidenced by state of poor crop stands around the site. The poor soils have driven communities to farm in the marshlands implying the planned development will go a long way to alleviate food situation in the areas. The crop stands of cassava are poor evidence that, the soils are poor to support cultivation.

4.8.2 Social Environment profile

4.8.2.1 Demographics and trends

Karuzi Province in 2003 had a population of 398,219 inhabitants, 191 527 being men and 206,692 women. The population under 25 years was estimated around 59%. The population density is estimated at 274 inhabitants per km2. The labor force is estimated at 187 614 inhabitants for 210 605 inhabitants of dependent population. The dependency ratio is 1.12%. The following table summarizes the physical, administrative and demographics of the Province of Karuzi.

Table 4.8-1 Census of the population in the Karuzi Province

Municipality	Surface area	Zone	Population	Density
Bugenyuzi	235	3	77.297	329
Buhiga	275	2	61.581	224
Gihogazi	192	3	66.906	348
Gitaramuka	211	3	78.225	370
Mutumba	178	2	35.208	198
Nyabikere	195	3	41.285	212
Shombo	170	3	37.717	221
Total	1456	19	398.219	274

Source: MPDR, 2003

4.8.2.2 Agriculture

The practice of cultivation is traditional, labour intensive with a hoe and a predominance of crops association. It was observed that field work is done mostly by women. According to data provided by the "Direction Provinciale de l'Agriculture er de l'elevage" (DPAE) of Karuzi, the main food crops by order of importance are: bananas, sweet potatoes, cassava and maize. Banana, sweet potato and cassava are the most daily cultivated in the areas of the planned project. The only industrial crop is coffee. Agriculture activities are undertaken based on the season of the year. Due to poor soils in most parts of the areas, communities living close to the marshlands have resorted to paddy rice cultivation for domestic and as a source of income for the communities. The cultivation of rice in marshlands is sometimes hindered due to poor rain regimes.

4.8.2.3 Livestock

The livestock sector was equally affected by the political crisis that hit Burundi in past year and this has affected livestock population which is worsened by rampant thefts in the communities. The farming practiced in Karuzi is of traditional type and constituted of cattle, goats, sheep, pigs and poultry. Local breeds make up most of the common herd in Karuzi, the exception of the urban area where the introduction of modern breeds has started.

Plate 4.8-2 Field of rice in a section of the proposed dam site in Gashayura River.

Plate 4.8-3 Cassava and beans at the fringes of the marshland areas.

The areas close to the marshlands are also planted with woodlots that supply woodfuel which serves as a source of energy for cooking.

4.8.2.4 Employment

Agriculture and livestock are practiced by farmers using unpaid and family labor. The movement of young people to Bujumbura and other urban areas and especially Kayanza and Gitega is extremely important cause of the scarcity of land, lack of activities income generation, idleness and very difficult social conditions.

4.8.2.5 Making of local clay products

The marshland fringes serve as sources of clay for brick making and the bricks are sold locally in the community. Apart from bricks, some youth in the community are engaged in the making of local roofing tiles called *tegura*. The bricks and tiles have transformed the local housing sector in that, there are virtually no mud and wattle grass thatched houses in the area (See Plate 3.9-4 and 3.9-5 below).

Plate 4.8-4 Drying of local tiles (tegura) at the fringes of project site

Plate 4.8-5 Brick burning near the site

4.8.2.6 Education

Karuzi Province has 92 primary schools of which 18 are to be rehabilitated. The number of students is 76,721 with 37,638 boys and 39,083 girls. The number of teachers is 962 or an average of one teacher per 80 students. Regarding the secondary schools, Karuzi has 17 schools, with 4 to be rehabilitated. The number of students is 479 for a number of teachers estimated to 5239 (Table 4.8-2).

Table 4.8-2 Primary and secondary schools in Karuzi Province

Schools	Schools in acceptable conditions	Schools to be Rehabilitated	Number of students	Number of Teachers
Primary	74	18	76,721	962
Secondary	10	4	5239	479

4.8.2.7 Health

Gitaramuka municipality where the proposed project site is located has the same main problems relating to health services delivery and these include; inadequate infrastructure in terms of facilities; lack of equipment and staffing. The area has 14 health centres, 2 hospitals, and 9 private pharmacies, and a paramedical school training the A2 and A3. As in all other municipalities the epidemiological picture is characterized by common prevalence of malaria, pneumonia among children under 5 years, diarrhoea among children under 5 years, malnutrition and occasional dysentery.

4.8.2.8 Water and sanitation

While the standards for optimal water supply are for a water point for 500 meters or two water points per square kilometer, 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 Karuzi. Thus, the number of households per water point is 14. All these facilities are inadequate to serve the total population of Karuzi 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.

