Chapter 7

Pre-Feasibility Study on Ayago Project

Chapter 7 Pre-Feasibility Study on Ayago Project

7.1 Flow Duration

The flow duration of the outflow from Lake Kyoga was described in section 6.1.5 and the flow duration curve is given in Figure 7.1-1.



(Source; Study Team)

Figure 7.1-1 Flow Duration Curve of the Lake Kyoga Outflow

The increment of the flow received from the intermediate basin of Lake Kyoga and Lake Albert is limited to 1% of its total flow. Therefore, it can be assumed that the flow duration of Lake Kyoga is identical to of the inflows into Lake Albert.

Consequently, the flow duration of Lake Kyoga outflows shown in Figure 7.1-1 above can be used as the flow duration of the Nile River between Lake Kyoga and Lake Albert. And in this study, this flow duration (in Figure 7.1-1) is applied.

7.2 Flood Analysis

7.2.1 General

The purpose of the analysis is to obtain the probable flood discharge at the Ayago intake and tailrace site. It is noted that the duration of flood event of tributaries differs from that of the Nile River. Therefore flood analysis is undertaken separately for the Nile River and the tributaries. Considering that the flood event of the Nile River has a long duration from months to years, it is likely that the flood in the Nile River and that of the tributaries occur simultaneously. For the flood analysis, however, the flood of the Nile River and that of the tributaries corresponding to specified return period are analyzed separately, and the results are then combined for each site. The combination of the floods at the Ayago intake and tailrace sites are as follows.

- (1) Ayago Intake: Nile River Flood + Flood between Masindi Port to Ayago intake
- (2) Ayago Tailrace; Nile River Flood + Flood between Masindi Port to Ayago tailrace

The intermediate basin between Masindi Port to Ayago intake site and Masindi Port to Ayago tailrace site are shown in Figure 7.2.1-1.



Masindi to Ayago Intake Intermediate Basin (red area)

Masindi to Ayago Tailrace Intermediate Basin (blue area)

(Source : Study Team)

Figure 7.2.1-1 Thiessen Polygon and Rainfall Gauging Station

The data of the Nile River discharge is available for more than 100 years while none of the discharge data is available for its tributaries. Therefore the flood peak discharges of the tributaries are estimated by applying the probable rainfall to run-off models. Run-off model applied in the study is the "Tank Model." The parameters of the model are determined by the recorded hydrograph and corresponding rainfall data based on the daily data. Since discharge data is available only on daily basis, and no hourly data is available for the study. Furthermore, since the availability of the data for rainfall and discharge are limited, the estimated flood peak discharge is doubly-checked by SCS unit hydrograph and Creager envelope curve.

7.2.2 Rainfall data

(1) Rainfall Station

The number of the active rainfall stations adjacent to Ayago site is not sufficient. The rainfall data available for the study is from only five stations Gulu, Masindi, Aduku, Apac and Lira.

The observation period for each of the listed rainfall stations are shown in Table 7.2.2-1.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Gulu		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Lira	0	0	0	0	0	0	0			۲	0	0	0	0	0	0	0	0	0	0
Aduku		-	-	0	-	0	0	0	-	-	-	0	0		٠	-	-	-	-	-
Apach	0	0	-	-	0	0	0		•	-	-	-	۲	-	-	•	-	-	-	-
Masindi	0	0	0	0	0	0	0	0	•	•	0	0	•	0	•	•	0		0	
	0	: con	nplete	daily	data s	et			-	: dat	a mi	ssing	,							
	•	: dail	y data	set w	ith so	me m	issing	data												

 Table 7.2.2-1
 Collected Rainfall Data

(Source: Study Team)

As shown in the table above, Gulu, Lira and Masindi have almost complete data set, while Aduku and Apach has long duration of missing data.

(2) Check of the Rainfall Data

The missing data is synthesized by the regression lines obtained through correlation analysis among all the rainfall stations. After synthesizing the missing data, the complete data set is checked for consistency by the double mass curve method.

The double mass curve analysis revealed some inconsistency in some years of the rainfall data for Apach gauging station. Considering this inconsistency and the short duration of observation period, the rainfall data for Apach is removed from further study.

(3) Thiessen Polygon and its Coverage Area

The Thiessen polygon and coverage area of the rainfall stations is shown in Figure 7.2.2-1.





Figure 7.2.2-1 Thiessen Polygon and Rainfall Gauging Station

The ratio of coverage area of the rainfall station to the total area of the intermediate basin is shown in Table 7.2.2-2.

Station	Factor
Gulu	0.262
Lira	0.174
Aduku	0.394
Masindi	0.159

 Table 7.2.2-2
 Area Factor of the Rainfall Gauging Station

(Source: Study Team)

(4) Depth-Duration Analysis

The depth duration analysis extracts the maximum one to 7 day(s) rainfall per annum from the observed data. In this study, the daily maximum rainfall data is extracted from the daily rainfall data between the year 1990 to 2009. The result of the depth-duration analysis is shown in the table below.

Duration	Gulu	Lira	Aduku	Masindi	Basin Average Rainfall
1-Day	100	99	90	79	49
2-Day	109	104	97	104	67
3-Day	116	147	131	120	77
4-Day	147	147	156	121	72
5-Day	151	170	163	131	104
6-Day	167	174	166	140	112
7-Day	173	209	179	174	134

 Table 7.2.2-3
 Depth-Duration Analysis of Observed Rainfall(mm/day)

(Source: Study Team)

Since the intermediate basin between Masindi Port and Ayago Intake, and the basin between Masindi Port and Ayago Tailrace have a large basin area covered by the four rainfall stations, therefore, for the flood analysis of the basin, the basin average rainfall is used. The frequency of the rainfall depth for the probability distribution function is analyzed by log Pearson type III, as recommended by the Engineering Manual (EM1110-2-1417: Flood-runoff Analysis) of the US Army Corp of Engineer.

By applying the daily maximum rainfall depth of the four rainfall stations, the result of the rainfall depth and its frequency (return period) is shown in Table 7.2.2-4.

Return Period	Excess Probability	Computed Probability
(Year)	(%)	Basin Rainfall (mm/day) (Gulu, Lira, Aduku, Masindi)
1,000	0.1	59.7
500	0.2	57.0
200	0.5	55.5
100	1	53.5
50	2	51.4
20	5	47.3
10	10	45.7
5	20	42.7
2	50	37.7
1.25	70	33.1
1.11	90	30.9
1.05	95	29.1
1.01	99	26.1

 Table 7.2.2-4
 Probable Maximum Daily Rainfall at Gulu and Bain Rainfall

(Source: Study Team)

7.2.3 Discharge Data

(1) Water Level and Discharge Monitoring Station

DWRM has three water level monitoring stations along the Nile River between the Lake Kyoga and Lake Albert such as Masindi Port, Kamdini, and Paraa. The water levels recorded are converted to discharges by rating curves for the gauging stations. The staff gauge Level measurements at these stations are taken by a gauge reader once or twice a day and the daily readings are compiled and sent to DWRD in Entebbe every month. The Study Team obtained some discharge data from DWRM in Entebbe as shown in Table 7.2.3-1.

 Table 7.2.3-1
 Collected Discharge Data of the Nile River

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Masindi port		0	0					0	0	0	0	0	0	0	
Kamidini					0	0	0	0	0	0	0		0	0	\bullet
Paraa			\bullet					0	0	0	\bigcirc	0	0	0	\bullet
	0	: com	plete	daily	data s	et									

: daily data set with some missing data

As aforementioned, the water level is measured once or twice a day, therefore the hourly data is not available.

(2) Extracting the Flood Events

Ideally, the flood event to the Ayago intake site can be found by taking the difference between the flow at Ayago Intake site and Masindi Port. However, since discharge data at Ayago intake site is not available for the study, therefore the local flood events were extracted by taking difference in the discharge data between Paraa and Masindi Port. The extracted flood event in each year from the year 1997 to 2008 is shown in Table 7.2.3-2.

Year	Date	Flood direct runoff (m ³ /s)
1997	07 Dec	200
1998	02 Oct	77
1999	22 Sep	60
2000	22 Oct	47
2001	29 Oct	159
2002	12 Nov	121
2003	10 Sep	77
2004	29 May	127
2005	07 Apr	53
2006	01 Nov	227
2007	15 Sep	176
2008	07 Nov	214

 Table 7.2.3-2
 Observed Annual Maximum Direct Runoff

(Source: DWRM)

As shown in Table 7.2.3-2, the flood events occurred generally from September to October, sometimes occurs in April and May. The maximum local flood recorded in the intermediate basin was 227m³/s at maximum, which is relatively small comparison of the scale of the Nile River.

7.2.4 Estimating the Probable Flood of the Nile River

The probable flood of the Nile River is analyzed by taking the annual maximum discharge at Masindi Port and fitting the maxima to the probability distribution function. The discharge data at the Masindi Port from the year 1896 to 2008 are used and the log Pearson type III is used as the probability distribution function. The probability distribution function yields the discharge corresponding to the specified frequency (return period). In this flood analysis, the discharge for the frequency of 1% (100-year return period), 0.5% (200-year), 0.1% (1000-year) are obtained. The plot of the annual maximum discharge and log Pearson type III is shown in Figure 7.2.4-1.



Figure 7.2.4-1 Annual Maximum Discharge and log Pearson type III Curve for the Nile River Discharge at Masindi Port

The probable flood of the Nile River obtained by probable distribution function is as follows.

- > 100 year flood : $2,400 \text{ m}^3/\text{s}$
- > 200 year flood : $2,650 \text{ m}^3/\text{s}$
- > 1,000 year flood : $3,400 \text{ m}^3/\text{s}$

7.2.5 Estimation of Probable Flood of the Nile Tributaries

(1) Estimation by Tank Model

1) General

Tank Model was introduced by Sugawara in 1972. The model represents the structured layer of the foundation soil or rocks to demonstrate the hydro-geological behavior of water storage in the soil/rock layers. As the model name describes, the tank model is composed of series of tanks. Each tank has infiltration hole and run-off holes. Tanks in low levels represent the long term base flow, and tanks in high row represent the flood event which generally completed in a short duration. If the river channel has a storage capacity to the scale of river discharge, then such storage effect of the river channel is represented by a river tank. The conceptual model of the tank model is illustrated in Figure 7.2.5-1.



Figure 7.2.5-1 Conceptual Model of the Tank Model

The parameters of Tank Model are run-off holes and infiltration holes place in each tank. The size of these holes is determined by the recorded data and the probable flood discharge is estimated based on daily data.

2) Determining Tank Model Parameters

As the rainfall and discharge data are both available after the year 1997, the data after 1997 is used for determining the model parameters. The procedure is to first extract the annual maximum rainfall and the corresponding flood event. Then the extracted rainfall data is input into the tank model to simulate the flood. The parameters are determined by adjusting to minimize the difference between the recorded and estimated hydrograph.

3) Estimation of Flood by Tank Model

After determining the tank model parameters, the flood discharge is estimated by applying the annual maximum of the daily rainfall. The basin rainfall is used for the flood estimation at Ayago intake and Ayago tailrace site for the period when the discharge was not observed from 1990 to 1996. Table 7.2.5-1 shows the observed maximum daily rainfall from the year 1990 to 1996.

Year	Date	Daily Maximum Rainfall (mm/day)
1990	10 Dec	35.5
1991	06 Aug	29.1
1992	29 Sep	40.7
1993	11 Jun	41.2
1994	03 Nov	31.0
1995	06 Nov	30.3
1996	22 Aug	37.9

Table 7.2.5-1	Observed	Daily	Maximum	Rainfall
1 anic 7.2.5-1	Observed	Dany	Mannum	Mannan

(Source: Study Team)

After estimation of the flood by tank model, the peak flood discharge corresponding to the maximum rainfall event is summarized in Table 7.2.5-2.

Table	e 7.2.5-2	Yea	rly Peak Flood Dischar	ge Estimated by Tank M	Iodel
	Date		Intermediate Masindi	Intermediate Masindi	

Date	Intermediate Masindi ~ Ayago Intake	Intermediate Masindi ~ Ayago Tailrace
1990	347	399
1991	155	177
1992	171	197
1993	241	277
1994	172	210
1995	111	127
1996	361	415

(Source: Study Team)

4) Flood Peak Discharge

The series of flood peak discharge data obtained through the tank model simulation and recorded peak discharge are fitted to the probability distribution function. The log Pearson Type III is employed for the probability distribution function as recommended by Engineering Manual of U.S. Army Corps of Engineer. The flood from the intermediate basin between Masindi Port to Ayago intake, and Masindi Port to Ayago tailrace is plotted together with log Pearson type III as shown in Figure 7.2.5-2.



Figure 7.2.5-2 Flood Peak and Probability Distribution Curve

The probable flood discharge from the intermediate basin is obtained from the above log Pearson type III plot. The probable discharge of the local floods for return period of 100-year, 200-year, and 1000-year are shown in the table below.

