Chapter 6

Hydropower Development Master Plan

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6.1 Hydrology and Meteorology

6.1.1 General

The area of the Uganda can be divided into eight major basins including that of Lake Victoria, and of Lake Kyoga, and these eight basins are all part of the Nile Basin. The boundaries of the major basins in Uganda are shown in Figure 6.1.1-1.

(Source: Wet Land Department)

Figure 6.1.1-1 Watershed Boundary in the Uganda

It can be seen from Figure 6.1.1-1, that the area of Lake Victoria basin is the largest, followed by that of Lake Kyoga and then the Victoria Nile basin. The total area of these three basins covers almost 62% of the country's total area.

Uganda has abundant of lakes running from small swamps to large lakes like Victoria. The total area of the lakes is estimated at 66 km^2 [1] which is almost 15% of the total area of Uganda. Principal feature of the major lakes in Uganda is shown in Table 6.1.1-1.

[1]World Water Assessment Program, "Case Study: Uganda, National Water Development Report: Uganda," 2006

Table 6.1.1-1 Major Lakes in Uganda

Lakes	Total Area (Km^2)	Area in Uganda (Km^2)	Mean Elevation above Sea level (m)	Maximum Depth (m)
Victoria	68,457	28,665	1,134	82
Albert	5,335	2,913	621	51
Edward	2,203	645	913	117
Kyoga and Kwania	2,047	2,047	1,033	7
Bisina (Salisbury)	308	308	1,047	-
George	246	246	914	3

(Source: National Water Development Report (2006), National Environment Action Plan (1992))

The Nile River connects Lake Victoria, Lake Kyoga, and Lake Albert as it flows downstream from Lake Victoria. The river stretch from Lake Victoria to Lake Albert is called the Victoria Nile River.

The location of the major lakes and rivers in Uganda is shown in the figure below.

(Source; Wet Land Department)

Figure 6.1.1-2 Major Rivers and Lakes in Uganda

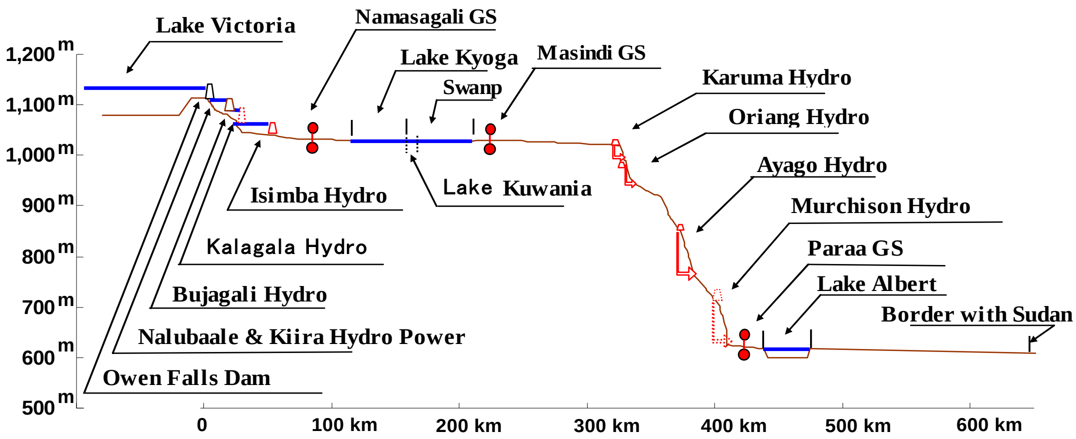


Figure 6.1.1-3 Profile of Major Rivers, Lakes and Hydro Site in Uganda

6.1.2 Collection of Hydrological and Meteorological Data

The Study Team obtained earlier study reports, research articles, operation records of Owen Falls dam, hydrological and meteorological data from Uganda Meteorological Department (UMD) and from the Department of Water Resources and Management (DWRM) for review. The hydrological and meteorological data referred in the Study is listed below,

- Owen Falls Dam Operation Records
- Hydrological data provided by DWRM and UMD
- Kennedy & Donkin Power Limited, "Hydropower Development Master Plan", November 1997
- Electricity de France, "Optimization Study, Hydrology of the Nile River", June, 1999
- Acres International Ltd., "Proposed extension to Owen Falls Generating Station: Feasibility study report", 1990
- Project reports (Bujagali, Karuma, Ayago, etc.) and articles.

In the Study, the Study team collected the latest hydrological data from UMD and DWRM as described below.

(1) Uganda Meteorological Department (UMD)

UMD carries out the rainfall monitoring and operates over 400 rainfall and meteorological gauging stations located all over Uganda. The distribution and location of those observatories in Uganda is shown in Figure 6.1.2-1.

(Source: UMD)

Figure 6.1.2-1 Rainfall Gauging Station Operated by UMD

The Study Team receives the list of observation stations from UMD. Study Team collected the hydrological and meteorological data for the following observatories considering the duration, period and location of the data.

Table 6.1.2-1 List of the Meteorological Data Collected from UMD

STATION_ID	STN_NAME	DISTRICT	ELEVATION	Latitude		Longitutde	
88320010	Masindi Port K.U.R.	Masindi	1,005.0	1.7000	N	32.0833	E
88330060	SOROTI METEOROLOGICAL	Soroti	1,132.0	1.7167	N	33.6167	E
87320380	Koich Laminato G. Farm	Gulu	1,093.3	2.5833	N	32.0167	E
88320020	Nakasongola (T.H.U)	Nakasongola	1,005.0	1.3167	N	32.4667	E
89320750	Entebbe Water Dev.Dept.	Mpigi	1,128.0	0.0500	N	32.4667	E
88320030	Kachung Port (K.U.R)	Apac	1,014.0	1.9000	N	32.9667	E
88330040	Serere Agric. Station	Soroti	1,080.0	1.5167	N	33.4500	E
87320040	Atura Port K.U.R.	Lira	990.0	2.1167	N	32.3333	E
87330010	Alebtong rainfall st.	Lira	1,200.0	2.2667	N	33.2333	E
88310030	MASINDI MET STATION	Masindi	1,147.0	1.6833	N	31.7167	E
87320000	GULU MET. STATION	Gulu	1,105.0	2.7833	N	32.2833	E
87320240	Opit Forest Station	Gulu	1,102.2	2.6167	N	32.4833	E
88320300	Apac Agricultural Stat.	Apac	1,020.0	1.9833	N	32.5333	E
86300100	ARUA MET. STATION	Arua	1,280.0	3.0500	N	30.9167	E
86340020	Kotido	Kotido	1,260.0	3.0167	N	34.1000	E
89300630	KASESE MET. STATION	Kasese	691.0	0.1833	N	30.1000	E
89310330	Mubende Hydromet	Mubende	1,290.0	0.5833	N	31.3667	E
89321230	Kampala Met.Station	Kampala	1,122.0	0.3167	N	32.6167	E
89330430	JINJA MET. STATION	Jinja	1,175.0	0.4500	N	33.1833	E
89340190	TORORO MET.STATION	Tororo	1,170.0	0.6833	N	34.1667	E
90300030	MBARARA MET.STATION	Mbarara	1,420.0	-0.6000	S	30.6833	E
90300320	BUSHENYI AGROMET STATION	Bushenyi	1,590.0	-0.5667	S	30.1667	E
91290000	KABALE MET. STATION	Kabale	1,869.0	-1.2500	S	29.9833	E
88340370	Namalu W.D.D.	Moroto	1,290.0	1.8167	N	34.6167	E

(Source: UMD)

The hydrological features of the received data from the above observatories are shown in Table 6.1.2-2.

Table 6.1.2-2 Principal Hydrologic Index of Major Cities in Uganda

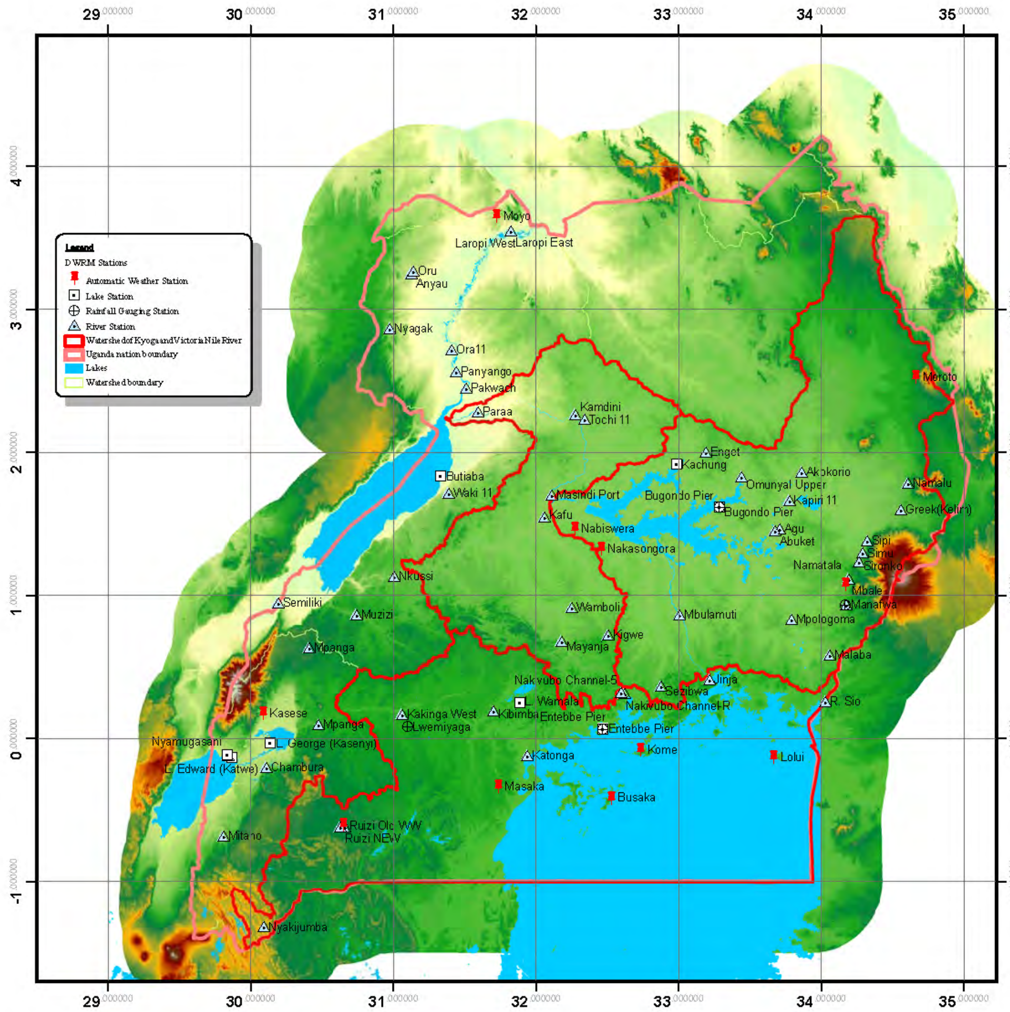
ID	Station	Data type	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
89330430	Jinja	Rainfall	mm	67.0	73.5	139.4	190.4	148.1	64.9	65.9	89.0	104.9	134.5	166.7	90.6
89321230	Kampala	Rainfall	mm	68.4	63.0	131.5	169.3	117.5	69.2	63.1	95.7	108.4	138.0	148.7	91.5
89300630	Kasese	Rainfall	mm	27.9	37.8	83.9	130.1	100.2	45.8	36.7	67.5	87.9	105.5	104.2	62.3
86300100	Arua	Rainfall	mm	17.5	36.6	90.7	120.4	127.6	146.4	154.5	216.9	173.0	209.5	125.1	29.8
87320110	Lira	Rainfall	mm	35.0	25.7	76.8	176.1	164.8	117.5	166.1	186.8	161.1	193.9	152.0	58.0
89320750	Entebbe	Rainfall	mm	91.9	82.2	182.0	253.3	251.9	117.2	71.8	79.2	77.4	135.7	172.1	135.8
89340190	Tororo	Rainfall	mm	55.0	78.0	138.0	225.0	224.0	108.0	96.0	118.0	111.0	125.0	109.0	78.0
88330060	Soroti	Rainfall	mm	37.8	34.1	90.6	167.9	171.1	105.8	130.2	163.1	136.1	158.4	113.6	37.7
87320000	Gulu	Rainfall	mm	18.2	16.2	71.2	163.8	161.5	147.4	170.4	216.0	147.8	197.7	108.1	37.2
88310030	Masindi	Rainfall	mm	30.3	32.5	109.7	157.0	151.9	80.3	108.6	138.4	143.2	184.1	130.4	60.8
87310090	Paraa	Rainfall	mm	15.6	37.8	100.1	154.5	111.2	82.0	96.3	114.2	150.9	166.3	127.1	43.1
88320300	Apach	Rainfall	mm	15.6	37.8	100.1	154.5	111.2	82.0	96.3	114.2	150.9	166.3	127.1	43.1
88320020	Nakasongola	Rainfall	mm	34.1	31.6	85.5	163.8	125.6	64.1	78.2	98.1	100.9	134.5	118.1	37.7
89330430	Jinja	Average Temperature	C°	22.8	23.5	23.4	22.8	22.4	21.9	21.5	21.9	22.5	22.7	22.5	22.5
89321230	Kampala	Average Temperature	C°	23.2	23.9	23.5	22.9	22.6	22.3	22.0	22.1	22.6	22.6	22.4	22.8
89300630	Kasese	Average Temperature	C°	23.8	24.5	24.6	24.6	24.4	24.1	23.9	24.2	24.2	23.6	23.4	23.4
86300100	Arua	Average Temperature	C°	23.9	25.0	24.9	23.8	23.2	22.5	21.8	21.8	22.4	22.5	22.6	23.0
87320110	Lira	Average Temperature	C°	22.8	23.6	23.4	22.4	21.8	21.3	21.1	21.2	21.4	21.5	22.0	22.1
89320750	Entebbe	Average Temperature	C°	22.9	23.4	23.3	22.7	22.4	22.1	21.8	22.0	22.4	22.6	22.3	22.7
89340190	Tororo	Average Temperature	C°	23.2	23.6	23.6	23.0	22.5	22.0	21.7	21.8	22.2	22.6	22.4	22.8
88330060	Soroti	Average Temperature	C°	25.3	26.2	26.0	25.0	24.2	23.8	23.3	23.5	24.4	24.3	24.3	24.9
87320000	Gulu	Average Temperature	C°	25.0	26.2	26.0	24.7	24.0	23.6	23.0	23.0	23.8	23.8	23.9	24.6
88310030	Masindi	Average Temperature	C°	21.8	21.7	21.3	20.6	20.3	20.3	20.0	19.8	20.0	20.2	20.5	22.3
88330060	Soroti	Relative Humidity	%	54.5	50.2	59.5	63.5	69.6	68.8	69.2	69.0	63.2	63.9	59.6	53.3
87320000	Gulu	Relative Humidity	%	44.4	38.6	50.8	64.8	66.7	66.2	68.7	71.0	65.2	65.9	61.3	50.1
88310030	Masindi	Relative Humidity	%	57.7	56.9	64.7	70.0	71.9	71.5	74.5	77.3	75.6	76.0	71.9	63.8
88330060	Soroti	Wind Velocity	km/h	12.0	13.3	11.5	10.0	7.8	8.5	9.4	9.1	10.4	8.8	10.9	10.8
87320000	Gulu	Wind Velocity	km/h	9.1	8.4	8.6	7.6	6.3	5.7	6.1	6.1	6.7	7.0	7.2	8.6
88310030	Masindi	Wind Velocity	km/h	7.7	8.1	7.5	7.4	7.0	5.9	6.0	5.8	6.1	6.3	6.6	7.2

(Source: UMD)

(2) Department of Water Resource Management (DWRM)

Department of Water Resources Management (DWRM) is the main regulatory authorities whose activities cover monitoring, assessing, planning, and regulating water resources through the issuance of water abstraction and wastewater discharge permits[2]. DWRM carried out discharge and water level monitoring using monitoring stations established by them at the locations shown on the map below.

[2] http://www.mwe.go.ug/DWRM



(Source: DWRM)

Figure 6.1.2-2 Hydrological Gauging Stations Operated by DWRM

Since this Study focuses on the Victoria Nile, the Study Team collected data from the Nile Basin between Lake Victoria and the confluence to Lake Albert as enclosed by the red line in Figure 6.1.2-2. The hydrological data received from DWRM is listed in the table shown in Table 6.1.2-3.

Table 6.1.2-3 List of the Discharge Data Collected from DWRM

ID	Name of Gauging Station	River	Duration	Period
81202	Lake Victoria at Jinja Pier	Lake Victoria	6 years	2004- 2009
82203	R. Victoria Nile at Mbulamuti	Victoria Nile	54 years	1956 - 2009
82201	Lake Kyoga at Bugondo Pier	Lake Kyoga	60 years	1950 - 2009
83209	R. Kyoga Nile at Paraa	Kyoga Nile	6 years	2004 - 2009
83203	R. Kyoga Nile at Masindi Port	Kyoga Nile	32 years	1978 - 2009
83206	R. Kyoga Nile at Kamdini	Kyoga Nile	2 years	2008 - 2009

The water level and discharge data received from DWRM are used for study of Lake Victoria water management and estimating river flow in the candidate hydropower sites.

6.1.3 Water Management of Lake Victoria

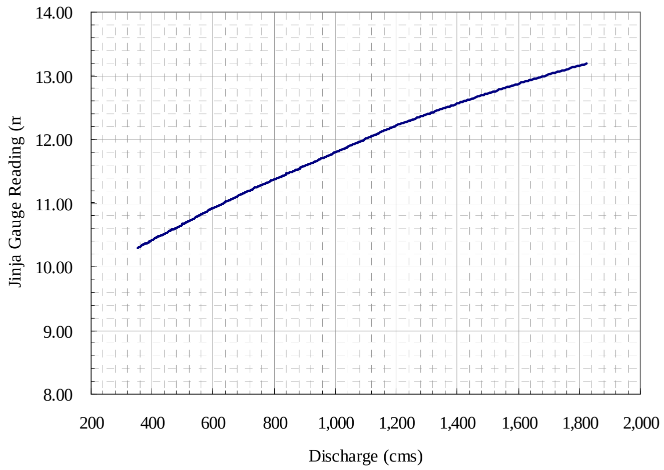
(1) Operation by Agreed Curve

Owen Falls Dam was constructed in 1954 at Jinja which is the sole outlet of Lake Victoria. Then the outflow from Lake Victoria has been dominantly regulated by Owen Falls Dam. Prior to construction of the dam, there was “Ripon Fall” which naturally regulated the outflow from Lake Victoria. The falls were located at three km upstream of the dam. The outflow from the falls was governed by the lake water level, as the discharged increased as the water level raised.

The relationship between the lake level and overflow discharge at Ripon Falls was measured and calibrated by the Egyptian Public Works Department and Department of Uganda Water Development. The relationship of water level and discharge rating curve has been called Agreed Curve, and is used as an operation guide by Owen Falls Dam. This is due to Uganda and Egypt agreement to keep natural flow regime after installation of the dam[3].

Ripon Falls was removed when the construction of the Owen Falls Dam was completed. However, the Agreed Curve basis of operation is still until recently adhered to for the operation of Owen Falls Dam. The Agreed Curve is expressed by the Jinja water level gauge reading and discharge as shown in below.

[3] the 1929 Nile Water Agreement and the 1959 Agreement for the Full Utilization of the Nile - that gave Egypt and Sudan extensive rights over the river's use



Agreed Curve unit : m^3/s

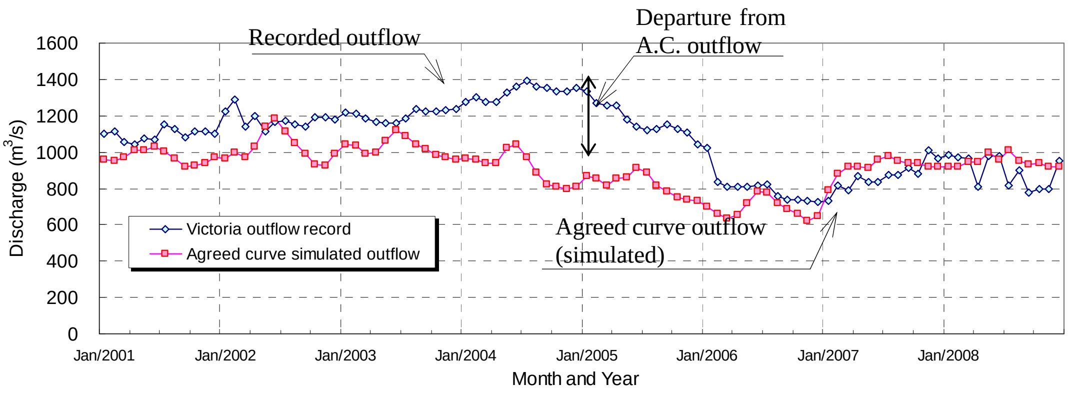
m	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
10.30	354	358	362	366	370	374	378	382	386	390
10.40	393	397	400	404	408	412	416	420	424	428
10.50	432	436	440	444	448	452	456	460	465	470
10.60	474	478	482	486	490	493	497	500	505	509
10.70	513	517	521	525	529	532	536	540	544	548
10.80	552	556	560	564	568	572	576	580	584	588
10.90	592	596	600	604	608	612	616	620	624	628
11.00	632	637	642	646	650	654	658	663	667	672
11.10	676	680	684	689	694	698	702	707	711	715
11.20	719	724	729	733	738	743	747	752	756	761
11.30	766	771	776	780	785	790	795	800	804	809
11.40	814	819	824	828	833	838	841	848	852	857
11.50	862	867	871	876	881	886	887	895	898	904
11.60	909	914	918	923	928	932	937	942	947	951
11.70	956	961	965	970	974	979	984	988	993	997
11.80	1,002	1,007	1,011	1,016	1,021	1,026	1,030	1,035	1,040	1,044
11.90	1,049	1,054	1,058	1,063	1,068	1,073	1,077	1,082	1,087	1,091
12.00	1,096	1,101	1,105	1,110	1,115	1,119	1,124	1,129	1,133	1,138
12.10	1,143	1,147	1,152	1,157	1,162	1,166	1,171	1,176	1,180	1,185
12.20	1,190	1,196	1,201	1,207	1,212	1,218	1,224	1,229	1,235	1,240
12.30	1,246	1,252	1,257	1,263	1,269	1,275	1,280	1,286	1,292	1,297
12.40	1,303	1,309	1,315	1,321	1,327	1,333	1,338	1,344	1,350	1,356
12.50	1,362	1,368	1,374	1,380	1,386	1,393	1,399	1,405	1,411	1,417
12.60	1,423	1,429	1,435	1,442	1,448	1,454	1,460	1,466	1,473	1,479
12.70	1,485	1,492	1,498	1,505	1,511	1,518	1,524	1,531	1,537	1,544
12.80	1,550	1,557	1,563	1,570	1,577	1,584	1,590	1,597	1,604	1,610
12.90	1,617	1,624	1,631	1,638	1,645	1,652	1,658	1,665	1,672	1,679
13.00	1,686	1,693	1,700	1,707	1,714	1,722	1,729	1,736	1,743	1,750
13.10	1,757	1,764	1,772	1,779	1,786	1,794	1,801	1,808	1,815	1,823

(Source: MEMD)

Figure 6.1.3-1 Agreed Curve

The discharge record of Owen Falls Dam showed that the operation of the outflow has strictly followed the Agreed Curve until year 1997. According to DWRM the study Team was informed that flooding at the downstream of the Victoria Nile River in 1997 necessitated slight modification to the outflow policy of Owen Falls Dam. The quantity of annual release is calculated by Agreed Curve, and then the release is distributed to each month.

The difference between the monthly release record and Agreed Curve flow in recent operation is shown in Figure 6.1.3-2.



(Source; DWRM and prepared by Study Team)

Figure 6.1.3-2 Difference of Outflow and Recorded Outflow in Recent Operation

As shown in Figure 6.1.3-2, there are some departures from the Agreed Curve flow between year 2004 and 2006, after which the flow again closely follows the Agreed Curve.

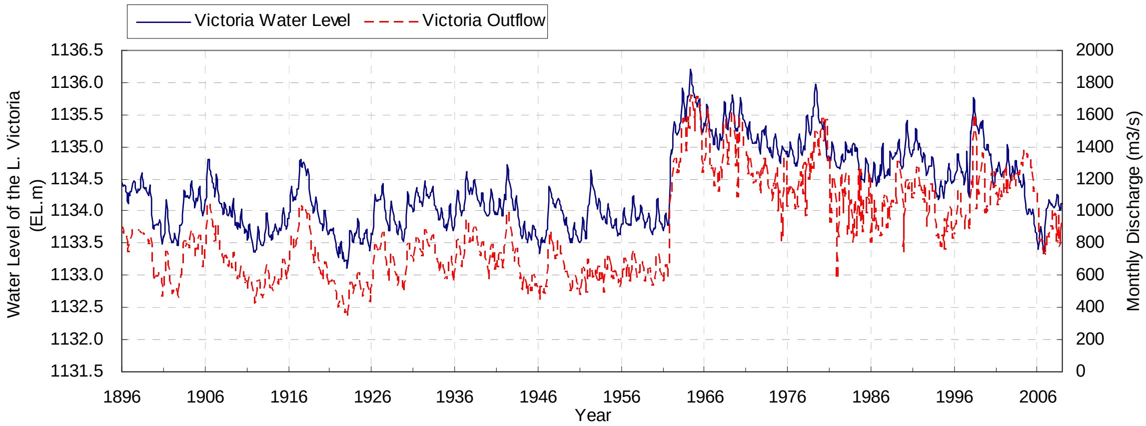
(2) Lake Victoria Water Balance

Main source of inflow into Lake Victoria is rainfall over the vast lake surface (68,457 km^2). According to “Hydrology of the Nile (Sutcliffe, 1999),” the average annual rainfall on the lake between year 1956 to 1978 is 1858 mm which amounts 84% of total inflow to Lake Victoria. The annual evaporation height from Lake Victoria is estimated to 1595 mm which indicates that 72% of total inflow is evaporated. The rest of 28% of the inflow is drained to the Victoria Nile River. However, the vast surface area of Lake Victoria hinders accurate estimation of inflow, rainfall and evaporation, therefore, the inflow from the Lake Victoria basin is estimated by the release from Owen Falls Dam and volume change of Lake Victoria. The resultant water balance is the effective inflow that is derived from subtracting evaporation from gross inflow. This amount is inflow which can be controlled by outlet and is called “Net Basin Supply (NBS)” or “Inflow Available for Outflow (IAO).” The NBS and IAO is studied in the past project and studies.

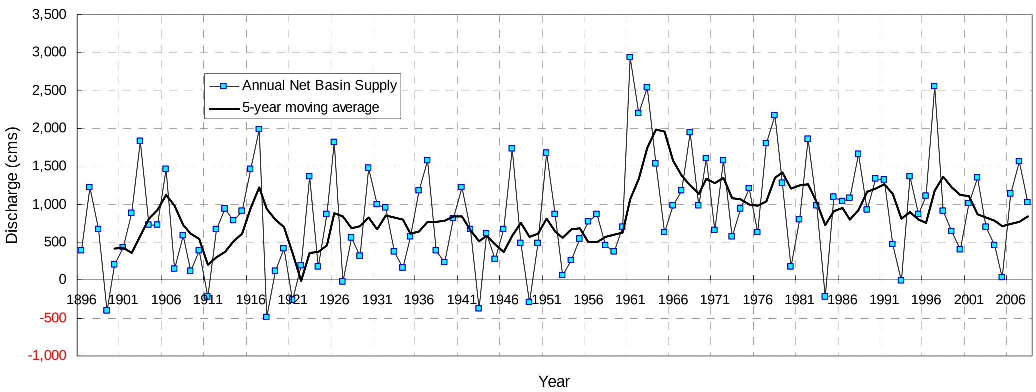
(3) Lake Victoria Water Level Change

Net Basin Supply (NBS) and the water level of Lake Victoria from year 1896 to 2008 is shown in the figure below.

a) Lake Victoria Water Level and Outflow



b) Lake Victoria Net Basin Supply (NBS)

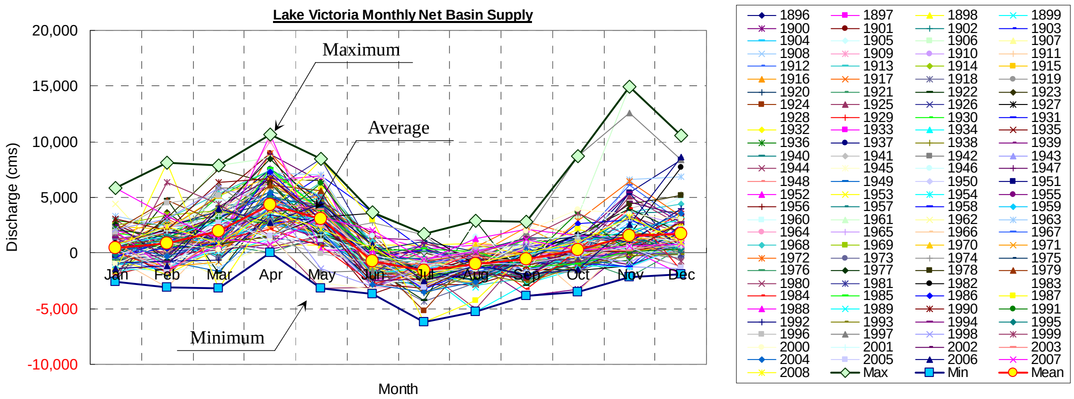


(Source: Hydropower Development Master Plan (1997), DWRM, Bujagali Economic and Financial Evaluation Report (2006))

Figure 6.1.3-3 Lake Victoria Water Level, Outflow and Net Basin Supply

As shown in Figure 6.1.3-3 above, the water level of Lake Victoria varies from EL.1130.0m to EL.1134.5m until the year 1960. The water level was risen from 10.80m to 12.07m at Jinja water level observatory by subsequent flood event in the year 1961-1963. Since then water level of Lake Victoria stays above EL.1134m, however, the drought after the year 2000 resulted in rapid water level fall and the water level recorded the lowest since 1960. In the year 2008, Lake Victoria water level is more or less recovered from the year 2006 level.