4.8.2.9 Energy

Karuzi as a whole has no hydropower plant. Due to scarcity of electricity, firewood and charcoal are other energy sources available to the public. However, there are no natural forests to supply the wood fuel even there are few woodlots for private supply of wood fuel. Communities sometimes try to source wood fuel from stumps and any other wood resources in their vicinity

4.8.2.10Transport and communication

Movement of people and transport of goods services are provided by road. Means of transport Most common are the transport head, bike, motorcycle and automotive. The most common ways of transport are vehicles, bikes and motorcycles. There are three categories of roads: - National Roads (RN) - Provincial Roads (PR) - Local roads (LC) Rural roads that facilitate intra-municipalities communication are numerous and most of them in poor conditions. The province of Karuzi has 2732 km of feeder roads, 2170km need rehabilitation.

4.8.3 Previous studies

While carrying out the current assignment, the following related study/studies were reviewed

- Rapid identification and assessment of potential sites for multi-purpose storage reservoirs, NELSAP, Kagera River Basin Management Project

4.8.4 Hydrology

4.8.4.1 Runoff

Available data between the years 1963 and 1990 showed that daily flow at the dam site ranged between 0.3 m^3/s on 16-Sep-1982 and 11 m^3/s on 23-April-1965 and averaged 2.6 m^3/s (Figure 4.8-3). Flow duration curve analysis (Figure 4.8-5) shows that mean flow has an exceedance probability of 61% while the median flow is 2.5 m^3/s.

The mean monthly total flows vary between 11 Million m^3 (Mm^3) in May and 2 Mm^3 in september (Figure 4.8-4). The total annual flow averages about 81 Mm^3.