Table 7.2.5-3Local Flood from the Ayago River and Intermediate Basin from Masindi to
Ayago Intake, Estimated by Tank Model

		Return Period	-
	100 year	200 year	1000 year
Masindi ~ Ayago Intake	500 m ³ /s	550m ³ /s	700 m ³ /s
Masindi ~ Ayago Outlet	$600 \text{ m}^{3}/\text{s}$	650m ³ /s	$800 \text{ m}^{3}/\text{s}$

(Source: Study Team)

(2) Checking the flood peak discharge

- SCS Unit Hydrograph

The flood discharge estimated by Tank Model is checked by SCS unit hydrograph. The SCS unit hydrograph (Mockus 1957) is a synthetic unit hydrograph derived from a large number of unit hydrographs developed with data from small rural basins¹. The synthetic unit hydrograph is shown in Figure 7.2.5-3. This method was introduced by Soil Conservation Service in 1972, and input of the model is time of concentration, rainfall depth and curve number which is a function of land use, soil type and land coverage conditions. Since the method uses synthetic unit hydrograph, the model is sometimes used for estimating run-off in the ungauged basin.

¹ U.S. Army Corps of Engineers "Flood-runoff analysis", Washington, USA, 1994



Figure 7.2.5-3 Standard Dimensionless Hydrograph by SCS Method

For applying SCS unit hydrograph method, the intermediate basin between Masindi Port and Ayago intake is divided into sub-basins. The sub-basins of the intermediate basin between Lake Kyoga and Lake Albert is shown in the figure below.



Figure 7.2.5-4 River Basin Division for SCS Unit Hydrograph Analysis

The flood run-off simulation of SCS unit hydrograph is analyzed by HEC-HMS which is a generalized hydrological analysis software developed by U.S. Army Corps of Engineers.. The hydrological model of HEC-HMS developed for the intermediate basin between Masindi Port to Ayago intake, and Masindi Port to Ayago tailrace is shown in Figure 7.2.5-5.



(Source: Study Team)

Figure 7.2.5-5 River Basin Model by HEC-HMS

In the analysis of the flood by HEC-HMS, the probable rainfall depth of 100 years, 200 years and 1000 years are distributed to the sub-basins corresponding to the rainfall station coverage area defined by the Thiessen method. The result of flood run-off analysis is shown in Figure 7.2.5-6.



(Source: Study Team)

Figure 7.2.5-6 Flood Hydrograph Estimated by SCS Unit Hydrograph

The peak flood discharge shown in Figure 7.2.5-6 was summarized in Table 7.2.5-4.

Table 7.2.5-4Local Flood from the Ayago River and Intermediate Basin from Masindi to
Ayago Intake, Estimated by SCS Unit Hydrograph

		Return Period	
	100 year	200 year	1,000 year
Masindi ~ Ayago Intake	$475 \text{ m}^{3}/\text{s}$	535 m ³ /s	678 m ³ /s
Masindi ~ Ayago Tailrace	563 m ³ /s	635 m ³ /s	803 m ³ /s

(Source: Study Team)

As the result, the peak flood discharge given by SCS unit hydrograph gives the similar to the tank model results.

(3) Checking the Peak Flood Discharge by Creager Envelop Curve

The obtained flood peak discharge is converted to specific discharge which is discharge per unit area of the river basin. The result of the peak flood discharge is plotted with adjacent project flood discharge together with the Creager envelop curve. The Creager envelop curve shows the relationship of estimated or recorded flood discharge among the other projects by the form of specific discharge. The equations of the Creager envelop curve is shown below.

$$Q_p = 0.503 \times C \times \left(\frac{A}{2.59}\right)^a$$
$$a = 0.894 \times \left(\frac{A}{2.59}\right)^{-0.048} - 1$$

Where,

 Q_p : flood peak specific discharge [m³/sec/km²]

- C: Creager's coefficient
- A: river basin area $[km^2]$

The flood specific discharge of intermediate basins is plotted with adjacent projects to the Ayago site. However, since there are not many water resource developments or river works projects in the area, the study therefore considered projects in Tanzania and Kenya for comparison.



Figure 7.2.5-7 Creager's Curve of Flood Discharge

In Figure 7.2.5-7, several Creager envelop curves are presented with varying coefficients in Creager envelop curve equation. The Creager coefficient for the peak flood discharge obtained in the study for Ayago intake and Ayago tailrace is around "4". This value is relatively small as the Creager coefficient of flood events in Japan ranges from 17 to 84. However, Creager coefficient in the adjacent projects also shows small values especially the projects along the Nile River. Therefore it indicates that the results obtained by Tank Model and SCS unit hydrograph are not different from other projects in the region.

(4) Summary

In this study, the flood peak discharge is estimated from existing flood record and estimated flood discharge simulated by Tank Model. The result given by Tank Model is checked by SCS unit hydrograph and both model give similar results. The peak flood discharge is also compared with other projects in Uganda, Kenya and Tanzania by the Creager envelope curve method. Checking by the Creager envelop curve shows that the flood specific discharge of the intermediate basin between Masindi Port to Ayago intake/tailrace site does not deviated considerably from other projects. This means that the flood peak discharge estimated by Tank Model is not different to other projects and therefore the results are acceptable for the study.

7.2.6 Summary of the Flood Discharge Estimate at Ayago Intake and Ayago Tailrace

As described in the precedent chapter, the flood discharge at Ayago intake and Ayago tailrace can be obtained by combining the Nile River and tributaries floods. The combination of the floods at Ayago intake and tailrace is as follows;

(1) Ayago intake:

Nile River + Flood from intermediate basin between Masindi Port to Ayago intake

(2) Ayago tailrace:

Nile River + Flood from intermediate basin between Masindi Port to Ayago tailrace

According to the above combination of the floods, the flood discharge is combined for the return period of 100 years, 200 years and 1000 years.

No			Return Period	Natas	
INU		100-year	200-year	1,000-year	Inotes
1)	The Nile River	2,400 m ³ /s	2,650 m ³ /s	3,400 m ³ /s	At Masindi Port
2)	Masindi~Ayago	$500 m^{3}/r$	/s 550 m ³ /s	700 m ³ /s	Masindi-Ayago Intake
2)	Intake Local Flood	500 m /s			Intermediate basin
3)	Ayago Intake	2,900 m ³ /s	3,200 m ³ /s	4,100 m ³ /s	1) + 2)
	Masindi~Ayago		650 m ³ /s	800 m ³ /s	Masindi-Ayago
4)	Tailrace Local	600 m ³ /s			Tailrace Intermediate
	Flood				basin
5)	Ayago Outlet	3,000 m ³ /s	3,300 m ³ /s	4,200 m ³ /s	1) + 4)

 Table 7.2.6-1
 Combination of Floods

(Source: Study Team)

The flood discharge at the Ayago intake and Ayago tailrace is summarized below.

 Table 7.2.6-2
 Applied Flood for Ayago Intake and Tailrace

		Return Period	
	100 year	200 year	1,000 year
Ayago Intake	$2,900 \text{ m}^3/\text{s}$	3,200 m ³ /s	$4,100 \text{ m}^{3}/\text{s}$
Ayago Outlet	$3,000 \text{ m}^3/\text{s}$	3,300 m ³ /s	$4,200 \text{ m}^{3}/\text{s}$

(Source: Study Team)

7.2.7 Issues on Flood Analysis

According to the document "Flood-Runoff Analysis" issued by U.S. Army Corps of Engineer, the number of rainfall gauging stations for the project scale of Ayago requires more than 10 stations. However, the number of rainfall gauging stations available for this study was only five and one was eliminated for data inconsistency, therefore only four rainfall stations data is used for the flood

analysis. Most of the rainfall stations and surrounding the area have missing or stopped observation. This inhibits accurate estimation of the flood discharge, and double number of rainfall stations is necessary for conducting more accurate flood analysis.

For the discharge data, the Nile river discharge is monitored by only three stations although the stretch of the rive reaches 200 km in length, the monitoring station of the Nile River is only Masindi Port, Kamdini and Paraa. It is preferable to have double number of water level monitoring stations to understand the inflow from the tributaries. Furthermore, since the flood run-off characteristics of tributaries are different to that of the Nile River, therefore, monitoring of the tributaries of the Nile River is required. Currently, the water level monitoring is done by daily basis. However, it is necessary to change to hourly basis, because the flood run-off from the tributaries could be completed within a day. If the hourly water level data is available for the project, it is possible that the peak discharges might be increased significantly.

Therefore, it is desirable to increase the number of rainfall monitoring station near the project area, and conduct to hourly water level monitoring at the Nile River and tributaries to understand the flood run-off feature in the basin.

7.3 Topography and Geology

7.3.1 Geology of Ayago Site

(1) Topography

The Nile River, with 200 m - 300 m wide river floor, meanderingly flow westward through gentle hills of 5-10 degrees. There are several cascades between the intake site and outlet site. Many tiny islands exposing bedrocks are found in the river. Both its banks have moderately steep slopes of 15 degrees - 25 degrees, up to 20 m - 30 m above the river floor. Ayago River, a major tributary in the Ayago site, flows into the Nile River approximately 3.3 km downstream of the intake site.

(2) Geology

Ayago site is underlain mainly by Pre-Cambrian biotite gneiss including some intercalated bands of metamorphic rocks such as granitic gneiss, quartzite, amphibolite etc.

Small amounts of Quaternary unconsolidated deposits composed of terrace deposits, talus deposits and recent river deposits are distributed along the Nile River.

Residual soil, composed of reddish lateritic soil or pale brown sandy soil, is generally 2 m-3 m in thickness. Organic soil, generally less than one meter in thickness, is found along creeks or small valleys.

Gneissosity of the metamorphic rocks trends a northwest to southeast striking structure, and 30-50 degrees dips to the northeast at the outlet site, and steeply dips to the northeast or southwest near the intake site. However, details of the geological structure along the planned

tunnel alignment still remain unclear due to shortage of information about outcrops worsened by thick weathering, in addition to many minor folds in gneiss rocks.

A northeast to southwest lineament near the outlet site indicates weak zone. No active faults are found and reported near the Ayago site. There are also no serious landslides.

7.3.2 Results of Site Investigation

(1) Topographic Survey

1) Survey items and quantities

The quantities of the following survey items carried out in this study are summarized in Table 7.3.2-1, while the survey areas are shown in Figure 7.3.2-1.

- Topographic maps covering the whole project area, scale 1:10,000 (5m contour interval)
- Topographic maps for main structures such as inlet weir, power station and outlet, scale 1:1,000 (1 m contour interval)
- Cross-section survey

Items	Area	Quantity
i) Topographic mapping scale	Whole project area covering access roads, intake	100 km^2
1:10,000 (5m contour interval)	weir site, reservoir area, power station site, outlet	
	site and temporary structure construction site etc.	
ii) Topographic mapping scale	Main structures including intake weir,	3 km^2
1:1,000 (1m contour interval)	powerhouse etc.	
iii) River/Land cross-section	Approximately 0.6km ~1.0 km in length	18
survey		sections

 Table 7.3.2-1
 Topographic Survey

(Source: Study Team)



(Source: JICA Study Team)



2) Results of topographic survey

Survey results are compiled in Appendix B: Topography.

(2) Geological Investigation

1) Survey items and quantities

Quantified items for geological investigation as shown in Table 7.3.2-2, consist of ground mapping, aerial photograph interpretation, core boring survey, laboratory tests and construction material survey, which were carried out for the purpose of obtaining subsurface geological data at the Ayago site. The survey areas are shown in Figure 7.3.2-2.

Items	Scope	Quantity	
i) Ground	Use of topographic mapping scale 1:10,000, for main	36 km^2	
mapping	structures		
ii) Aerial	Use of aerial photographs for the 1:10,000 topographic	100 km^2	
photograph	maps		
interpretation			
iii) Core drilling	iii) Core drilling Underground hydropower station: 100 m		
	Intake weir site, channel etc. 20 m-30m	6 holes (150 m in total)	
	permeability test	46 nos.	
iv) Laboratory	Specific gravity, absorption and unconfined	20 samples	
tests	compressive strength		
v) Construction	Lump sum		
material survey	(soundness test, abrasion test and alkali reactivity test)		

 Table 7.3.2-2
 Geological Investigation

(Source: Study Team)



(Source: Study Team)

Figure 7.3.2-2 Location Map of Geological Investigation

2) Ground Mapping

According to the results of ground mapping, the Ayago site is underlain by gneiss rocks including blocks/bands of quartzite. The following structural orientations dominate the survey area. Faulting in the rocks is not so evident.

- Foliation: 30-50/050 to 070 (dip/dip direction)
- Major joint sets: 60-80/190 to 210 and 70-85/350-010 (dip/dip direction)
- Minor joint set: 40-60/310 to 330 (dip/dip direction)

3) Aerial Photograph Interpretation

Result of the aerial photograph interpretation is shown in Figure 7.3.2-3. A clear lineament extending to the northeast to southwest direction passes near the outlet area. Some east-northeast to west-southwest lineaments, which are not clear, cross the tunnel alignment. These lineaments indicate some weak zones or geological boundaries.



(Source: Study Team)

Figure 7.3.2-3 Results of Aerial Photo Interpretation

4) Drilling Survey

Rock masses are classified based on the rock mass classification prepared by the Central Research Institute of Electric Power Industry (CRIEPI), Japan (Tanaka 1964), as shown in Table 7.3.4-1. The Results of drill coreanalysis are summarized in Table 7.3.2-3 (See Appendix C for drill logs and photographs of core boxes). Photographs of typical rock faces for each rock class (CRIEPI) are shown in Table 7.3.2-4.