While NBS of Lake Victoria changes from 1,500m$^{3/}$s to 500 m^3/s, NBS becomes negative when the rainfall is smaller than evaporation. NBS is peaked in around April, and the amount is decreased until July, then it gradually increases. The monthly NBS from the year 1896 to 2008 is shown in Figure 6.1.3-4.



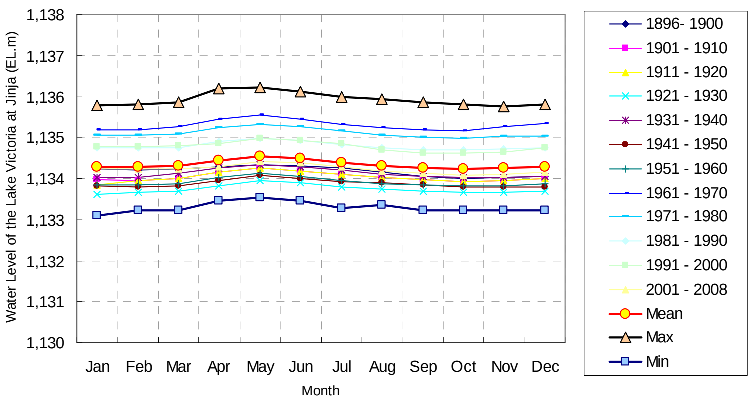
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	408	877	1,958	4,333	3,051	-708	-1,576	-1,009	-550	246	1,573	1,700
Max	5,838	8,082	7,876	10,659	8,484	3,649	1,746	2,883	2,835	8,668	14,974	10,565
Min	-2,623	-3,056	-3,174	47	-3,158	-3,666	-6,236	-5,284	-3,810	-3,517	-2,130	-1,917
STDV	1,456	1,800	2,031	2,334	2,128	1,508	1,377	1,266	1,264	1,561	2,447	2,182

(Source: Hydropower master plan (1997),DWRM, Bujagali II-Economic and Financial Evaluation Study (2006))

Figure 6.1.3-4 Monthly Net Basin Supply of the Lake Victoria

As shown in Figure 6.1.3-4, there is some deviation in some year; however, it generally shows the clear tendency of monthly changes of NBS.

While the changes in water level of Lake Victoria is rather small than the changes in NBS, the annual difference in water level is 20cm to 30cm. The monthly average water level for every 10 years of Lake Victoria is shown in Figure 6.1.3-5.



Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1896- 1900	1,134.2	1,134.2	1,134.2	1,134.3	1,134.3	1,134.3	1,134.2	1,134.2	1,134.1	1,134.0	1,134.0	1,134.1
1901 - 1910	1,134.0	1,134.0	1,134.0	1,134.2	1,134.3	1,134.2	1,134.1	1,134.0	1,134.0	1,133.9	1,134.0	1,134.0
1911 - 1920	1,133.8	1,134.0	1,134.0	1,134.2	1,134.3	1,134.2	1,134.1	1,134.0	1,134.0	1,133.9	1,134.0	1,134.0
1921 - 1930	1,133.6	1,133.7	1,133.7	1,133.8	1,134.0	1,133.9	1,133.8	1,133.8	1,133.7	1,133.7	1,133.7	1,133.7
1931 - 1940	1,134.0	1,134.0	1,134.1	1,134.3	1,134.3	1,134.3	1,134.2	1,134.1	1,134.1	1,134.0	1,134.0	1,134.0
1941 - 1950	1,133.8	1,133.8	1,133.8	1,134.0	1,134.1	1,134.0	1,133.9	1,133.9	1,133.8	1,133.8	1,133.8	1,133.8
1951 - 1960	1,133.8	1,133.8	1,133.9	1,134.0	1,134.1	1,134.1	1,133.9	1,133.9	1,133.8	1,133.8	1,133.8	1,133.9
1961 - 1970	1,135.2	1,135.2	1,135.3	1,135.4	1,135.5	1,135.5	1,135.3	1,135.2	1,135.2	1,135.2	1,135.3	1,135.3
1971 - 1980	1,135.1	1,135.1	1,135.1	1,135.2	1,135.3	1,135.3	1,135.2	1,135.1	1,135.0	1,135.0	1,135.0	1,135.0
1981 - 1990	1,134.7	1,134.7	1,134.7	1,134.9	1,135.0	1,134.9	1,134.8	1,134.8	1,134.7	1,134.7	1,134.7	1,134.8
1991 - 2000	1,134.8	1,134.8	1,134.8	1,134.8	1,135.0	1,134.9	1,134.9	1,134.7	1,134.6	1,134.6	1,134.6	1,134.7
2001 - 2008	1,134.2	1,134.2	1,134.2	1,134.3	1,134.4	1,134.4	1,134.3	1,134.2	1,134.1	1,134.1	1,134.1	1,134.2
Mean	1,134.3	1,134.3	1,134.3	1,134.4	1,134.5	1,134.5	1,134.4	1,134.3	1,134.3	1,134.2	1,134.3	1,134.3
Max	1,135.8	1,135.8	1,135.9	1,136.2	1,136.2	1,136.1	1,136.0	1,135.9	1,135.8	1,135.8	1,135.8	1,135.8
Min	1,133.1	1,133.2	1,133.2	1,133.5	1,133.5	1,133.5	1,133.3	1,133.4	1,133.2	1,133.2	1,133.2	1,133.2
STDV	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6

(Source: Study Team)

Figure 6.1.3-5 10-year Average of Monthly Water Level of the Lake Victoria

As shown in Figure 6.1.3-5, the annual lake water level change is limited comparing to the changes NBS. This is mainly due to the effect of massive storage capacity of Lake Victoria.

(4) Time Series Analysis of Lake Victoria Water Level

1) Long Term Moving Tendency of Lake Victoria Water Level

The behavior of the lake water level is categorized into to two periods. One is before 1960s and one is after the year 1961. The statistics of the lake water level record from the year 1896 to 1960, and 1896 to 2008 are tabulated in below.

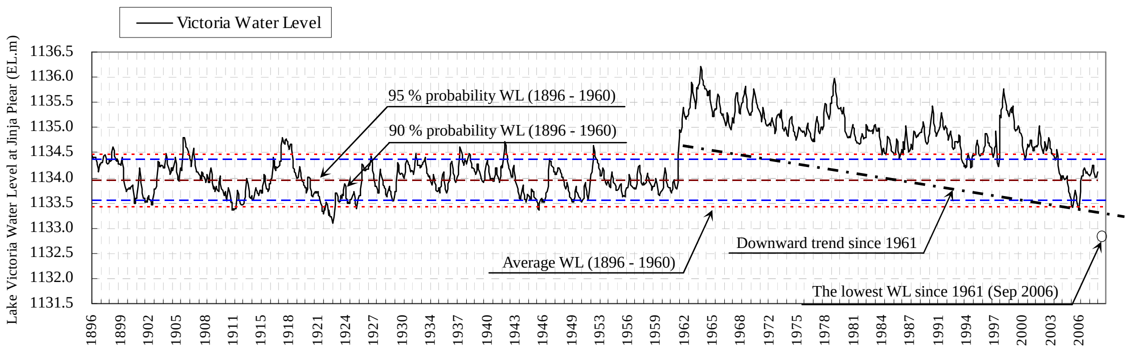
Table 6.1.3-1 Statistics o Lake Victoria Water Level Record between 1896 and 1960, and 1896 to 2008

Water Level Statistics

Duration	1896 to 1960	1896 to 2008
Average	1133.94	1134.34
Standard error	0.01	0.02
Median	1133.92	1134.23
Mode	1133.76	1133.78
Standard deviation	0.32	0.61
Variance	0.10	0.37
Interval	1.7	3.11
Min	1133.09	1133.107
Max	1134.79	1136.217
95 % Exceedance WL		
High	1,134.46	1,135.34
Low	1,133.41	1,133.34
90 % Exceedance WL		
High	1,134.35	1,135.12
Low	1,133.53	1,133.56

(Source: Study Team)

According to the above table, when the lake water level is in steady condition from the year 1896 to 1960, 95% non-exceedance water level is EL.1134.46m and 95% exceedance water level is EL.1133.41m. These exceedance/non-exceedance water levels are superimposed on the historical lake water level record as shown in Figure 6.1.3-6.



(Source: Study Team)

Figure 6.1.3-6 Long Term Trend of the Lake Victoria Water Level

As shown in Figure 6.1.3-6, the Lake Victoria water level has a long term downward trend since the flood event of 1961/1963. This trend seemed to end in September, 2006 when the water level dropped to the 95% exceedance water level. According to past literature, there was a similar flood event causing sudden water rise in the year 1876[4]. However, it is unknown whether this phenomenon is the cyclic behavior of Lake Victoria or not.

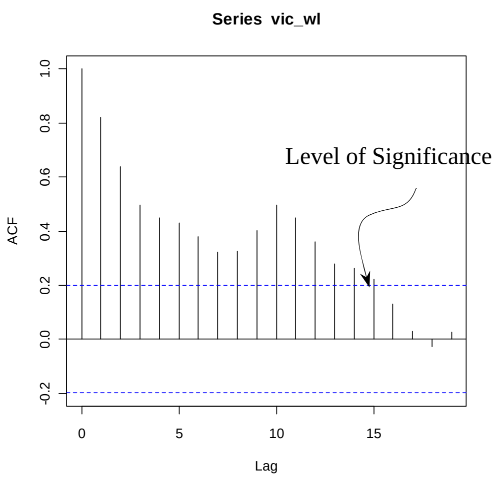
According to the Bujagali project report of “Economic and Financial Evaluation Study (2006),” it distinguished the hydrological state period from 1961 to 1999, and other duration by recognizing the NBS is return to steady level of pre-1960 in the year 2000. In this Study, it is reasonable to say that the lake water level is returned to the pre-1960 level by referring to Lake Victoria water level record.

While it may difficult to predict the hydrological state until the year 2023, the water level records infers that the future hydrologic state of Lake Victoria is similar to the steady state experienced in pre-1960.

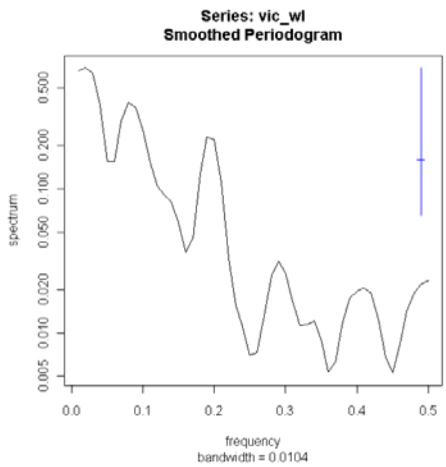
2) Cyclic Fluctuation of Lake Victoria Water Level

The time series water level fluctuation indicates that the water level fluctuate with 10-year cycle by visual inspection. The spectrum of dominant frequency of time series data can be extracted by autocorrelation diagram (Correlogram) or Periodgram. The correlogram and periodgram of annual average water level is shown in Figure 6.1.3-7.

i) Correlogram



ii) Periodgram



*Correlogram and Periodgram are obtained through using generalized statistics software “R”

(Source: Study Team)

Figure 6.1.3-7 Periodgram and Autocorrelation of Historical Lake Victoria Water Level

[4] J.V. Sutcliffe & Y.P. Parks, “The Hydrology of the Nile,” IAHS Special Publication no. 5, 1999

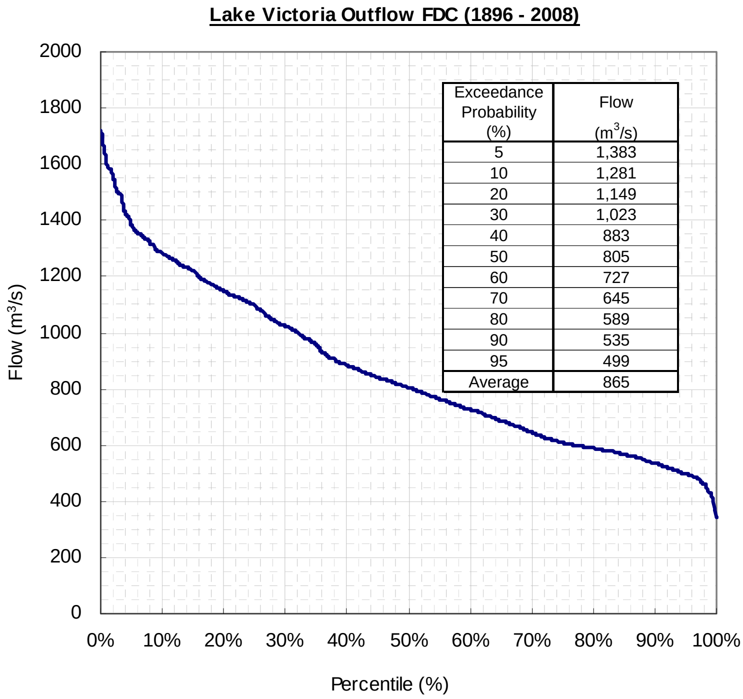
The above figures are derived by using 100-year data from the year 1896 to 1995 as presented in the Hydropower Development Master Plan (1997). Correlogram shows correlation with past data, and periodgram extract the dominant frequency of the time series wave. X-axis in Periodgram is frequency equals to cycle/data duration. Thus, if frequency is 0.1, the data duration is 100 years, therefore, 0.1= cycle/100 provides that the cycle is calculated to 10 years.

Correlogram shows that the correlation between the current and past water level is decreased as time of water level is older. However, correlation increases when it closes to 10 years past water level. The correlation coefficient is greater than the level of significance, therefore, the correlation between the current and 10-year past water level is accepted. Since result of the periodgram indicate that the lake water level has 10-year cycle, and correlogram shows that the water level is correlated to 10-year past water level, 10-year cycle is confirmed in these time series analysis.

The recent lake water level is peaked in the year 1998, thus next peak should be occurred in the year 2008. In the year 2008, the lake water level is recovered from the low water level in 2006; however it reaches to the average water level of pre-1960. Therefore, if the water level is not going to rise in next few years, then further drawdown of the lake water level is anticipated.

3) Flow Regime and Discharge from Lake Victoria

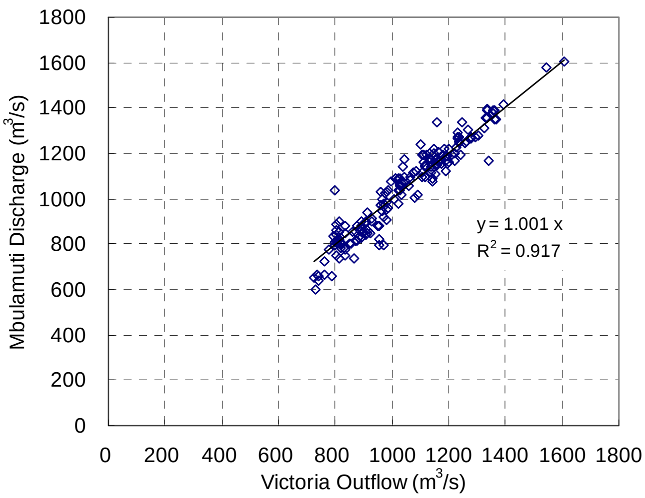
Study Team referred the discharge data of Owen Falls Dam from the operation records, Bujagali Economic and Financial Report (2006), and Hydropower Development Master Plan (1997). The discharge data is used to develop the flow duration curve of the discharge from Owen Falls Dam as shown in the figure below.



(Source: Study Team)

Figure 6.1.3-8　Flow Duration Curve of the Lake Victoria Outflow

According to the past studies, the inflow into the Victoria Nile River from the intermediate basin between Owen Falls Dam and inlet of Lake Kyoga is negligibly small. Study Team received the discharge data at Mbulamuti gauging station where is located at 50km downstream of the Victoria Nile River from Owen Falls Dam. The relation between Owen Falls Dam and discharge at Mbulamuti is shown in the figure below.



(Source: DWRM)

Figure 6.1.3-9　Relation Between Victoria Outflow and Mbulamuti Discharge

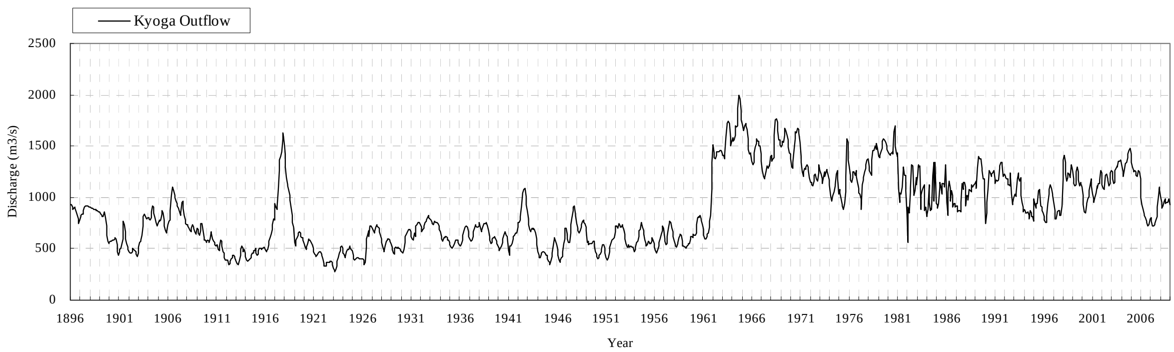
According to the figure above, the outflow from the Owen Falls Dam is almost equivalent to the Owen Falls Dam release, therefore, it is confirmed that the inflow from the intermediate basin is negligibly small. In the Study, it is assumed that the outflow from Owen Falls Dam equals to inflow into Lake Kyoga from the Victoria Nile River.

6.1.4 Water Balance of Lake Kyoga

According to Hydropower Development Master Plan (1997), and the Hydrology of the Nile (1999), the annual evaporation from Lake Kyoga is estimated to 1600mm, and the monthly evaporation height is almost constant through a year. In dry season, the water evaporates from the lake surface that exceeds the rainfall and local inflow, while vice versa in wet season.

6.1.5 Flow Regime of Downstream of Lake Kyoga

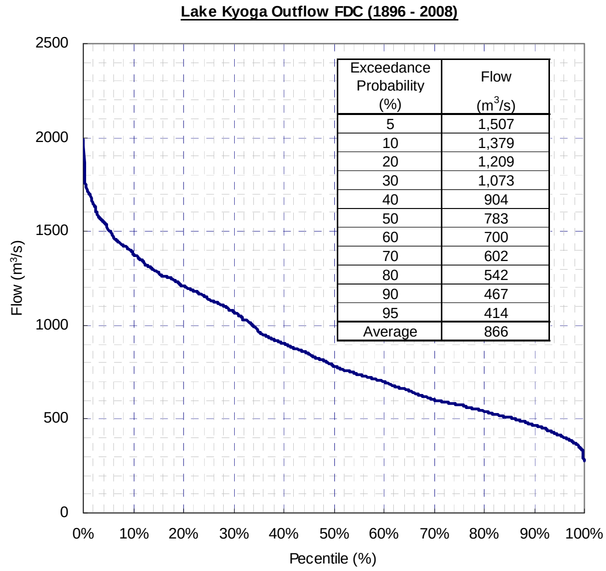
According to the Hydrology of the Nile (1999), the river flow at Kamdini from the 1940 to 1977 shows high correlation with Lake Victoria outflows, especially with the one-month lag flow. The data set of Kyoga Lake discharge was estimated in the Hydropower Development Master plan (1997) using Kamdini and Masindi port observed hydrological data with regression analysis of outflow from Lake Victoria and Lake Kyoga. The period of the data is from the year 1896 to 1995, and the data is also used for the Study. The Lake Kyoga outflow after the year 1995 employs the data observed at Masindi port where is located at outlet of Lake Kyoga. The monthly outflow from Lake Kyoga is shown in the figure as below.



(Source: Study Team)

Figure 6.1.5-1 Extended Lake Kyoga Outflow

Flow duration of Lake Kyoga outflow is shown below.



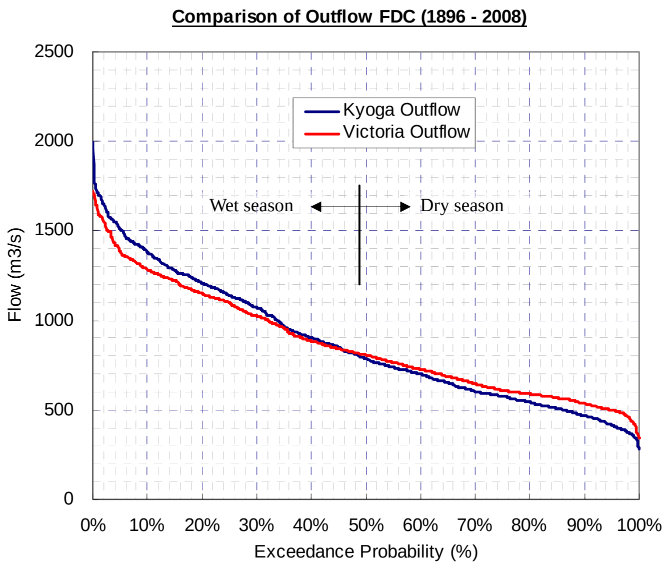
Exceedance Probability (%)	Flow (m^3/s)
5	1,507
10	1,379
20	1,209
30	1,073
40	904
50	783
60	700
70	602
80	542
90	467
95	414
Average	866

(Source: Study Team)

Figure 6.1.5-2 Flow Duration Curve of the Lake Kyoga Outflow

6.1.6 Comparison of Lake Kyoga and Lake Victoria Outflow

The flow duration curve of the Lake Kyoga and Lake Victoria outflow is shown in Figure 6.1.6-1.



Exceedance Probability (%)	Lake Victoria Outflow (m3/s)	Lake Kyoga Outflow (m^3/s)
5	1,383	1,507
10	1,281	1,379
20	1,149	1,209
30	1,023	1,073
40	883	904
50	805	783
60	727	700
70	645	602
80	589	542
90	535	467
95	499	414
Average	865	866

(Source: Study Team)

Figure 6.1.6-1 Flow Duration Curve of the Lake Kyoga and Lake Victoria Outflow

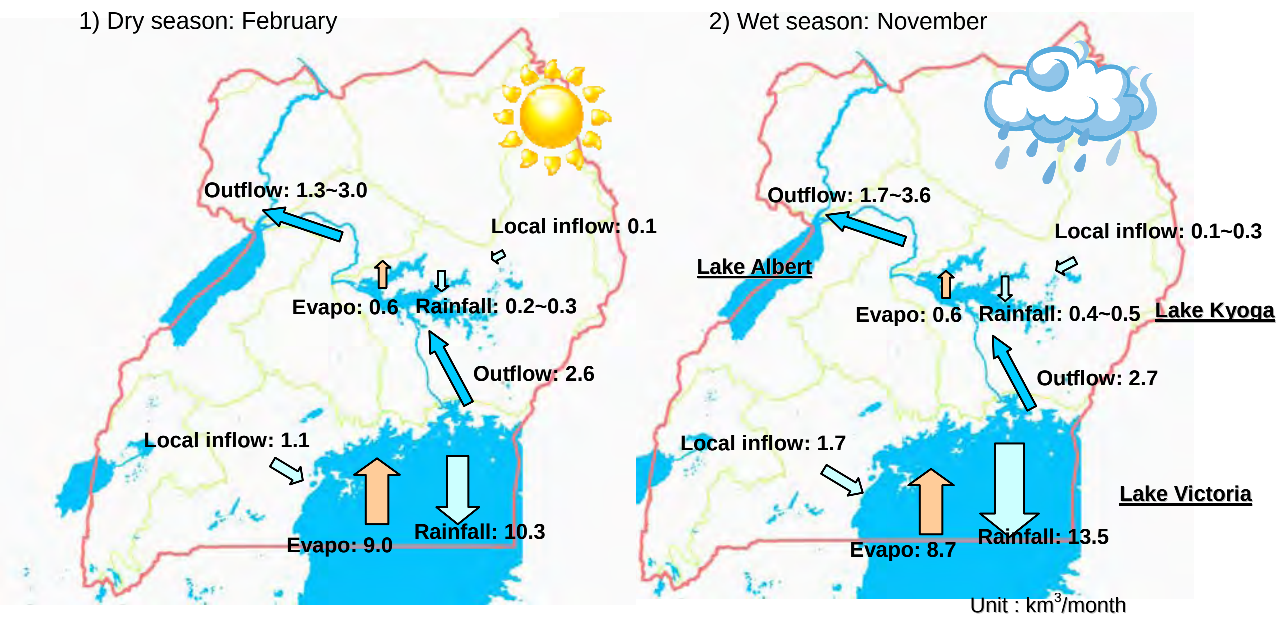
The above flow duration curve indicates that evaporation in dry season exceeds the rainfall that results to decrease in flow, while in wet season, the net inflow is positive therefore the flow is increased. Such boundary is found around 50% of flow exceedance.

6.1.7 Inflow from Intermediate Basin from Lake Kyoga and Lake Albert

According to "The Hydrology of the Nile(1999)," the tributaries such as the Tochi River or the Ayago River inflow to the Nile River from Lake Kyoga outlet to Lake Albert inlet. However, inflow from these tributaries is estimated to amount less than 1% increase therefore it is negligible. This Study also assumes that the inflow from the intermediate basin is neglected.

6.1.8 Water Balance between Lake Victoria to Lake Albert

The accurate estimation of water balance of the study target area from the Lake Victoria outlet to inlet of Lake Albert may be difficult due to the vast lake surface area of Lake Victoria and Lake Kyoga. However, there were some studies and researches to investigate the water balance of the Lake Victoria and Lake Kyoga basin system. The water balance of those systems is exemplified by the Hydrology of the Nile (1999) as shown in Figure 6.1.8-1.



(Source: The Hydrology of the Nile (1999))

Figure 6.1.8-1 Water Balance of Lake Victoria and Lake Kyoga System

As shown in Figure 6.1.8-1, there are some differences between rainfall in dry and wet season, however, the outflow is almost constant comparing to the magnitude of rainfall and evaporation. Water balance of Lake Kyoga shows that evaporation generally exceeds local inflow and rainfall in Lake Kyoga in dry season, and vice versa in wet season.

6.1.9 Conclusion

(1) Long Term Change in Victoria Water Level

The analysis of the hydrological study shows that there is downward trend of the lake water level since the flood event of 1961/1963. This trend it appears ended in the year 2006 when the lake water recorded the lowest water level since the year 1960. Since then hydrological state of Lake Victoria returned to its pre-1960 condition. Times series analysis confirms that Lake Victoria water level has 10-year cycle which is more than 1-year cycle that ordinal reservoir has. In this context, the last peak of the lake water level occurred in the year 1998, therefore the next peak should be happened in the year 2008. The lake water level in 2008 is somewhat recovered from the low water level in the year 2006 and it reaches to the average water level of pre-1960 era. If the water level in the year 2008 is the peak of 10-cycle wave, then the water level may change to a downward trend. This may be accelerated if Owen Falls Dam releases water more than the quantity determined by Agreed Curve.

(2) Base Hydrological Data

In order to realize the correct hydrological state of the Lake Victoria, long duration of base hydrological data is preferable. Considering the availability of more than 100 years of data, and fluctuation in the water level record in Lake Victoria, the Study Team selected the period of base hydrological data from the year 1896 to 2008. This means that the hydrological condition shown in Figure 6.1.5-2 is employed for the Study. The flow from the intermediate basin between Lake Victoria and Lake Kyoga, and between Lake Kyoga and Lake Albert are confirmed to be negligibly small. Therefore, for the candidate project in the Victoria Nile River (Kalagala and Isimba) applies the outflow from the Owen Falls Dam and those in-between Lake Kyoga and Lake Albert (Karuma, Oriang, Ayago, Kiba, and Murchison) applies the Lake Kyoga outflow as shown in Figure 6.1.3-8.

The hydrological data for the Study is derived from the past study reports, Owen Falls Dam operation record, data from UMD and DWRM. If the data is compared the hydrological data such as Karuma hydropower project, there is some difference between the two hydrological data set. In Karuma hydropower case, the 30 years duration data is generated from the autocorrelation regression with random variable generation. This procedure may be adequate for preparation of the base hydrological data. However, this process resulted in producing the larger guaranteed discharge (90% exceedance flow) than that of observed in the 100 years duration. Therefore, in this Study, the Study Team doesn’t employ the data generated by estimating probabilistic distribution model. Study Team selected the observed data rather than using the generated data by a model.