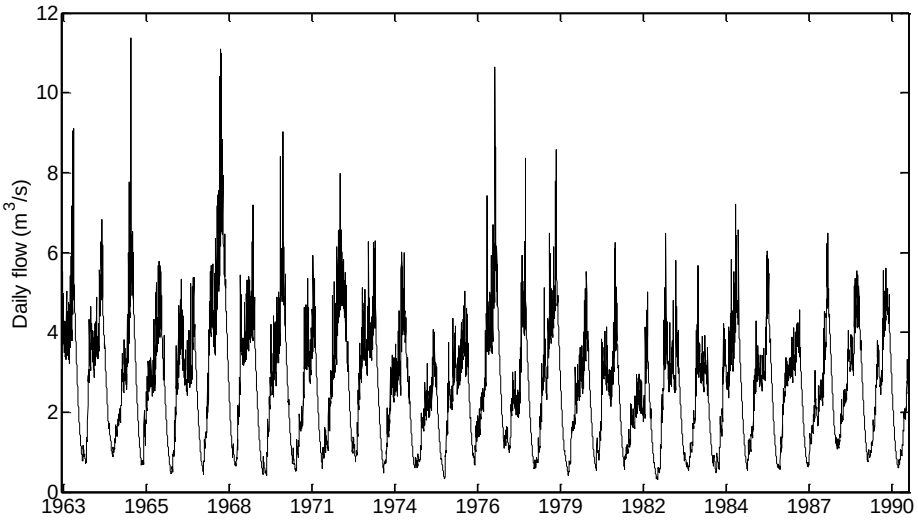

Figure 4.8-3: Gashayura Daily flow variation

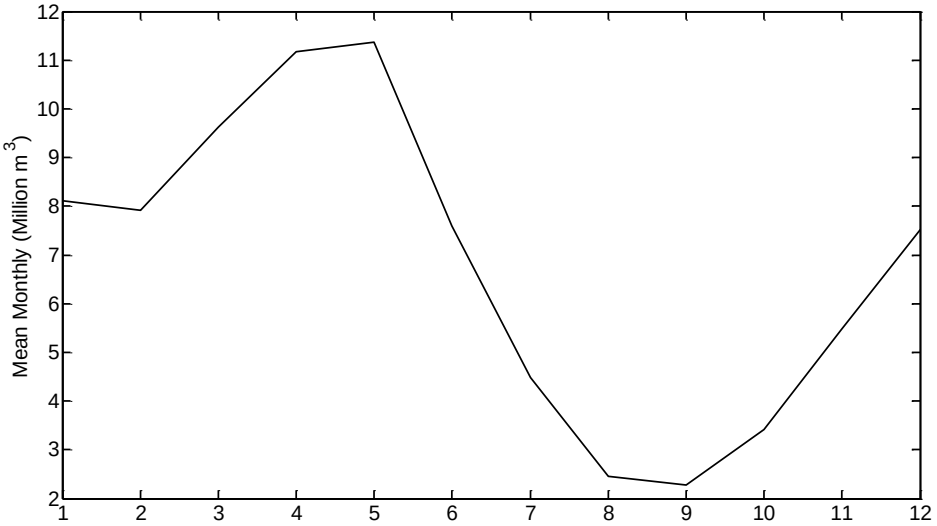

Figure 4.8-4: Gashayura Mean monthly flow variation

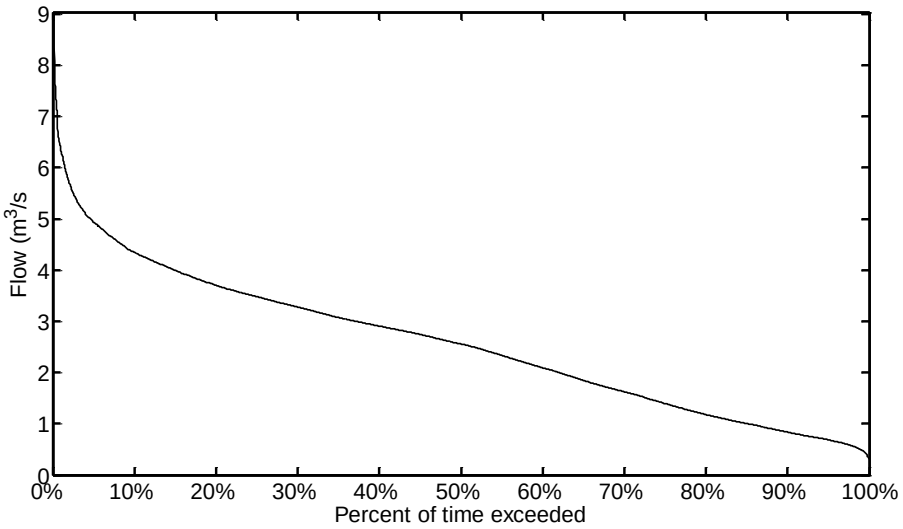

Figure 4.8-5: Gashayura Flow duration curve

4.8.4.2 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 4.8-6 and Figure 4.8-7 respectively. Figure 4.8-6 shows that the inundation continues increasing with elevation at a uniform rate. However, an elevation of about 1565 m asl provides a physical limit as the reservoir may overflow into nearby watersheds. An elevation of 1555.5 m asl is an optimum target for the maximum reservoir level for the Gashayura site. Detailed socioeconomic assessments at the feasibility and detailed design stages will be necessary to assess the relative costs of different possible reservoir maximum elevations in terms of displacement of people and inundation of agricultural lands.

The proposed reservoir elevation will inundate 280 ha of land and will have a total volume of 20.4 million cubic meters of water. The reservoir fetch will be 6 km along the main river while the average width of the reservoir will be about 400 m.

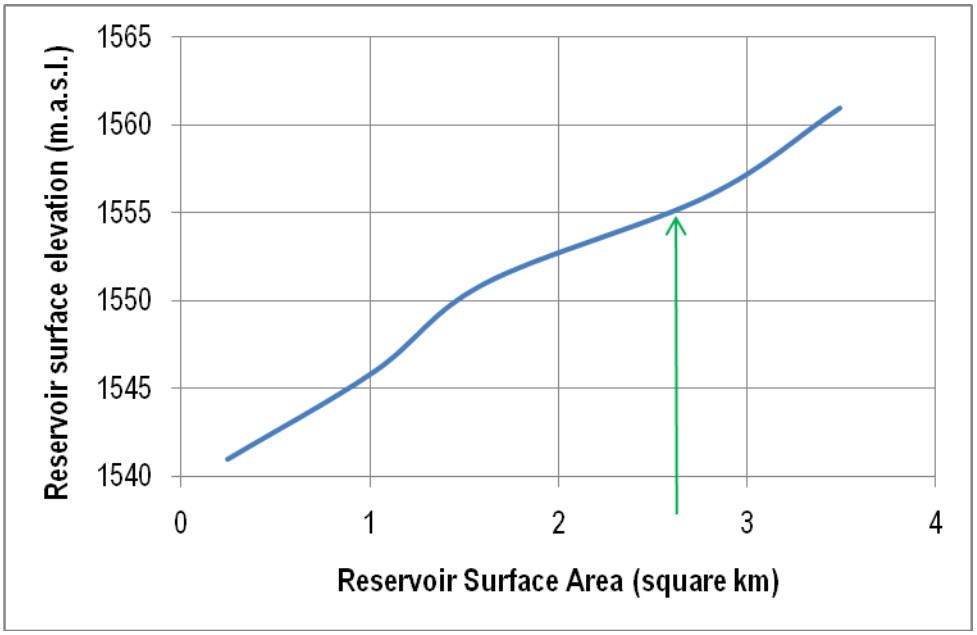

Figure 4.8-6: Plot of Gashayura reservoir surface elevation versus reservoir surface area