Drill Hole	Depth (m)	Geology	Depth (m)	Rock Condition	Permeability and Groundwater Level
	0-1	Residual soil	0-6	D	
	1-25	Biotite gneiss	6-11	CL	5-25 m 2.3-0.9 Lu
B-1	_	(20.6-20.8 quartz vein)	11-19	СМ	Water level 13.9 m
			19-25	СН	
	0-3.6	Residual soil	0-3.6	D	0.20 - 15.0 (L
B-2	3.6-25	Biotite gneiss	3.6-12	СМ	0-20 m 1.5-0.0 Lu Water laval 0.0 m
		_	12-25	CH	water level 9.0 m
	0-2	Residual soil	0-5	D	
D 2	2-25	Biotite gneiss	5-9.7	CL	No Lugeon test data
D-3			9.7-20.4	CM	Water level 15.2 m
			20.4-25	СН	
	0-0.4	Residual soil	0-0.4	D	
B /	0.4-15	Quartzite	0.4-8.6	CL	No Lugeon test data
D-4		(11.6-12 basic rock)	8.6-13	CM	Water level 11.3 m
	15-20	Basic rock/quartz	13-20	CH	
	0-2.2	Residual soil		D	
	2.2-115	Biotite gneiss (quartz	0.5	CL	
		veins)	595	CM	10.25m2.4.10Lu
D 5		(38.5-40.8 basic	05135	CH-B	$25 115 \pm 0.01$ Lu
D- 3		rock/quartz vein,	9.5-15.5 13 5-115	(100.3-101	Water level 23.2 m
		100.3-101 fracture zone of	13.3-113	CL,	
		60 degrees)		101-103.6	
				CM)	
	0-1	residual soil			
	1-100	garnet biotite gneiss	0-3.8	D	10-20 m 1.8-1.5 Lu
		(quartz veins)	3.8-5	CL	20-55 m 0.9-0.1 Lu
B-6		(12-12.8 basic rock, 39-41	5-10	CM	55-100 m less than
		quartz, 53.5-55 felsic	10-17.8	СН	0.1 Lu
		gneiss, 80-85 felsic gneiss,	17.8-100	B	Water level 17.6 m
		88-90 quartz)			
B-7	0-1	Residual soil	0-5.2	D	No Lugeon test data
Ъ /	1-25	Biotite gneiss	5.2-25	CL	Water level 20.2 m
	0-1	Residual soil			
	1-2	Biotite gneiss	0-2	D	No Lugeon test data
B-8	2-10 Felsic gneiss (5.5-5.6		2-9	CL	Water level 11 7 m
		quartz, 8.2-8.7 quartz)	9-20	CM	
	10-20	Biotite gneiss			

Table 7 3 2.3	Results of Core	Observation
1 abie 7.3.4-3	Results of Core	Obset valion

(Source: JICA Study Team)

Note: Water level in each drilled hole section defines the depth of water surface immediately after completion of drilling.

Class	Drilling Core Photographs	Geological Condition
В		 B-6 45 m-50 m Drilling Core Condition Fresh and hard Crack spacing larger than 50 cm Cracks are closely adhered; no deterioration or discoloration. Outcrop Condition The rock mass is solid. There are no opening joints and cracks.
СН	Sample for test	B-3 20.4 m-25 m Drilling Core Condition Relatively hard Crack spacing is about 30-50cm Limonite adhered along cracks Outcrop Condition The rock mass is relatively solid. The rock forming minerals and grains undergo slight weathering except for quartz. The rock is contaminated with limonite etc.
СМ		 B-1 11 m-15 m Drilling Core Condition Somewhat soft Crack spacing is about 10-30 cm Thin clay is found between the opening. Outcrop Condition The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softened by weathering, expect for the quartz.
CL		 B-7 5 m-10 m Drilling Core Condition Soft rock fragments are with clayey to sandy materials Crack spacing are smaller than 10 cm in general Outcrop Condition The rock is soft. The rock forming minerals and grains are softened by weathering.
D		 B-3 0 m-5 m Drilling Core Condition Clayey and sandy materials are with soft rock fragments Outcrop Condition The rock mass is remarkably soft. The rock forming minerals and grains are softened by weathering.

Table 7.3.2-4 Typical Rock Classification Faces

(Source: JICA Study Team)

5) Laboratory Test

Test results are summarized in Table 8.3.2-5 (See Appendix C for details).

Test results show that unconfined compressive strength seemed rather low. The main reason of the relatively low strength is probably due to about 60 degrees dipping foliation, although

unsuitable trimming for samples is also undeniable. Gneiss rocks are generally very strong against the direction perpendicular to foliations; however, these are relatively easily divided along the foliation.

It should be noted that effects of anisotropy on the strength of gneiss rocks are considered in the estimation of the mechanical parameters of the foundation rocks.

Laboratory Test Parameters	Unit	No. of Sample	Average	Maximum	Minimum
Water absorption	%	20	0.14	0.61	0.05
Bulk density	g/cm ³	5	2.84	2.88	2.75
UCS	MPa	20	31.7	56.59	10.61
Soundness	%	1	1.5		
Abrasion	%	1	40		
Alkali Reactivity		1	innocuous		

Table 7.3.2-5Results of Laboratory Tests

(Source: Study Team)

Note: As test results of bulk density in B-5 and B-6 are remarkably large, they are eliminated in the table given above.

6) Water Level Monitoring of the Nile River

Water level monitoring of the Nile River was carried out using staff gauges installed at the intake and outlet sites from 15 August to 13 October, 2010. Results of the monitoring are compiled in Appendix C.

7.3.3 Site Geology for Principal Structures

Site geology of each structure based on the results of the geological investigations in this study and points of concern in the F/S are described as below.

(1) Intake Weir

1) Geology

Hard biotite gneiss rocks, striking northwest to southeast and steeply dipping to the northeast or southwest are exposed at both river sides. There are few unconsolidated deposits including talus deposits at both abutments. River sands would also be few based on the site observation. The main course of the river remains unclear due to its rapid flow.

2) Engineering Assessment

Sound rock both in terms of strength and water tightness, suitable for the foundation of the weir, will be obtained by trimming the river floor and by executing several meters of excavation at both abutments based on the results of the drilling survey. According to the results of permeability tests carried out at both abutments of the weir site, borehole sections below 5 m from ground surface have satisfactory water tightness of less than 2 Lu.

Additional drilling survey with testing including permeability tests is necessary during the F/S to confirm the distribution of sound rock surface for the optimization of the weir layout.

(2) Intake Tunnel Portal

1) Geology

According to the drilling survey, the geology of the intake tunnel portal area of underground Powerhouse No.1consists of biotite gneiss covered with approximately 5 m thick soil while that of Powerhouse No.2 consists of quartzite covered with approximately 1 m thick soil respectively. There are no serious landslides at the portal areas.

2) Engineering Assessment

Residual soil would be less than 5 m in thickness while the surface of moderately hard rock (CM class) would be less than 10 m in depth (See Figure 7.3.3-1). Recommended gradient of cut slope for long-term slope stability is estimated based on experiences in Japan as shown in Table 7.3.3-1

Character of soil or bedrock	Height (m)	Gradient (V:H)
Better than CM class		1:0.3 ~ 1:0.8
CL class		1:0.5 ~ 1:1.2
Sandy soil	Less than 5 m	1:1.0 ~ 1:1.2
Cohesive soil	Less than 10 m	1:0.8 ~ 1:1.2

 Table 7.3.3-1
 Recommended Gradient of Cut Slope

Note: Silt is placed under cohesive soil.

Reference: Japan Road Association (1999), Manual for Slope Protection

Slope protection of cut slope with mortar spray/shotcrete is recommended because quartzite is relatively thin jointed and biotite gneiss is likely to be deteriorated due to weathering after being exposed.

Most of the structures of these bedrocks steeply dip to the cut slope at a direction, which is good in stabilizing the slope. However, careful cut slope treating of cut slope surface is necessary to avoid small wedge slides or topping failures, as the direction of the structures significantly varies.



(Source: Study Team)



(3) Pressure Tunnel –Underground Powerhouse

1) Geology

Pressure tunnel and underground powerhouse site is underlain by hard biotite gneiss, striking northwest to southeast and dipping 60 degrees -90 degrees to the southwest

2) Engineering Assessment

Most of the pressure tunnel will encounter hard biotite gneiss classified as CH-B.

The underground Powerhouse No.1 site is underlain mainly by hard biotite gneiss classified as CH-B. Permeability coefficient is estimated to be less than 0.1 Lu based on drilling survey.

Only one small fracture dipping 60 degrees (main fracture zone is about 30 cm thick, and a cracked zone is about 2.2 m thick) iwas found at 100.4 m deep at drill core B-5. However, its cracks are probably tight and such fracture will not be critical for the underground powerhouse, considering that the permeability of rocks is very low at this section and no clay materials are intercalated in the fracture zone.

The underground Powerhouse No.2 site is underlain mainly by hard gneiss rocks classified as B-CH class. Permeability coefficient is estimated to be less than 0.1 Lu according to drilling survey. Cracks are not evident in drill core B-6.

Both underground powerhouse sites are underlain mainly by hard gneiss rocks, which are suitable in strength and in water tightness for supporting the foundation of the structure. No serious problems for the construction of the underground powerhouses are detected in this study. Points to be considered in the F/S are the effect of anisotropy in gneiss rocks in terms of strength which is correlated to the mechanical parameters of foundation rocks. It should be noted that gneiss rocks are likely to be divided along the foliation due to unloading after excavation. Furthermore, rock slides might occur during this unloading process.

Since the underground powerhouse requires huge underground space, rock condition needs to be assessed carefully for its safety. Additional geological investigations, including drilling surveys with testing, are necessary in the F/S.

(4) Tailrace Tunnel

1) Geology

Most of the tailrace tunnel will be located in the hard biotite gneiss. Based on the ground mapping, the structure of the biotite gneiss seems to strike towards a northwest to southeast direction, and dips about 30 degrees to the northeast at the outlet site. It then steeply dips 70-90 degrees to the northeast or southwest at the upstream side. Many minor folds are found at the upstream section of the tunnel.

2) Engineering Assessment

Drilling survey for this study was carried out only at the both portals of the tunnel, because geology of the portals is essential in the designing of the structures.

Rock condition along the tunnel alignment (about 10km) is roughly estimated based mainly on the results of the ground mapping, aerial photograph interpretation and drill survey at both portals. Relationships between rock class (CRIEPI) and rock class (JH) for tunnel structure is shown in Table 7.3.3-2.

Rock class	Rock tunne	Rock Mass	
(CRIEPI)	Rock type	Description (during excavation)	(RMR)
В	В	Generally sound fresh rock, massive-poor gneissosity and very hard. Full face excavation is possible. Rock is generally stable.	Very Good (I) 80-100
СН	CI	Generally sound fresh rock to slightly weathered. Gneissic structure is obvious, micaceous gneiss. Full face excavation is possible. Rock is generally stable.	Good (II) 60-80
СМ	CII	Slightly to moderately weathered rock with occasional seams and fault zones. Full face excavation is also possible even though strong plastic earth pressure may develop.	Fair (III) 41-60
CL	DI-DI	Moderately weathered to completely weathered rock, with seams and fault zones.Full face excavation is also possible. There is the possibility that strong plastic earth pressure may develop.	Poor (IV) 21-40
D	E	Soil, comprised of an uncommented to poorly cement compact mass of particles. Tunnel section where the depth of tunnel is less than 2D (tunnel diameter).	Very Poor (V) 0-20

Table 7.3.3-2	Relationships between Rock classifications and Rock Type
for th	e Tunnel Structure of Ayago Hydropower Project

CRIEPI: Central Research Institute of Electric Power Industry, Japan JH: Japan Highway

No serious problems for the tailrace tunnel have been identified in this study.

Most of the tailrace tunnel will encounter hard biotite gneiss. Tunnel inflow will be minimal except for fracture zone. A clear lineament extending to the northeast to southwest direction passes near the outlet area. Some east-northeast to west-southwest or southwest to northeast lineaments, which are not clear, cross the tunnel alignment. These lineaments indicate some weak zones or geological boundaries.

Results of probable rock conditions along the tailrace tunnel alignment are shown in Table 7.3.3-3. In this study, all lineaments in Figure 7.3.2-1including unclear ones are regarded as weak zones for safety, although some lineaments might be neglected in the course of the geological investigation for the F/S based on new findings.

In view of the inconclusive geological information along the tailrace tunnel and lineaments mentioned above, additional geological investigation, including drilling survey and seismic prospecting are highly recommended to be carried out along the tailrace tunnel alignment in the F/S.