6.2 Sustainable Hydropower Development in the Nile River

6.2.1 Hydrological Characteristics of the Victoria Nile River

The Victoria Nile River originating from Lake Victoria has abundant water resources and stable flow due to storage effect of Lake Victoria as shown in Figure 6.2.1-1. Therefore hydropower development in the Victoria Nile River does not necessitate the poundage to stabilize the seasonal variation in flow.

While, there is some fluctuation in annual outflow from Lake Victoria, it is not reasonable to try to regulate such fluctuation, since it may require five billion cubic meter capacity reservoirs. This requires massive structures to accommodate such a reservoir capability. Secondly, there is no suitable location to build such a large capacity reservoir on the Victoria Nile River.

The construction of the Nalubaale hydropower plant, located 3km downstream of the beginning point of the Victoria Nile River, was completed in 1968. In the year 2005, Kiira hydropower plant commenced its operation. Both hydropower plants are supplying base and peak power, resulting in varying discharges from 500m^3/s to 1,200m^3/s in a day. This daily fluctuation in discharge of the Victoria Nile River is regulated by Lake Kyoga by its natural storage effect. Thus the downstream of Lake Kyoga is constant flow and has no daily fluctuation.

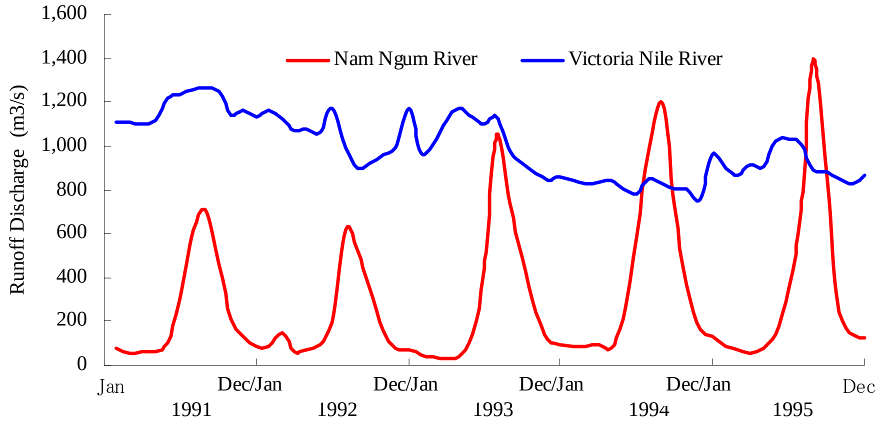


Figure 6.2.1-1 Comparison of Runoff between Nile River and Nam Ngum River in Laos

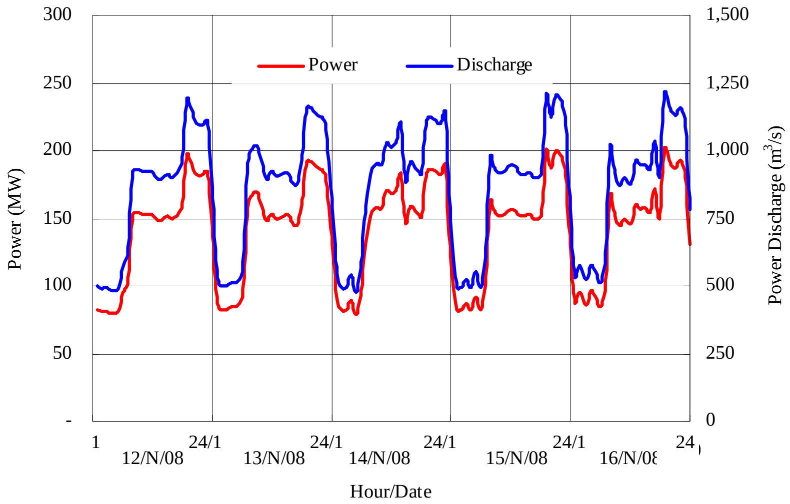


Figure 6.2.1-2 Operation of Owen Falls Dam

6.2.2 Flow Stably Available for Hydropower

In the hydropower planning, the steadily available discharge throughout the year for hydropower generation is called firm discharge. The firm discharge is used for the estimation of the guaranteed power output which is steadily available power provided by the objective power plant. To estimate the firm discharge, mass curve method is generally used for the poundage type hydropower scheme. For the run-of-river scheme, firm discharge is equivalent to the 90% or 95% discharge of the flow duration curve. As described in the preceding section of 6.1.6, 90% and 95% discharge of the Owen Falls Dam are 535 m^3/s and 499 m^3/s, and the outflow from the Lake Kyoga are 467 m^3/s and 414 m^3/s respectively.

However, since the fluctuation of the water level caused by hydrologic cyclic of the Lake Victoria takes long duration, therefore, an extreme phenomenon may take several years although such event is a rare case. For example, the flood in the year 1961 has affected to rising the water level more than 40 years. This fact indicates that using short period of hydrological data sometimes result in focusing extreme phenomena and this would lead to planning too large or too small project scale for the normal hydrological conditions. Therefore, theses conditions should be considered as hydrological risks and these hydrological risk should be involved in the determination of the development scale.

6.2.3 Water Use for Sustainable Hydropower Development

In order to follow the recent power demand increase, the release from the Owen Falls Dam has sometimes been made to exceed the discharge determined by Agreed Curve. However, as described in previous chapter, abandoning Agreed Curve rule may spoil the sustainable water use of Lake Victoria. Regarding Lake Victoria as a massive reservoir, it is important to follow the Agreed Curve for sustainable use of Lake Victoria water resources.

According to discussion with DWRM, current Owen Falls Dam release is made by the estimating the annual discharge quantity by Agreed Curve then the water is distributed to each month considering the water balance and electricity demand. This procedure allows developing annual generation plan including the hydropower, back-up thermal power plant, and import power from neighboring country in advance.

In order to achieve sustainable development of the hydropower in the Nile River in Uganda, it is important to follow the Agreed Curve, and develop hydropower plants as electricity demands surged rather than releasing excessive quantity of water beyond Agreed Curve rule.

6.2.4 Future Water Use in Lake Victoria Basin

The changes in water use in the riparian countries around Lake Victoria such as Tanzania or Kenya arises concerns for competing water use and changes in water balance of Lake Victoria. If the water balance of Lake Victoria is changed, the release policy based on the Agreed Curve should also be reviewed. This will result in enforcing to modifying the national generation plan.

The water use and water management of Lake Victoria has been discussed among the concerning countries in Nile Basin Initiative (NBI) or East African Community (EAC). However, the following Agreed Curve rule was consent with Egypt; therefore EAC’s opinion on water release issue is not for Egyptian’s concern. Further the release policy is important for Uganda’s power supply. Those factors complicate to modify the release policy. According to DWRM, the coordination of water use and modification of Owen Falls Dam release policy are still discussed among the riparian countries, and the discussion is still not converging to agreement.

It is unknown that how the water release policy is modified in the future. However, the modification of release policy more or less gives impact on hydropower generation plan in Uganda. Therefore, it is necessary to pay attention to the direction of the discussion among the concerning countries.

6.3 Selection of Prospective Hydropower Projects and Integrated Hydropower Development on the Victoria Nile River

6.3.1 Existing and Under Construction Hydropower Projects

Development of hydropower projects on the Victoria Nile River has been initiated from the upstream of Owen Falls dam and Nalubaale Hydropower Project commissioning in 1954 at 2 km down stream from the source of the Victoria Nile River. Kiira Hydropower Project was completed at the right bank of the Victoria Nile after 1 km length of headrace open channel in 2005. The Bujagali Hydropower Project is now under construction 8 km down stream of the Owen Falls Dam.

The Bujagali Project expected to be completed in 2011 envisages to develop 250 MW of hydropower utilizing 21.9 m of head and 1,375 m^3/s of power discharge by constructing a 30 m high rock fill dam that provides a regulating pond with 12.8 million m^3 of effective capacity. Table 6.5.3-1 shows the technical characteristics of the Nalubaale Hydropower Project, Kiira Hydropower Project and Bujagali Hydropower Project.

The Nalubaale and Bujagali Projects are dam type hydropower projects having a powerhouse immediately downstream of the dam while the Kiira Project is a dam and waterway type hydropower project with a 1 km short length headrace open channel. The Nalubaale and Kiira Projects are operated as peak power stations utilizing the regulating capacity of the Victoria Lake and the same applies to Bujagali Project which will also be operated as a peak power station utilizing the regulating capacity of the Bujagali Dam.

On the other hand combined plant factors of these 3 projects for the total energy base and the firm energy base will be 40 % and 30 % respectively which deviates from 69 % of current Uganda system load factor. Accordingly these projects will not be able to operate with their full capacity. Therefore if it is possible to have a new hydropower Plant to share the base load in the system, the above peak power projects can be operated more effectively.

Table 6.3.1-1 Technical Characteristics of Existing and Under Construction Hydropower Project

Name of Hydropower Project	Nalubaale	Kiira	Bujagali	Total
Reservoir/Regulating Pond				
Catchment Area	263,000 km^2		263,000 km^2	
Annual Average Runoff	865 m^3/s		865 m^3/s	
Firm Discharge	535 m^3/s			
High Water Level	1,135 m		1,111.5m	
Low Water Level	1,132 m		1,109.5m	
Gross Storage Capacity	(Victoria Lake)		$54.0\times10^6 m^3$	
Effective Storage Capacity	(Victoria Lake)		$12.8\times10^6 m^3$	
Dam				
Type	CG		RF/CG	
Height × Crest Length	30m×345m		30m×560m	
Power Station				
Tail Water Level	1,114 m	1,111 m	1,089.5m	
Gross Head	21.0m–18.0 m	24.0m-21.0m	22.0m	
Effective Head	*20.5 m–17.5m	22.5m-19.5m	19.7m – 21.9m	
Maximum Power Discharge	*1,140 m^3/s	1,260 m^3/s	1,375 m^3/s	
Installed Capacity	180 MW	200 MW	250 MW	630 MW
Unit Capacity	18 MW	40 MW	50 MW	
Numbers of Unit	10	5	5	
Annual Energy Production				
Total Energy	1,340 GWh		1,397 GWh	2,762 GWh
Firm Energy	843 GWh		879 GWh	1,709 GWh
Annual Plant Factor				
Total Energy	40.6 %		64.4 %	50.0 %
Firm Energy	25.1 %		39.8 %	31.0 %
Construction Period				
Start of Construction	1949	1993	Dec. 2007	
Commissioning of First Unit	1954	2000	Dec. 2010	
Completion of Project	1968	2005	Jul. 2011	

(Source: MEMD, World Bank Bujagali Project Appraisal Document April 2, 2007 and others)

6.3.2 Prospective Hydropower Project

The Victoria Nile River can be divided into the following 4 sections that are, the 40 km of upstream section from Victoria Lake to the Isimba site, the 280 km of middle section from the Isimba site to the Karuma site through the Kyoga Lake, the 80 km of the downstream section from the Karuma site to the Murchison site and the 30 km of the most downstream section as shown in Figure 6.3.2-1-and 6.3.2-2.

The upstream section has a rather gentle gradient of about 1:600 but total head in the section is about 70 m and shows gorge type topography with about 15 m ~ 30 m height cliff of both river banks. The Kalagala Project and Isimba Project have suitable topography for construction of dams like Owen Falls Dam and the Bujagali Dam. Accordingly, the dam type (regulating pond type) hydropower project with regulating pond for peak power operation will be possible with these projects.

The river gradient of the middle section is only about 1:6,000. Accordingly this section is not suitable for hydropower development.

The downstream section is meandering river and flows down in the plain with fairly steep river gradient and the height of cliffs of both banks is not so high hence not suitable for construction of dams but very suitable for development of water way type (run of river type) hydropower projects. The waterway (run of river type) type development does not need large dams but low height intake weirs, waterways and powerhouse. Incremental cost for capacity of waterway type projects is larger than the dam type project, but because of the natural regulating effect of the Kyoga Lake for peaking operation discharge from projects in the upstream section, run of river development for base load is suitable in the downstream section.

The furthest downstream section is not suitable for hydropower development because the river gradient of this section is about 1:4,000.

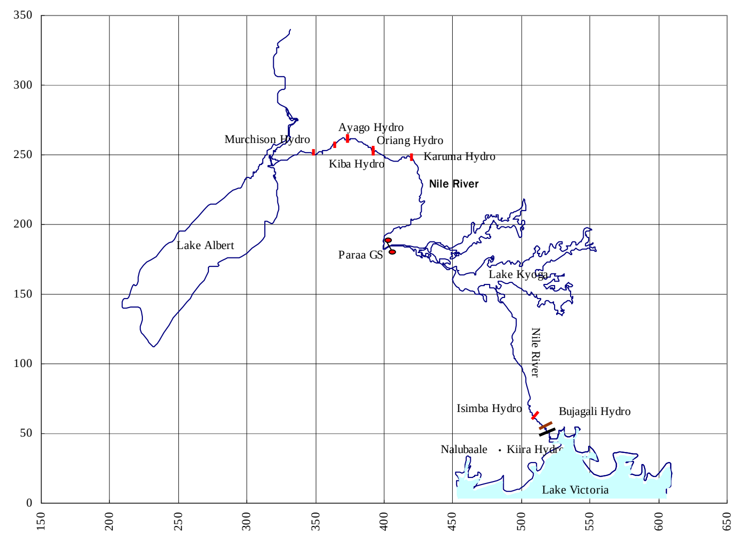


Figure 6.3.2-1 General Plan of Victoria Nile River

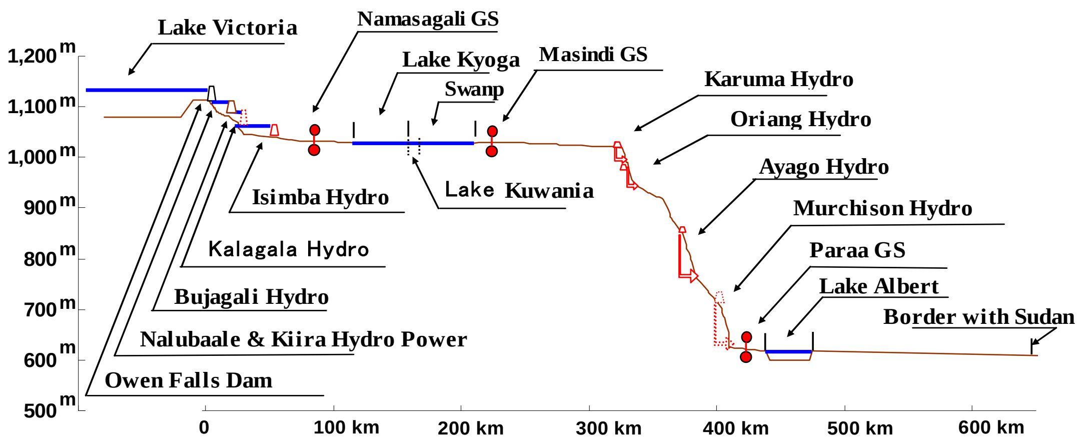


Figure 6.3.2-2 Profile of Victoria Nile River

Annual load factor of Uganda during 2009 - 2012 is 67% as described in section 4.1.1 (3) and as shown in Figure 6.3.2-3 the daily load pattern of the Uganda system is that peak demand appears in the night and load factor is 67 %. This type of load pattern which peak load appears by lightning in the night is a typical load pattern for the developing countries. Because of the low electrification rate in Uganda, at 10 %, planned in 2012 by GDP 2009-2025 expansion of future supply capacity will be mainly for newly electrified areas therefore it is considered that the load pattern in the future is expected will not be changed so much and the annual load factor during 2013 - 2023 is expected will be 66 % by the demand forecast as described in section 4.1.2.

Therefore considering hydrological and topographical characteristics of the Victoria Nile River and the load pattern of the Uganda System, as shown in Figure 6.3.2-4, integrated hydropower development of Victoria Nile River that envisages to develop the regulating pond type peak power projects in the upstream section and the run of river type base load projects in the downstream section is the most appropriate development of hydropower projects on the Victoria Nile River.

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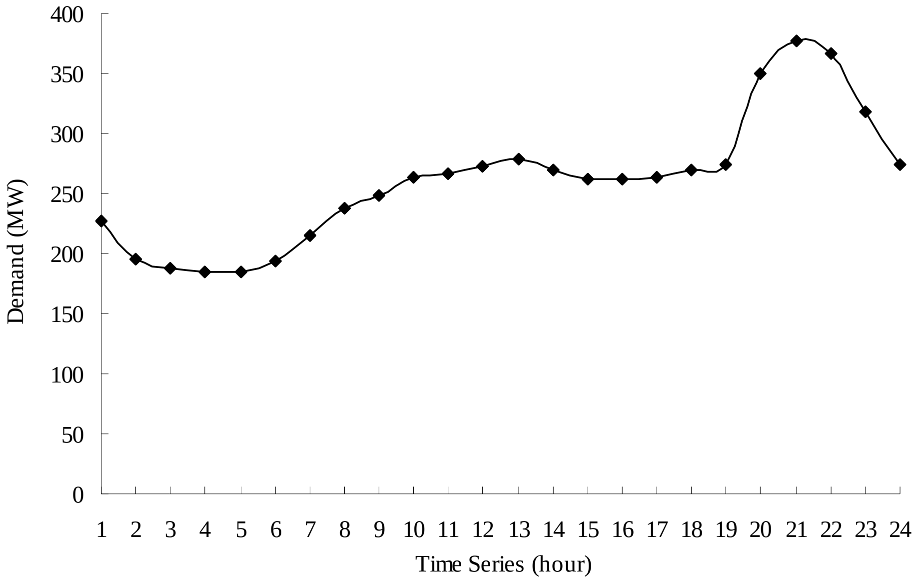


Figure 6.3.2-3 Daily Load Curve of Uganda on 10th August 2009

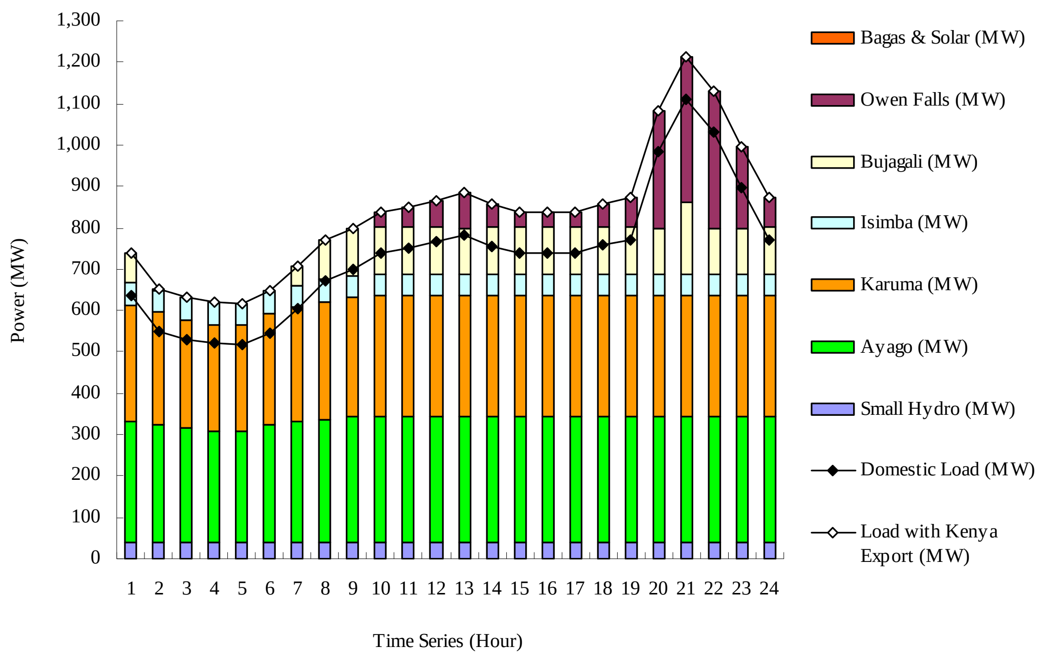


Figure 6.3.2-4 Estimated Daily Load Curve of Uganda on 2023

By these studies mentioned above, following 7 projects that are all potential hydropower project in the Victoria Nile River were selected as prospective hydropower projects in the Victoria Nile River as shown in Figure 6.3.2-4.

- Kalagala Site
- Isimba Site
- Karuma Site
- Oriang Site

- Ayago Site
- Kiba Site
- Murchison Site

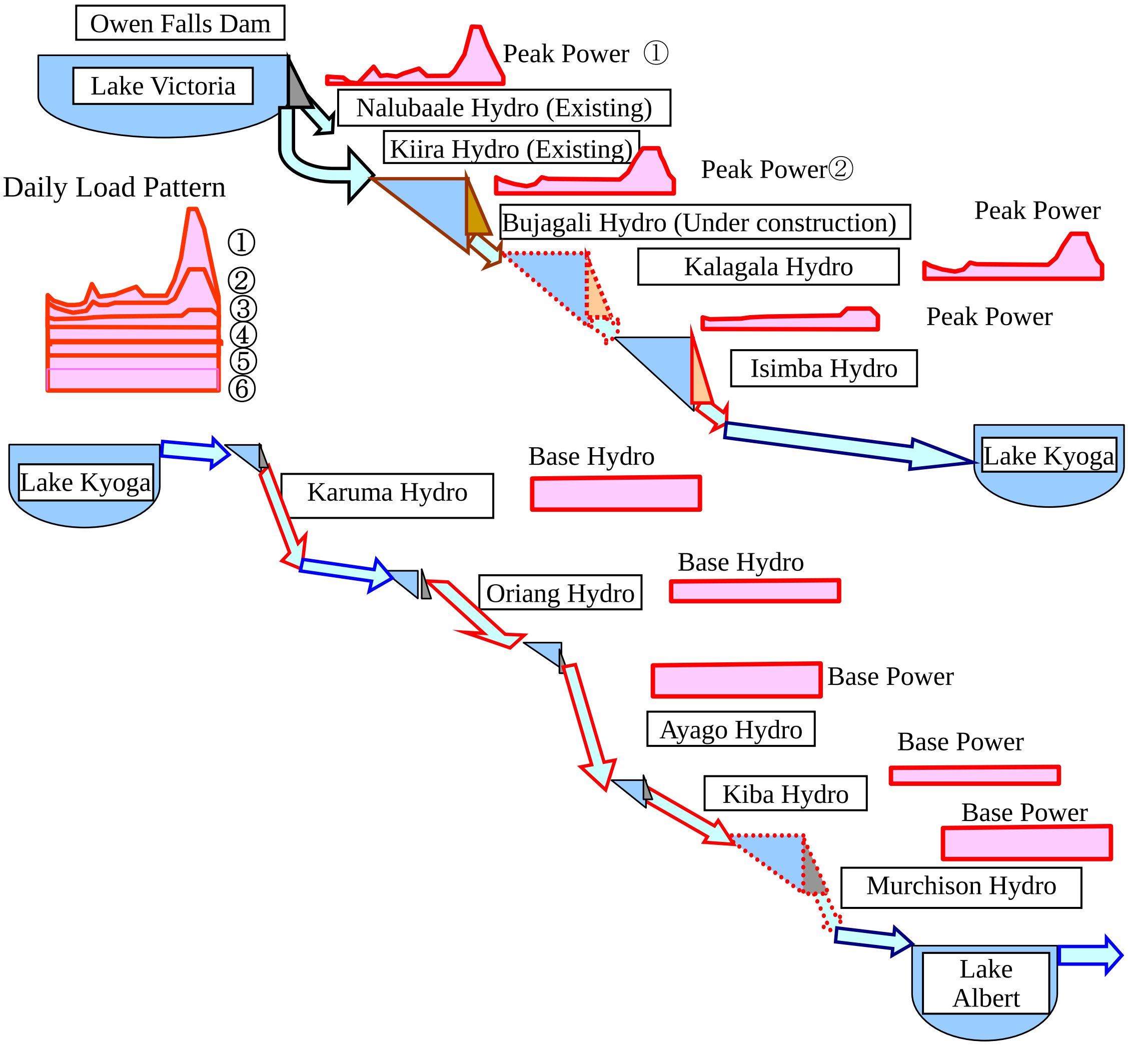


Figure 6.3.2-4 Integrated Hydropower Development Plan in Victoria Nile River

6.4 Formulation of Development Plan

6.4.1 General

Estimation of the energy production was carried out based on the following method.

(1) Discharge

Monthly outflow discharge from Victoria Lake from January 1896 to December 2008 is utilized for calculation of energy of the hydropower in the upstream Nile River from Lake Victoria to Lake Kyoga. Monthly outflow discharge from Lake Kyoga from January 1896 to December 2008 is utilized for calculation of the hydropower in the downstream Nile River from Kyoga Lake to Lake Albert.

(2) Firm Discharge

For the hydropower in the upstream Nile River from Lake Victoria to Lake Kyoga firm discharge is determined 535m^3/s which is 90 % probability monthly outflow discharge of Lake Victoria from January 1896 to December 2008 as shown in Figure 6.1.5-2. 90% of probability is internationally accepted criteria for form discharge.

Firm discharge of the downstream Nile River from Lake Victoria to Lake Kyoga is determined 467m^3/s which is 90 % probability monthly outflow discharge of Kyoga Lake from January 1896 to December 2008 as shown in Figure 6.1.5-2. However firm discharge for the hydropower in the downstream Nile River is determined 417m^3/s which deducts 50m^3/s of amenity flow from firm discharge of 467m^3/s of downstream Nile river.

The 90 % of probability discharge is internationally accepted criteria for the firm discharge and during the joint study by the Ugandan counterpart and the JICA study team Ugandan counterpart agreed with the JICA study team about application of the criteria of 90 % probability discharge to this study.

Amount of amenity flow should be determined based on the result of environmental impact assessment study which will be carried out during feasibility study but in this study 50m^3/s of amenity flow which has been applied in the feasibility study of the Karuma Project was applied for the other waterway type projects in this study temporarily.

(3) Annual Total Energy Production

For the hydropower in the upstream Nile River from Lake Victoria to Lake Kyoga available mean monthly power discharge were calculated by the maximum power discharge and monthly outflow discharge from Lake Victoria from January 1896 to December 2008. Effective head were calculated by mean water level of dams because all hydropower in the upstream Nile River are regulating pond type. Combined efficiency of turbine and generator for determination of installed capacity was adopted as the efficiency for calculation of the annual total energy production. Annual total energy productions of hydropower in the upstream of Nile River were calculated by the above mentioned mean monthly power discharge, the effective head and combined efficiency.

For the hydropower in the downstream Nile River from Lake Kyoga to Lake Albert, available mean monthly power discharge was calculated by the maximum power discharge and monthly outflow discharge from Lake Kyoga from January 1896 to December 2008. Effective heads for run of river type hydropower were calculated by high water level (intake water level) of intake weirs. Effective heads of regulating pond type hydropower were calculated by mean water level of dams. Combined efficiency of turbine and generator for determination of installed capacity were adopted as the efficiency for calculation of the annual total energy production. Annual total energy productions of hydropower in the downstream of Nile River were calculated by the above mentioned mean monthly power discharge, effective head and combined efficiency.

Detail of calculation of the annual total energy production is as shown in Appendix I.

(4) Annual Firm Energy Production

For the hydropower in the upstream Nile River from Lake Victoria to Lake Kyoga available mean monthly power discharge was calculated by the firm discharge of 535m^3/s as maximum power discharge and monthly outflow discharge from Lake Victoria from January 1896 to December 2008. Effective head and combined efficiency were adopted as same manner as the calculation of annual total energy production as described in (3).

For the hydropower in the downstream Nile river from Lake Kyoga to Lake Albert available mean monthly power discharge was calculated by the firm discharge of 417m^3/s as maximum power discharge and monthly outflow discharge from Lake Victoria from January 1896 to December 2008. Effective head and combined efficiency were adopted as same manner as the calculation of annual total energy production as described in (3).

Detail of calculation of the annual total energy production is as shown in Appendix I

(5) Firm Power

Firm power of each hydropower was calculated by firm discharge of each hydropower and effective head and combined efficiency for determination of installed capacity of each hydropower.

(6) Outline of Each Site

Outline of each site is described bellow.

1) Kalagala Site

This site was studied in the Hydropower Master Plan in 1997and evaluated as a one of dominant prospective site. However as described later due to the offset of the Bujagali Falls, the Kalagala Site is not nominated as scheduled development site in the GDP 2008-2023.

The Kalagala Site located at 0°36’14” about 15 km downstream from the Bujagali Site envisages to develop 29 m head exists between the Bujagali Falls and Kalagala Falls. The river gradient of this section is about 1:500. As described in section 6.9 unit energy price of the Kiba site where river bed gradient is 1:303 is about 12 Cent/kWh which is higher than the price of alternative thermal power (about 10 Cent/kWh). Accordingly 1:250 of river bed gradient must be limit of waterway type hydropower. Therefore this section is not suitable for run of river type development but because this section shows gorge type topography with about 30 m height cliff of both river banks and 0.5 km ~ 1.0 km wide river bed, the Site is planned the dam type (regulating pond type) project selecting dam site at the point of island in the River where river diversion work will be easy and provides powerhouse immediately downstream of the dam.