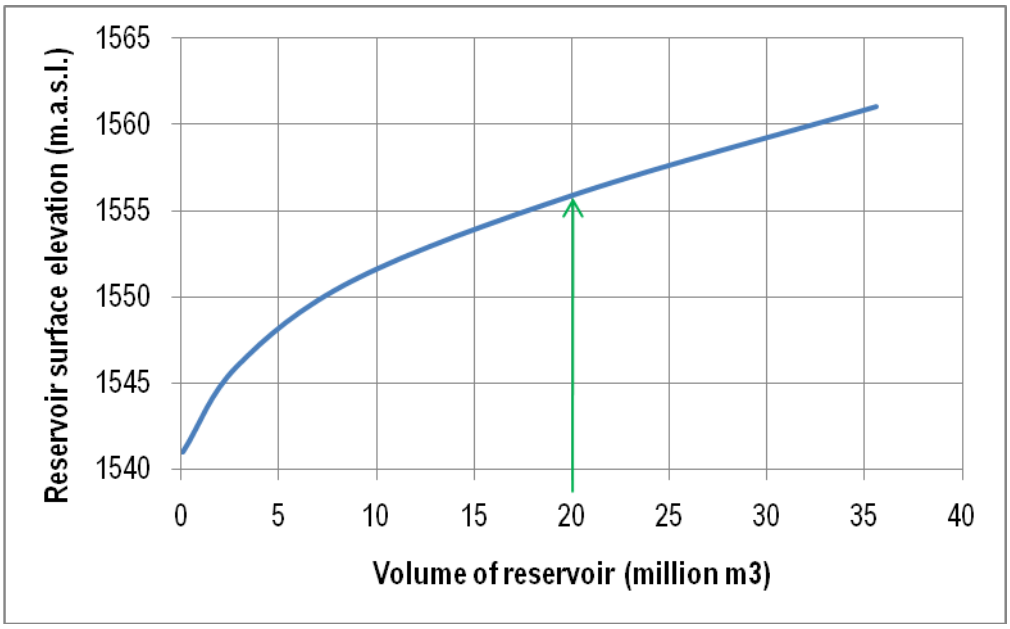

Figure 4.8-7: Plot of Gashayura reservoir surface elevation versus reservoir volume

4.8.4.3 Evaporation

Being an open water body, the reservoir evaporation rates would be expected to be close to the potential evapotranspiration rates. **Table 4.6-3** shows the daily and monthly potential evaporation rates estimated from data at 3 meteorological stations located close to the Kavurungu dam site.