Rock class				
CRIEPI	JH	Length (m)		
B-CH	B-CI	6,941	-	Rock condition along tailrace tunnel are roughly-estimated based on the following assumptions
CH	CI	105		
СМ	CII	247		1. Weak zone
CL	DI-DII	80		 All lineaments are regarded as weak zones for safety.
CL-D	E	28		- 30 m thick in total (CL class: 10 m, CM class: 20 m) for each weak zone
	total	7,401		 No thick clay seams intercalated, and relatively tight condition in cracks
Tailrace	Tunnel			
Rock class	length (m)			2. Tunnel will encounter good rocks classified into B or CI except for the weak zones mentioned
В	4,165	ከ 🔶		above and portal sections.
CI	2,881	B:CI=6:4		- Rock condition near the intake site is classified mainly into B class according to drilling survey.
CII	247			- The percentage of relatively foliated rocks classified into CI class increase toward the outlet side.
DI-DII	80			- The ration of B class and CI class in good rock sections is estimated to be 6 to 4.
E	28			
TOTAL	7,401			3. E class: Tunnel section where the thickness of earth covering of the tunnel is less than
				twice the width of the tunnel

Table 7.3.3-3	Rock Type	along the	Tailrace	Tunnel .	Alignment
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(5) Tailrace Outlet

1) Geology

Outlet site is underlain by biotite gneiss and quartzite. Not many outcrops are found on the ridges of the site due to weathering. Small fragments of quartzite are scattered near the portal area. Small terraces are distributed around 30 m above the river floor along the Nile River. A few pebbles are also found on the terrace.

A northeast to southwest lineament near the outlet site indicates a weak zone.

2) Engineering Assessment

According to drill core B-7, bedrocks of the outlet site are cracked and deeply weathered. Large excavation or tunnel supports will be required. According to the ground mapping, the rock condition seems to be more preferable by modifying the layout of the outlet.

Additional geological investigations including drilling survey and seismic prospecting are necessary to optimize the layout of the outlet.

(6) Disposal Area

1) Geology

According to the results of the aerial photograph interpretation, residual soil is not thick. Surface of bedrocks seems to be less than several meters in depth. Open forests or grassland cover hilly areas while relatively dense forests (less than 5 m-7m in general) cover the valley.

2) Engineering Assessment

No serious problems such as landslides, are detected for the embankment according to the results of the aerial photograph interpretation. There seems to be no permanent water flow in the valley.

Water treatments are necessary. Chemical safety of excavated rocks against weathering after exposure is recommended to be ensured for long-term safety of disposal area.

7.3.4 Strength of Foundation Rocks

(1) Rock Classification

Rock classification of foundation rocks was carried out through observation of drill cores based on rock mass classification prepared by CRIEPI, Japan (Tanaka 1964) as shown in Table 7.3.4-1. Mechanical properties assumed based on the CRIEPI Rock Class of solid rock mass as shown in Table 7.3.4-2.

Grade	Description					
А	The rock mass is very fresh, and the rock forming minerals and grains undergo neither weathering nor alternation. Joints are extremely tight and their surfaces have no visible sign of weathering. Sound by hammer blow is clear.					
В	The rock mass is fresh and solid. There is no open joint and crack. But rock forming minerals and grains undergo a little weathering and alteration partly. Sound by hammer blow is clear.					
СН	The rock mass is slightly weathered and relatively solid. The rock forming minerals and grains undergo weathering except for quartz. The rock is contaminated by limonite, etc. The cohesion of joints and cracks is slightly decreased and rock blocks are separated by firm hammer blow along joints. Clay minerals remain on the separation surface. Sound hammer blow is a little dim.					
СМ	The rock mass is moderately weathered and somewhat softened by weathering, except for quartz. The cohesion of joints and cracks is somewhat decreased and rock blocks are separated by ordinary hammer blow along the joints. Clay materials remain on the separation surface. Sound by hammer blow is somewhat dim.					
CL	The rock mass is highly weathered and soft. The rock forming minerals and grains are softened by weathering. The cohesion of joints and cracks is decreased and rock blocks are separated by soft hammer blow along the joints. Clay materials remain on the separation surface. Sound by hammer blow is dim.					
D	The rock mass is completely weathered and decomposed, and remarkably soft. The rock forming minerals and grains are softened by weathering. The cohesion of joints and cracks is almost absent. The rock mass collapses by light hammer blow. Clay materials remain on the separation surface. Sound by hammer blow is remarkably dim.					

Table 7.3.4-1	Rock Classification	(CRIEPI)
		(-)

Note: Central Research Institute of Electric Power Industry (CRIEPI).

Table 7.3.4-2	Rock Mass Classification and Rock Parameters (by K. Kikuchi, et al)
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Rock Grade	Uniaxial compressive strength (kgf/cm ²)	Static modulus of elasticity (kgf/cm ²)	Modulus of Deformation (kgf/cm ²)	Cohesion (kgf/cm ²)	Internal friction angle (deg.)	Velocity of elastic wave (km/sec)
В	800	80,000	50,000	40	55-65	3.7
	or more	or more	or more	or more		or more
CH	800-400	80,000-	50,000-	40-20	40-55	3.7-3.0
		40,000	20,000			
CM	400-200	40,000-	20,000-	20-10	30-45	3.0-1.5
		15,000	5,000			
CL-D	200	15,000	5,000	10	15-38	1.5
	or less	or less	or less	or less		or less

(Source: Dr.K.Kikuchi, Mr.K.Saito & Mr.K.Kusunoki, ICOLD, May, 1982)

(2) Estimate of Strength of Foundation Rocks

According to on the results of the shear strength tests conducted in Japan, related parameters are estimated based on rock class and the directions of bedding plane/foliation as shown in Figure 7.3.4-1.



(Source: Saito et al (1985), Dam Engineering, vol.3, No.2, pp.58-65 (partially modified))

Figure 7.3.4-1 Directions of Bedding Plane/Schistosity and Shear Strength of CM Class Rocks

Considering the rock condition of the outcrops along the Nile River, the results of drilling survey and laboratory tests, as well as assumed parameters are shown in Table 7.3.4-3. It should be noted that it is necessary to review and clarify these parameters by further laboratory tests and by further analysis of data and results of in-situ tests during the F/S. For the assessment of shear strength, the effects of anisotropy on the strength of foundation rocks should be considered as mentioned before.

 Table 7.3.4-3
 Physico-mechanical Parameters of Foundation Rocks

Rock	Elastic	Deformation	Bulk	Shear strength	
class	module	module	density	Cohesion	Internal friction angle
	GPa	GPa	g/cm3	MPa	degree
В	10	6	2.8	3.5	50
СН	6	3.5	2.8	2.5	45
СМ	3	1.5	2.5	1.5	40
CL	1.5	0.5	2.2	0.7	35

Note: Shear strength parameters should be reviewed based on results of laboratory tests and in-situ tests.

7.3.5 Concrete Aggregates

(1) Coarse Aggregates

There are almost no river sands or terrace deposits. Development of quarry site is essential for coarse aggregates. Since Ayago site is located in Murchison Falls National Park, use of rock materials obtained from tunnel excavation will be preferable from the viewpoints of natural conservation.

1) Rock Materials to be obtained by tunnel excavation

Based on the drilling survey, rock materials at the location of underground Powerhouse No.2 are suitably adequate in quality. Additional drilling survey and laboratory tests are necessary to confirm available volume for concrete aggregates.

Tailrace tunnel will largely encounter biotite gneiss, which is not of good quality due to its poor abrasive resistance. Based on the ground mapping, quality for concrete aggregates seems to be poorer at the downstream section.

Additional drilling survey with laboratory tests is also necessary along the tunnel alignment to evaluate adequacy of excavated materials both in quantity and quality.

2) Material Sources out of National Park

The candidate quarry site outside the Murchison Falls National Park area is shown in Figure 7.3.5-1. Survey results for the four candidate quarry sites, obtained during the site reconnaissance on 23 October 2010, are summarized in Table 7.3.5-1.

It appears that site 4 is most suitable in terms of quality and accessibility. Although the said site is located about 70 km (road distance) away from Ayago site, it would still be feasible as an alternative quarry site during the early stage of the construction.



Figure 7.3.5-1 Locations of Construction Material Sources Outside Murchison Falls National Park Area (Source: Study Team)

Material source	Site 1	Site 2	Site 3	Site 4
Photos				
	Mashindi	Kiryandango	Bweyale,	Mutanda
	36 N	36 N	Nyamusasa	36 N
Location	350894E,	404187E,	36 N	419336N,
	197103N	215976N	404196E,	237238E
			218228N	
	Commercial quarry	Local quarry	Grass land,	(Used for materials
Site			cultivated area	of
Condition				Karuma-Pakuche
				Road)
	Granitic gneiss,	Granitic gneiss,	Granitic gneiss,	Metabasite,
Geology	suitable for	suitable for	suitable for	suitable for
	concrete	concrete	concrete	concrete
	aggregates	aggregates	aggregates	aggregates, better
				than the other three
				sites
Distance	107 km	100 km	90 km	84 km

Table 7.3.5-1Summary Description of Construction Material Sources Outside MurchisonFalls National Park Area

(Source: Study Team)

Note:

1. Datum of coordinates is ARC1960.

2. Comments on geology are based on the results of site inspection (23/10/2010). Detailed geological investigations are necessary to confirm availability of each quarry site both in terms of quantity and quality.

3. Distance: approximate road distance from Ayago site.

(2) Fine Aggregates

Fine aggregates can be obtained by crushing excavated rocks.

Biotite gneiss, largely distributed in the Ayago site, is not suitable as concrete aggregates due to its friable characteristics. Materials will be obtained from massive gneiss rocks intercalated in biotite gneiss.

Processed natural sands can be obtained from sand deposits/beaches along the shores of Lake Albert. Potential sources of granular material can be sourced within the vicinity of Wanseko, Buliisa and Butiaba along the Lake Albert shores. There are no specific



Lake Albert, near Wanseko town



Terrace deposits of Nile River

Electric Power Development Co., Ltd. • Nippon Koei Co., Ltd.

suppliers of sand in these areas since the sand deposits are only intermittently exploited for local use. The land where the sand deposits are located is owned either by the local communities or by the local governments in these areas.

Terrace deposits on the left bank of the Nile River on the far shore of Paraa Lodge are potential for sources of concrete aggregates, although the exploration in Murchison Fall National Park will be difficult. These materials are used by UWA as subgrade materials for the maintenance of existing roads in the national park.

7.3.6 Seismicity

(1) Collection of Existing Seismic Data

Shallow earthquakes due to normal faults have occurred along the West Rift Valley in the western area of Uganda (See Figure 7.3.6-1). No active faults have been recorded near the Ayago site, which is located about 20 km to 30 km away from the West Rift Valley.



(Source: E.M. Twesigomwe (1997), Seismic hazards in Uganda, Journal of African Earth Sciences, Vol.24 No.1/2, pp.183-195 and partially modified.)

Figure 7.3.6-1 Epicenters in Uganda (1900-1999) and Main Faults & Seismic Zone

According to the "Compilation of the GSHAP regional seismic hazard for Europe, Africa and Middle East" prepared by The Global Seismic Hazard Assessment Program (GSHAP), the peak of acceleration at the Ayago site ranges from 0.8 m/s^2 to 1.6 m/s^2 (0.08g-0.16g) as shown in Figure 7.3.6-2.

The former F/S report (1984) has proposed an acceleration coefficient of 0.2g for seismic design. According to an interviewed staff of Bujagali, design seismicity considered for Bujagali Dam is 0.19g.



Source: Compilation of the GSHAP regional seismic hazard for Europe, Africa and Middle East. The Global Seismic Hazard Assessment Program (GSHAP), a demonstration project of the UN/International Decade of Natural Disaster Reduction, 1998.

Note: The GSHAP Global Seismic Hazard Map has been compiled by joining the regional maps produced for different GSHAP regions and test areas; it depicts the global seismic hazard as peak ground acceleration with a 10% chance of exceedance in 50 years, corresponding to a return period of 475 years.

Figure 7.3.6-2 Peak Ground Acceleration of Africa

(2) Estimation of Design Seismicity

Probable maximum peak accelerations of Ayago site were estimated using the existing data from "Ntungwa Maasha (1975), The Seismic and Tectonics of Uganda, Tectonophysics, 27 pp. 381-393" and Seismic Record (1973-Present), issued by the US Geological Survey.

The biggest earthquake within 500 km radius from the intake site since 1973 was recorded to be of magnitude 7.2 at the remote distance of 307.5 km from the intake site. Although the accuracy of magnitude is low since it was obtained from an old data, the biggest earthquake within 300 km from the intake site since 1912 was recorded to be of magnitude 6.8 at the remote distance of 138.9 km from the intake site.

Location of the intake site is Latitude N2.348°, longitude E31.9337°.

The formula used for estimation of the ground acceleration is as follows.

A = 2000 e^{0.8M} / (d² + h² + 400) (Cornell) where,

- *M*: Magnitude of earthquake in Richter Scale
- d : Distance from epicenter to the project site in km
- h: Depth of focus in km
- A: Maximum acceleration in gal or cm/sec²
- e: The exponential constant
The results of analysis are shown in Figure 7.3.6-3 below.





Figure 7.3.6-3 Acceleration vs Return Period

(3) Design Seismicity

Considering available data and experiences in existing dam site, parameters for design seismicity are estimated to be 0.20g for maximum credible earthquake (MCE), and 0.10g for the operating basis earthquake (OBE).

7.3.7 Recommended Geological Investigation for the F/S

(1) Recommended Survey Items

Recommended survey items and their quantities are summarized in Table 7.3.7-1.