This development plan is reasonable for the aspect of the integrated hydropower development of Victoria Nile River that envisage to develop the regulating pond type peak power projects in the upstream section and the run of river type base load projects in the downstream section as mentioned in section 6.3.

In the Hydropower Master Plan in 1997 the Kalagala Site was planned as of 450 MW of installed capacity with 2,190 m^3/s of maximum power discharge but in this JICA study the installed capacity of the Site is planned as of 330 MW with maximum power discharge of 1,375 m^3/s that is as same as the discharge of Bujagali Project.

In the Hydropower Master Plan in 1997, 1:12,500 maps with 25ft (7.62m) were prepared but these maps are not available for this JICA study. Accordingly public 1:50,000 maps were used this study. Figure 6.4.1-1 and Figure 6.4.1-2 show area capacity curve and result of energy production calculation results respectively.

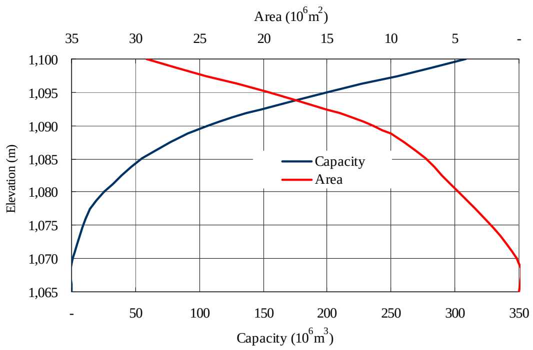


Figure 6.4.1-1 Area Capacity Curve of Kalagala Hydropower Project

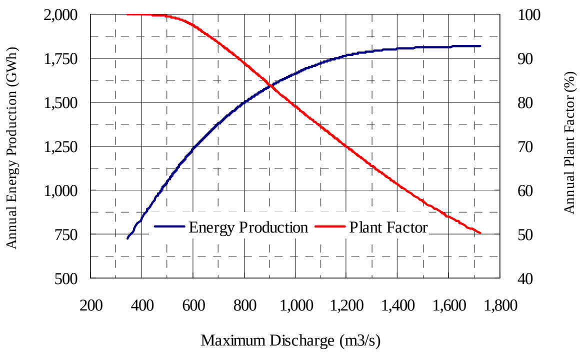


Figure 6.4.1-2 Annual Energy Production of Kalagala Hydropower Project

Box 6.4.1-1 The Kalagala Offset

Kalagala Offset refers to measures for ensureing sound environmental management of the Mabira ecosystem housing Bujagali Falls/Dam for purposes of "counter balancing or making up for" some of the negative effects caused by Bujagari Hydropower Project (BHPP) on the environment as stipulated in the 2007 Indemnity Agreement.

Therefore, Kalagala Offset is part of the mitigation measures against the likely negative impacts of Bujagari dam which include: submerging the present Bujagali falls and displace the several social, economic and cultural activities and benefits accruing from the Bujagali Fall area. Futhermore, the BHPP would result into other negative environment and social-economic effects at Bujagali and its environs. The Kalagala and Itanda falls area was selected to house the offset considering its closecharacteristics with those of Bujagali (water, water falls, islands, cultural assets, and tourism potential, among others). In addition, the Central Forest Reserve close to Kalagala and Itanda Falls (Kalagala, NileBank and Namavundu) and the entire Mabira Forest Reserve are included in the offset because of their ecological and social economic values in the region.

The mitigation measures for addressing the effects of BHPP as described under the Conditions for approving BHPP by NEMA are presently implemented under various programmes, especially under the Social and Environment Action Plan (SEA) for BEL. The description of starategies and actions for addressing the Kalagala Offset takes into account this ongoing implementation of mitigation measures and seeks to compliment these efforts by providing ecosystemlevel planning framework that guides future conservation and development actions relevant to addressing the negative impacts of BHPP.

Physically, the implementation of the Kalagala Offset covers the following: a) Water catchment following the hydrology directly into the Nile system within or near Kalagala and Itanda Falls area, b) natural assets and ecosystems whose ecological, social and economic functions impact on the integrity of Kalagala and Itanda Falls area or get impacted on existence of Kalagala and Itanda Falls (Forests, River bank, Islands and Wetlands); c) natural and modified production systems extending 3-5 km either side of the Nile river (consisting of adjacent land and infrastructure) stretching between 0.45o and 0.67o north and people therein; d) cultural assets whose values are associated with Kalagala and Itanda Falls area.

(Source: Kalagala Offset Sustainable Management Plan 2010-2019)

2) Isimba Site

Isimba Site is located 15 km downstream from the Kalagala Falls in the lowest section of the upstream section of the Victoria Nile where the gorge topography ends. After the Isimba Site the gradient is about 1:5,000 and no potential site exists until the Karuma Site.

MEMD intends to develop this Site as dam type hydropower project.

The Isimba Site was not identified in the Hydropower Master Plan in 1997 and MEMD only carried out site reconnaissance but did not carry out any topographic and geological survey on the Site. In February 2010, signing of the contract for consulting services including feasibility study, definite design and preparation of tender documents for EPC contract for the Isimba Site and related transmission line was done between MEMD and Fichtner Company. Because there was no study result of the consulting services up to now, the JICA study team carried out site reconnaissance several times utilizing 1:50,000 maps and formulated development plans of the Isimba site.

The head of the section after the Kalagala Site to the Isimba Site is only 14 m and the river gradient is less than 1:1,000. Therefore it is considered that dam type development is the only option for this Site.

The left bank of the dam site is not formed mountain ridge rather 1:30 ~ 1:50 gradient flat slope and the difference in elevation between the river bed and the top of the right bank of the dam site is about 15 m. The backland of the site is fairly flat. In case the high water level of the dam is 1,059 m a number of houses will be in the pond area of the dam. MEMD put the tail water level at 1,045 m but this elevation was only determined by GPS measurement during the MEMD site reconnaissance. Therefore to confirm the suitability of this development scheme and area of inundation by the dam, new topographic maps covering the project area including backland area of inundated area prepared by topographic survey is required. Detailed maps for the dam and powerhouse should also be prepared.

MEMD considers that since the dam site is at the island where river diversion work will be easy, and a low dam (less than 20 m) height Isimba Site can be developed in short period, and construction work will be started immediately after the consulting works by Fichtner Company. Figure 6.4.1-3 and Figure 6.4.1-4 show area capacity curve and result of energy production calculation results respectively.

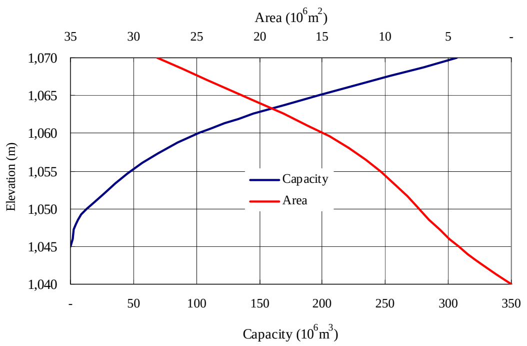


Figure 6.4.1-3 Area Capacity Curve of Isimba Hydropower Project

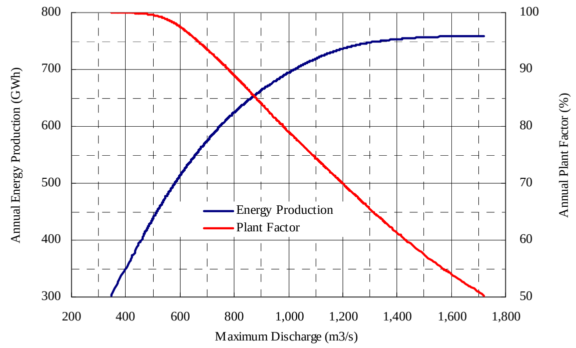


Figure 6.4.1-4 Annual Energy Production of Isimba Hydropower Project

3) Karuma Site

Karuma Site is located 110 km downstream from Kyoga Lake where the section of extremely gentle river gradient about 1:30,000 ends, and envisages to develop 84.5 m head between the site mentioned above and 15 km downstream from the Karuma Falls. Until now the site was being developed in two phases of Karuma Site A and Karuma Site B.

The Old Karuma had been considered for development by IPP scheme and the concession was given to NORPAK. The Ugandan Government intended to participate in the development by administrative works for development and to share the cost of preparation of infrastructure of the project area. In 1999 the project definition report including design up to feasibility study level and the environmental impact assessment survey were completed but due to various problems such as lack of financial cooperation by the World Bank, initiation of construction work was delayed and eventually NORPAK withdrew from the project.

In September 2009, signing of the contract for consulting services including feasibility study, definite design and preparation of tender documents for EPC contract for the Karuma Site was done between MEMD and Energy Infratech Pvt. Ltd. India. The Consultant submitted an inception report to MEMD in December 2009 and MEMD intends to start construction of the plant by the end of 2011 in accordance with the implementation schedule proposed by the Consultant.

According to the inception report the Site will be a run of river type project. The intake weir is located 3.5 km upstream from the Karuma bridge and the intake water level is set at 1,029.5 m. an underground powerhouse is located immediately downstream of the intake and 11.4 km tailrace tunnel is provided.

At the intake weir site the width of the Nile River is about 300 m and both banks are composed of about 20 m height of cliff from the river bed, however the difference in elevation between the intake weir site and the water level of Kyoga Lake is only about 3 m ~ 4 m. Accordingly it is not appropriate to provide a reservoir by constructing a dam at the site because a large inundated area equal to the Kyoga Lake will appear after 2 km downstream of the intake weir site both banks of the Nile River are of flat slope topography which is not appropriate for a dam site. Therefore it is judged that the run of river type development by waterway type layout proposed by the Consultant is reasonable.

According to the inception report of the Consultant, the unit capacity of the Karuma Site is 114MW but because of the capacity will be equivalent to more than 16 % of the total demand of the Uganda system, when the first unit commissioned the 114 MW unit capacity will be too big in case damage or trip of the unit is considered. The tailrace has two tunnels of 12.5 m diameter but the plan may lead to latent investment because of too much capacity by one tunnel. Technical problems are also expected in tunnels of that capacity. Therefore around 50 MW of unit capacity and 6 lines of tailrace tunnel are suggested by the JICA Study. Figure

6.4.1-5 shows energy production calculation results.

The plant factor of the firm energy of the Karuma Site is 49 % and because there is no regulating pond the Karuma Site will be operated for base load constantly. Because principally only the firm energy is evaluated in the long term power development plan, later units after the 6th unit will not contribute to demand and supply balance of the long term power development plan. This tendency is common for all run of river sites of Oriang Site, Ayago Site and Kiba Site.

On the other hand the plant factor of the installed capacity by 840 m^3/s of the maximum power discharge is 81 % which is rather high compared to the conventional run of river type hydropower projects. If it is possible to reduce fuel cost of existing thermal power projects by absorption of energy over firm energy and to export to neighboring countries, a big economic benefit of the Site can be expected. This tendency is also common for all run of river sites of Oriang Site, Ayago Site and Kiba Site.

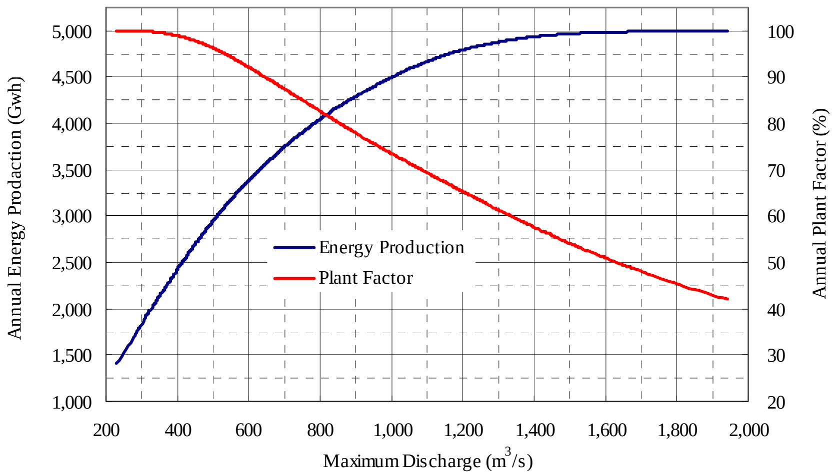


Figure 6.4.1-5 Annual Energy Production of Karuma Hydropower Project

4) Oriang Site

The Oriang Site has not been identified in the past studies and MEMD proposes the Site for the JICA study. During the JICA Study for one of the 7 projects formulation of development plan of the Site was carried out utilizing 1:50,000 public maps and result of site reconnaissance by the Study team.

The Oriang Site development envisages utilizing a 58 m head exists in the 15 km section between the point 35 km downstream from the Karuma intake weir site and the point 2 km upstream from the Ayago Site. There is no appropriate site for damming because both sides of the river bank are composed of a gradient of 1:50 ~ 1:100 of fairly gentle flat slope. Accordingly a development plan of run of river type project was formulated. The plan utilizes an island at 2 km downstream from the junction of the Playa creek as the intake weir site and an underground powerhouse is arranged immediately downstream of the intake. A tailrace tunnel 11.4 km is provided. Figure 6.4.1-6 shows energy production calculation results.

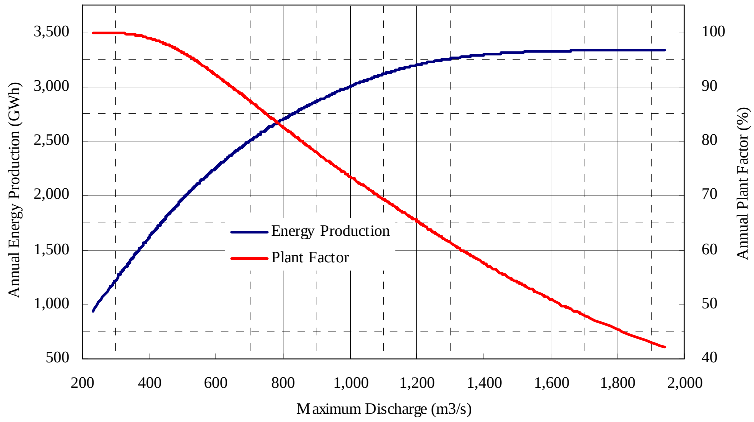


Figure 6.4.1-6 Annual Energy Production of Oriang Hydropower Project

5) Ayago Site

The Ayago Site development envisages utilizing a 87 m head which exists in the 9 km section between 3 km upstream from the junction of Ayago River Site and 4.5 km downstream from the junction of Kiba River. The Nile River is separated into 3 waterways by islands, which will be used for the appropriate intake weir site for the Ayago. By short cutting of meandering river the Ayago site can be developed efficiently.

In 1984, feasibility study report of the Ayago Site was prepared by Norconsultant. In this report left (south) bank waterway route was selected to utilize the head of Ayago rapid section by shortest waterway and this plan was called Ayago South Alternative. In addition to the Ayago South Alternative another alternative development plan which envisages utilizing the most rapid part in the 9 km section was proposed. This alternative selected the waterway route in the right (north) bank of the Nile River to short cut the meandering river, and was called Ayago North Alternative. But because of this small scale alternative (60MW) can not be with stand for present demand growth which envisages to develop only 34 % of the 87 m of total head of this section to meet expansion of demand during end of 1980's. Accordingly, effectiveness of this Alternative has been decreased considerably. In the Hydropower Master Plan Report in 1997 the run of river type development plan by the South Alternative and the regulating pond type development plan for peak power operation in which the waterway was provided in the right (north) bank were proposed. JICA Study Team carried out the comparison between the above alternatives from economical and environmental point of view, and then the left bank run of river type alternative was selected as the development plan of the Ayago Site. Figure 6.4.1-7 shows the result of energy calculations for the Ayago Site.

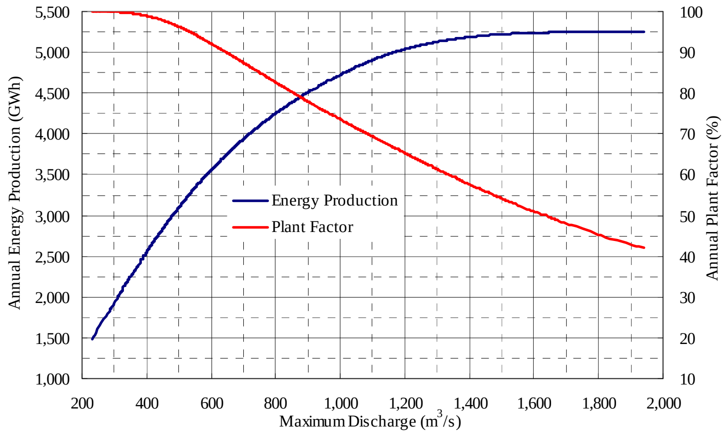


Figure 6.4.1-7 Annual Energy Production of Ayago Hydropower Project

6) Kiba Site

The Kiba Site development envisages developing a 47 m head which exists in the 17 km section between the outlet site of Ayago and the end point of the back water of Murchison Dam. The area of this section is fairly flat with gentle gradient together with the gradient of the Nile River. Accordingly there is no site appropriate for the damming in this section. Therefore it is considered that the run of river type development by waterway type layout with intake weir 0.5 km downstream from the Ayago tailrace, underground powerhouse immediately downstream of the intake and 14 km length of tailrace tunnel are appropriate. Figure 6.4.1-8 shows the result of energy calculations for the Kiba Site.

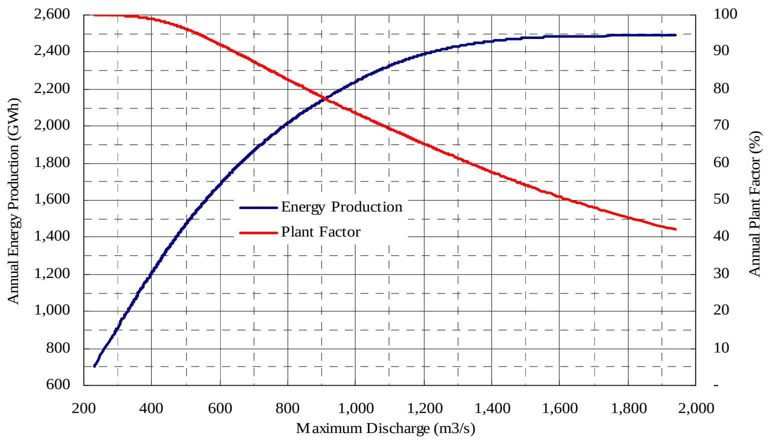


Figure 6.4.1-8 Annual Energy Production of Kiba Hydropower Project

7) Murchison Site

Murchison Site development envisages utilizing a 50 m head of the Murchison Falls at the extreme downstream part of the rapid section in the Nile River. In the Hydropower Master Plan Report in 1997 the dam and waterway type of development plan was proposed, with a dam 1.9 km upstream from the Murchison Falls, underground powerhouse immediately downstream of the dam and tailrace tunnel short cutting meandering of the Nile River in the section between the upstream and downstream of the Murchison Falls. The layout intends to avoid any damage for the landscape of the Murchison Falls by locating all structures underground except the dam and the outlet of the tailrace tunnel, however these structures are also located at opposite side of mountains between the Falls and the structures.

In the Study, together with the dam and waterway type alternative, run of river type alternative instead of the dam was studied and compared to the dam type alternative. As a result of the comparison the dam and waterway alternative was judged to be more economical than the run of river alternative. In the Study the operation times are limited only 12 hours at night to keep landscape of sightseeing at the Murchison Falls. Figure 6.4.1-9 shows the result of energy calculations for the Murchison Site.

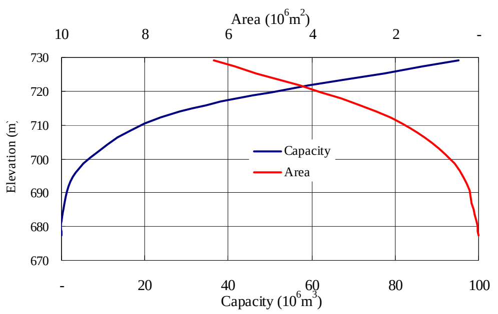


Figure 6.4.1-9 Area Capacity Curve of Murchison Hydropower Project

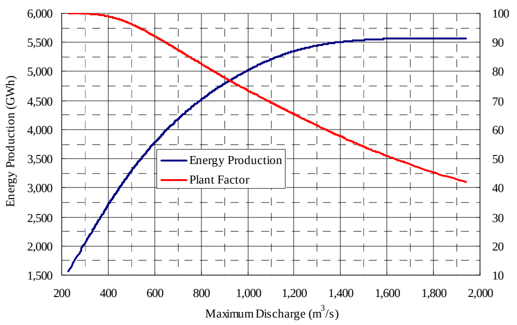


Figure 6.4.1-10 Annual Energy Production of Murchison Hydropower Project

6.4.2 Technical Characteristics of 7 Prospective Projects

As the results of the studies described above, the technical characteristics of the 7 prospective projects are shown in Table 6.4.2-1.

Table 6.4.2-1 Potential Hydropower Development Project in Victoria Nile River

Project	Unit	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Catchment Area	km^2	264,450	264,620	336,000	346,700	346,850	348,120	348,600
Intake Water Level	m	1,088	1,059	1,029.5	910	852	765	718
Tail Water Level	m	1,059	1,045	945	852	765	718	625
Regulating Capacity	10^6m^3	19	22					19
Head	m	29	14	84.5	58	87	47	93
Dam								
Type	-	RF/CG	RF/CG	Weir	Weir	Weir	Weir	CG
Height	m	55	16	5	5	10	5	40
Tailrace Tunnel								
Numbers of Tunnel	-	-	-	6	4	6	6	5
Diameter	m			8.40	9.80	8.40	8.40	9.00
Length	m			11,277	11,097	7,400	14,261	1,800
Power Station								
Power Discharge	m^3/s	1,375	1,375	840	840	840	840	840
Installed Capacity	MW	330	138	576	392	612	288	648
Unit Capacity	MW	33	23	48	49	51	48	54
Numbers of Unit	-	10	6	12	8	12	6	12
Annual Energy Production								
Total Energy	GWh	1,801	752	4,145	2,768	4,357	2,066	2,314
Firm Energy	GWh	1,114	465	2,514	1,679	2,641	1,253	1,403
Annual Plant Factor								
Total Energy	%	64	65	82	81	81	82	41
Firm Energy	%	40	40	50	49	49	50	25

(Source: Hydropower Master Plan, November 1997)

As for the screening of candidate site, following points are determined as evaluation items.

(1) Maximum Power

Following A to E ranking has been determined taking the satisfaction with power demand into consideration in accordance with big order.

Table 6.4.2-2 Rating on Maximum Power

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Maximum Power (MW)	330	138	576	392	612	288	648
Rating	C	E	B	C	A	D	A

(2) Effective Head

Following A to E ranking has been determined taking the efficiency of development into consideration in accordance with high order.

Table 6.4.2-3 Rating on Head

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Head (m)	28	13	79	53	83	40	88
Rating	E	E	B	C	A	D	A

(3) Length of waterway

Following A to E ranking has been determined taking the site characteristic and economical efficiency into consideration in accordance with big order.

Table 6.4.2-4 Rating on Length of Waterway

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Length (km)	0	0	12	12	8	14	2
Rating	A	A	D	D	C	E	B

6.5 Design

6.5.1 General

Hydropower plant can be classified from view points of "power supply capability" and "measure to acquire the head for power generation". Since the structural component and types of the hydro power plant are described in this section, layout outline of the Candidate Hydropower Projects are explained based on classification from view points of "measure to acquire the head for power generation".

Types of the hydropower plant can be classified into the dam type, waterway type and dam & waterway type. Suitable type is selected taking into consideration of topographic condition of a site. In addition, the waterway type as well as the dam & waterway type are classified into a) the head type, which powerhouse locates upstream of the waterway, and b) the tail type, which powerhouse locates downstream of the waterway. Layout arrangements of the principal structures of both types are as shown in Figure 6.5.1-1. Selection whether the head type or the tail type will be determined talking into consideration of the topographic condition or restriction.

Most of the Candidate Projects, which can adopt the waterway type and/or dam & waterway type, may allow only head type waterway or have advantages for the head type due to topographic condition. Hence, head type waterway is selected for the waterway and the dam & waterway type in this alternative study of the Candidate Projects.

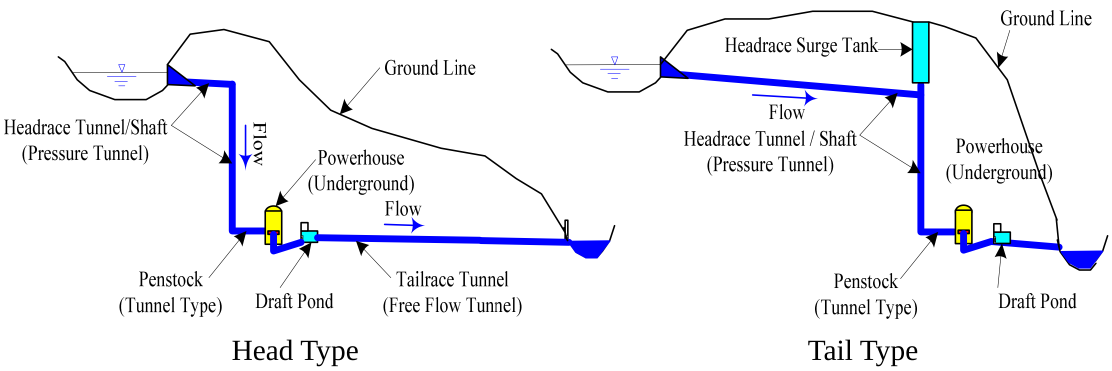


Figure 6.5.1-1 Types of Waterway

Applicable hydropower plant types for the Candidate Hydropower Projects are as shown in following table.

Table 6.5.1-1 Applicable Powerhouse Type for Prospective Sites

Candidate Projects	Classification by method of head acquisition	Type
Kalagala	Dam Type	-
Isimba	Dam Type	-
Karuma	Waterway Type	Head Type
Oriang	Waterway Type	Head Type
Ayago	Waterway Type. Dam & Waterway Type	Head Type (Tail Type can be applicable)
Kiba	-	Head Type
Murchison	Dam & Waterway Type	Head Type

(Source: Study Team)

6.5.2 Layout Summary of Candidate Hydropower Project

Layout of the Candidate Hydropower Projects is summarized below;

(1) Kalagala Hydropower Project (Dam Type: Refer to Figure-6.5.2-1)

Dam type hydropower plant can be applied to the Kalagala Hydropower Project. Principal structures of the Project consist of the spillway portion, powerhouse portion and non-overflow dam portion. There are two types of the spillway; one is overflow type spillway and the other is the gated type spillway. There are many house holed around the reservoir area of the Project and resettlement due to food water rising should be minimized. Since the gated type can avoid and/or minimize the flood water rising, the gated type spillway is selected in this alternative study. The open air type powerhouse is placed just downstream of the concrete dam and the dam and the powerhouse are combined structurally. Center core type rockfill dam is selected for the non-overflow dam section mostly due to minimize construction cost and concrete dam for non-overflow section also is arranged for connection between the rockfill dam and the powerhouse. Hence combined dam is selected for the non-overflow dam section.

The above structures are as same composition as the Bujagali Hydropower Project which is constructing just upstream of the Kalagala Project.

One of technical issue of the Kalagala project is that 2.9 million cubic meters volume of the rockfill material is too large and construction of the dam depends on whether rock material and core material can be procured with reasonable cost or not.

(2) Isimba Hydropower Project (Dam Type: Refer to Figure-6.5.2-2)

Dam type hydropower plant can be applied to the Isimba Hydropower Project. Principal structures of the projects consist of the spillway portion, powerhouse portion and non-overflow dam portion. Types of the structures are as same as the Kalagala Project. In addition, earthfill type dam can be applied instead of the rockfill ram, since 30m height of dam is relatively low.

Technical issue of the Project depends on accuracy of the topographic map. Regardless 30m height of small dam, the layout is planned based on 1:50,000 scale topographic map with 20m interval contour. There are many house hold and topographic condition around reservoir area is relatively gentle. Therefore few meters difference of elevation will cause unexpected large reservoir area and large amount of structure volume in further stage. It is strongly recommended to carry out accurate topographic map around the Project area prior to precede further study.

(3) Karuma Hydropower Project (Waterway Type: Refer to Figure-6.5.2-3)

Feasibility Study of Karuma Hydropower Project is being carried out by Indian company, Infratec Pvt. Ltd. Tunnel waterway type hydropower plant is selected.

Principal structures of the Project 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 in order to flush out sediment material. Application of the weir, whether overflow type or gated type, may be considered during the feasibility study taking into consideration of the topographical, technical and economical aspects. Pressure flow type headrace tunnel, steel penstock (tunnel embedded type), and underground powerhouse, which are generally applied to the head type waterway, are 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 provability to fill water in the tailrace tunnel with pressure due to usual food water rising, the non-pressure type tunnel is economical under such river conditions. Hence, the non-pressure type concrete lining tunnel is selected for the type of the tailrace tunnel.