Table 4.8-3: Gashayura Daily and monthly potential evaporation rates

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

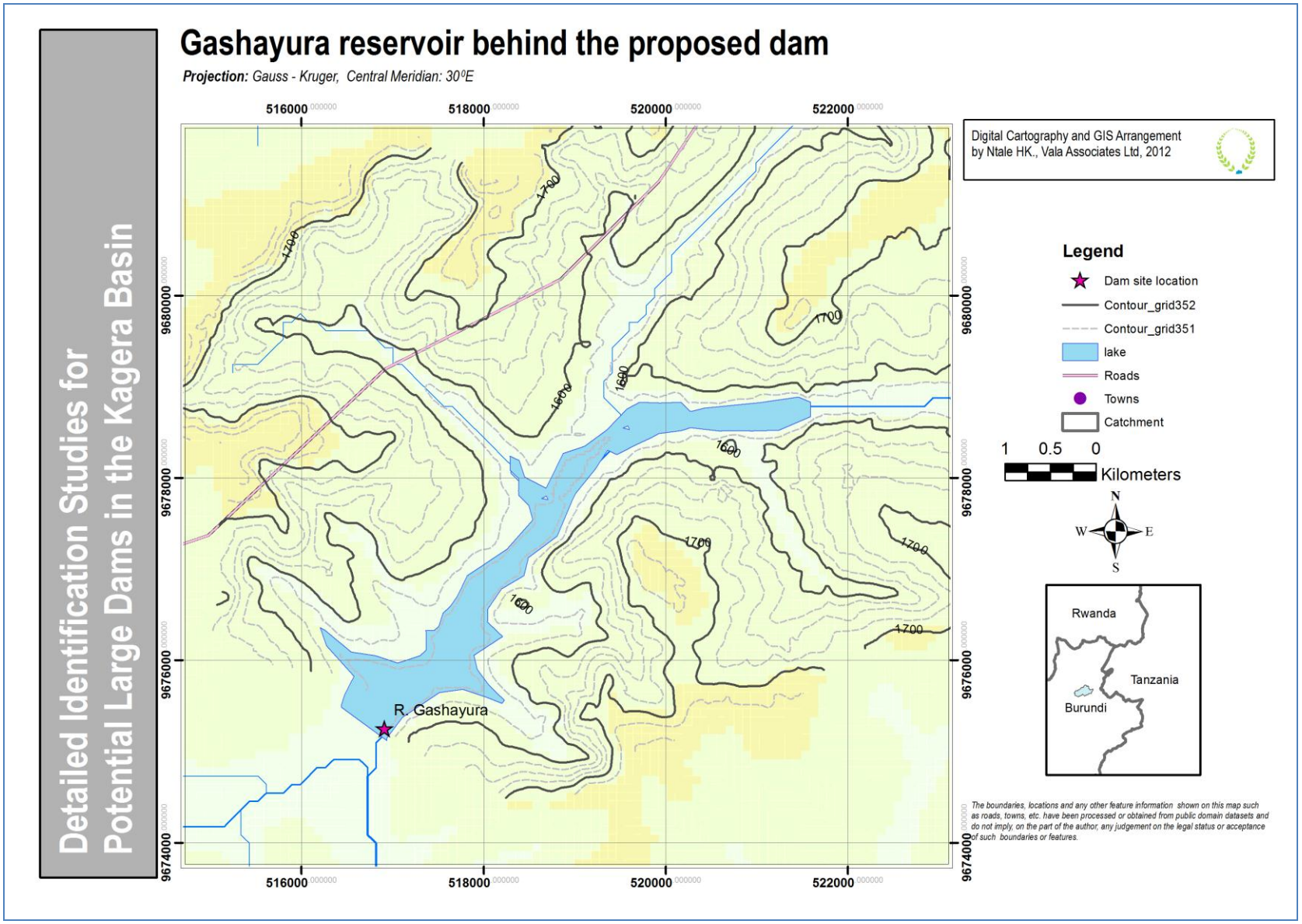

Figure 4.8-8 Gashayura Reservoir at 1555 m above sea level

4.8.4.4 Floods

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

i). Selection of the annual maximum 24-hour flows from the measured flow

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 4.8-4: Flood estimates for the Gashayura Project (assuming the design life of the dam to be 50 years)

Return period, T (years)	Flood magnitude (m3/s)	Risk of failure for a 50 year design life (%)
50	13	63.6
100	14	39.5
200	16	22.2
500	19	9.5
1000	21	4.9
2000	23	2.5
5000	27	1.0
10000	30	0.5

4.8.4.5 Sedimentation

Reservoir sedimentation estimates were carried out using a procedure developed by Lawrence et al (2004) for small dams in Zimbabwe and Tanzania. The study developed a regionalisation approach to predicting catchment sedimentation rates based on an assessment of catchment factors like area, rainfall, catchment slope, signs of active soil erosion, vegetation conditions over the catchment, soil type and drainage pattern. Table 4.8-5 shows the estimate of annual sedimentation rates.

Table 4.8-5: Gashayura Estimation of annual sedimentation rates

Site Name	R. Gashayura
Reservoir Volume (Mm3)	20.4
Catchm't area	159
SY (t/km2/yr)	789
Assumed Sediment density (t/m3)	1.1
Dead Volume (Mm3)/yr	0.05

Dead storage after 50 years	2.48
Percentage of Reservoir filled with sediment after 50 years	12%

4.8.5 Irrigation command area

The Gashayura site is very suitable for irrigation immediately downstream of the dam. Already, there is intensive mixed farming in the downstream valley. Availability of water all year around would enable the valley residents to engage in more profitable agriculture. (Figure 4.8-9) .below shows the potential command area (1212 ha) located in the province(s) shown in Table 4.8-6. which can be directly irrigated using the Gashayura reservoir waters.

Table 4.8-6: Irrigation command area for Gashayura

Province	Commune	Area (ha)
Karuzi	Buhiga	210
	Gitamiruka	964
Ngozi	Tangara	38
Total		**1,212**