1) Core Drilling

Core drilling is necessary for obtaining subsurface geological data at related structures. It should be noted that the required core drilling to be carried out at both candidate sites of the underground powerhouse are essential for evaluating the two layouts of headrace type and tailrace type.

2) Observation of Borehole Using Borehole TV

The long axis of the powerhouse cavern should be laid out perpendicular to the strike of gneissosity for its safety purposes. Borehole wall observation using borehole TV is necessary

to determine the orientation of gneissosity.

If the borehole TV is unavailable, the orientation of the gneissosity can be estimated using vertical hole and inclined holes, although accuracy of calculation results that will be obtained are relatively low.

3) Seismic Prospecting

Seismic prospecting is very useful to efficiently and effectively evaluate subsurface rock condition of long structures such as tunnels. Regarding the geological investigation of the Ayago site, it is particularly effective in investigating underlying faults along the tunnel alignment and to optimize the layout of the outlet.

Seismic prospecting is sometimes difficult to be carried out due to delays in obtaining permission for use of explosive in addition to requirements for high degree of operational skills in data analysis. Hence, adequate amount of time for preparation is necessary.

If seismic prospecting cannot be carried out for some reasons, locations and quantities of the drilling survey should be increased.

4) Ground mapping

Ground mapping will be carried out to obtain geological data of related structures using the 1:1,000 and 1:10,000 scale map prepared by this study.

5) Laboratory Tests

Physico mechanical properties will be estimated using the results of laboratory tests. Suitability of construction material source and safety of disposed materials will be also evaluated.

6) Initial Stress Measurement (Acoustic Emission Method: AE method)

Initial stress measurement is necessary for underground design. This is carried out through acoustic emission method (AE method), since such method is superior in terms of facility and cost as compared to the other methods. Work addicts are not necessary for the AE method. The initial stress measurement by AE method will be done with the use of core sample after measuring the orientation of gneissosity using the borehole TV. The sample will be transported to Japan for the measurement.

No	Surve	y Items	Quantity						
I	Core d	rilling							
		Weir site	4	holes	x	25	m	100	m
		Power house (head type)	8	holes	x	120	m	960	m
		Power house (tailrace type)	2	holes	x	120	m	240	m
		Tunnel	6	holes	x	50	m	300	m
		Tailrace	4	holes	x	30	m	120	m
		Work adit	2	holes	x	25	m	50	m
		Access tunnel	2	holes	x	25	m	50	m
	Total							1770	m
II	Boreho	le TV observation							
		Power house (head type)	6	holes	x	120	m	720	m
		Power house (tailrace type)	2	holes	x	120	m	240	m
	Total							960	m
III	Seismi	c refraction prospecting							
		Tunnel alignment						11.5	km
IV	Ground	d mapping							
		1:10,000 scale						30	km2
		1:1,000 scale						3	km2
V	Labora	tory Test							
		Physical and mechanical test						1	L.S.
		Construction material						1	L.S.
		Dissolution test for excavated ma	ateria	s				1	L.S.
VI	Initial s	stress measurement							
		Acoustic emission method						1	L.S

Table 7.3.7-1	Recommended	Geological	Investigations	for the F/S
	Recommended	Geological	mesugations	IOI the I/D

(2) Points of Concern in the F/S

1) Required permission to work in Murchison Falls National Park from NEMA and UWA

Since the Ayago site is located in a national park, all activities in the park need permission from NEMA and UWA. Obtaining permissions during the conduct of the F/S may be required for a long time and necessary huge cost.

Adequate amount of time for the preparation prior to the commencement of the work will be necessary. Thus, the permissions for conducting the F/S should be obtained under the initiative of MEMD.

2) Maintenance of Access Road

Access route provided under the Pre Feasibility study will be available during the F/S by implementing necessary maintenance works.

Some valleys need improvement by providing soil embankment with drainage works. Stabilization of the access route is necessary for long-term use as well as for natural conservation during the F/S stage.

3) Camping and Safety

The Ayago site is located on the left bank of the Nile River, about 90 km (road distance) from Karuma Town. It takes about two hours by car to reach the site. The establishment of a camp in the national park is inevitable during the execution of the F/S. and hence it is important to ensure the safety of workers in cooperation with UWA and to minimize negative impact to the natural environment in the national park.

4) Timing of Geological Investigation

Considering accessibility and workability, geological investigation is recommended to be carried out in the dry season from December to next March.

7.4 Biological Environment at Ayago Project Site

7.4.1 Survey Methods

Literature survey and site survey are conducted to know the biological condition at the project site. Surveyors, survey date and time, and survey area are shown below.

Name	Position	Organization
Dr. Paul Ssegawa	Plant ecologist/botanist	WSS/MUK
Dr. Kityo Robert	Zoologist / Fauna Specialist	WSS Services (U) Ltd.
Dr. Behangana Mathias	Herpetofauna Specialist	WSS Services (U) Ltd.
Ms. Akite Perpetra	Butterflies Specialist	WSS Services (U) Ltd.
Dr. Eric Sande	Birds Specialist	WSS Services (U) Ltd.
Ms. Jalia Kiyemba	Field Assistant Butterflies Surveys	WSS Services (U) Ltd.
Ben Kirunda	Assistant	MUK
Dr. Twongo Timothy	Aquatic /Fisheries Specialist	WSS Services (U) Ltd.
Dr. Okello William	Water Quality Specialist	WSS Services (U) Ltd.

Table 7.4.1-2	Survey Date and Time
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Date	Time	Area	Surveyors
9th August - 15	6am - 9pm	Survey Areas A and B	Dr. Robert Kityo
August 2010			Dr. Behangana Mathias
			Ms. Akite Perpetra
			Dr. Eric Sande
			Ms. Jalia Kiyemba
29th July - 2nd	9 am - 5pm	Detailed and large area	Paul Ssegawa
August 2010			Ben Kirunda
21st September -	6am - 5pm	Survey points	Dr. Twongo Timothy
24th September			Dr. Okello William
2010			
12th October -	6am - 5pm	Survey points	Dr. Twongo Timothy
15th October			
2010			

Survey area is divided in two, survey area A and survey area B. Survey area A covers around 1,020 km^2 which includes access roads and transmission lines of all options. Brief survey of flora and fauna was conducted in the survey area A. Survey area B² covers around 119 km^2 which includes intake, penstock, generating facilities, and disposal area. Detail vegetation map was generated by satellite image and detail survey of flora and fauna was conducted in the survey area.



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Figure 7.4.1-1 Survey Area

7.4.2 Flora and Vegetation

A total of 244 vascular plant species belonging to 54 families and 168 genera are recorded by the site survey. Among the species recorded to as red listed include Milicia excelsa (LR/nt) and Khaya anthotheca (VU) in reiverine forest. According to Kalema (2005), other globally threatened species that occur in MFNP include Afzelia Africana, Vitellaria paradoxa, Entandrophragma cylindricum, Hallea stipulosa, Khaya grandifolia, Pouteria altissima, and Dalbergia melanoxylon.

Recorded vegetation types in the detail survey area are Riverine vegetation, Combretum dominated grassland, Acacia dominated wooded grassland, and Piliostigma-Acacia wooded grassland. The riverine vegetation is the most diverse vegetation type. Although this vegetation is not unique to

² The ccoordinate values of the corners of Survey area B are 31°51'6.000"E 2°24'31.000N, 31°51"6.000"E 2°17'30.000"N, 31°58'15.00E 2°17'30.000"N, 31°58'15.000" 2°24'31.000"N. Coordination system is WGS_1984_UTM_Zone_36N.

MFNP, the vegetation is also critical because of their relatively higher sensitivity to disturbance, presence of globally threatened species, higher species richness, role in stabilization of river banks and control of erosion, and unique habitats. Detail survey result is shown in Annex 1 of Appendix D: SEA report.



Figure 7.4.2-1 Survey Area (WGS_1984_UTM_Zone_36N)

7.4.3 Mammals

26 species of mammals are recorded at the site survey. The specie of Vulnerable (VU) category of IUCN redlist is Hippopotamus. The species of Near Threatened (NT) category are Leopard, Spotted Hyena, and African Elephant. Hippopotamus and African Elephant are recorded relatively high in the survey area. The maps of recorded area are shown in Figure 7.4.3-1 and Figure 7.4.3-2. Detail survey result is shown in Annex 2 of Appendix D: SEA report.

Name IUCN Presence				Population in the MFNP									
Family	English name	Scientific name	Red List status	area A	area B	pre-1973 a	1980b	1991c	April 1995d	Dec. 1995e	June 1999f	May 2002g	Jul-05
Carconithacidaa	Olive Baboon	Papio Anubis	LC										
Cercopiniecidae	Black & White Colobus	Colobus guereza	LC										
	Red-tailed Monkey	Cercopithecus ascanius	LC										
Felidae	Leopard	Panthera pardus	NT										
	Lion	Panthera leo	VU										
Hyenidae	Spotted Hyena	Crocuta crocuta	NT		\checkmark								
Hippopotamidae	Hippopotamus	Hippopotamus amphibius	VU		\checkmark	12,000	7,565	-	1,498	1,238	1,792	-	2,104
Suidae	Bush Pig	Potamochoerus porcus	LC										
Suidae	Common Warthog	Phacochoerus africanus	LC			-	-	-	411	856	1,639	-	2,298
	African Buffalo	Syncerus caffer	LC			30,000	15,250	1,610	1,087	2,477	3,889	8,200	11,004
	Bushbuck	Tragelaphus scriptus	LC		\checkmark								
	Sitatunga	Tragelaphus spekii	LC										
Povideo	Common (Bush) Duiker	Sylvicapra grimmia	LC										
Dovidae	Hartebeest	Alcelaphus buselaphus	LC		\checkmark	-	14,000	-	3,068	2,431	2,903	-	4,101
	Uganda Kob	Kobus kob	LC		\checkmark	10,000	30,700	-	6,355	4,373	7,458	-	9,315
	Oribi	Ourebia ourebia	LC										
	(Defassa) Waterbuck	Kobus ellipsiprymnus	LC			-	5,500	-	539	566	792	-	1,441
Giraffidae	Giraffe	Giraffa camelopardalis	LC			150-200	-	78	100	153	347	229	245
Elephantidae	African Elephant	Loxodonta africana	NT	\checkmark		12,000	1,420	308	201	336	778	692	516

 Table 7.4.3-1
 IUCN listing status and population trends for important species of mammals in MFNP

(Source: ^aUNP (1971), Laws et al (1976); ^bMalpas (1978), Douglas-Hamilton et al (1980); ^cOlivier (1991); ^dSommerlatte & Williamson (1995); ^eLamprey and Michelmore (1996); ^fLamprey (2000); ^gRwetsiba et al (2002))

Note: Numbers in italics are from sample counts with standard errors omitted for clarity. Numbers in normal script are from aerial total counts.

VULNERABLE (VU) : considered to be facing a high risk of extinction in the wild

NEAR THREATENED (NT): close to qualifying for or is likely to qualify for a threatened category in the near future

LEAST CONCERN (LC): does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened

Project for Master Plan Study on Hydropower Development in the Republic of Uganda

Name	General Habitat	General Behavior	Estimated Distribution in Ayago Area
Leopard (Panthera pardus- NT)	An extremely wide habitat tolerance: from coastal plains to high altitude mountains, from semi-desert areas to tropical rainforests.	Solitary with the exception of pairs coming together for mating, or when a female is accompanied by cubs. They are mainly active at night but in areas where they are not disturbed they can be observed moving during the cooler daylight hours. Most activity takes place on the ground but they are also capable climbers and swimmers. Adult males mark and defend a territory against other males, and a male's range may overlap those of several females. Territories are marked with urine scrapes, droppings, tree-scratching points and the deep 'sawing', or grunting, call. Females also call but this presumably serves no territorial function. Home ranges may be as small as 10km2 in optimal habitat, to several hundred square kilometers where pray densities are low. They stalk and then pounce on their prey and do not rely on running at high speed like the cheetah.	Population in the park is unknown. The population in the Ayago project area, their range, and routes have not yet been clearly mapped
Lion (Panthera leo – VU)	Very wide tolerance, from desert fringes to woodland and fairly open grasslands. Absent from true forest.	The most sociable larhe cat, living in prides ot between three and 30 individuals. Pride size is largely dictated by prey availability and various from region to region. The social groupings are complex, with each composed of a relatively stable core of related females, their dependent offspring, and usually a 'coalition' of two, or more, adult males. Most hunting takes place at night and during the cooler daylight hours. A pride territory is defended against strange lions by both males and females, but some prides and solitary males may be nomadic. Territories are marked with urine, droppings, earth-scratching and their distinctive roaring. These calls are audible over distances several kilometers. Pride home ranges vary from 26 to 220 km2 but in some cases may exceed 2000 km2.	There is no record yet near the project site, but the possibility of occurrence exists given the presence of suitable hunting grounds such as the lekking grounds and wallow areas. The population in the park is unknown but could be under 500 individuals. Population in the Ayago site, home range, moving route, and resting area has not been mapped yet.
Spotted Hyena (Crocuta crocuta – NT)	Open and lightly wooded savanna, dense woodland types, rugged, broken country; also penetrates drier areas along vegetated water-courses.	Solitary animals may be encountered, they usually live in family groups, or 'clans', led by an adult female. Clan size ranges from three to 15 or more individuals, with each clan defending a territory, which is marked with urine and anal gland secretions and the distinctive bright white droppings, usually deposited in latrine sites. They are both nocturnal and crepuscular, with more limited daytime activity. They frequently sunbask in the vicinity of their daytime shelters. Contrary to popular opinion, they are not skulking scavengers, although they are not above driving other predators such as lions from their kills.	Population in the park is unknown. Population in the Ayago site, home range, moving route, and resting area has not been mapped yet.
Hippopotamus (Hippopotamus amphibious – VU)	Sufficient water to allow for complete submergence is a requirement, and preference is shown for permanent waters with sandy substrates. Access to adequate grazing is also essential but these animals will move several	Semi-aquatic, spending most of the daylight hours in water, but emerging frequently to bask on sand- and mudbanks and on occasion to feed, particularly on overcast, cool days and in areas where they are not disturbed. They emerge at night to move to the grazing grounds, which may be a few 100 meters to several kilometers away (distances of up to 30km have been recorded), depending largely on the quantity and quality of grazing and the size of the population. They normally live in heads, or schools, of between 10 and 15 individuals, although larger groups and solitary bulls are not uncommon. In areas of high density heads of 30 or more animals are common. Territories in the water are very narrow but broaden towards the grazing grounds. Territorial defense is greatedt in and close to the water but the	Around 2000 hippopotamus are living between Karuma to Murchison. Average population density is 14.3/km. High populated area is unknown. They disperse for grazing at least 1km away from the River Nile. Preferred grazing areas have not been