(4) Oriang Hydropower Project (Waterway Type: Refer to Figure 6.5.2-4)

Only waterway type (head type) can be applied to the Oriang Hydropower Project due to topographic conditions. Left river bank side waterway route is selected, since the route is shorter than right bank route and obviously economical. Composition of the main structures and their structural types are as same as the Karuma Project.

(5) Ayago Hydropower Project (Waterway Type: Refer to Figure 6.5.2-5)

Waterway type and dam & waterway type can be applied to the Ayago Hydropower Project. Since waterway type has relatively-small impact to the natural environment around the project area, the waterway type was selected for the Ayago Project in this alternative study of the Candidate Projects.

Head type and tail type waterway can be applied to the alternative. As mentioned above, head type is applied in this alternative study, since the head type can be applied to the all Candidate Projects except dam type hydropower plant. Left bank side waterway route is selected, since the route is shorter than the right bank route and obviously economical. Composition of the main structures and their structural types are as same as the Karuma Project.

(6) Kiba Hydropower Project (waterway Type: Refer to Figure 6.5.2-6)

Only waterway type (head type) can only be applied to the Kiba Hydropower Project due to topographic conditions. Left river bank side waterway route is selected, since the route is shorter than right bank route and obviously economical. Composition of the main structures and their structural types are as same as the Karuma Project.

(7) Murchison Hydropower Project (Dan & Waterway Type: Refer to Figure 6.5.2-7)

Dam & waterway type can be applied to the Murchison Hydropower Project. Waterway type also can be applied, however, only dam & waterway type can fully utilize hydropower potential at the Murchison site. Hence, dam & waterway type was selected for the Murchison Hydropower Project in this alternative study of the Candidate Projects.

Dam site as described in Figure 6.5.2-7 may be suitable, since the dam site can make sorter waterway route and the site can make target power generation head. However, there are some possibilities to shift the dam site to the upstream site depending on topographic and geological conditions around the dam abutment. Since the Murchison Project is planned to construct in the National Park area and the land alteration should be minimized, the concrete gravity dam is deselected. The concrete gravity dam consists of gated portion, which has function of normal food spillway and amenity flow gate, overflow portion, which has function of excess flood spillway, and un-overflow portion. Composition of the main waterway structures including powerhouse and their structural types of are as same as the Karuma Project.

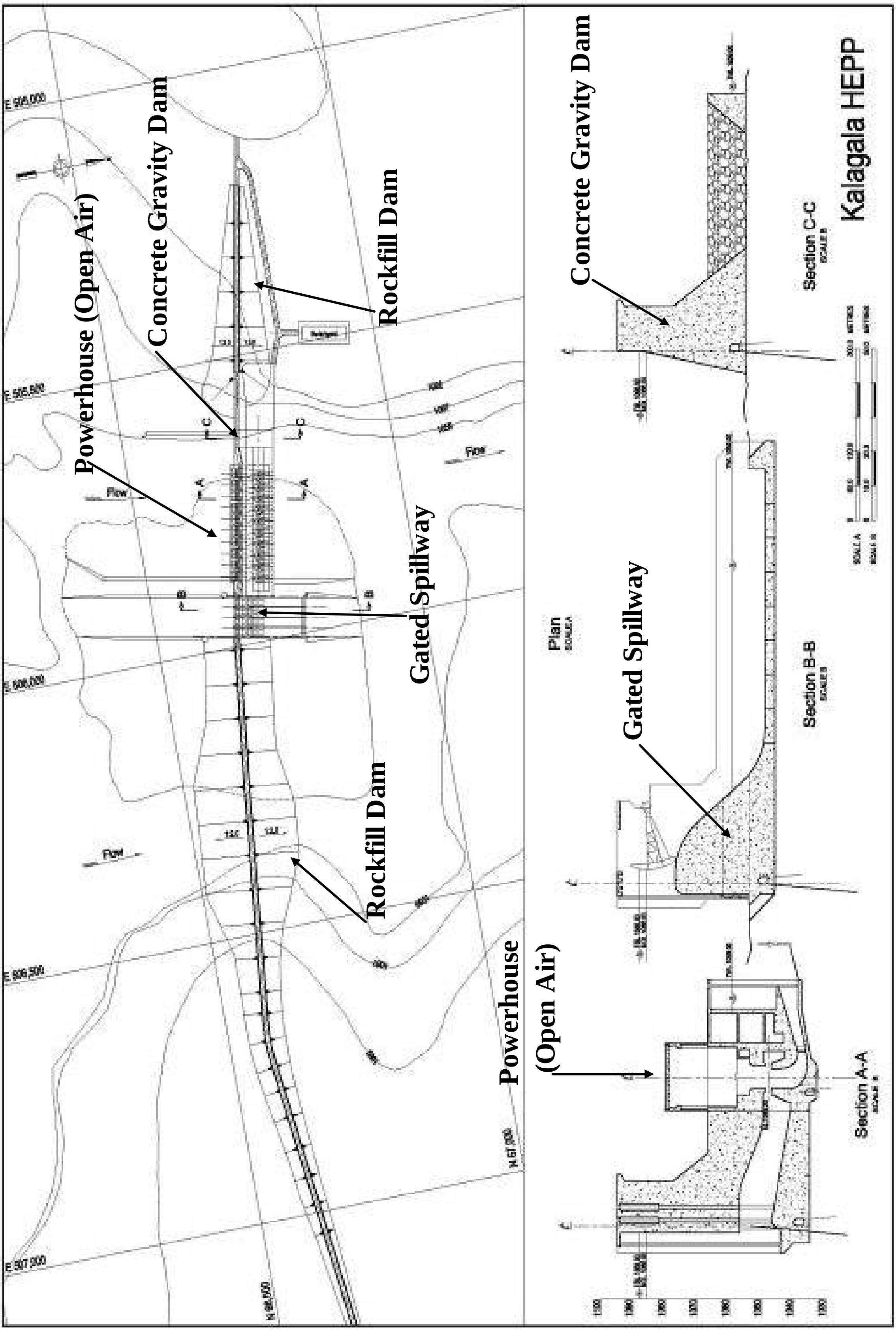


Figure 6.5.2-1 Kalagala Site (Dam Type)

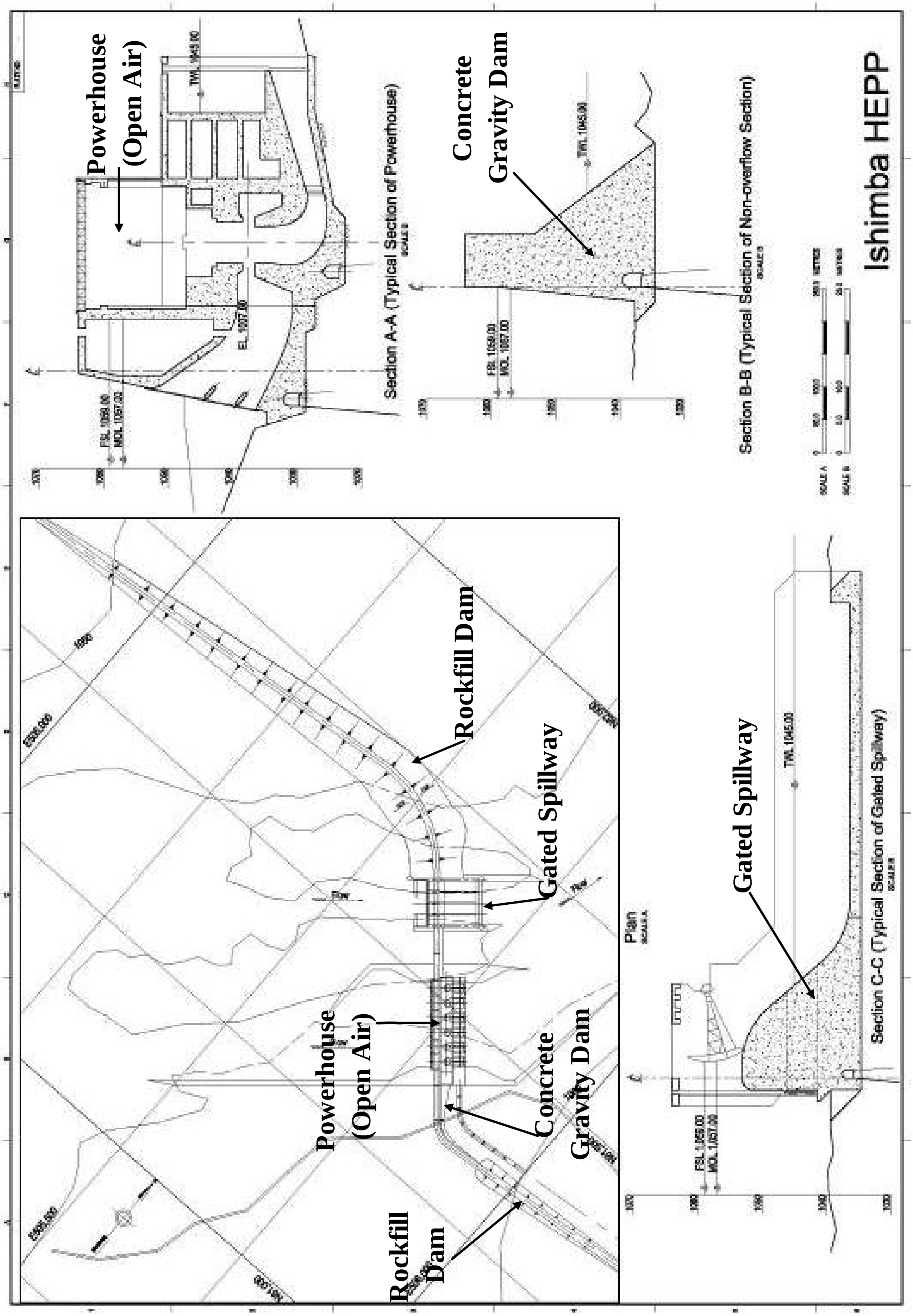


Figure 6.5.2-2 Isimba Site (Dam Type)

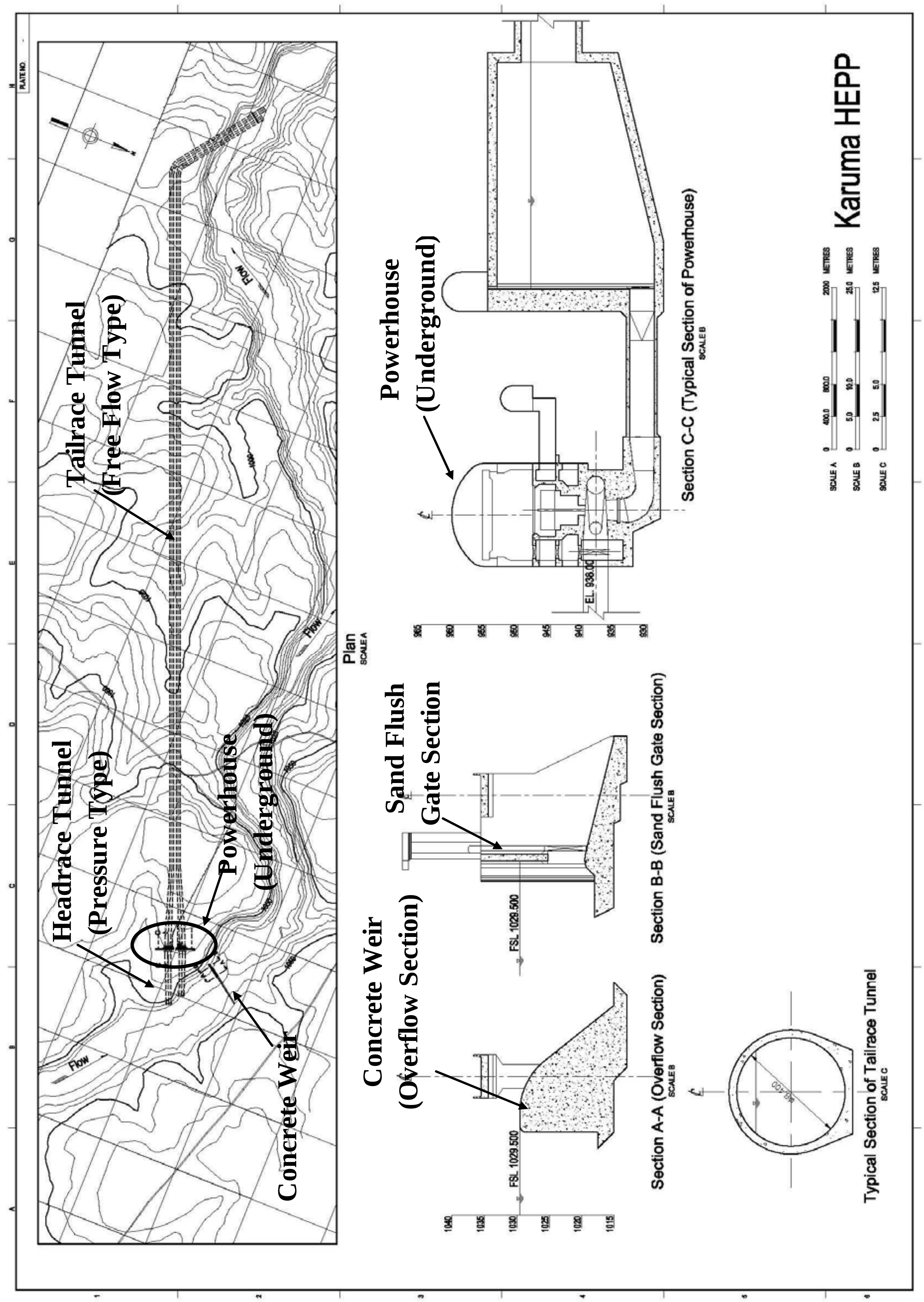


Figure 6.5.2-3 Karuma Site (Waterway Type)

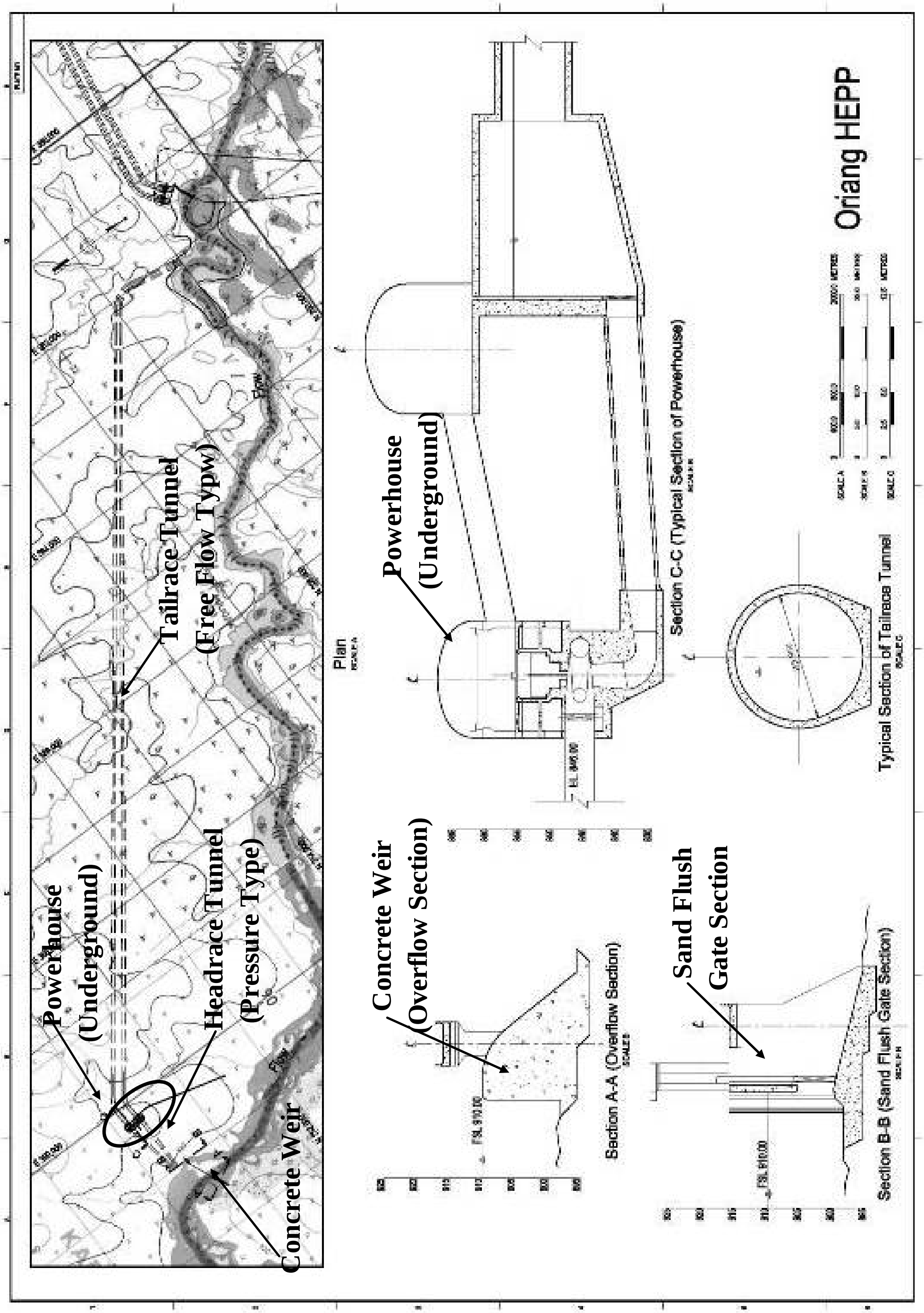


Figure 6.5.2-4 Oriang Site (Waterway Type)

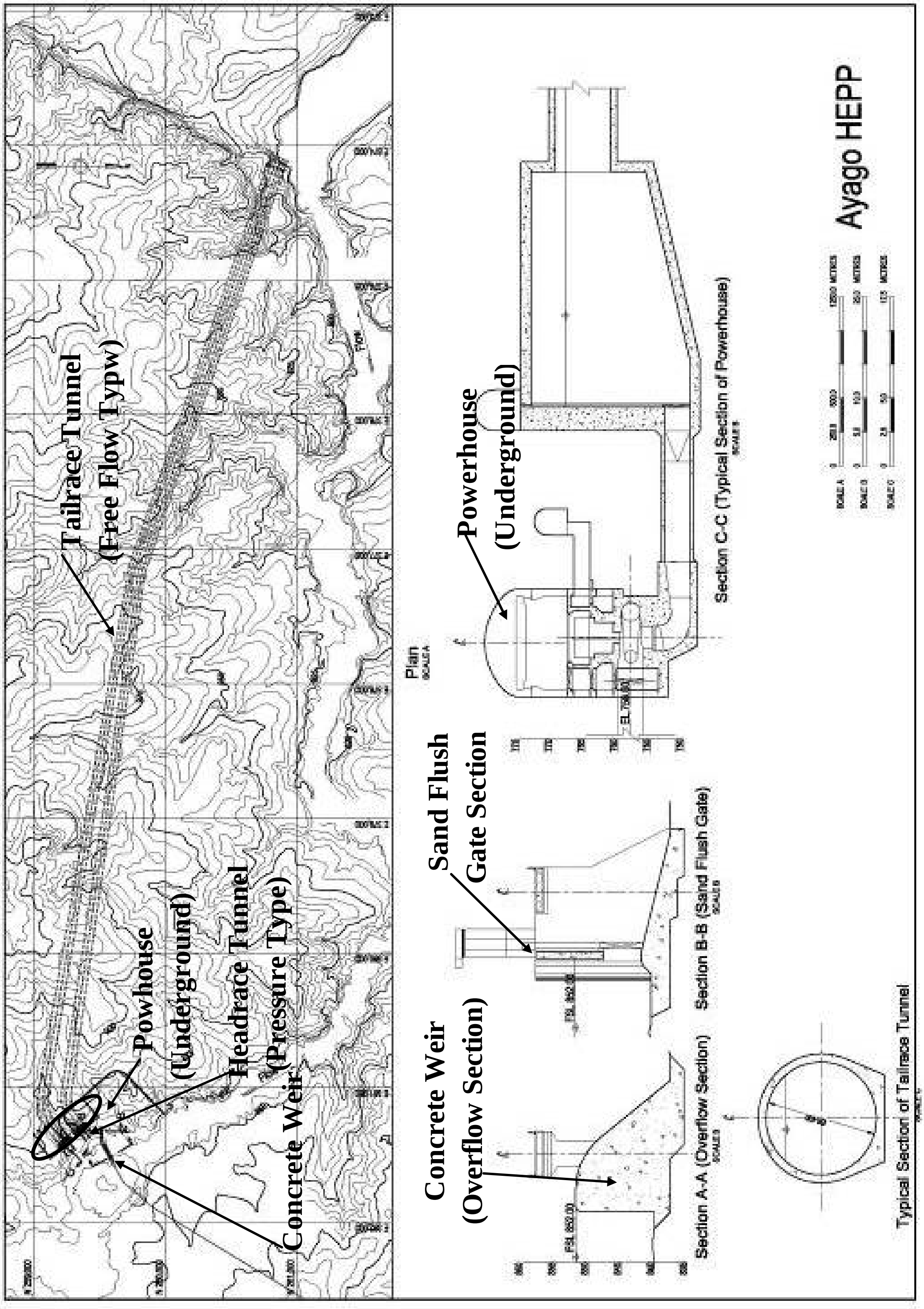


Figure 6.5.2-5 Ayago Site (Waterway Type)

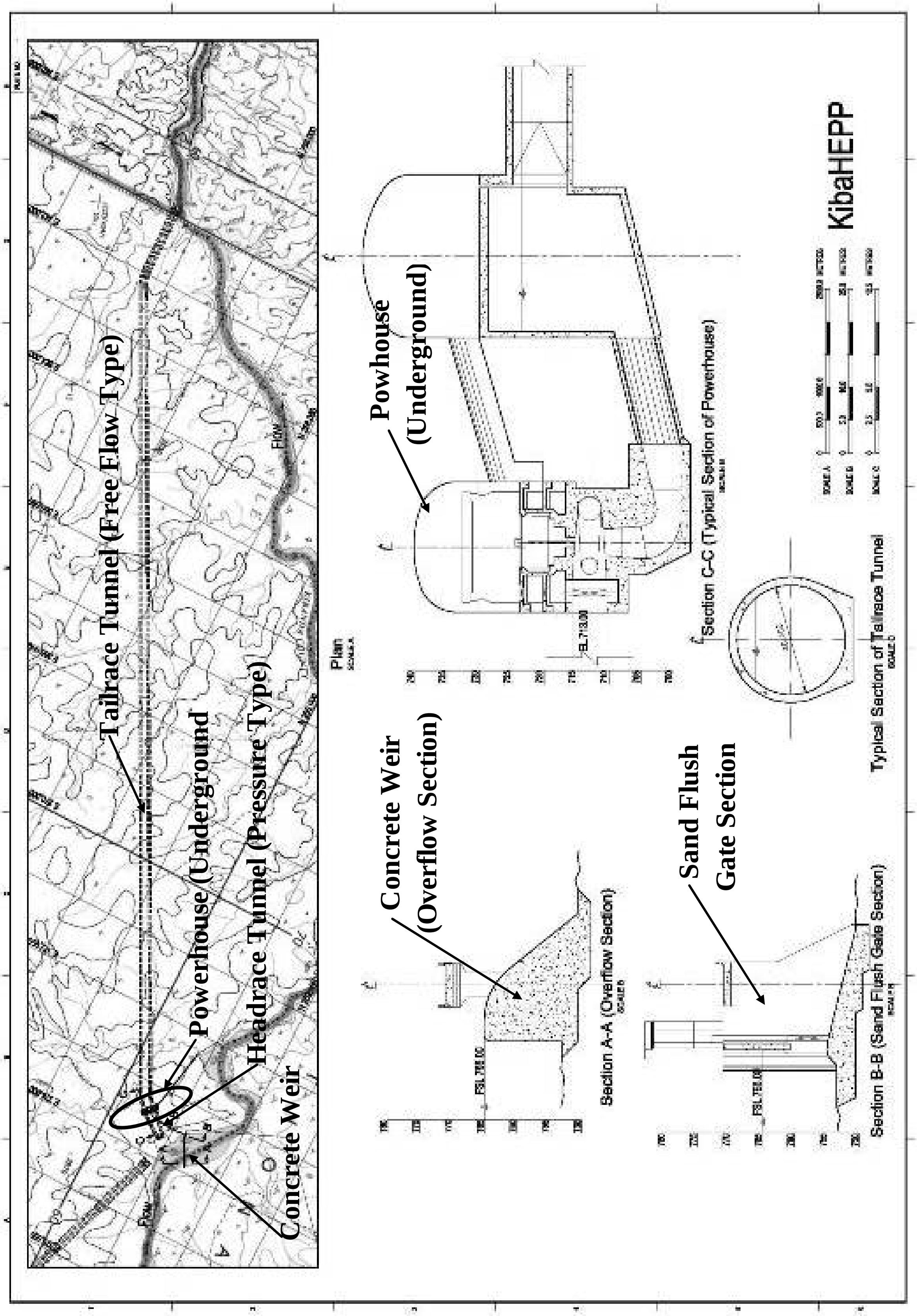


Figure 6.5.2-6 Kiba Site (Waterway Type)

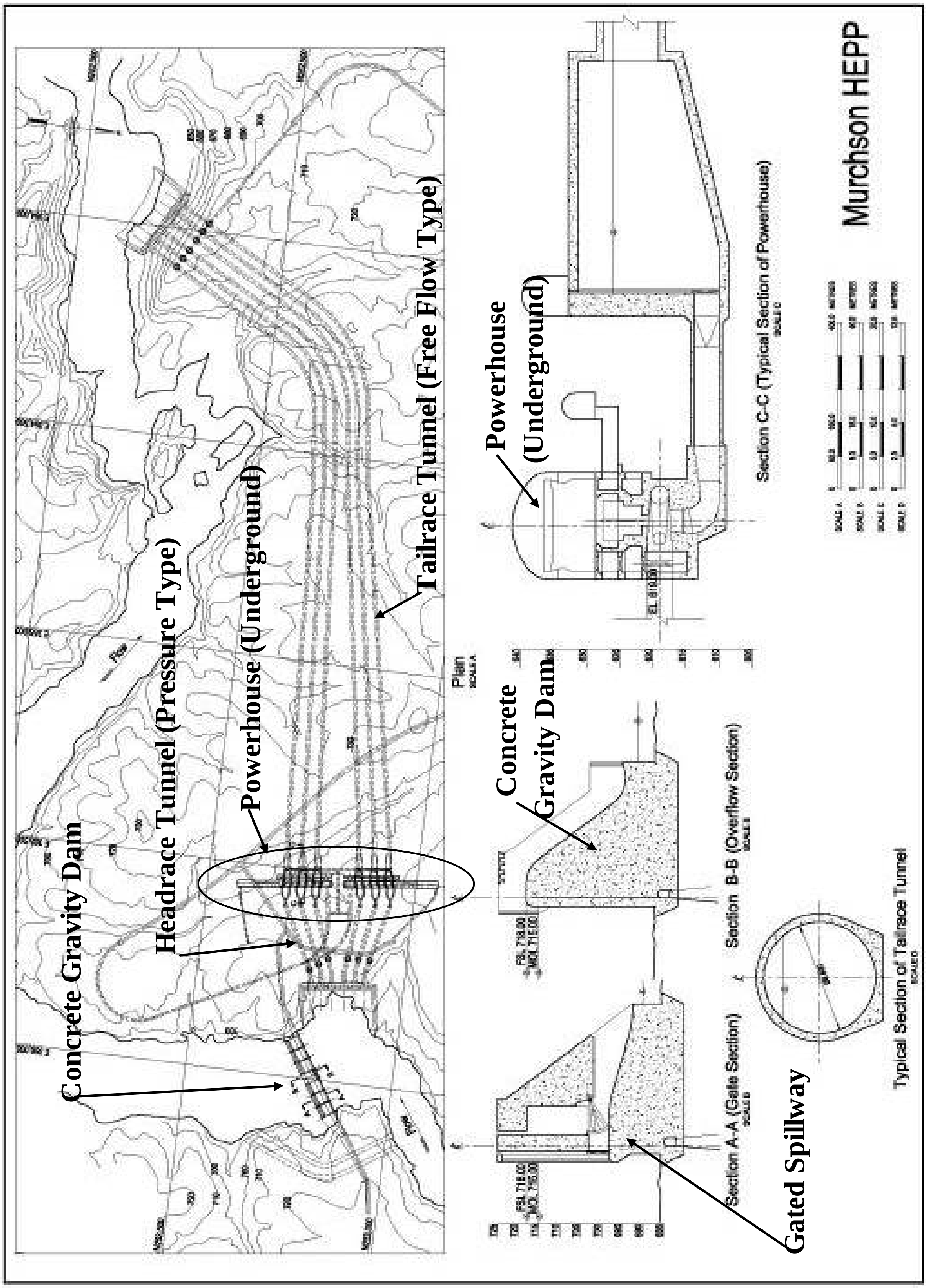


Figure 6.5.2-7 Murchison Site (Dam and Waterway Type)

6.5.3 Salient Features for Each Project

The salient features of 7 project sites are shown in Table6.5.3-1.