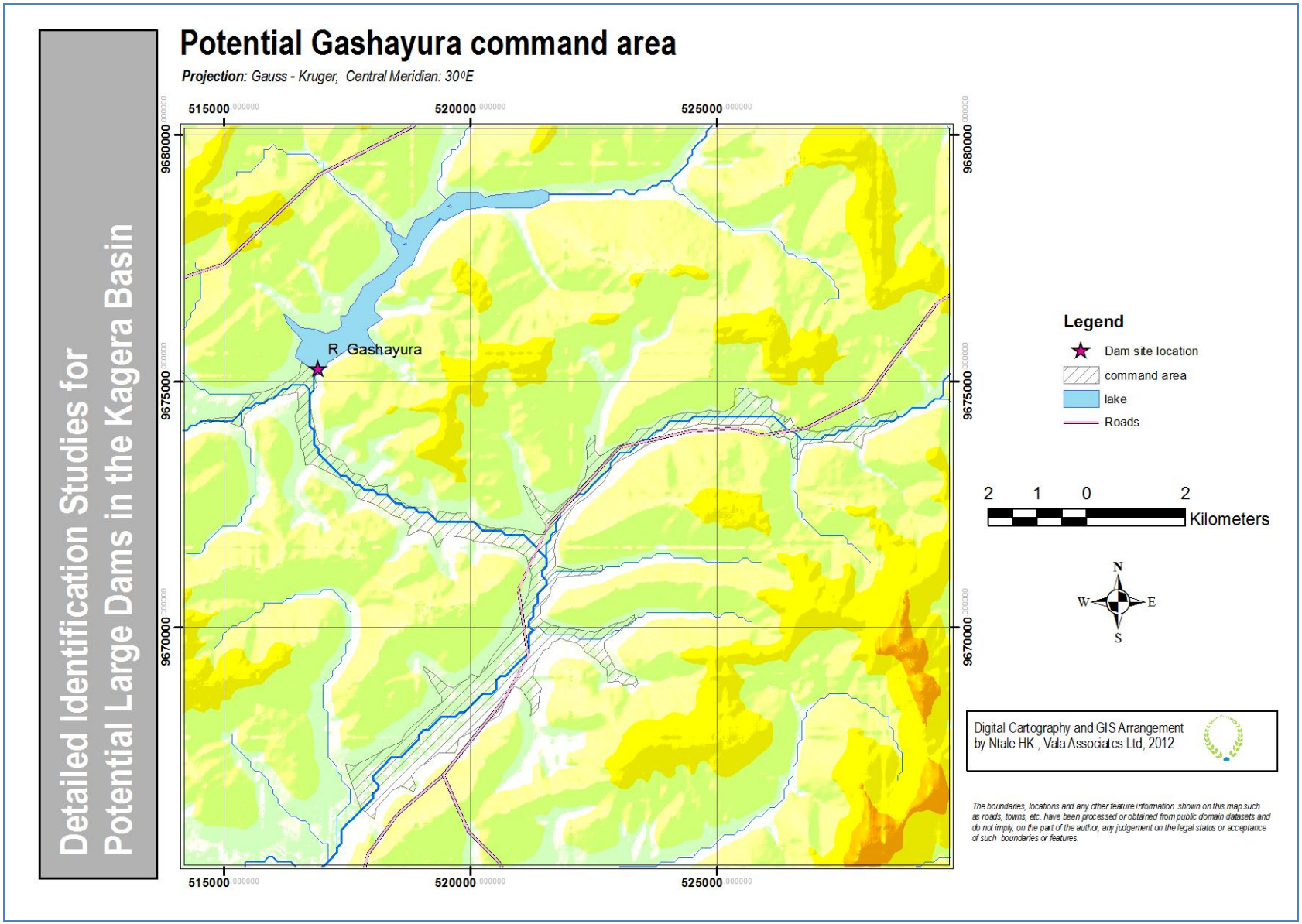

Figure 4.8-9 Gashayura Command area

4.8.6 Water Supply

The total population that can benefit from water supply from the Gashayura project in 2012 and 2062 was estimated at 169,135 and 640,847 people respectively (Table 4.8-7). The annual water demands are 2 Mm^3 and 7.1 Mm^3 for 2012 and 2062, respectively.

Table 4.8-7: Potential water supply beneficiaries for Gashayura

Province	Commune	Population (2012)	Population (2062)
Karuzi	Bugenyuzi	4,894	18,543
	Buhiga	34,023	128,911
	Gitaramuka	89,032	337,339
Muyinga	Gasorwe	20,540	77,825
	Muyinga	5,478	20,757
Ngozi	Tangara	16,754	63,480
Total		**170,720**	**646,856**

4.8.7 Dam Design Elements

4.8.7.1 Dam

The dam at Gashayura has been designed as an earth fill dam with 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 4.8-8: Gashayura dam design

Variable			Units	Value
Dam location				Gashayura
Dam type				Earth Dam
Reservoir base elevation			m asl	1539
Reservoir top elevation			m asl	1555.5
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	1558.0

Spillway crest elevation	m asl	1555.5
Crest length	m	601
Top width (7-12 m depending on dam height)	m	7

4.8.7.2 Diversion works

During the construction of the dam, the river will be diverted by an upstream coffer dam through 2 culverts on the left of the bank. The culverts will be made of concrete and will be 160 m long. The culverts will be circular with a cross-sectional area of 2 m^2 that is needed for safely discharging a 100-year flood of 23 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 1888 m asl while that of the downstream cofferdam will be 1388 m asl. After construction, the two cofferdams will be breached and the culverts will be plugged.

4.8.7.3 Spillway

The spillway will be of the chute type. It will be located on the right side of the dam. Table 4.8-9 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 4.8-9: Gashayura Spillway design parameters

Variable	Units	Value
Spillway type	Chute, over crest	
Return period	years	10,000
Spillway crest elevation	masl	1,555
Design flood	cumecs	26
Discharge coefficient, Cd (assumed)		1.7
Spillway crest length, L	m	20.0
Head on spillway, H	m	1.0
Spillway discharge, Q=Cd*L*H^(3/2)	cumecs	34.0

4.8.7.4 Construction materials

A full investigation of the availability of good quality construction materials will be carried out at the feasibility stage. Impervious materials can be obtained from silt and clayey deposits which are probably available within the river flood plain. 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.

4.8.8 Project costs

The estimated costs for the Gashayura project total to 17.2 million US dollars as broken down in Table 4.5-9 below.