Table 7.4.3-2 important mammals in the project area

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Name	General Habitat	General Behavior	Estimated Distribution in Ayago Area
	kilometers away from	little consequence in feeding areas. Herds disperse when feeding, only retaining their	identified.
	water-bodies to reach	integrity when in the water. Fixed painways to and from feeding grounds are used and these	
	suitable feeding areas.	are characterized by a tram-line trail, consisting of two parallel tracks separated by a	
		slightly raise centre ridge.	
		The hippopotamus is considered dangerous mammal, as attacks almost invariably result in	
		death for the unfortunate who provokes, wittingly or unwittingly, on of these animals.	
African Elephant	Extremely wide habitat	Home range size varies considerably and usually relates to the abundance of food and access	Around 500 elephants are
(Loxodonta	tolerance, including	to water, with matriarchal, or family, groups ranging over $15 \text{ to} > 50 \text{ km2}$, but are frequently	living in the MFNP. High
Africana – NT)	coastal, montane, forest,	smaller. Ranges of the forest race are generally much smaller, primarily because of greater	populated area, home range,
	different savanna	abundance of food. They are highly social, living in small family herds consisting of an older	number of the herds,
	association, semi-desert	cow and her offspring, with larger groups including other related cows and their calves of	migration routes has not been
	and swamp, woth the only	different ages. At certain times, usually at water points or at abundant and localized food	identified. Population in the
	requirements being access	souces, several of these matriarchal groups may gather to form temporary 'herds', sometimes	northern bank seems higher
	to adequate food, water	up to several hundred, but each family unit retains its integrity.	than southern bank.
	and usually shade.		

(Source: Field guide to the larger Mammals of Africa (Chris & Tilde Stuart, 2006))



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7.4.4 Birds

A total of at least 491 species of birds are known to occur in MFNP (Wilson 1995). Twelve of them are categorized in EN, VU, or NT of IUCN redlist. 116 migrant species (Wilson 1995) are the intra African or inter continental migrants. 199 species are recorded at the site survey and 9 of them are conservation concern species.

Briton Number	Common name Scientific name	Threat	Habitat preference	Survey area A	Survey area B
	Purple Heron				
B36	Ardea purpurea	R-NT	WW	\checkmark	\checkmark
	Brown Snake Eagle				
B178	Circaetus cinereus	R-NT		\checkmark	\checkmark
	Western Banded Snake Eagle				
B180	Circaetus cinerascens	R-VU	F	\checkmark	\checkmark
	Ring-necked Francolin				
B324	Francolinus streptophorus	R-VU/RR		\checkmark	\checkmark
	Rock Pratincole				
B468	Glareola nuchalis	R-VU	WW	\checkmark	
	Swallow-tailed Bee-eater				
B876	Merops hirundineus	R-NT		\checkmark	
	Spot-flanked Barbet				
B984	Tricholaema lacrymosa	R-RR		\checkmark	\checkmark
	White-headed Saw-wing				
B1120	Psalidoprocne albiceps	R-RR	f	\checkmark	\checkmark
	Sharpe's Starling				
B1949	Cinnyricinclus sharpii	R-NT	FF	\checkmark	

 Table 7.4.4-1
 Species of birds of conservation concern recorded in the project area

Over 53% of the known avifauna of MFNP has recognized habitat preferences (Wilson 1995). Woody vegetation and water are the preferred habitats and they are thought to be important habitats for birds. Detail survey result is shown in Annex 2 of Appendix D: SEA report.

 Table 7.4.4-2
 Summary of habitat preferences for species recorded in the project area

II. 1. 4. 4	Number per category					
Habitat preference	Wilson(1995)	JICA study (2010)				
Af/FF	1					
AW	1					
F	103	26				
f/F	1					
FF	9	2				
fW	9	2				
FWW	6	1				
W	41	8				
WW	90	8				
Grand Total	261	47				

W - always resident in or near water (WW refers to a species strictly tied to a water habitat), w - often resident or observed in or near water, F -Forest resident (FF- refers to species of strictly forested habitats), f - resident in and near forests, Af - intra-African migrant.

7.4.5 Amphibians and Reptiles including Crocodiles

A total of 12 amphibian species belonging to three families and 16 reptiles belonging to two orders (the true reptiles and turtles and tortoises) and 12 families are documented during the study. The list of the species is shown in the following table. 11 amohibian species are LC, one amphibian is DD, and one reptile, Crocodile, is LC of IUCN redlist. The reptiles apart from the Nile Crocodile which is a resident of the rivers, were randomly distributed throughout the habitats sampled. However, tortoises are only encountered in the wooded grassland while the Pelomedusids are only recorded in rain pools of water or wetlands/marshes. Most important habitat for amphibians and reptiles are wetland and river banks. The detail survey result is shown in Annex 2 of Appendix D: SEA report.

	Na	ame	IUCN Red List	Sur	vey are	ea A	Sur are	vey a B
	Family name	Scientific name	status	Ι	II	III	IV	V
Amphibians Re	Family Bufonidae	Amietophrynus maculatus	Least Concern (LC)	1	0	0	1	0
		Amietophrynus regularis	LC	1	0	1	1	1
		Amietophrynus vittatus	Data deficient (DD)	1	0	0	0	0
A		Afrixalus osorioi	LC	1	1	0	0	0
npl	Family Hyperoliidae	Hyperolius viridiflavus	LC	1	0	0	1	1
nibi		Kassina senegalensis	LC	1	0	1	1	1
ian		Amietia angolensis	LC	1	0	1	1	0
Ś		Phrynobatrachus acridoides	LC	1	0	1	1	1
	Esmily Donidos	Phrynobatrachus natalensis	LC	1	0	1	1	1
	Family Randae	Ptychadena anchiateae	LC	0	1	1	0	1
		Ptychadena chrysogaster	LC	0	1	0	0	0
		Ptychadena mascareniensis	LC	1	1	1	1	1
	Family GecknoniidaeHemidactylus brookii		Not evaluated	0	1	0	0	0
	Family Scincidae	Mabuya maculilabris	Not evaluated	0	1	1	1	1
		Mabuya megarula	Not evaluated	0	0	0	0	1
	Family Chamaelionidae	Chamaeleo gracilis	Not evaluated	0	1	1	0	0
		Chamaeleo laevigatus	Not evaluated	0	0	1	0	1
	Family Agamidae	Agama agama	Not evaluated	0	1	1	1	0
Ŧ	Family Varanidae	Varanus niloticus	Not evaluated	1	1	1	1	0
Cep	Family Crocodilydae	Crocodylus niloticus	Least Concern	1	0	0	0	0
tile	Family Typhlopidae	Typhlops sp.	Not evaluated	0	1	0	0	0
ŝ	Family Colubridae	Dasypeltis scabra	Not evaluated	0	0	0	0	1
		Philopthamnus sp	Not evaluated	0	1	0	1	1
	Family Elapidae	Naja melanoleuca	Not evaluated	1	1	0	1	1
	Family Viperidae	Bitis arietans	Not evaluated	0	0	0	0	1
	Family Pelomedusidae	Pelomedusa subrufa	Not evaluated	0	1	0	0	1
	Family Testudinidae	Geochelone pardalis	Not evaluated	0	1	1	1	1
		Kinixys belliana	Not evaluated	0	1	0	0	1

 Table 7.4.5-1
 Amphibians and Reptiles of Ayago

I. Habitats Adjacent to the Nile River Banks near the point of dam placement

II. Woodlands and Bushlands on the northern bank

III. The areas along the Karuma-Rabongo Forest

IV. Woodlands and Bushlands on the southern bankV. Grassy Plains on the southern bankWhere 1= Presence and 0 = Absence

7.4.6 Invertebrates (butterfly)

66 butterfly species are recorded at the field survey. No IUCN redlist species are found. None of the swamp/wetland species that have limited continental distribution are recorded by this study. 14 forest specialists (F and FL-ecotypes) butterfly species are recorded in the areas surveyed and one swamp species (S) as well. Important habitats for butterflies are forest and wetland because of high species diversity. The detail survey result is shown in Annex 2 of Appendix D: SEA report.

7.4.7 Fish

Literature survey suggests the possibility of 8 fish species are living in the survey area. Five fish species of them are recorded at the field survey. Seven LC species of IUCN redlist are found. Most important habitat for fishes is the river mouths of relatively large water shed. The result of detail survey is shown in Annex 3 of Appendix D: SEA report.

				Population in the survey area*																
		IUCN Red List]	Left	Banl	K		North Bank										
	Sientific names	status Habitat preferences	Intake Or		Ou	tlet	Intake		Ayago River		Outlet				Kibaa					
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		I	1			1	1													
	Lates niloticus	Least concern	open water; not very turbulent	E	R		E	E	R	E	E			R		E	E	Е	R	
	Barbus altianalis	Least concern	open turbulent waters; upstream migrant	R	E	R	Е	Е	E	E	E					E	Е	Е	Е	Е
	Mormyrus kannume	Least concern	open turbulent/flowing water	Е	Е	Е	R	Е	Е	Е	Е			R		Е	Е	Е	Е	Е
	Bagrus docmac	Least concern	open flowing water	Е	Е		R	Е	Е	Е	Е			R		Е	Е	Е		
Survey result	Oreochromis niloticus	Least concern	shallow non-turbulent open	Е	Е	R			Е	Е	Е	Е	Е	R				Е		Е
	Oreochromis variabilis	Least concern	shallow, non-turbulent, open			Е						Е	Е						Е	Е
	Clarias gariepinus	Least concern	near shore, aquatic vegetation			Е						Е	Е							
	Protopterus aethiopicus	not determined	aquatic vegetation			Е						Е	Е							
-	Synodontis afrofischeri	not determined	upstream spawner, clean water																	
	Synodontis victorie	not determined	upstream spawner, clean water																	
	Intermedius mystus	not determined	upstream spawner, clean water																	
	Tilapia zillii	not determined	aquatic vegetation																	
	Rastrineobola argentia	Least concern	pelagic clean water																	
	Labeo victorianus	Threatened	upstream spawner, clean water																	
		Normhan af an 1	· 	5	5	6	4	4	5	5	5	4	4	4		4	4	5	4	4
		Number of spe	ecies		1	3		4	5	4	5		7			5	5		5	;
Evaluation	Importance of the habitat	Breeding, nurser	y, feeding, shelter/refugia		1	4		I	3	I	3		А			E	3		P	\$
	* Detailed survey needed	R	Record					-		-		-								
		Е	Expected																	

Table 7.4.7-1Evaluation of the Survey Sites

7.5 Social Environment at Ayago Project Site

7.5.1 Administrative Boundaries

Murchison Falls National Park is surrounded by the Districts of Amuru (Nwoya since July 2010) to the North, Masindi (Kiryandongo since July 2010) to the South, Oyam (Apace before July 2006) to the East, and Bulisa and Nebbi to the West. Survey Area C, which has a border with the Park, includes six Sub-counties: Purongo, Anaka, Koch Goma, Minakulu (Myene since July 2010), Aber, and Mutunda. The figure below shows administrative boundaries around the Ayago site (Survey Area B) in 2009.



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7.5.2 Land Use and Land Ownership

Land cover around the Ayago site is mainly grassland, bush land, and woodland. The northwest area near access roads (Anaka and Purongo Sub-counties) and most of the Eastern area (Myene/Minakulu, Aber, and Mutunda Sub-counties) is characterized by small-scale farmland. A part of the southern area (Mutunda Sub-county) and most of the northern area (Koch Goma Sub-county) are woodland and forest reserve. The characteristics of land use by sub-county in Survey Area C can be seen in Annex 4 of Appendix D: SEA report.