Table 6.5.3-1 Salient Feature of 7 Projects

Item	Unit	Kalagala	Ishimba	Karuma	Oriang	Ayago	Kiba	Murchison
		Dam Type	Dam Type	Waterway Type	Waterway Type	Waterway Type	Waterway Type	Dam &Waterway Type
Dam / Weir								
Type		Comnbined Dam	Comnbined Dam	Concrete Weir	Concrete Weir	Concrete Weir	Concrete Weir	Comnbined Dam
Height	m	45	30	20	20	20	20	45
Clest Length	m	235	320	620	610	480	550	650
Width of River Bed	m	175	70	-	-	-	-	240
Catchment Area	km^2	264,450	264,620	346,000	346,710	346,850	348,120	348,600
Full Supply Level	m	1,088	1,059	1,030	910	852	765	718
Rated Water Level	m	1,087	1,058	1,030	910	852	765	715
Minimum Operation Level	m	1,086	1,057	-	-	-	-	712
Gross Storage Capacity	MCM	82	88	-	-	-	-	42
Effective Storage Capacity	MCM	19	22	-	-	-	-	19
Waterway								
Headrace Tunnel								
Number of Tunnel	nos.	-	-	6	4	6	6	6
Inner Diameter	m	-	-	8.4	9.8	8.4	8.4	9.0
Length	m	-	-	555	740	96	390	290
Penstock								
Number of Penstock	nos.	-	-	12	8	12	6	12
Inner Diameter	m	-	-	3.8	4.9	3.8	5.4	5.9
Length	m	-	-	70	90	50	55	46
Tailrace Tunnel								
Number of Tunnel	nos.	-	-	6	4	6	6	6
Inner Diameter	m	-	-	8.4	9.8	8.4	8.4	9.0
Length	m	-		11,000	11,000	7,600	14,000	1,800
Tail Water Level	m	1,059	1,045	945	852	765	718	625
Powerhouse								
Type		Open Air	Open Air	Underground	Underground	Underground	Underground	Underground
Number of Unit	nos.	10	6	12	8	12	6	12
Type of Turbine		Kaplan	Kaplan	Francis	Francis	Francis	Francis	Francis
Transmission Line								
Length	km	28	47	1	34	46	56	122
Voltage	kV	220	220	400	400	400	400	400

6.6 Site Geology

6.6.1 General

The Victoria Nile River, forming some small cascades, meanders through gently hilly terrain of gneiss rocks. General topographic features along the Victoria Nile River consist of approximately 200 m to 300 m wide riverbed, 15 to 25 degrees slopes on the both river sides and gentle hilly terrains of 30 m to 50 m in height above riverbed.

Volume of unconsolidated deposits such as river sand and gravels, terrace deposits and talus deposits distributed along the river is not considerable. Overburdens are estimated at less than 3 m to 5 m in thickness according to surface observations, but gneiss rocks on the hilly terrains are possibly highly weathered along joints deeper to the closest river floor level.

According to the site reconnaissance carried out in this study, the Candidate Hydropower Projects are underlain mainly by hard gneiss rocks, which are suitable for the foundation of the structures for power stations structures.

Kalagala and Isimba sites are underlain mainly by massive granitic gneiss and mafic gneiss, while the bedrocks of Karuma, Kiba Ayago, Oriang and Murchison site are composed mainly of biotite gneiss including mafic gneiss. Generally, biotite gneiss is not suitable as construction materials such as concrete aggregates, due to its high abrasion characteristics. It should be noted that disposal of excavated materials and construction material sources for concrete aggregates are necessary to be studied in the early stages of the feasibility study (F/S), especially for Karuma, Kiba Ayago, Oriang and Murchison Falls site.

6.6.2 Geology of Candidate Hydropower Projects

Site geology of candidate hydropower project is described as below.

(1) Kalagala

Kalagala site is underlain by granitic gneiss with intrusive layers of mafic gneiss, which are exposed on some river floors. Outcrops are generally massive and very hard. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are possibly good. Overburdens on the terrains are estimated at about 5 to 6 m in thickness. It should be noted that gneiss rocks at both abutments are possibly weathered and weakened even at rather deep sections.

(2) Isimba

Isimba site is underlain by granitic gneiss with intrusive layers of mafic gneiss, which are exposed on some river floors. Outcrops are generally massive and very hard. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are possibly good. Overburdens on the terrains are estimated at about 5 to 6 m in thickness. It should be noted that gneiss rocks at both abutments are possibly weathered and weakened even at rather deep sections.

(3) Karuma

Karuma site is underlain mainly by biotite gneiss with remarkable gneissosity, which are exposed on some river floors. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are possibly good. However, according to results of core drilling, highly weathered rocks along joints were found at the borehole location of approximately 40 m deep.

(4) Oriang

Oriang site is underlain mainly by biotite gneiss with remarkable gneissosity, which are exposed on some river floors. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are possibly good. It should be noted that gneiss rocks at both abutments are possibly weathered and weakened even at rather deep sections.

(5) Ayago

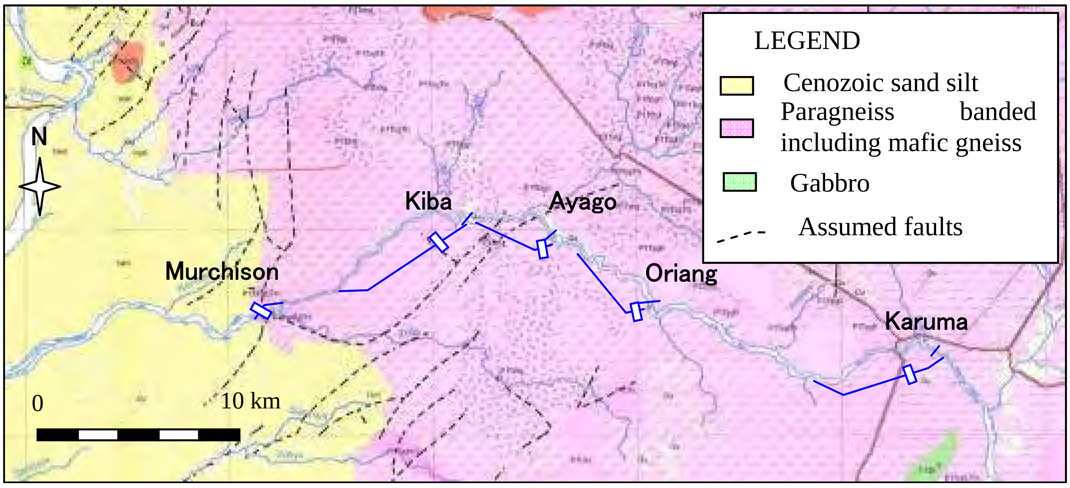
Ayago site is underlain mainly by biotite gneiss with remarkable gneissosity, which are exposed on some river floors. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are possibly good. Gneissosity dips 30-50 degrees to the northeast in general. However, the structure at the intake for the underground powerhouse site is rather steeply inclined. It should be noted that gneiss rocks at both abutments are possibly weathered and weakened even at rather deep sections. Northeast to southwest extending topographic lineaments crossing the tunnel alignment indicate possible fracture zones (refer to Figure 6.3.1-1).

(6) Kiba

Kiba site is underlain mainly by biotite gneiss with remarkable gneissosity, which are exposed on some river floors. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are potentially good. It should be noted that gneiss rocks at both abutments are possibly weathered and weakened even at rather deep sections.

(7) Murchison

Murchison site is underlain mainly by biotite gneiss with remarkable gneissosity. The bedrocks are exposed on some river floors. Gneissosities of bedrocks are almost flat to gently dip to the right bank. Murchison Falls is a good location for observing the rock conditions. Surface rocks at the falls, are slightly weathered, vary from hard to moderately hard, having well developed gneissosities and somewhat easily broken by hammering. Sound rocks which are suitable for structural foundations will be exposed through surface excavation of river floor. Watertight conditions of weir site and reservoir area are possibly good. It should be noted that gneiss rocks at both abutments are possibly weathered and weakened even at rather deep sections.



(Source: UGANDA North of 1° N, Preliminary Geological Map of Uganda 1:500,000 (unpublished))

Figure 6.6.2-1 Geological Map of Karuma, Oriang, Ayago, Kiba and Murchison

As for the screening of the candidate sites, the following B to C ranking method has been adopted taking construction work into consideration based on the geological condition.

Table 6.6.2-1 Rating on Geological Condition

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Characteristic	Sound	Sound	Moderate	Moderate	Moderate	Moderate	Moderate
Rating	B	B	C	C	C	C	C

6.7 Construction Plan

6.7.1 Access Road to Project Site

(1) Kalagala Site

Kalagala site is located at 27 km downstream of Victoria Lake. It takes 3 hours from Kampala to site (110km) via Jinja.

Road improvement between the nearest highway to the site is required for transportation of construction material due to unpaved and narrow road condition.

The existing highway may not interfere with load restriction and minimum turning radius for the transportation.

(2) Isimba Site

Isimba site is located 42 km downstream of lake Victoria. It takes 3.5 hours from Kampala to the site (130km) via Jinja.

Road improvement between the nearest highway to the site (15km) is required for transportation of construction material due to unpaved and narrow road condition.

The existing high way may not interfere with load restriction, and minimum turning radius for the transportation.

(3) Karuma Site

Karuma site is located at 130 km downstream of Lake Kyoga. It takes 4 hours from Kampala to the site (260km) via Nakasongola.

Construction of a new road between the nearest highways to the site (1km) is required for transportation of construction material.

The existing high way may not interfere with load restriction, and minimum turning radius for the transportation.

(4) Oriang Site

Oriang site is located 160 km downstream of Lake Kyoga or 40km downstream of Karuma site. It takes 5 hours from Kampala to the site (275km) via Nakasongola.

Construction of a new road between nearest highway to the site (30km) is indispensable for transportation of construction material.

The existing highway may not interfere with load restriction and minimum turning radius for the transportation.

(5) Ayago Site

Ayago site is located at 175 km downstream of Kyoga Lake or 15km downstream of Oriang site. It takes 5.5 hours from Kampala to site (290km) via Nakasongola.

Construction of a new road between the nearest highway to the site (45km) is required for transportation of construction material.

The existing highway may not interfere with load restriction and minimum turning radius for the transportation.

(6) Kiba Site

Kiba site is located at 185 km downstream of Kyoga Lake or 10km downstream of Ayago site. It takes 5.5 hours from Kampala to site (300km) via Nakasongola.

Construction of a new road between the nearest highways to the site (55km) is required for transportation of construction material.

The existing highway may not interfere with load restriction and minimum turning radius for the transportation.

(7) Murchison Site

Murchison site is located at 210 km downstream of Kyoga Lake or 25km downstream of Ayago site. It takes 7 hours from Kampala to the site (450km) via Nakasongola.

Construction of a new road between the nearest highways to the site (30km) is required for transportation of construction material.

The existing highway may not interfere with load restriction and minimum turning radius for the transportation.

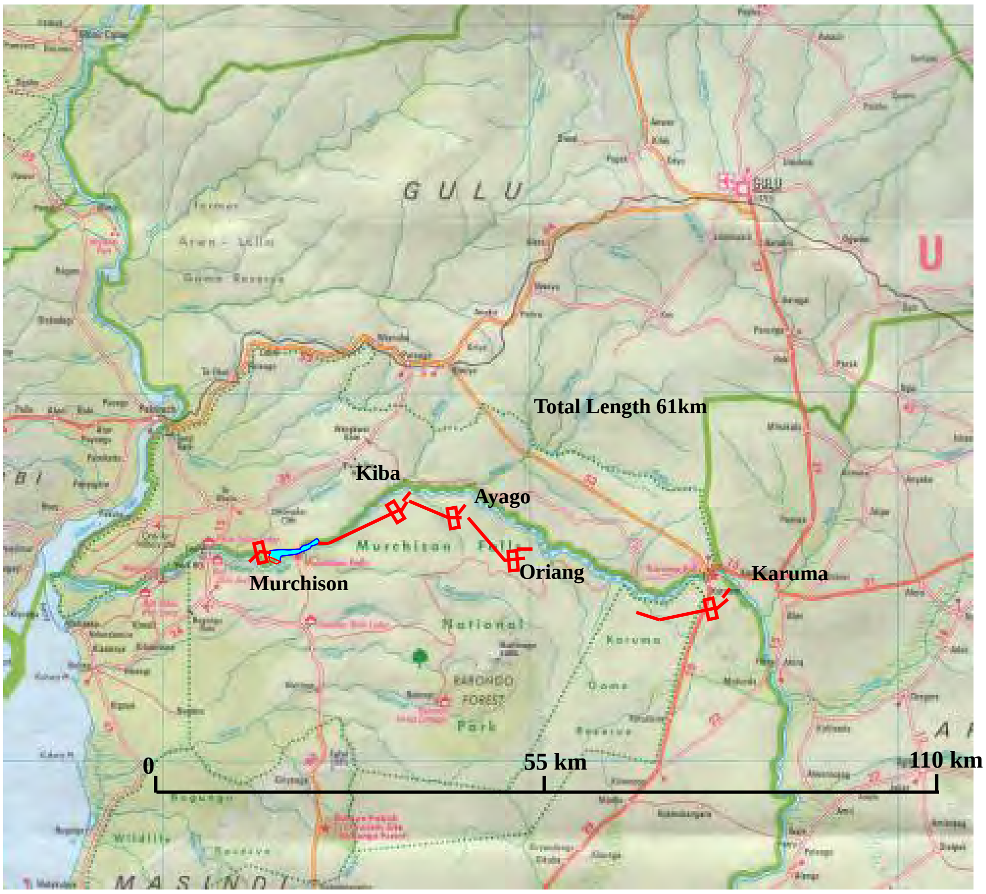


Figure 6.7.1-1 General Layout-1

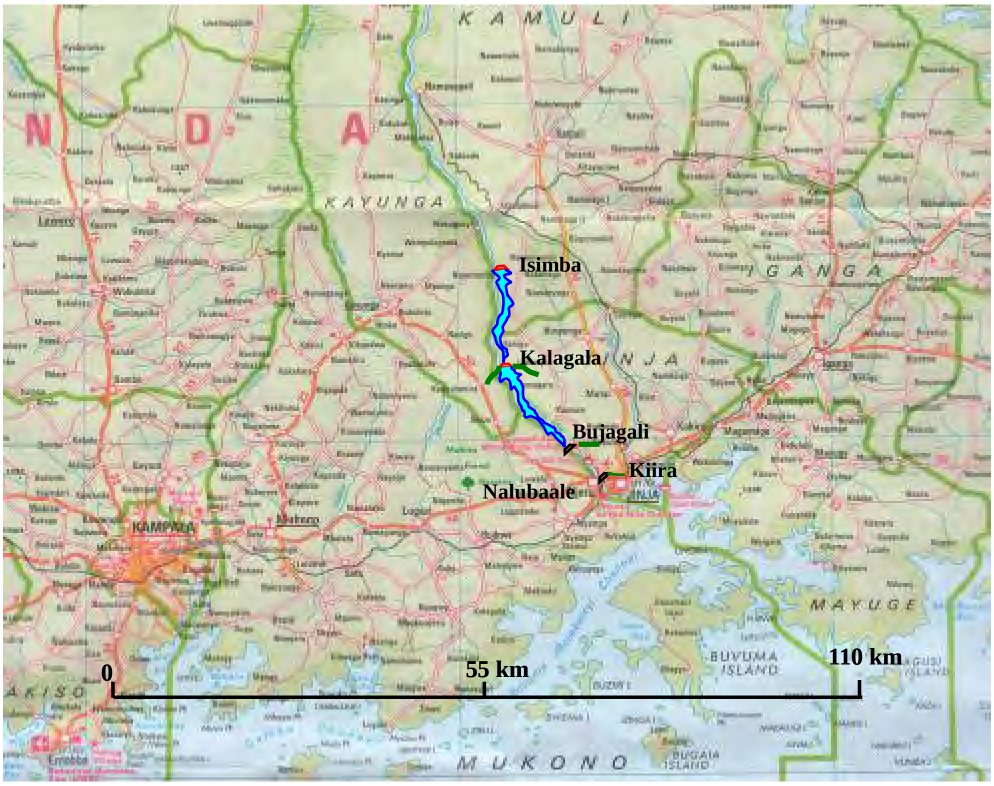


Figure 6.7.1-2 General Layout-2

The distances from Kampala to each site and from the nearest highway to each site are shown in Table 6.7.1-1.

Table 6.7.1-1 Approximate Distance

Site	Distance from Kampala (m)	Distance from nearest highway (m)
Kalagala	110 km	3 km
Isimba	130 km	15 km
Karuma	260 km	1 km
Oriang	275 km	30 km
Ayago	290 km	45 km
Kiba	300 km	55 km
Murchison	450 km	30 km

As for the screening of candidate sites, following A to D ranking has been determined taking accessibility to site into consideration in accordance with less order.

Table 6.7.1-2 Accessibility

Accessibility	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Length of new access road (km)	3	15	1	30	45	55	30
Rating	A	A	A	B	C	D	B

6.7.2 Construction Period

Based on the salient features mentioned in Table 6.6.1.2-1, the construction period is estimated 4 years for dam type and 5 years for dam and waterway (run-of-river) type considering the achievement of similar hydro projects.

The construction period for each project are shown in Table6.7.2-1.

For the construction period, the ranking of A to B has been used for the screening of the candidate sites.

Table 6.7.2-1 Construction Time

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
	Dam	Dam	RoR	RoR	RoR	RoR	Dam
Construction Period (year)	4	4	5	5	5	5	4
	A	A	B	B	B	B	A

6.7.3 Lead Time to the Commissioning

The following criteria in terms of lead time to the commissioning are established.

a: A candidate hydropower project is mentioned in GDP2008-2023 prepared by UETCL

b: Preparatory surveys and studies such as feasibility study have been conducted and the lead time is relatively short.

During the lead time, as the project is maturing, the important milestones are:

i) The project is recognized in the long-term power development plan of the government,

ii) The project feasibility is established in technical, economic and environmental terms in a feasibility study already conducted;

iii) Project funding is secured or prospective or probable even if it is partial.

The criterion a concerns whether the hydropower project is planned in GDP2008-2023 of UETCL, the organization in charge of preparation of long-term power expansion plans of the Uganda government. If it is planned in GDP, it means that the government is committed to develop the project and that it is prepared to make governmental budget allocation and to take actions for foreign aid for project funding。

The criterion b is to determine project maturity by checking to what extent preparatory surveys and studies such as FEASIBILITY STUDY have so far been conducted or whether such surveys and studies are planned. A feasibility study, which is important to determine whether the project is viable to develop, is essential for decision making by possible investors as well as the Uganda government.

Nevertheless, it is difficult, in most cases, to secure funding for a feasibility study before the project viability is established. If a feasibility study has already been conducted or under way or probable to be conducted, it can become an important factor to shorten the lead time. This hydropower master plan has a planning horizon to 2023, that criterion also considers whether the project can be commissioned not later than 2023 taking account of the estimated lead time. The lead time includes those periods required for preparatory surveys and studies such as feasibility study and environmental impact assessment, design, preparation of tender documents for construction and financial arrangement.

Taking above mentioned criteria into consideration, following from A to C ranking has been determined in accordance with short period order.

Table 6.7.3-1 Lead Time

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Lead time to the commissioning (Survey, design, financing, bidding, Relocation etc.) (year)	6	6	5	5	5	5	5
Rating	C	C	A	A	A	A	A

6.7.4 Work Quantities

(1) Civil Work

Quantities for construction works were estimated based on the hydropower development layout and features for each structure prepared by power generation planning. By referring to the "Guide Manual for Development Aid Programs and Studies of Hydro Electric Power Projects" prepared by New Energy Foundation (Tokyo, Japan 1996), simple empirical equations were applied to estimating the work quantity. Quantities of major work items (excavation, concrete, reinforcing bar and gates) are shown in Table6.7.4-1.

Table 6.7.4-1 Quantities of main items

Item	Unit	Kalagala	Ishimba	Karuma	Oriang	Ayago	Kiba	Murchison
		Dam	Dam	Run-of-River	Run-of-River	Run-of-River	Run-of-River	Dam
1. Dam								
1.1. Care of river	LS	1	1	1	1	1	1	1
1.2. Dam								
(i) Excavation	m^3	645,800	555,900	403,200	395,800	301,200	351,700	292,500
(ii) Concrete	m^3	161,800	434,500	90,400	89,300	75,600	83,100	447,500
(iii) Banking		2,900,000	513,000					
(iv) Reinforcement bar	ton	0	0	400	400	300	300	0
2. Intake								
(i) Excavation	m^3	149,900	120,800	82,800	76,200	82,800	82,800	88,300
(ii) Concrete	m^3	52,200	42,300	29,400	27,100	29,400	29,400	31,300
(iii) Reinforcement bar	ton	2,100	1,700	1,200	1,100	1,200	1,200	1,300
3. Headrace Tunnel								
(i) Excavation	m^3	0	0	266,400	329,700	46,100	187,200	139,200
(ii) Concrete	m^3	0	0	82,000	106,600	14,200	57,600	42,800
(iii) Reinforcement bar	ton	0	0	3,300	4,300	600	2,300	1,700
4. Penstock								
(i) Excavation	m^3	0	0	15,200	19,700	10,900	10,600	14,600
(ii) Concrete	m^3	0	0	5,700	6,100	4,100	3,100	4,600
(iii) Reinforcement bar	ton	0	0	70	70	50	40	60
5. Powerhouse								
(i) Excavation	m^3	215,400	122,100	170,600	157,800	173,400	169,500	176,800
(ii) Concrete	m^3	127,200	68,300	37,300	32,700	37,900	29,700	38,700
(iii) Reinforcement bar	ton	6,400	3,400	1,500	1,300	1,500	1,200	1,500
6. Transformer Hall								
(i) Excavation	m^3	0	0	107,600	101,200	109,300	92,200	111,500
(ii) Concrete	m^3	0	0	37,300	32,700	37,900	29,700	38,700
(iii) Reinforcement bar	ton	0	0	1,500	1,300	1,500	1,200	1,500
7. Tailrace Tunnel								
(i) Excavation	m^3	0	0	4,866,000	4,259,200	3,362,000	6,193,200	796,300
(ii) Concrete	m^3	0	0	1,210,300	942,000	836,200	1,540,400	198,100
(iii) Reinforcement bar	ton	0	0	48,400	37,700	33,400	61,600	7,900
8. Outlet								
(i) Excavation	m^3	25,000	25,000	19,800	21,300	19,800	19,800	19,800
(ii) Concrete	m^3	15,100	15,100	10,800	12,000	10,800	10,800	10,800
(iii) Reinforcement bar	ton	100	100	80	90	80	80	80
9. Access Tunnel								
(i) Excavation	m^3	0	0	76,500	63,000	58,500	45,000	45,000
(ii) Concrete	m^3	0	0	17,000	14,000	13,000	10,000	10,000
(iii) Reinforcement bar	ton	0	0	5,100	4,200	3,900	3,000	3,000

Total Excavation Volume	m3	1,036,100	823,800	6,008,100	5,423,900	4,164,000	7,151,900	1,684,000
Total Concrete Volume	m3	356,300	560,300	1,520,100	1,262,400	1,059,100	1,793,800	822,400
Total Reinforcement bar	ton	8,500	5,200	61,500	50,300	42,600	70,900	17,100

For the screening of candidate sites, the ranking of A to E has been adopted taking construction volume into consideration.

Table 6.7.4-2 Excavation Volume

Volume of Excavation	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Excavation Volume(10^3m^3)	1,036	824	6,008	5,424	4,164	7,152	1,684
Rating	B	A	D	C	C	E	B

Table 6.7.4-3 Concrete Volume

Construction material	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Concrete Volume (10^3m^3)	356	560	1,520	1,262	1,059	1,794	822
Rating	A	A	B	B	B	C	A

(2) Transmission Line and Electrical Equipment

1) Transmission Line

A Line length and an approximate construction cost of each project are shown as follow:

Table 6.7.4 -4 Transmission Line for Hydropower Project

	From	To	Voltage (kV)	No. of Circuit	Length (km)
Kalagala	Kalagala	Bujagali	220	2	28
Isimba	Isimba	Bujagali	220	2	47
Karuma	Karuma	Kawanda	400	2	260
Oriang	Oriang	Karuma	400	2	34
Ayago	Ayago	Karuma	400	2	46
Kiba	Kiba	Karuma	400	2	56
Murchison	Murchison	Karuma	400	2	122

The transmission line route downstream from Oriang hydropower project have been planned for south side of Nile River taking minimum influence to the wildlife into consideration. However, transmission line route of Murchison hydropower project has been planned for northern part of national park to the highway and then along the highway to Karuma.

As for the Isimba and Kalagala transmission line projects, they have been planned along the existing highway to the Bujagali switchyard.

The transmission line routes of each project are shown as follows:

Figure 6.7.4-1 Transmission Line Route Map of Oriang Project

Figure 6.7.4-2 Transmission Line Route Map of Ayago Project

Figure 6.7.4-3 Transmission Line Route Map of Kiba Project

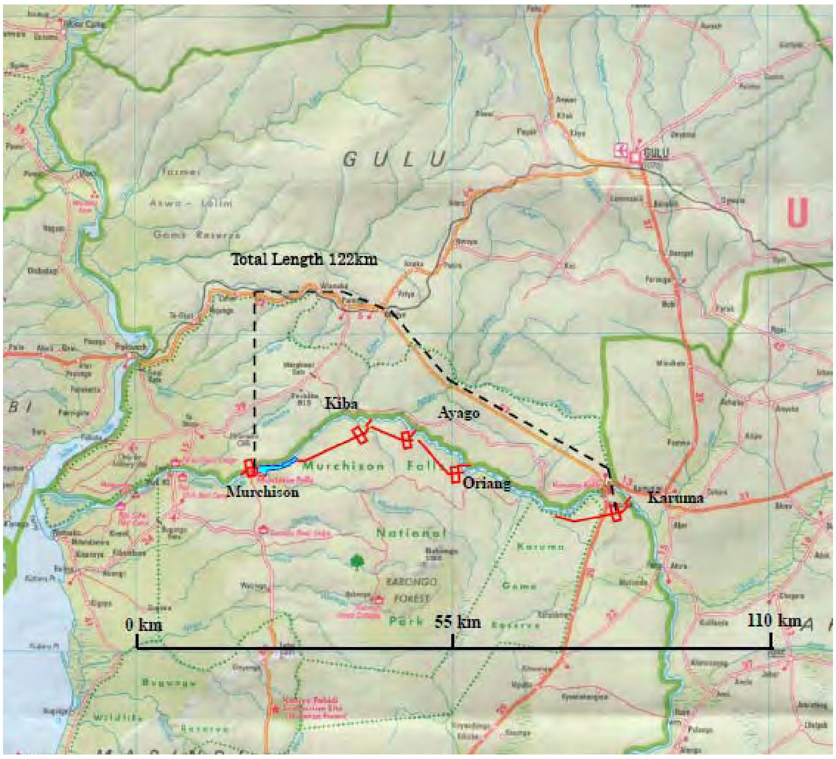


Figure 6.7.4-4 Transmission Line Route Map of Murchison Project

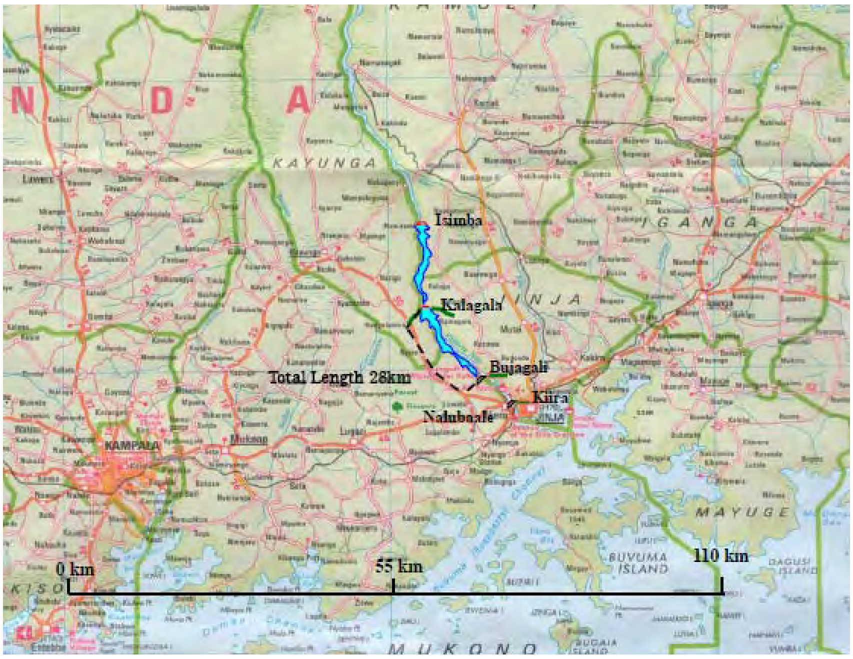


Figure 6.7.4-5 Transmission Line Route Map of Kalagala Project

Figure 6.7.4-6 Transmission Line Route Map of Isimba Project

For the screening of candidate sites, the ranking of A to E has been adopted taking transmission efficiency and losses into consideration.