Table 4.8-10 Estimated Gashayura Project costs

No	Item	Units	Quantity	Rate (USD)	Amount (USD)
1.0	**PREPARATORY WORKS**				
	Mobilisation and demobilisation	Lumpsum	1	800000	800000
	Permanent access	km	2	100000	600000
	Temporary access	Lumpsum	1	100000	100000
	River diversion during construction	Lumpsum	1	500000	500000
	Resettlement and compensation	ha	231	2500	700000
	Subtotal				2700000
2.0	**MAIN DAM**				
	Excavation, loose	m3	52000	15	1500000
	Excavation, rock	m3	13000	22	550000
	Foundation preparation	Lumpsum	1	300000	300000
	Dam earthworks - random fill	m3	170000	15	3675000
	Dam earthworks - impermeable core	m3	110000	20	3400000
	Subtotal				9425000
3.0	**SPILLWAY, INTAKE**				
	Excavation, loose	m3	1200	15	18000
	Excavation, rock	m3	4000	22	88000
	Concrete Spillway	m3	5000	200	1000000
	Concrete intake	Lumpsum	1	250000	250000
	Other civil structures	Lumpsum	1	300000	300000
	Subtotal				1656000
	TOTAL, CONSTRUCTION COST				13781000
	ADMINISTRATION AND ENGINEERING		10%		1378100
	CONTINGENCIES		15%		2067150
	CAPITAL COST (WITHOUT VAT)				**17226250**

4.8.9 Project Anticipated Impacts and Mitigation Measures

4.8.9.1 Positive 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 food security. The areas of Gashayura are reportedly food insecure hence, the need for this project;
- Production of electricity will go along way to addressing needs related to the establishment of agro-processing and some cottage industries (clay bricks and tegura tiles) which are locally produced through use of crude facilities;
- 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;
- The need to manage the watershed areas will bring about general improvement of environment and sanitation in the areas; 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.

4.8.9.2 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;
- The project will displace sand miners and this equally will affect the youth who currently benefit from sand mining as source of income;
- The dam will take up access road that passes through the planned site thereby denying communities access route to the neighboring villages south of the site;
- The dam construction willinterfere 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;
- 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 4.8-11 as follows:

Table 4.8-11 Key impacts and mitigation measures for the planned Gashayura dam site

Nº.	**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. For the women who are likely to be affected by the loss of the marshland, the project

Nº.	Project Impact	Mitigation measures
		should propose feasible measures to for women to earn income upon uptake of the marshland. Such measures have to be discussed participartorily; Some of the possible measures could include some group revolving fund from which they can borrow at lower interest rates to support start up and improvement of any of their on-going income ventures
02.	Impact on san miners	Alternate source of employment such as working on the project should be accorded to the youth.
03.	The dam site will take up a community road that passes through the site connecting the north-south villages.	Alternate route for the community be set up by the project.
04.	Land uptake through construction of the dam and access roads, camp sites, etc	Compensation for land uptake after Resettlement Action Plan (RAP) studies.
05.	Concerns relating to management of cut to spoil materials	Disposal sites for cut to spoil have to be approved by the Supervising consultant.
06.	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
07.	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.
08.	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.
09.	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.
10.	Soil erosion concerns which will likely arise through loose soil materials causing sedimentation	Soil control measures have to be instituted during works implementation.
11.	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.
12.	Equipment related concerns in terms of oil spillages, used batteries and oil filters as well	Preparing decommissioning plan and site restoration and re-grassing.

Nº.	Project Impact	Mitigation measures
	as used tyres.	
13.	Human waste management especially in irrigation fields and workers camp sites.	Measures for human waste management to be instituted on the sites.
14.	Noise and vibrations	Noise from equipment and the workforce
15.	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 To sustainably address HIV/AIDS issues, the project liaises with existing health institutions to build capacities on need to address challenges of the scourge.
16.	Air Quality concerns likely to arise from project works	Dust suppression measures will be instituted to ensure air quality levels are kept appropriate.
17.	Possible increase in crime rate in the areas of the project.	Working together with the police and law enforcement agencies to control crime in the areas.
18.	Impacts on socio-cultural sites	No impact
19.	Impacts on biodiversity areas of high conservation concerns (Important Bird Areas-IBAs, national and central forest reserves etc).	Need to assess the existing biodiversity resources on the project sites thereafter, evaluate the impacts of the project on the ground.

4.9 Kavuruga Dam Site

4.9.1 Physical Environment Profile

4.9.1.1 Location

The coordinates of the proposed Kavuruga dam site are 30° 22' 15.42" East and 2° 55' 32.52" South. It is located 1.5km northwest of Muramba Town, in Ntobwe Colline, Buhinyuza Commune, Muyinga Province in Burundi (Plate 4.9-10). The 136 km^2 catchment has a length of 20 km and an average width of about 7 km (Figure 4.9-1). The catchment slope averages 17% though it can be higher than 50% especially in the highlands to the west and south. The catchment elevation ranges between 1387 m asl at the dam site to a maximum 1876 m asl while the mean is 1535 m asl.