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(Source: National Forest Authority, 2005)

Figure 7.5.2-1 Land Use Map around Ayago Site, 2005 (WGS_1984_UTM_Zone_36N)

In Northern Uganda in general, the land is commonly owned under customary tenure, and land rights are vested in the clan elders or chiefs. Customary tenure actually means that the right to use land is regulated by local customs and linked to family inheritance and lineage. The clan heads have powers regarding access and use rights by the clan members.

However, Women have limited access and control over land and other household assets. Women do not usually own land, due to traditional culture in Uganda. A woman can purchase and own land only when her husband dies or she doesn't have one. More detailed information on land ownership can be seen in Annex 4 of Appendix D: SEA report.

7.5.3 Population

There are no residents at the Ayago site, since the area is inside the National Park. Population by sub-county in Survey Area C is shown in the table below. Population by parish can be found in Annex 5 of Appendix D: SEA report.

Sub-county	Male	Female	Total
Aber	33,000	35,100	68,100
Anaka	7,600	8,100	15,700
Purongo	4,100	4,200	8,300
Mutunda	35,200	36,900	72,100
Myene/ Minakulu	26,700	26,900	53,600
Koch Goma	5,500	5,100	10,600

 Table 7.5.3-1
 Population Estimates of Survey Area C by Gender, 2010

(Source: Sub National Projections Report Northern, Western Region 2008-2012)

7.5.4 Ethnic Groups

Figures 7.5.4-1, 7.5.4-2, and 7.5.4-3 show the composition of ethnic groups in three districts in Survey Area C. In Masindi District, there are a variety of ethnic groups. Banyoro and Alur account for 25.53% and 21.82%, respectively. Chope accounts for only 3.07%, but they are dominant in Mutunda sub-county. In Minakulu/Myene and Aber sub-counties in Oyam District, the majority of people (98.30%) are Langi, while in Purongo, Anaka, and Koch Goma sub-counties in Amuru, people are mainly Acholi settlers (91.09%). Out of fifteen sub-counties surrounding the park and reserves, nine of them are occupied mainly by Luo-speaking tribes.



(Source: 2002 Population and Housing Census, Masindi Report)

Figure 7.5.4-1 Distribution of Population by Ethnic Groups in Masindi District, 2002



(Source: 2002 Population and Housing Census, Apac Report)

Figure 7.5.4-2 Distribution of Population by Ethnic Groups in Oyam (Apac) District, 2002



(Source: 2002 Population and Housing Census, Gulu Report)

Figure 7.5.4-3 Distribution of Population by Ethnic Groups in Amuru (Gulu) District, 2002

7.5.5 Internally Displaced Persons

Due to activities of the Lord Resistance Army (LRA), Northern Uganda has experienced instability over the last two decades, resulting in the internal displacement of some 1.1 million people (UNOCHA, 2010). IDP camps were established along the main roads, trading centres, town centres, and suburbs. In Amuru District, there were 34 original camps with the population of 257,000 in 2005.

As the figure below shows, most camps were located in the northern part of Survey Area C, in Amuru and Oyam Districts.



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(Source: Northern Uganda Rural Road Project, 2009)



Following the end of the insurgency in 2006, the Internally Displaced Persons (IDPs) have been returning and resettling on their ancestral lands under the auspices of the peace and recovery program initiated by the government of Uganda and other development partners, including JICA. According to UNHCR ("Camp phase out update as of 6th December, 2010"), all camps in Amuru District were officially closed by 30th July, 2010. The details are shown in the table below.

 Table 7.5.5-1
 Decommissioned Internally Displaced Persons'
 Camps in Amuru District

Date of	Total	Camps	Names of camps and comments			
closure	camps	closed				
24 th /25 th Feb.	34	15	Amuru, Atiak, Palukere, Parabongo, Awer, Guruguru, Pagak,			
2010			Kaladima, Keyo, Lacor, Pabbo, Alero, Anaka, Aparanga and			
			Purongo were closed			
19 th May	19	18	Tegot Latoro, Lolim, Corner Nwoya, Agung, Wii Anaka,			
2010			Langol, Wii Anono, Koch Goma, Olwiyo, Omee I, Omee II,			
			Olwal, Labongogali, Bira, Otong, Olinga, Jengari and			
			Palukere. Bibia is considered "problematic". Joint team lead			
			by RDC and LCV shall hold a meeting with the commun			
			in June 2010.			
30 th July,	0	1	Bibia, a problematic camp was closed, witnessed by			
2010			UNHCRs Director of Africas Bureau.			

(Source: UNHCR Gulu, December 2010)

However, according to UNHCR camp mapping data from November 2010, 36,400 IDPs were estimated to still be residing in the former camps with 11,260 in transit sites in Amuru District. There are many extremely vulnerable individuals/persons with specific needs, including older persons, female/child-headed households, persons with disabilities, and the chronically ill.

7.5.6 Local Economy

The main source of household livelihoods in survey area C is subsistence farming. According to the Census in 2002, subsistence farming is the main source of livelihood for 67.4% of the household in Masindi, 77.4% in Amuru, and 94.0% in Apac.

	Masindi	Amuru (Gulu)	Oyam (Apac)
Subsistence Farming	67.4 %	77.4 %	94.0 %
Earned Income	20.1 %	9.0 %	3.8 %
Property Income	1.7 %	10.8 %	2.1 %
Other	10.7 %	2.8 %	0.1 %

 Table 7.5.6-1
 Main Source of Household Livelihood in Survey Area C

(Source: 2002 Population and Housing Census 2002, District Reports of Masindi, Gulu, Apac)

The main crops grown include maize, cassava, millet, sorghum beans, ground nuts, sweet potatoes, and sesame. Being largely peasant farmers, they consume domestically what they produce and sell the surplus in local markets for cash.

Livestock rearing in small numbers is also a key economic activity in survey area C, and these include cattle goats, pigs, sheep, duck and turkey.. It was reported by the community that the LRA related war, which lasted twenty years in the areas, made large-scale livestock rearing impossible.

The communities in Survey Area C carry out fishing activities on the River Nile outside the park area, and in the vast swamps and wetlands, the small rivers, and streams which act as breeding places for the fish. Fishing is on a small scale and what is caught is locally consumed.

Other activities include petty businesses such as operating small kiosk grocery shops in the village and trading centres, brick making, charcoal burning and selling, and roadside sale of farm products. Annex 8 of Appendix D: SEA Report explains the characteristics of the local economy by Sub-county.

7.5.7 Education

The figure below shows the location of Educational institutions such as primary, secondary, and tertiary schools around Ayago.



Figure 7.5.7-1 Location of Educational Institutions around Ayago Site, 2010 (WGS_1984_UTM_Zone_36N)

School attendance by gender by three districts in Survey Area C is shown in the figure below. Compared to male, female attendance is low. More than 25% of females have never been to school, as compared with less than 15% of males.



(Source: 2002 Population and Housing Census, District Reports of Masindi, Gulu, Apac)

Figure 7.5.7-2 School Attendance by Sex in Survey Area C, 2002

Similarly, the literacy rate of women is lower than that of men in three districts, as the figure below indicates.



(Source: 2002 Population and Housing Census, District Reports of Masindi, Gulu, Apac)

Figure 7.5.7-3 Literacy Rate by Sex in Survey Area C, 2002

7.5.8 Health

The figure below shows the locations of health facilities such as health centres and hospital around the Ayago site.



(Source: UNOCHA, 2009) Figure 7.5.8-1 Location of Health Facilities around Ayago Site, 2010

(WGS_1984_UTM_Zone_36N)

The Government policy provides that there should be HC II from the Parish level, HC III at sub-county, and so on up to the national referral hospital level. The public health facilities in the survey area are mostly HC II and HC III, except in Aber and Anaka Sub-counties, where there are hospitals.

The health centres, including hospitals, in the surveyed sub-counties are not only few but also fall short of the expected service standards. The most frequently raised complaints against the health facilities are inadequate drugs and supplies, unqualified health workers, and long waiting period before getting the services. The long waiting time at the health centre also means that there are limited health facilities in the sub-counties. As a result, some people obtain health care services from private health outlets such as clinics and drug shops.

7.5.9 Water Use

The major sources of water around Ayago site include rivers, boreholes, protected springs, shallow wells, rainwater, and streams. The locations are shown in the figure below.



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(Source: Directorate of Water Development, 2010)

Figure 7.5.9-1 Location of Water sources around Ayago Site, 2010 (WGS_1984_UTM_Zone_36N)

The Table below shows the accessibility of water by local people in Survey Area C. The majority of people do not have a water source on premises. The responsibility of fetching water lies mainly

with women and children; hence it reduces their time for other productive activities.

Sub country	Water Source						
Sub-county	On premises Up to 1km		Over 1km				
Aber	163	6,287	3,532				
Minakulu	312	7,100	1,056				
Anaka	127	2,219	65				
Purongo	104	1,419	75				
Koch Goma	84	1,786	107				
Mutunda	104	5,156	3,660				

 Table 7.5.9-1
 Distance to Nearest Water Sources of Households by Sub County

(Source: 2002 Population and Housing Census, District Reports of Masindi, Gulu, Apac)

7.5.10 Tourism

The tourism industry in Murchison Falls National Park has not been fully developed. The annual number of tourists has been less than 50,000, as indicated in the figure below. Contributing factors towards the small number of visitors include rebel activities in Northern Uganda that posed a security threat, and failure to adapt to tourism needs and expectations. According to interviews with UWA officials, the current number of visitors accounts for only 30 to 40% of the carrying capacity of the Park.





Figure 7.5.10-1 Number of Visitors to Murchison Falls National Park

Tourism activities in Murchison Falls National Park are generally limited to boat/launch trips to view wild animals and the falls, visits to the falls, and game drive. The list of tourism activities and their fees are shown in Annex 9 of Appendix D: SEA report.

The table below shows the tourism revenue of Murchison Falls National Park in 2009. It indicates that most revenue (70%) was collected through the entrance fees. Tourism activities such as boat rides, nature walk game drives, and fishing are not major sources of revenue. This means that currently, many of the visitors are on self-drive and they do not pay anything except entrance fee to see all the beautiful wildlife in the Park (Performance Evaluation of the Murchison Falls Protected Area General Management Plan Report, 2007).

Tourism Activity	Annual Revenue in Ush.	%
Entrance fees (visitors)	1,649,033,319	63.7
Entrance fees (vehicles)	192,906,513	7.4
Canping fees	40,526,570	1.6
Landing fees	10,775,951	0.4
Photographic fees	29,938,677	1.2
Ranger Guide Fees	51,735,529	2.0
Ferry Crossing	301,849,052	11.7
Fishing Permits	39,960,836	1.5
Nature Walk fees	71,325,277	2.8
Lauch Hire	71,768,241	2.8
Vehicle Hire	3,941,737	0.2
Accomodation Bandas	16,452,950	0.6
Accomodation Ugandan Students	31,449,980	1.2
Boat rides	78,722,312	3.0
Total	2,590,386,944	100.0

 Table 7.5.10-1
 Murchison Falls National Park Tourism Revenue in 2009

(Source: Uganda Wildlife Authority)

To diversify tourism activity in the Park, UWA has considered the potentials for sport fishing, walking safari, and white water rafting (Murchison Falls Protected Area General Management Plan for 2001-2011). More detailed information is provided in Annex 9 of Appendix D: SEA Report.

The Murchison Falls Protected Area (MFPA) includes Murchison Falls National Park, Bugungu Wildlife Reserve, and Karuma Wildlife Reserve. It is one of the most important tourism resources in Uganda. The area has been divided into several zones to clarify tourism development and to protect important and sensitive resources. The figure below shows the location of the zones.



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(Source: UWA 2010, NFA 2010, Nature Uganda 2010, Ministry of Water and Environment 2008, World Database on Protected Area 2009)

Figure 7.5.10-2 Management Zones of Murchison Falls Protected Area (WGS_1984_UTM_Zone_36N)

The areas that have a potential for tourism development include an Intensive Tourism Zone, the Moderate (Low) Tourism Zone, and the Falls Zone. Ayago is located in the Moderate (Low) Tourism Zone.

The table below shows the classification of the zones from the viewpoint of tourism development, natural resource management, and community collaboration.