Table 6.7.4-5 Distance to Load Center or Existing Grid

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Distance to load center or existing grid (km)	28	47	1	34	46	56	122
Rating	B	D	A	C	D	D	E

Table 6.7.4-6 Relative Transmission Loss Compare to Karuma Project

	Isimba	Kalagala	Karuma	Oriang	Ayago	Kiba	Murchison
Voltage (kV)	220	220	-	400	400	400	400
Length (km)	47	28	0	34	46	56	122
Transmission Loss (%)	168	100		36	50	60	131
Rating	C	C	A	B	B	B	C

(3) Electrical Equipment

Large unit capacity of turbine-generator is more economical for designing of electrical equipment in general. However, the unit capacity has been determined taking following reasons into consideration.

- Influence to the whole power system in case of dropping off the unit
- Transportation restriction from Mombasa in Kenya
- Reliability and flexibility for operation and maintenance

Salient feature of electrical equipment for each projects are shown as follows

Table 6.7.4-7 Salient Feature of Electrical Equipment

Items	Unit	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
		Dam	Dam	Run of River	Run of River	Run of River	Run of River	Dam
Maximum Discahrge	m^3/s	1,375	1,375	840	840	840	840	840
Effective Head	m	27.5	12.5	79.0	52.8	83.0	40.4	88.0
Number of Units	No.	10	6	12	8	12	6	12
Type of Turbine		Kaplan	Kaplan	Francis	Francis	Francis	Francis	Francis
Maximu Discharge per Unit	m^3/s	137.5	229.2	70.0	105.0	70.0	140.0	70.0
Turbine Efficiency	%	91.3	84.3	92.5	92.4	92.5	89.9	92.5
Generator Efficiency	%	97.5	97.0	97.6	97.6	97.5	97.6	97.7
Combined Efficiency	%	89.0	81.8	90.3	90.2	90.2	87.7	90.4
Capacity per Unit	kW	33,000	23,000	48,900	49,000	51,400	48,700	54,500
Installed Capacity	kW	330,000	138,000	586,800	392,000	616,800	292,000	654,000
Construction Cost for Electrical Equipment	M US$	151.8	114.0	241.7	178.7	245.2	146.5	249.1

6.8 Project Cost

6.8.1 General

The construction cost has been estimated as of the end of 2010 in consideration of the international market prices. All costs are expressed in US Dollars. Cost estimation is based on the following conditions according to the achievement of similar projects and guideline for hydropower development in Japan.

(1) Compensation cost of 10 MUS$ is appropriated for Kalagala, Isimba and Karuma where resettlement of residents is required and 5 MUS$ is appropriated for Oriang, Ayago, Kiba and Murchison where the resettlement is not needed.

(2) Environmental cost is estimated at 3% of total civil construction cost for the projects outside of national park (Kalagala, Isimba and Karuma) and 5% for the projects inside of national park (Oriang, Ayago, Kiba and Murchison).

(3) The construction costs of civil work are basically calculated in manner of multiplying the unit price by the quantity of each work item. The unit prices of civil work items are estimated by using those of similar hydropower projects undertaken by the Consultant, and allowing for cost escalation.

(4) Hydro mechanical and electromechanical equipment costs are estimated by considering the international market price.

(5) Transmission from each project site to the planned switchyard at Karuma is evaluated for the cost estimation by considering the international market price.

(6) Administration and engineering costs are assumed at 15% of the direct cost (total cost of preparatory works, environmental cost, civil works, hydro mechanical equipment, electromechanical equipment and transmission).

(7) Contingency is assumed at 10% of the direct cost.

(8) Interest rate during construction period is estimated at 10%.

(9) Unit prices and construction costs do not include VAT and customs duties for imported materials or equipment.

Project costs consist of the following items.

Table 6.8.1-1 Composition of Construction Cost

(1) Preparatory Construction Cost	Land acquisition, Compensation for resettlement, Access road Existing road improvement, Office and camp facilities, power supply facilities etc.
(2) Environmental cost	Cost for compensation, mitigation, monitoring, etc.
(3) Civil Works	Dam : Dam body, Care of river etc. Waterway : Intake, Headrace , Penstock, Tailrace and Outlet etc. Powerhouse : Powerhouse foundation and structure
(4) Hydro-mechanical Equipment	Dam gate, Penstock, Intake and Outlet gates etc.
(5) Electromechanical Equipment	Turbine, Generator, Transformer, Control equipment, Related auxiliary equipment etc.
(6) Transmission Line	Transmission line from each site to planned switchyard at Karuma
(7) Administrative and Engineering Costs	Administrative/management and engineering costs on detailed design and construction supervision (15% of the direct cost (total cost of preparatory works, environmental cost, civil works, hydro mechanical equipment, electromechanical equipment and transmission))
(8) Physical Contingency	10% of the direct cost (total cost of preparatory works, environmental cost, civil works, hydro mechanical equipment, electromechanical equipment and transmission)
(9) Interest during construction	10%
(10) Customs duties/VAT	Not considered

6.8.2 Project Cost Estimation

Project cost is estimated as shown in Table 6.8.2-1 based on the conditions mentioned in 6.8.1. See Appendix H for further details.

Table 6.8.2-1 Project Cost

(x 1000USD)

Item	Kalagala Dam	Isimba Dam	Karuma Run of River	Oriang Run of River	Ayago Run of River	Kiba Run of River	Murchison Dam
1. Preparation and Land acquision	17,503	29,391	30,735	52,078	63,811	83,490	42,816
(1) Access road	3,000	15,000	1,000	30,000	45,000	55,000	30,000
(2) Compensation & Resettlment	10,000	10,000	10,000	5,000	5,000	5,000	5,000
(3) Camp & Facilities	4,503	4,391	19,735	17,078	13,811	23,490	7,816
2. Environmental mitigation cost	6,755	6,586	29,602	42,696	34,528	58,724	19,540
3. Civil work	225,155	219,547	986,739	853,915	690,562	1,174,489	390,790
(1) Dam	113,328	147,502	35,954	35,486	29,285	32,652	136,101
(2) Intake	17,310	14,023	9,712	8,954	9,712	9,712	10,339
(3) Headrace	0	0	40,964	51,942	7,086	28,786	21,405
(4) Penstock	0	0	2,235	2,696	1,596	1,416	2,008
(5) Powerhouse	79,845	43,618	34,919	31,530	35,498	31,624	36,197
(6) Transformer Hall	0	0	27,782	25,122	28,243	22,873	28,799
(7) Surge chamber	0	0	0	0	0	0	0
(8) Tailrace tunnel	0	0	769,895	641,760	531,928	979,867	125,983
(9) Outlet	3,950	3,950	2,873	3,173	2,873	2,873	2,873
(10) Access tunnel	0	0	16,741	13,787	12,802	9,848	9,848
(11) Miscellaneous	10,722	10,455	45,665	39,466	31,539	54,839	17,238
4. Hydraulic euipment	43,529	43,529	28,543	28,854	26,937	25,342	34,813
(1) Gate and screen	43,529	43,529	23,617	23,955	23,350	23,084	29,572
(2) Penstock	0	0	4,926	4,899	3,588	2,258	5,241
5. Electro-mechanical equipment	151,800	114,000	241,700	178,700	245,200	146,500	249,100
6. Transmission line	7,812	13,113	390	13,260	17,940	21,840	47,580
Direct cost	452,554	426,166	1,317,710	1,169,503	1,078,978	1,510,385	784,639
7. Administration and Engineering servi	67,883	63,925	197,656	175,426	161,847	226,558	117,696
8. Contingency	45,255	42,617	131,771	116,950	107,898	151,039	78,464
9. Interest during construction	90,511	85,233	329,427	292,376	269,745	377,596	156,928
Total cost	**656,203**	**617,940**	**1,976,565**	**1,754,255**	**1,618,468**	**2,265,578**	**1,137,727**

For the screening of candidate sites, the ranking of A to E has been adopted taking construction costs into consideration.

Table 6.8.2-2 Construction cost

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Construction Cost (MUS$)	656	618	1,977	1,754	1,618	2,266	1,138
Rating	A	A	C	C	C	D	B

6.9 Economic Comparison

Capital cost represent the greater part of the generation cost in conventional hydro power and there is no significant difference in annual cost factor regardless of the actual location of the project site. Therefore, comparison of economic value is judged by using "Construction Cost per kW" and "Generation Cost per kWh".

- Construction Cost per kW（US$/kW）＝Construction Cost（US$）/ Installed Capacity（kW）
- Generation Cost per kWh（US ¢ /kWh）＝Construction Cost（US$）×Annual cost factor / Annual Generation (kWh)

Where;

Annual cost factor = Capital recovery factor: i $(1+i)^t/(1+i)^t-1$+Operation and maintenance cost: 1%

i = Interest rate 10 %　　t = Life time 50 years

Table 6.9-1 shows the unit construction cost (US$/kW) and the generation cost (US ¢ /kWh).

Table 6.9-1 Construction and Generation Cost

Items	Unit	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
		Dam	Dam	Run of River	Run of River	Run of River	Run of River	Dam
Project Evaluation								
Construction Cost	USD/kW	1,989	4,478	3,367	4,475	2,627	7,759	1,737
Generation Cost								
For Firm Energy	Cent/kWh	6.5	14.7	8.7	11.6	6.8	20.0	9.0 *1
For Total Energy	Cent/kWh	4.0	9.1	5.3	7.0	4.1	12.2	5.5 *1

*1 : Cost is based on only night time operation

The following criteria in terms of economic and investment aspects are established.

a: The generation cost of a candidate hydropower project is lower than the average generation price of the existing major thermal power plants(23.25 US cent/kWh).

b: The generation cost of a candidate hydropower project is lower than the export tariff to Kenya.

c: There is a prospect or possibility of funding.

The criteria a and b are established in terms of power project economics. The criterion a considers that, if the generation cost of a hydropower project is higher than that of the existing thermal power plants, it is more economical to adopt thermal power than to construct the hydropower project. The criterion b considers that, unless the generation cost of a hydropower project is lower than the export tariff to Kenya, the most probable export market, the export of electricity is loss making.

The criterion c is related with funding prospect: committed or possible funding from the Uganda government, foreign aid or private sector investment. Such possibility of funding can be a decision factor for investment decision making.

As a result of screening of the candidate hydropower projects against the above criteria, following A to E ranking has been determined taking economic point of view, generation cost and donors' funding possibility into consideration in accordance with economical order.

Table 6.9-2 Rating on Generation Cost

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Generation Cost (cent/kWh)	4.0	9.1	5.3	7.0	4.1	12.2	(5.5)
Rating	A	D	B	C	A	E	B

*: Generation cost of Murchison is estimated on half of its capacity, because generation hour would be half day.

Table 6.9-3 Rating on Financial Negotiation and Close

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Donor	To Be Determined (TBD)	TBD	TBD	TBD	TBD	TBD	TBD
Rating	C	C	C	C	C	C	C

6.10 Environment

6.10.1 Present Condition of Natural Environment

(1) Endangered Species

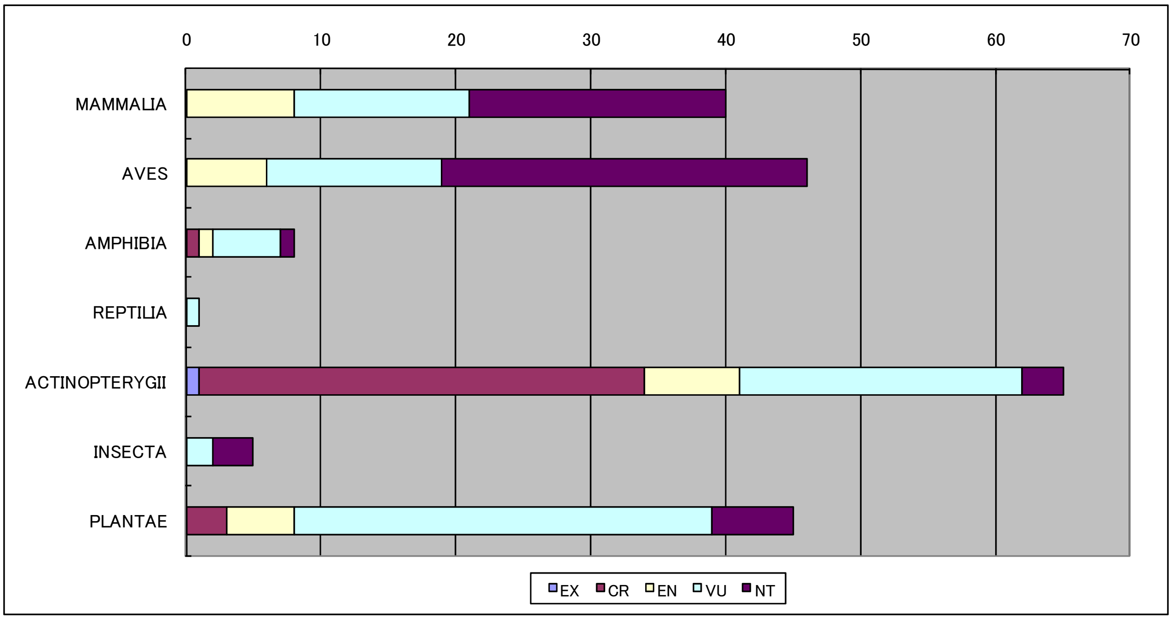
Uganda is one of the species-rich countries in the world, with 315 species of mammals, over 1,000 birds and 1,200 butterflies. The number of IUCN red list species in Uganda is 1,838, including Animalia and Plantae. The number of ACTINOPTERYGII categorized in CR (Critically Endangered) is relatively high. This is considered attributable to the impact on domestic species by Nile perch *(Lates niloticus*) stocked in Lake Victoria. Among mammals, 8 species, including mountain gorilla, are EN (Endangered), and 13 species, including Hippopotamus, are VU (Vulnerable).

Table 6.10.1-1 Number of IUCN Red List species in UGANDA

Kingdom	Class	Red List status*						Total
		EX	CR	EN	VU	NT	LC	
ANIMALIA	MAMMALIA			8	13	19	259	299
	AVES			6	13	27	872	918
	AMPHIBIA		1	1	5	1	52	60
	REPTILIA				1		17	18
	ACTINOPTERYGII	1	33	7	21	3	87	152
	INSECTA				2	3	220	225
	GASTROPODA		2	4	2	6	25	39
	BIVALVIA		1				5	6
	CRUSTACEA			2	2		7	11
PLANTAE			3	5	31	6	65	110
Grand Total		1	40	33	90	65	1,609	1,838

*Extinct (EX); Critically Endangered (CR); Endangered (EN); Vulnerable (VU); Near Threatened (NT); Least Concern (LC)

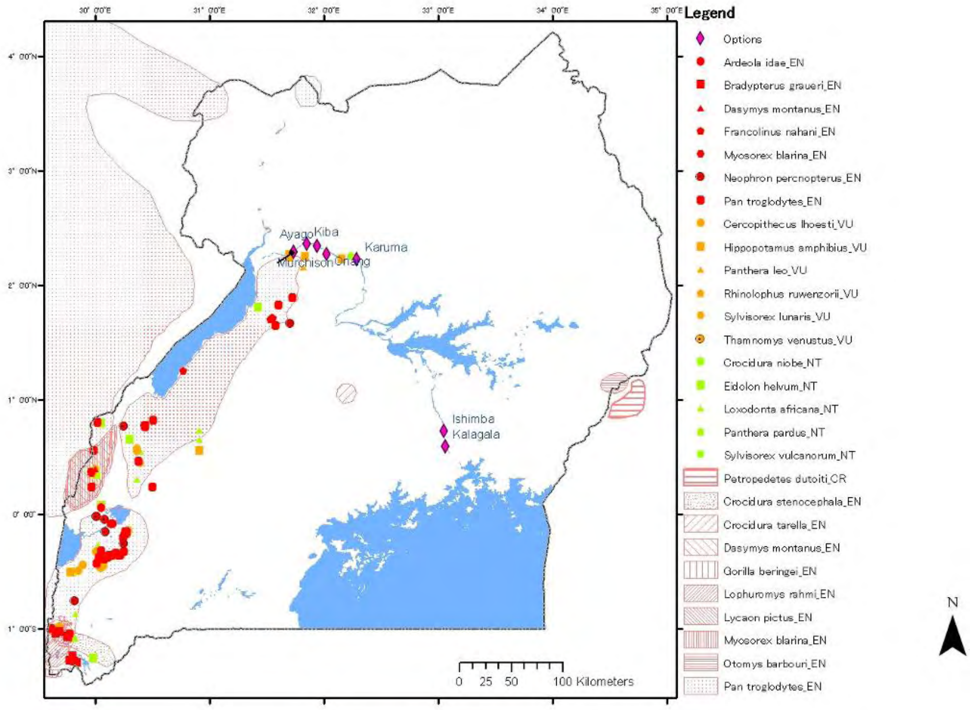
(Source: IUCN Web site (http://www.iucnredlist.org/))



(Source: IUCN Web site (http://www.iucnredlist.org/))

Figure 6.10.1-1 Number of IUCN Red List species in UGANDA

In terms of Mammal and Amphibian, the distribution of EN, VU, and NT of IUCN red list species are mainly concentrated around the lakes on the western side of the country.

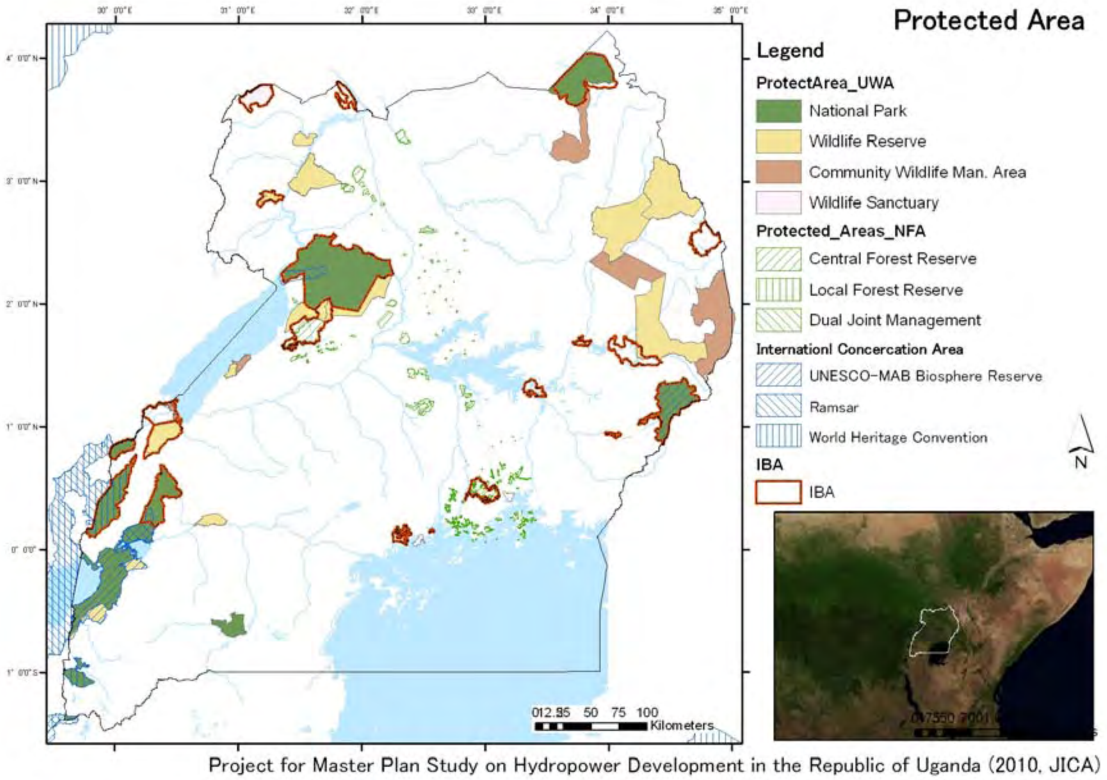


(Source: IUCN Web site (http://www.iucnredlist.org/))

Figure 6.10.1-2 Distribution of endangered species (Mammal and Amphibian)

(2) Protected Area

Many kinds of protected areas, such as national parks, Wildlife Reserves, and Community Wildlife Management Areas, are in Uganda. The largest national park is Murchison Falls National Park, which is 3,867km^2, the same size as Saitama Prefecture (see Figure 6.10.1-3).



Source: World Database on Protected Areas (http://www.wdpa.org)/ National Forest Authority Uganda/ Nature Uganda (JICA revised)

Figure 6.10.1-3 Protected Area in UGANDA

Table 6.10.1-2 Protected area designated by Government of Uganda

<table>
<tr><th colspan="3">Name of the protected area</th><th>Law</th><th>Management Organization</th><th>Definition / Purposes</th><th>Prohibited Action</th><th>Allowed Action</th></tr>
<tr><td rowspan="4">Wildlife Conservation Areas</td><td rowspan="2">Wildlife Protected Area</td><td>National Park</td><td>Uganda Wildlife Act 1996</td><td>Uganda Wildlife Authority (UWA)</td><td rowspan="2">(a) to preserve selected examples of the biotic communities of Uganda and their physical environments;
(b) to protect areas of aesthetic beauty and of special interest;
(c) to preserve populations of rare, endemic and endangered species of wild plants and animals;
(d) to assist in water catchment conservation;
(e) to generate economic benefits from wildlife conservation for the people of Uganda;
(f) without prejudice to the purposes listed in paragraphs (a) to (d), of this subsection, and within any limitations imposed by them, to provide facilities for studying the phenomena in the wildlife conservation area for the advancement of science and understanding; and
(g) without prejudice to the purposes listed in paragraphs (a) to (e), of this subsection, and within any limitations imposed by them, to provide facilities for public use and enjoyment of the resources in the wildlife conservation area.</td><td rowspan="4">(a) hunts, takes, kills, injures or disturbs any wild plant or animal or any domestic animal;
(b) takes, destroys, damages or defaces any object of geomorphological, archaeological, historical, cultural or scientific interest, or any structure lawfully placed or constructed;
(c) prepares land for cultivation, prospects for minerals or mines or attempts any of these operations;
(d) drives, conveys or introduces any wild animal into a wildlife conservation area;
(e) wilfully drives, conveys or introduces any domestic animal into a national park or negligently permits any domestic animal, of which he or she is for the time being in charge, to stray into a wildlife conservation area;
(f) starts or maintains a fire without lawful authority, commits an offence.</td><td>(a) biodiversity conservation;
(b) recreation;
(c) scenic viewing;
(d) scientific research; and
(e) any other economic activity.</td></tr>
<tr><td>Wildlife Reserve</td><td>Uganda Wildlife Act 1996</td><td>Uganda Wildlife Authority (UWA)</td><td>(a) conservation of biological diversity;
(b) scenic viewing;
(c) recreation;
(d) scientific research; and
(e) regulated extractive utilisation of natural resources.</td></tr>
<tr><td rowspan="2">Wildlife Management Area</td><td>Wildlife Sanctuary</td><td>Uganda Wildlife Act 1996</td><td>Uganda Wildlife Authority (UWA)</td><td rowspan="2">(a) to so manage and control the uses of land by the persons and communities living in the area that it is possible for wildlife and those persons and communities to coexist and for wildlife to be protected;
(b) to enable wildlife to have full protection in wildlife sanctuaries notwithstanding the continued use of the land in the area by people and communities ordinarily residing there;
(c) to facilitate the sustainable exploitation of wildlife resources by and for the benefit of the people and communities living in the area;
(d) to permit the sustainable exploitation of the natural resources of the area, by mining and other like methods in a manner which is compatible with the continued presence in the area of wildlife;
(e) to carry out such of the purposes of a wildlife conservation area as are compatible with the continued residence of people and communities in the wildlife management area and the purposes under paragraphs (a) and (b) of this subsection.</td><td>Activities which are not going to be destructive to the protected species or its habitat</td></tr>
<tr><td>Community Wildlife Area</td><td>Uganda Wildlife Act 1996</td><td>Uganda Wildlife Authority (UWA)</td><td>individuals who have property rights in land may carry out activities for the sustainable management and utilisation of wildlife if the activities do not adversely affect wildlife</td></tr>
</table>

Name of the protected area	Law	Management Organization	Definition / Purposes	Prohibited Action	Allowed Action
Central Forest Reserve	National Forestry Tree Planting and Tree Planting Act	National Forest Authority (NFA)	A Forest Reserve is an area of land designated for development of forests or tree growing activities.	Habitation (?)	Various areas are gazzetted as CFRs for different purposes including conservation of biodiversity and critical habitats, protection of water catchments, environment protection and production in terms of goods and services.
Local Forest Reserve	Forest Policy (2001)	Local Government			
Dual Joint Management Reserve		National Forest Authority (NFA)			

Table 6.10.1-3 Definition of International Conservation Area

Name of the protected area	Programme/ Convention	Related Organization	Definition
UNESCO-MAB Biosphere Reserve	Man and the Biosphere Programme	UNESCO/ UWA	* Sites of excellence where new and optimal practices to manage nature and human activities are tested and demonstrated; * Tools to help countries implement the results of the World Summit on Sustainable Development and, in particular, the Convention on Biological Diversity and its Ecosystem Approach; * Learning sites for the UN Decade on Education for Sustainable Development.
World Heritage Convention	-	UNESCO/ UWA	Natural Criteria (i) "contains superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance" (ii) "is an outstanding example representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features" (iii) "is an outstanding example representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems, and communities of plants and animals" (iv) "contains the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation"
Ramsar	The Convention on Wetlands (Ramsar, Iran, 1971)	Wetlands Management Department (WMD)	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Important Bird Areas (IBA)	-	Bird Life International	IBAs are key sites for conservation – small enough to be conserved in their entirety and often already part of a protected-area network. They do one (or more) of three things: •Hold significant numbers of one or more globally threatened species •Are one of a set of sites that together hold a suite of restricted-range species or biome-restricted species •Have exceptionally large numbers of migratory or congregatory species

6.10.2 Environmental and Social Impacts of Candidate Hydropower Projects

Environmental and Social impact on each candidate project is evaluated by quantitative assessment based on the collected data such as length of recession and protected area. The evaluations are ranked as A: Negligible Impacts, B: Minor Impacts, C: Moderate Impacts, D: Major Impacts, E: Catastrophic Impacts.

(1) Environmental Aspect

1) Length of Water Recession

The evaluation of water recession was based on the distance of water recession. The ratings of Kalagala and Isimba are "A" because there is no water recession. The rating of Kiba is "E" because the length of water recession is more than 15 km.

Table 6.10.2-1 Length of Water Recession

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Length of water recession (km)	0	0	14.5	13.4	8.8	16.7	4.4
Rating	A	A	D	D	C	E	B

2) Rate of Recession

The rates of water recession were evaluated by the percentage of recession based on the brief design. The ratings of Kalagala and Isimba are "A" because of no water recession. The other projects have "D" because their recession rates are 89%, which is the rate for the amenity flow (50m^3/s) to the dependable discharge (470m^3/s).

Table 6.10.2-2 Rate of Recession

	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Rate of recession (%)	0	0	89	89	89	89	89
Rating	A	A	D	D	D	D	D

3) Impact on Protected Area

Impact on protected area was evaluated based on the number of protected areas which are affected and the extent of its impact; in other words, either the project area covers protected areas partially or it covers fully. The rating of Karuma is "B" because a part of the project area is inside the wildlife reserve. The rating of Murchison is "E" because the project area is inside three protected areas, the National Park, the Ramsar site, and the Important Bird Area.