River Kavuruga at the dam site is fed by 2 tributaries that drain parts of Mwakiro and Bihunyuza. which confluence about 1 km upstream of the proposed dam site. The larger tributary drains up to 75% of the basin covering the central and western parts. The smaller tributary drains 25% of the eastern part of the basin on the eastern part. Downstream of the dam site, the river is joined by some minor tributaries before it joins the main Ruvubu River 12 km downstream. River Kavuruga generally flows in a north easterly direction. The average channel slope upstream of the dam site is about 0.6% while the slope downstream is about 0.2%.

The main purposes of the dam will be irrigation. The areas that would benefit from extra water for irrigation resulting from the project include Karongwe, Gitaramuka, Nkoyoyo and maybe Kayenzi, and Kibongera. Some hydropower could also be generated however there is an existing 0.85MW hydropower facility at Kayanza approximately 6km downstream which limits the amount of irrigable area that can be served by the dam.

Plate 4.9-1 Kavuruga River, just downstream of the proposed dam site

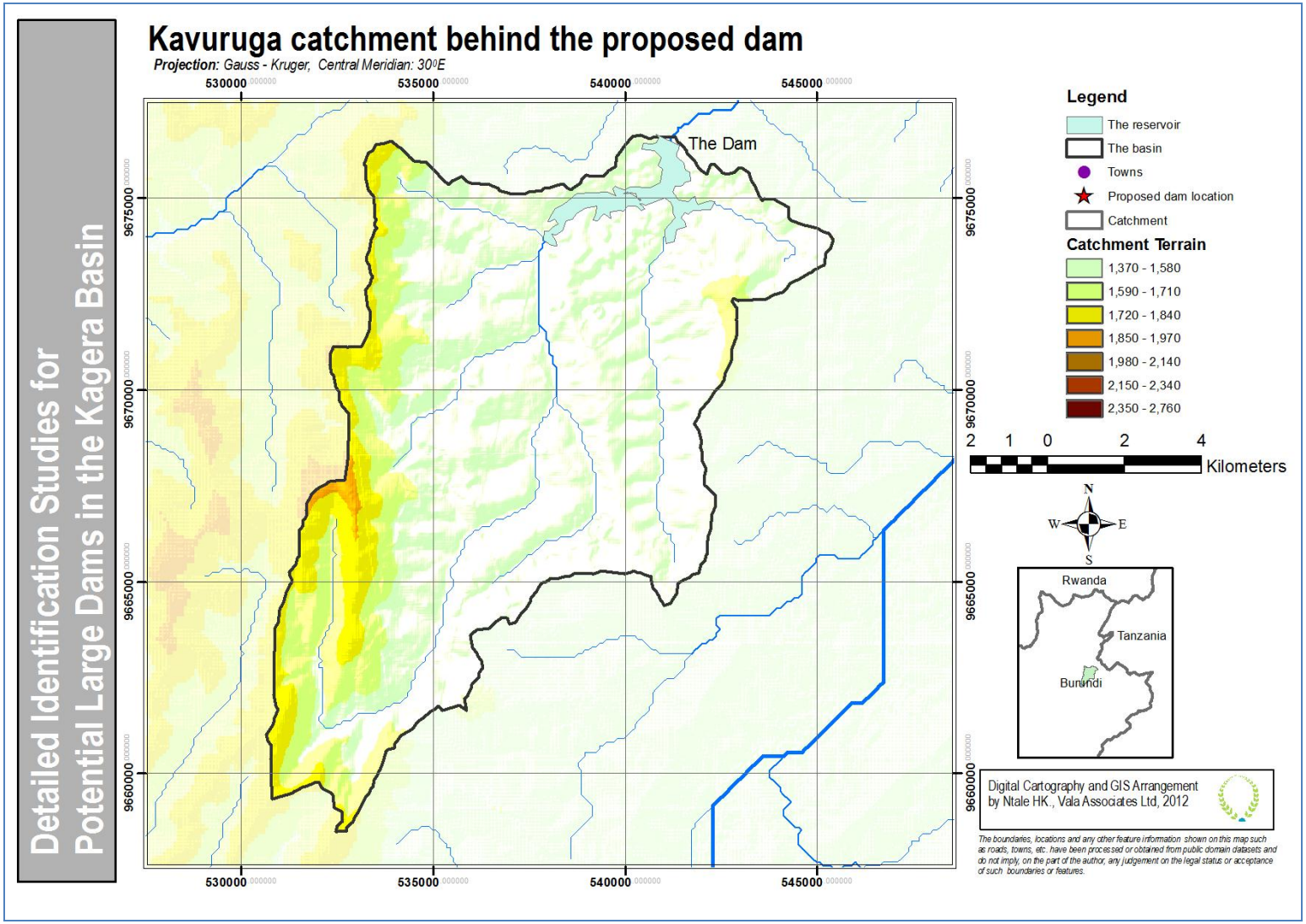

Figure 4.9-1 Kavuruga Catchment