Management	Tourism	Natural Resource	Community
Zones	Development	Management	Collaboration
The Falls Zone	 Proposed for nomination for the World heritage Site list. All developments are carefully designed to give the visitor the fullest exposure to the spectacular landscape of the Falls. 	 It is the main breeding area for Nile Crocodiles. There is the unique spray forest around the Falls. 	• None

 Table 7.5.10-2
 Classification of Management Zones of Murchison Falls Protected Area

Management Zones	Tourism Development	Natural Resource	Community Collaboration
The Intensive Tourism Zone	 Activities comprise the launch trip to the Falls, the drive to the Falls, game drive, walking safari, bird watching, and sport fishing. Activities will continue to be promoted with diversification of visitor experience. 	None	• None
The Moderate (Low) Tourism Zone	 It is confined to game drive, walking safari, and sport fishing by concession. Development is conducted in a particularly sensitive way. 	• The central part of this area is a unique habitat to almost half of the large mammals of the entire conservation area.	• None
The Wilderness Zone	• Although tourism activities suggested by operators may be allowed, the area does not appeal to tourists.	• It comprises dense bushland and thicket with low numbers of wildlife. Tsetse flies are abundant. Wildlife and habitats will remain undisturbed.	• None
The Integrated Resource Use Zone	• None	• None	• Local community may use resources such as firewood and thatching materials in a sustainable manner under MoUs.
Administrative Zones	• It contains the developed areas where resources are allocated for operations and visitor accommodation.	• The environment in this zone is kept as natural as possible.	• None
Wildlife Reserve (Alternative Management Area)	 It will be offered for long-term management by concessionaries. Sport hunting may be permitted. 	• Wildlife populations are low. The vegetation is thick, infested with tsetse flies.	• None

(Source: Murchison Falls Protected Area General Management Plan for 2001-2011)

7.5.11 MFNP and the Community

According to the Murchison Falls Protected Area General Management Plan 2001-2011, UWA has promoted better relationships with local communities for collaborative management of the area. The objectives of community collaboration include the following.

- To conserve and protect natural resources in MFPA, in collaboration with adjacent communities
- To minimize the impact of problem animals and vermin on local communities
- To support local communities in implementing benefit-sharing programs
- To develop programs to enable local communities to use MFPA resources in a sustainable manner

In order to meet the above challenges, UWA established the Community Protected Areas Institutions (CPIs). CPIs are integrated within Local Environment Committees, and report to local councils. They are expected to address community issues in PA management, to act as intermediaries facilitating communication, and to plan and implement revenue sharing projects. According to UWA officials, the institutions have been functioning well to link with the communities.

In communities adjacent to MFPA, the rapidly growing human population and changes in land use have led to increased conflicts between people and wildlife. Problem animals such as elephant, hippopotamus, baboon, and buffalo sometimes damage crops and livestock. There are strong complaints by local people that the MFPA management is not sufficiently staffed or equipped to respond when communities need help in controlling problem animals (Murchison Falls Protected Area General Management Plan 2001-2011).

The Wildlife Statute 1996 provides that 20% of gate entrance fees are given to local communities to be used in funding development projects. The park disbursed USh.896,396,296 (nearly equal to US\$487,453) from July 2002 to June 2009. The communities have utilized this revenue mainly for the constructions of primary schools, health centres, pit latrines, community roads, and livestock production.

The Wildlife Statute 1996 clearly indicates that no resources should be taken from a protected area without the permission of the UWA Executive Director. At the same time, UWA considers local community incentives powerful tools for encouraging and promoting wildlife conservation. One of such incentives is the access to resources within PAs. Under the collaborative management strategy, PA managers prepare Memoranda of Understanding (MoUs) with community groups specifying which resources may be used in what quantities, control mechanisms for resource use, and penalties for violation of the agreement. The MoU allows them to carry out sport fishing, and to collect firewood, grass, and local herbs in designated areas and on designated days. As a result of implementing the collaborative park management policy, the communities have played an

instrumental role in protecting and conserving the environment within the park.

However, illegal activities such as hunting wildlife, collecting firewood, and encroachment have been continued by local people. Two figures below show examples of poaching and encroachment. More detailed information is provided in Annex 10 of Appendix D: SEA report.



(Source: UWA)

Figure 7.5.11-1 Location of Poaching in Murchison Falls Protected Area, 1989-2009 (WGS_1984_UTM_Zone_36N)



(Source: UWA)

Figure 7.5.11-2 Location of Encroachment in Murchison Falls Protected Area, 1989-2009(WGS_1984_UTM_Zone_36N)

7.5.12 Culture and Archaeology

The locations of historical/cultural and archaeological sites around the Ayago site are shown in the figures below. The historical/cultural sites in the figure were recognized by the Government of Uganda. Although many archaeological sites were found in the project area (Survey Area B), some of them can be ignored since they are common in the region. Others need to be investigated further through deep archaeological work and analysis to assess the importance of the sites. More detailed information, including field survey sheets, can be seen in Annexes 11 and 12 of Appendix D: SEA Report.



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(Source: Study Team, 2010)

Figure 7.5.12-1 Location of Cultural and Historical Sites around Ayago Site, 2010 (WGS_1984_UTM_Zone_36N)



Project for Master Plan Study on Hydropower Development in the Republic of Uganda (2010, JICA)

(Source: Study Team, 2010)



7.6 Study on Development Type and Optimum Layout

7.6.1 Development Types and Their Characteristics

There are three hydropower development types classified by water utilization: run of river type, regulating pond type and reservoir type. The hydropower development can also be classified by structure configuration to obtain head: i.e. waterway type, dam and waterway type and dam type. The general features, advantages and disadvantages of each type are shown in Figure 7.6.1-1.

Generally, natural characteristics of rivers such as runoff, head, topography, geology as well as social and natural environment are quite diverse. And so, in order to develop the potentials optimally, the most appropriate development type should be selected considering all the parameters and characteristics of the site..



Figure 7.6.1-1 Development Type

7.6.2 Characteristics of Ayago Hydropower Site

The Ayago is one of the most important large scale hydropower development projects in the Victoria Nile river envisaged to utilize the abundant water resources and stable flow of the Nile river due to the large storage effect of Lake Victoria and 84 m head drop between the location points 472.6 km and 481.5 km from the beginning point of the Nile river. Characteristics of outflow from the Lake Victoria are as follows.

- Almost no seasonal fluctuation and far less yearly fluctuation compared to other ordinary rivers.
- Complete daily flat flow due to regulation effect on the outflow from the peak power stations –Owen Falls and Bujagali- in the upstream of the Lake Kyoga.
- > Large amount of flow, of which the average flow is $924m^3/s$ and the firm discharge is $467m^3/s$.

By considering the characteristics described above a large scale hydropower development can be expected even for run of river type development which has less environmental impact. And, as shown in Figures 7.6.2-1 and 7.6.2-2, if the Ayago project is developed as a run of river type hydropower for base load, economical and stable electric power supply would be secured in 2020 and 2023 by integrated river system operation with Owen Falls hydropower and Bujagali hydropower as peaking power station.



Figure 7.6.2-1 Load and Operation Pattern of Hydropower Projects in 2020



Figure 7.6.2-2 Load and Operation Pattern of Hydropower Projects in 2023

On the other hand, the option of construction of the dam at a site immediately downstream from the junction point of the Nile River and the Ayago River is also possible. In this case, the project would be dam-and-waterway type development with a dam height of 45m and 1,400m crest length and with a 6.1 km-long tunnel, which would shorten by 20% the tunnel length of the waterway type development on the left bank.

The optimum layout is determined by comparative study concerning economics, environment, topography and geology between the waterway type and the dam type. Result of the study on the optimum layout is described in the next section.

7.6.3 Optimal Layout Study

As described in the above section, waterway type and dam & waterway type can be applicable to the Ayago Hydropower Project.

Outline of layout alternatives for the Ayago Hydropower Project is described below;

(1) Dam & Waterway Type Layout (Alternative-1, refer to Figure 7.6.3-1)

There is only one suitable location for the dam site just downstream of the confluence between the Ayago River and the Nile River. Right bank side waterway route is selected, since the route is shorter than the left bank route and obviously economical.

Principal structures of the dam & waterway type hydropower plant consist of the intake dam, the headrace tunnel, the penstock (tunnel embedded type), the underground powerhouse, and the tailrace tunnel. The Ayago Project is planned to be constructed in the National Park area and the land alteration should be minimized. Hence the concrete gravity dam is selected, since the concrete dam can minimize the land alteration comparison of the other dam type. The concrete gravity dam consists of 1) gated section, which has function of normal food spillway and amenity flow gate, 2) overflow section, which has function of excess flood spillway, and 3) non-overflow section.

(2) Waterway Type Layout

1) Left Bank Route (Alternative-2, refer to Figure 7.6.3-2)

Head type and tail type, which are layout types of vertical alignment of the waterway, can be applied to the left bank route. Head type layout is applied as a type of the vertical alignment for the left bank route with following reasons;

- Selection of the layouts should be determined considering not only topographic conditions but also geological conditions along the waterway.
- Geological condition along the waterway is unclear, except geology at intake and tailrace outlet sites (means; geology at origin and end points of the waterway), in this Pre-feasibility Study stage.
- It seems that the head type layout can be taken thicker ground cover than the tail type layout. Therefore, it is highly likely that geological condition along the waterway is relatively-good by means of applying the head type layout.

Principal structures of the left bank route (waterway type) consist of the intake weir, the headrace tunnel, the penstock (tunnel embedded type), underground powerhouse and the tailrace tunnel. Overflow type concrete weir for typical section is selected due to economical advantage and gated weir section for sand flushing also required at the left bank side of the weir in order to flush out sediment material. Underground powerhouse option is selected due to vertical alignment of the waterway and topographic conditions. Pressure flow type of concrete lined tunnel is selected as a structural type of the headrace tunnel and embedded type of steel lined tunnel penstock is selected. Pressure flow type and free flow type tunnel structure can be applied to the tailrace tunnel. Since water level fluctuation of the Kyoga Nile Rive is not so high and it is low probability to fill water in the tailrace tunnel with pressure due to usual food water rising, the non-pressure type tunnel is selected for the type of the tailrace tunnel.

2) Right Bank Route (Alternative-3, refer to Figure 7.6.3-3)

The right bank route requires considerably longer waterway than the left bank route and the right bank route seems to be uneconomical. However, if the left bank rout has fatal problem in geological and/or environmental aspects, the right bank rout may be considered as an optional layout of the Ayago Project. Hence, the right bank route also is nominated as one of
alternative layout of the Project.

Composition of the main structures and their structural types are as same as the left bank route.

Principal feature of the alternative layouts is shown in Table 7.6.3-1, typical layout drawings for the alternatives are shown in Figures 7.6.3-1 to 7.6.3-3 respectively.

Table 7.6.3-1	Principal Feature of Alternativ	e Layouts at Ayago Site
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14 mm	Unit	Dam and Waterway Type	Waterway Type	
Item			Left Bank Route	Right Bank Route
General				
Catrchment Area	km ²	348,120	346,850	346,850
Reservoir Area	km ²	4.2	0.03	0.03
Full Supply Level	m	852	852	852
Rated Water Lvel	m	850	852	852
Minimum Operation Level	m	848	-	-
Gross Storage Capacity	mil.m3	100	-	-
Effective Storage Capacity	mil.m3	20	-	-
Tail Water Level	m	765	765	765
Gross Head	m	87	87	87
Effective Head	m	80	80	80
Plant Discharge	m3/s	840	840	840
Installed Capacity	MW	600	600	600
Dam / Weir				
Type		Concrete Gravity Dam	Concrete Weir	Concrete Weir
Height	m	45	15	15
Crest Length	m	1.400	245	245
Headrace / Pressure Shaft		-,		
Туре		Pressure Flow Tunnel	Pressure flow Tunnel	Pressure flow Tunnel
Number of Tunnel	Nos.	6	6	6
Inner Diameter	m	8.4	8.4	8.4
Length	m	940	113	113
Steel Penstock				
Number of Tunnel	Nos.	6	6	6
Inner Diameter	m	8.4 to 5.4	8.4 to 5.4	8.4 to 5.4
Length	m	6.9	6.9	6.9
Number of Tunnel	Nos.	6	6	6
Inner Diameter	m	5.4	5.4	5.4
Leigin Number of Turnel	III	44	44	44
Inner Diameter	m	12	12	3.8
I ength	m	3.8	3.0	3.8
Total Length	m	87.9	87.9	879
Tailrace	m	01.5	01.5	01.9
Type		Free Flow Tunnel	Free Flow Tunnel	Free Flow Tunnel
Number of Tunnel	Nos.	6	6	6
Inner Diameter	m	8.4	8.4	8.4
Length	m	5050	7450 (#1 to #3) / 7890 (#4 to #6)	9350 (#1 to #3) / 9900 (#4 to #6)
Powerhouse				,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
a) Machine Bay and Erection Bay Cavern				
a) Inner Height	m	40	40	40
b) Innter Width	m	23	23	23
c) Number	Nos.	2	2	2
d) Length	m	150	150	150
b) Transformer and GIS Room Cavern				
a) Inner Height	m	20.5	20.5	20.5
b) Innter Width	m	18	18	18
c) Number	Nos.	2	2	2
d) Length	m	67	67	67
c) Main Acces Tunnel	m	1330	1740	1490
Access Road				
Improved	km	103	122	103
New	km	27	6	32
	km	130	130	130
Transmission Line	km	56	58	51
volume of Disposal Material	mil. m [°]	5.2	6.1	7.6
Area of spoil bank	ha 3	43.2	57.1	66.7
Volume of Rock Material from Quarry	mil. m ³	0.17	negligible	negligible

(Source: Study Team)



Figure 7.6.3-1 Layout Altenative-1 at Ayago Site (Dam and Waterway Type)



Figure 7.6.3-2 Layout Altenative-2 at Ayago Site (Waterway Type, Left Bank Route)



Figure 7.6.3-3 Layout Altenative-3 at Ayago Site (Waterway Type, Right Bank Route)