Table 6.10.2-3 Impact on Protected Area

Evaluation items	Uganda							International				Rating
	National Park	Wildlife Reserve	Community Wildlife Management Area	Wildlife Sanctuary	Central Forest Reserve	Local Forest Reserve	Dual Joint Management Reserve	UNESCO-MAB Biosphere Reserve	World Heritage Convention	Ramsar	IBA	
Kalagala					X						X	C
Isimba					X						X	C
Karuma		X										B
Oriang	XX	X									XX	D
Ayago	XX	X									XX	D
Kiba	XX	X									XX	D
Murchison	XX									XX	XX	E

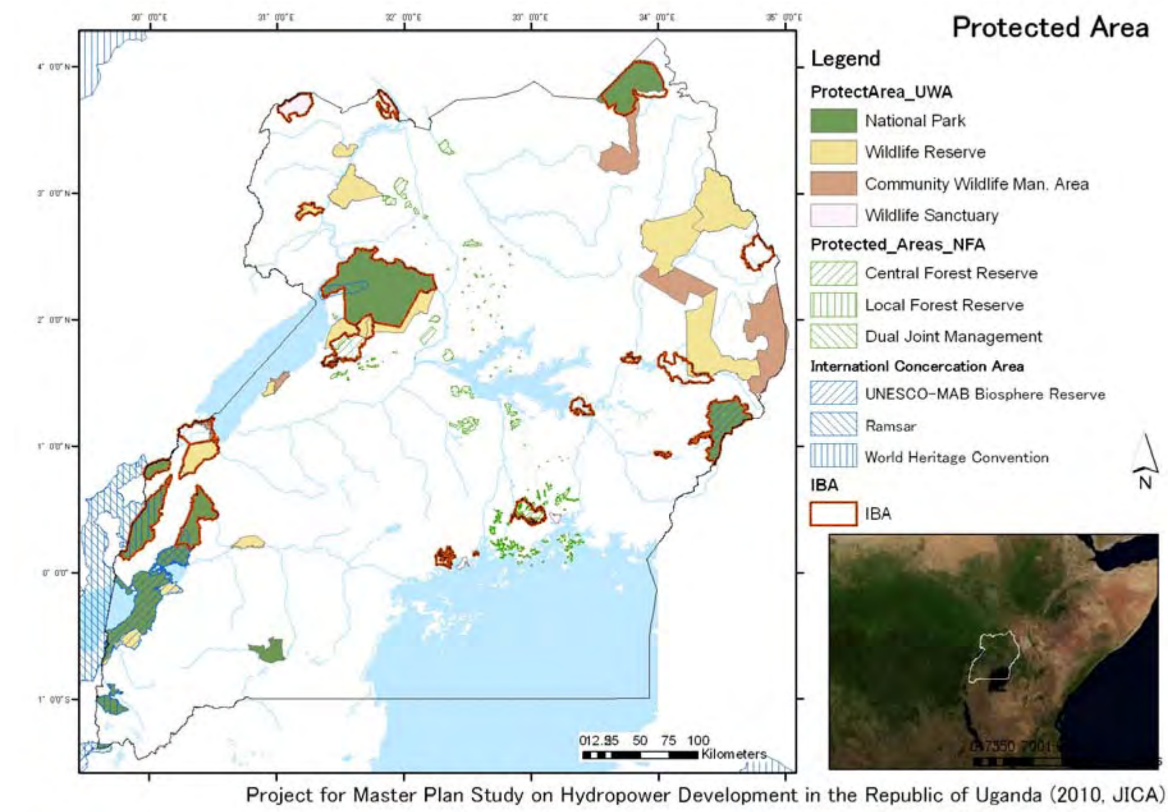


Figure 6.10.2-1 Protected Area

4) Impact on Wetlands

Impact on wetlands was evaluated by how much the wetland area in the land use map is covered by the affected area (1 km buffer from the project area). Rating of Karuma is "C" because 63.28 km^2 of the wetland area is covered. The ratings of the other projects are "A."

Table 6.10.2-4 Impact on Wetlands

Type	Wetland (km^2)	Rating
Kalagala	0	A
Isimba	0.16	A
Karuma	63.28	C
Oriang	0.06	A
Ayago	0.04	A
Kiba	0.02	A
Murchison	0.05	A

5) Impact on Endangered Species

Impact on endangered species was evaluated by the overlay of the distribution map of IUCN red list species and the map of project areas. The number of species on IUCN red list in Uganda is 1,823 in January 2010. However, UWA recorded only 51 species, which account for 3% of the 1,823 (See Table 6.10.2-5).

Table 6.10.2-5 Number of the IUCN Red List Species in Uganda

IUCN Category	Number of species on the list in Uganda	Number of the species which have information of distribution
CR – Critically Endangered	32	1
EN – Endangered	40	13
VU – Vulnerable	90	8
LR/cd – Lower Risk: Conservation Dependent	1	0
NT or LR/nt – Near Threatened	67	6
D/D – Data Deficient	45	0
LC or LR/lc – Least Concern	1548	23

Impact on each species was evaluated as “XX” when the project is inside the distribution area, “X” when the project is near the distribution area. Ratings of Isimba and Kalagala are “A” because of no affected species. Rating of Murchison and the others are “E,” because many26 endangered species may be affected.

Table 6.10.2-6 Habitat of Red List Species and Projects

Common names (Eng)	Red List status	Information Source				Projects						
		Polygon by IUCN	Ranger Survey (1988-2009)	Aerial survey (2005)	Point by UWA (1897-2007)	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Du Toit's Torrent Frog	CR	*										
Madagascar Pond-heron	EN				*							
Grauer's Swamp-warbler	EN				*							
Nahan's Francolin	EN				*							
Egyptian Vulture	EN				*							
Kahuzi Swamp Shrew	EN	*										
Ugandan Shrew	EN	*										
Montane Shaggy Rat	EN	*			*							
Mountain Gorilla	EN	*			*							
Rahm's Brush-furred Rat	EN	*										
African Wild Dog	EN	*										
Montane Mouse Shrew	EN	*			*							
Barbour's Vlei Rat	EN	*										
Chimpanzee	EN	*			*						X	X
Shoebill	VU		*									
Crested Crane	VU			*								
Mountain Monkey	VU				*							
Hippopotamus	VU		*	*	*			X	XX	XX	XX	XX
Lion, African Lion	VU		*		*			XX			XX	XX
Ruwenzori Horseshoe Bat	VU				*							
Crescent Shrew	VU				*							
Charming Thicket Rat	VU				*							
Stony Shrew	NT				*							
Straw-coloured Fruit Bat	NT				*							
Hyena	NT		*					X	X	X	X	X
African Elephant	NT		*	*	*			X	XX	XX	XX	XX
Leopard	NT		*		*			XX		XX	XX	XX
Volcano Shrew	NT				*							
Ground Hornbill	LC		*					XX	X	XX	X	XX
Saddle-billed Stork	LC		*		*					X		X
Fish Eagle	LC		*	*	*							XX
Great Cormorant	LC		*		*			X				
Hartebeest	LC		*	*	*			XX	XX	XX	XX	XX
Porcupine	LC		*									
Blue Duiker	LC		*	*	*			XX	XX	XX	XX	XX
Red-tailed Monkey	LC		*		*				X	X	X	X
Vervet Monkey	LC		*		*			XX	XX			X
Colobus (BW)	LC		*		*			XX	XX	XX	XX	XX
Giraffe	LC		*	*	*			XX	XX	XX	XX	XX
Waterbuck	LC		*	*	*			XX	XX	XX	XX	XX
Ugandan kob	LC		*	*	*			XX	XX	XX	XX	XX
Oribi	LC		*	*				XX	XX	XX	XX	XX

Common names (Eng)	Red List status	Information Source				Projects						
		Polygon by IUCN	Ranger Survey (1988-2009)	Aerial survey (2005)	Point by UWA (1897-2007)	Kalagala	Isimba	Karuma	Oriang	Ayago	Kiba	Murchison
Baboon	LC		*	*	*			XX	XX	XX	XX	XX
Warthog	LC		*	*	*			XX	XX	XX	XX	XX
Bushpig	LC		*	*				XX	X	XX	X	X
Bohor Reedbuck	LC		*	*	*			XX				XX
Buffalo	LC		*	*	*			XX	XX	XX	XX	XX
Bushbuck	LC		*	*	*			XX	X	XX	XX	XX
Sitatunga	LC		*						XX	X	X	X
Crocodile	LC		*					XX			XX	XX
Monitor Lizard	LC		*					XX				
Number of species	CR					0	0	0	0	0	0	0
	EN					0	0	0	0	0	1	1
	VU					0	0	2	1	1	2	2
	NT					0	0	3	2	3	3	3
	LC					0	0	18	16	16	16	20
	Total					0	0	23	19	20	22	26
Rating						A	A	DE	DE	DE	DE	E

X: Project is near the habitat XX: Project is in the habitat

6) Recession of Underground Water

Recession of underground water was evaluated by the length of the tail race tunnels, because it is caused by tunnel excavation. The ratings of Kalagala and Isimba are A because of no tunnel excavation. The rating of Kiba is E because of long tail race tunnel.

Table 6.10.2-7 Impact on Underground Water

Projects	Length of tail race tunnel (km)	Rating
Kalagala	0	A
Isimmba	0	A
Karuma	11	D
Oriang	11	D
Ayago	7	C
Kiba	14	E
Murchison	2	B

7) CO_2 Emission from the Reservoirs

The amount of CO_2 emission from the reservoirs was calculated by the basic unit, which is 4,000 mg (m^2/day). The rating of Isimba is “E” because of large reservoir. The ratings of Karuma, Oriang, Ayago, and Kiba are “A” because of run-off river type.

Table 6.10.2-8 CO_2 emission form the reservoirs

Projects	Riverbed Area (km^2)	CO_2 (t/day)	Rating
Kalagala	9.4	37.6	D
Isimmba	11.8	47.2	E
Karuma	0.03	0.12	A
Oriang	0.03	0.12	A
Ayago	0.03	0.12	A
Kiba	0.03	0.12	A
Murchison	3.3	13.2	C

(2) Social Aspects

1) Land acquisition

Land acquisition was evaluated by the necessary size of the area for spoil bank, temporary facility, inundation, transmission tower, and ROW for transmission lines. The rating of Karuma is A because of no transmission line and no private land acquisition. The ratings of Kalagala and Isimba are "E" because of larger inundation area. Although land acquisition will not be need for National Park, EIA procedure based on Uganda Wildlife Act (1996) will be needed. Payment of land use in National Park to UWA might be needed during construction and operation (see Box.6.10.2-1).

Table 6.10.2-9 Needed land for the projects

Items	Land acquisition					ROW for Transmiss ion Line	Rank
	Spoil Bank	Temporary Facility Area	Inundation area	Transmission Towers	Total		
	m^2	m^2	m^2	m^2	m^2	m^2	
Kalagala	65,000	60,000	3,400,000	9,300	3,534,300	1,120,000	E
Isimba	54,000	60,000	6,600,000	15,600	6,729,600	1,880,000	E
Karuma	697,000	60,000	30,000	0	787,000	0	BA
Oriang	605,000	60,000	30,000	11,300	706,300	2,040,000	CB
Ayago	484,000	60,000	30,000	15,300	589,300	2,760,000	CB
Kiba	849,000	60,000	30,000	18,600	957,600	3,360,000	CB
Murchison	197,000	60,000	2,400,000	40,600	2,697,600	7,320,000	D

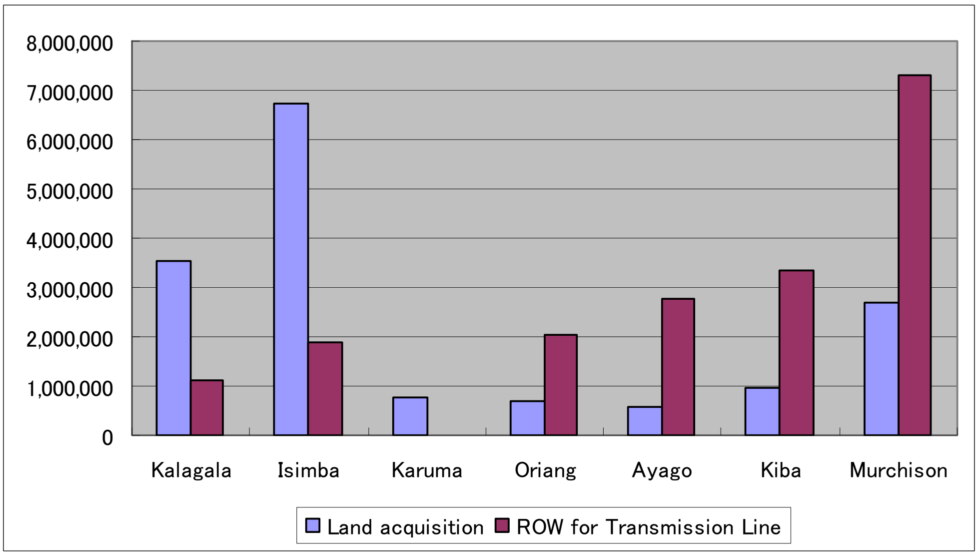


Figure 6.10.2-2 Area of land acquisition and ROW for new transmission line

Box.6.10.2-1 Procedure of unlawful act in a wildlife conservation area

24. Authority to carry out an otherwise unlawful act in a wildlife conservation area.

(1) If the executive director is satisfied that an otherwise unlawful act specified by this Act should be carried out in any wildlife conservation area in the interests of better wildlife management, he or she shall require an environmental impact assessment to be carried out on the subject and shall submit the results of the environmental impact assessment to and request the opinion of the board.

(2) If the board, having considered any matter submitted by the executive director under subsection (1), is of the opinion that an otherwise unlawful act should be carried out in the interest of better wildlife management, it shall issue written instructions to any officer or person authorizing him or her to undertake the otherwise unlawful act.

(3) The board may, at any time delegate, in writing, to the executive director, power to permit certain acts covered by this section which are determined by the board to be of a minor character.

(Source: Uganda Wildlife Act, 1996)

2) Inundation area

Inundation area was evaluated by the riverbed area, which is calculated by subtracting acquisition area from reservoir area. The ratings of Karuma, Oriang, Ayago, and Kiba are “A” because of no reservoir area. The rating of Isimba is “E” because of larger reservoir area.

Table 6.10.2-10 Inundated Area

Project	Riverbed Area (km^2)	Acquisition Area (km^2)	Reservoir Area (km^2)	Rating
Kalagala	6.00	3.40	9.40	D
Isimmba	5.20	6.60	11.80	E
Karuma	0.00	0.03	0.03	A
Oriang	0.00	0.03	0.03	A
Ayago	0.00	0.03	0.03	A
Kiba	0.00	0.03	0.03	A
Murchison	0.90	2.40	3.30	C

3) Affected people

Impact on affected people was evaluated by the number of households for resettlement and the estimated population within a 1 km buffer from the project area. 1km is defined as the area which may get damage on people's lifestyle by noise, vibration and dust. The ratings of Oriang, Ayago, Kiba, and Murchison are "A", since they are inside the National Park. The ratings of Kalagala and Karuma are "D" because of the larger number of resettlement and population.

Table 6.10.2-11 Number of Affected People

Projects	Resettlement	Population Within 1km [6]	Remarks	Rating
Kalagala	165 household [7]	36,145		D
Isimba	26 household	49,744		E
Karuma	200 [8] (people)	33,015	Resettlement has been finished.	D
Oriang	0	4,854		A
Ayago	0	5,049		A
Kiba	0	5,434		A
Murchison	0	1,890		A

4) Impact on Ethnic Minority

Impact on ethnic minorities was evaluated by the number of ethnic groups which are affected by the project and the types of impact, because it is difficult to define which ethnic groups are minorities. The ratings of Oriang, Ayago, Kiba, and Murchison are "B" because they are located in the National Park. The rating of Karuma is "D" since many ethnic groups can be affected.

Table 6.10.2-12 Impact on Ethnic Group

Projects	Ethnic Group	Affected by the project	Rating
Kalagala	Basoga, Banyole, Jopadhola, Basamia, Bagwere, Iteso, Baganda, Bagisu	Resettlement, Loss of farm land, Noise, Vibration, Dust	C
Isimba	Basoga, Jopadhola, Baganda, Bagisu, Ik-teuso, Iteso, Bakenyi, Banyole, Lugbara, Basamia, Bagwere	Resettlement, Loss of farm land, Noise, Vibration, Dust	C
Karuma	Acholi, Iteso, Kumam, Banyakole, Bagungu, Alur, Chope, Baruli, Langi, Kuku, Lugbara, Jonam, Babwisi, Bagisu, Basamia, Banyarwanda, Karimojongo, Madi, Banyoro, Ik-teuso, Babukusu, Baganda, Kebu-okebu	Resettlement, Loss of farm land, Noise, Vibration, Dust	D
Oriang	Acholi, Iteso, Alur, Chope, Langi, Lugbara, Jonam, Babwisi	Hunting might be affected	B
Ayago	Acholi, Lugbara, Jonam, Chope, Langi, Iteso, Alur, Bafumbira, Babwisi	Hunting might be affected	B
Kiba	Acholi, Jonam, Chope, Langi, Iteso, Alur, Bafumbira, Banyakole, Lugbara, Bakiga, Bakhonzo, Kakwa, Babwisi	Hunting might be affected	B
Murchison	Acholi, Madi, Banyoro, Jonam, Langi, Alur, Bafumbira, Banyakole, Iteso, Lugbara, Bakiga, Bakhonzo, Kakwa, Baamba, Babwisi, Chope, Lendu, Baganda	Hunting might be affected	B

5) Impact on Fisheries

Impact on fisheries was evaluated by the fishery activity around the project area. The rating of Karuma is “B” because of the existence of small scale fishery. The ratings of the others are “A” because of no fishery activities.

Table 6.10.2-13 Impact on fish breeding and/or fishing

Projects	Fish breeding	Fishing	Rating
Kalagala		-	A
Isimba		-	A
Karuma	-	Small Scale Fishing	B
Oriang	-	-	A
Ayago	-	-	A
Kiba	-	-	A
Murchison	-	-	A

6) Impact on Agriculture

Impact on agriculture was evaluated by the agricultural area within a 1 km buffer from the project area. The ratings of Oriang, Ayago, Kiba, and Murchison are “A” because of no farmland. The rating of Karuma is “E.”

Table 6.10.2-14 Direct and Indirect Impact on Agriculture

Type	Subsistence Farmland(km²)	Subsistence Farmland (Permanently wet) (km²)	Subsistence Farmland (Seasonally wet) (km²)	Commercial Farmland(km²)	Rating
Kalagala	54.95	0.00	20.59	2.13	C
Isimba	78.27	0.10	25.96	2.55	D
Karuma	140.27	0.00	14.06	0.00	E
Oriang	21.17	0.00	0.14	0.00	A
Ayago	21.84	0.00	0.20	0.00	A
Kiba	22.49	0.00	0.29	0.00	A
Murchison	26.78	0.00	0.00	0.00	A

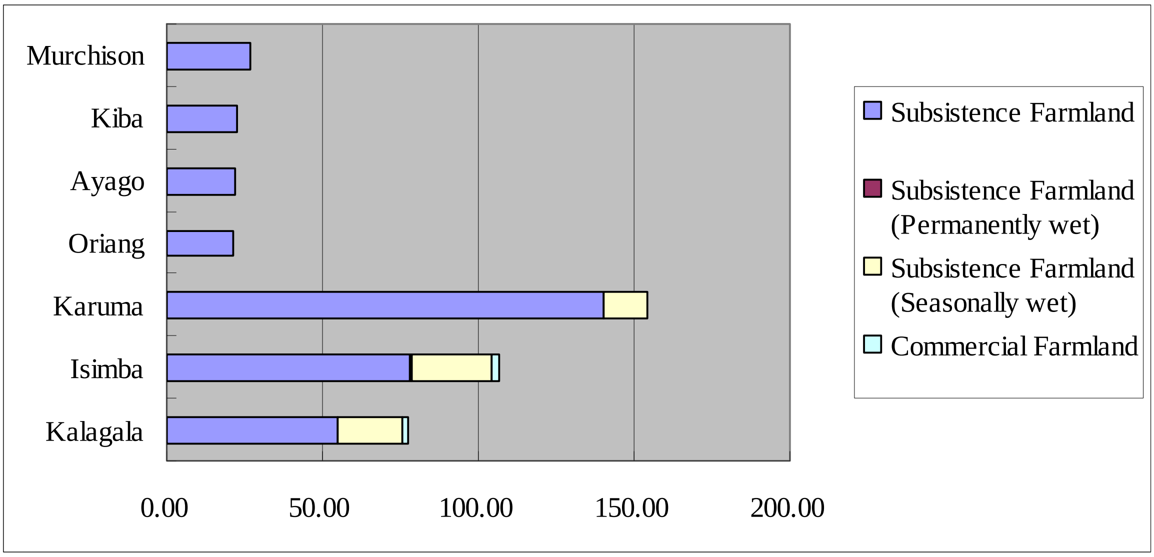


Figure 6.10.2-3 Impact on Agricultural Land

7) Impact on historical and cultural properties

Impact on historical and cultural properties was evaluated by their existence and the impact on them. The ratings of Isimba, Oriang, Ayago, and Kiba are “A” because of no existence and no impact. The rating of Kalagala is “E” because of Kalagala shrine and Itanda Falls.

Table 6.10.2-15 Impact on Cultural Property

Project	Cultural Property	Impact	Rating
Kalagala	Kalagala shrine Itanda Falls	XXX XXX	E
Isimba	Mbuiamuti Landing Site	-	A
Karuma	Karuma Falls	XXX	D
Oriang	-	-	A
Ayago	-	-	A
Kiba	-	-	A
Murchison	Murchison Falls	-	C

8) Impact on tourism potentials

Impact on tourism potentials was evaluated by their existence and the impact on them. The rating of Isimba is “A” because of no tourism potential. The ratings of Kalagala and Murchison are “E” because of serious damage on the tourism potentials.

Table 6.10.2-16 Impact on Tourism

Project	Nature observation	Sight seeing	Sports and relaxing	Rating
Kalagala	-	Itanda falls XXX	XX (Rafting)	E
Isimba	-	-	-	A
Karuma	X	Karuma Falls XXX	-	C
Oriang	National Park XX	-	-	D
Ayago	National Park XX	-	-	D
Kiba	National Park XX	-	-	D
Murchison	National Park XXX	Murchison Falls XX	X (Fishing)	E

9) Impact on current tourism

Impact on current tourism was evaluated by the types of tourism, tourism facilities, and the number of tourists. The rating of Isimba is “A” because of no existing tourism. The ratings of Kalagala and Murchison are “E” because of active tourism such as rafting and safari.

Table 6.10.2-17 Impact on Tourism

Project	Interest on tourism	Tourism Facility	Number of the tourists	Rating
Kalagala	Itanda falls, Rafting	Rafting business, Lodge	XXX	E
Isimba	-	-	-	A
Karuma	Karuma Falls		X	B
Oriang	National Park	Safari Tour, Chobe Lodge	X	B
Ayago	National Park	Safari Tour, Chobe Lodge	X	B
Kiba	National Park	Safari Tour, Chobe Lodge	X	B
Murchison	National Park	Safari Tour, Parra Lodge	XXX	E

10) Impact on existing infrastructure

Impact on existing infrastructure was evaluated by the number of the roads within 1 km buffer from the project area. The ratings of Oriang, Ayago, and Kiba are “A” because of no existing roads. The rating of Karuma is “D” because of 7 roads can be affected.

Table 6.10.2-18 Impact on Existing Road

Projects	Number of affected Road	Rating
Kalagala	3	C
Isimba	4	C
Karuma	7	D
Oriang		A
Ayago		A
Kiba		A
Murchison	1	B

11) Impact on landscape

Impact on landscape was evaluated by the existence of attractive landscape and impact on them. The rating of Isimba is “A” because of no attractive landscape. The ratings of Kalagala and Murchison are “E” because of famous landscape known as Kalagala Falls and Murchison Falls.

Table 6.10.2-19 Impact on landscape

Evaluation items	Attractive landscape	Impact	Rating
Kalagala	Kalagala Falls	XXX	E
Isimba			A
Karuma	Karuma Falls	XXX	D
Oriang	Natural landscape	XX	C
Ayago	Natural landscape	XX	C
Kiba	Natural landscape	XX	C
Murchison	Murchison Falls, Natural landscape	XXX	E

12) Impact on human health

Impact on human health was evaluated by the size of population within 1 km from the project, the sources of drinking water, and the type of toilet. The ratings of Oriang, Ayago, Kiba, and Murchison are “A” because of better hygienic environment and smaller population. The rating of Karuma is “D” because of the higher dependence rate of rain water for drinking.

Table 6.10.2-20 Impact on Health Hazard

Evaluation items	People in affected area	Dependence rate of rain water for drinking	Rate of uncovered pit latrine and no toilet	Rating
Kalagala	36,145	1.5%	23.4%	C
Isimba	49,744	1.4%	22.6%	C
Karuma	33,015	3.2%	44.1%	D
Oriang	4,854	0.9%	28.8%	A
Ayago	5,049	0.8%	28.7%	A
Kiba	5,434	0.8%	27.0%	A
Murchison	1,890	1.0%	30.2%	A

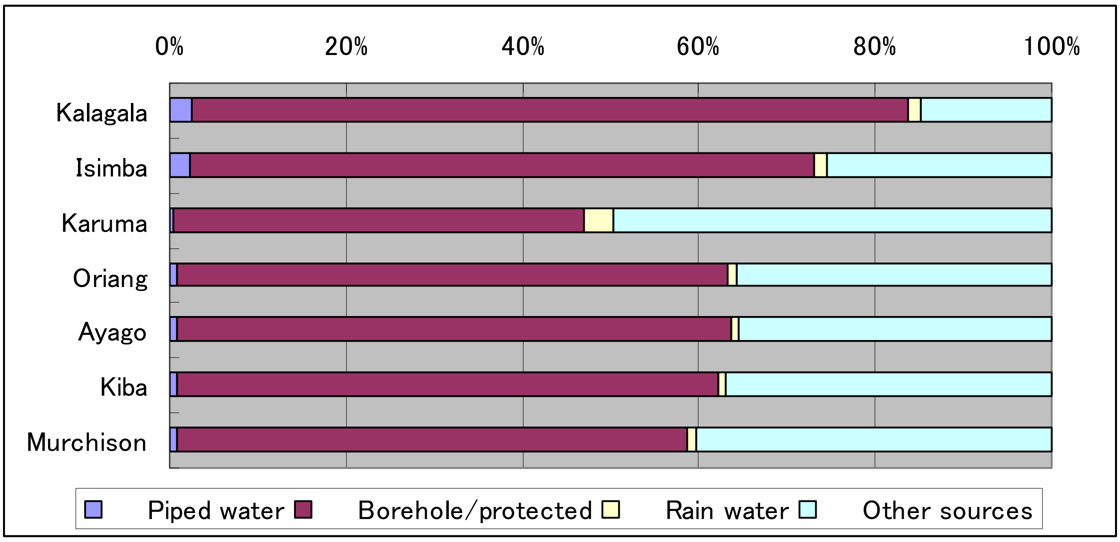


Figure 6.10.2-4 Source of drinking water

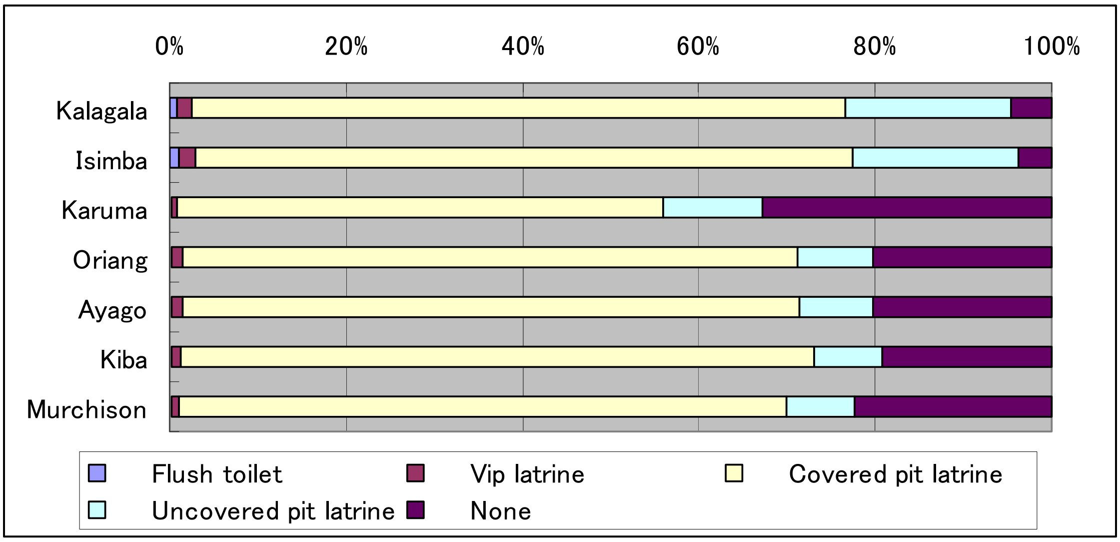


Figure 6.10.2-5 Type of toilet

6.11 General Evaluation of the Candidate Projects

6.11.1 Weighting of the Evaluation Criteria for the Candidate Projects

Multi Criteria Decision Analysis was conducted for the comparative evaluation of the candidate projects. The evaluation criteria included economic and technical aspects such as development cost and geological condition, environmental aspects such as length of water recession and impact on protected area, and social aspects such as resettlement and impact on tourism. The total number of criteria was 33. All candidate projects were evaluated from A to E by all criteria. The evaluations from A to E were converted from 5 to 1, multiplied by the weights, and summed up by the projects. For sensitivity analysis, four cases of weightings were applied: even case, environmental weighting case, social weighting case, and economic weighting case. The evaluated general ranking from A to C based on the total points by project are not a absolute ranking. They are relative ranking which means rank A is better than the others, rank B is middle and rank C is worse than the others. The evaluation items and weightings are shown in the table below.

Table 6.11.1-1 Evaluation Items and weighting

Evaluation items			Even Case			Environmental weighting case			Social weighting case			Economic Werighting Case		
Economic and technical	Cost	Construction Cost (MUS$)	34	9	2	30	8	2	30	8	2	40	11	3
		Generation Cost (cent/kWh)			7			6			6			8
	Effectiveness	Maximum Power (MW)		19	5		17	4		17	4		22	5
		Construction time (year)			2			2			2			2
		Head (m)			2			2			2			2
		Distance to load center or existing grid (km)			2			2			2			3
		Length of Waterway			1			1			1			1
		Geological Condition			2			1			1			3
		Excavation Volume			1			1			1			1
		Construction material (availability)			1			1			1			1
		Accessibility			2			2			2			3
		Loss of transmission			1			1			1			1
	Development progress	Lead Time		6	5		5	4		5	4		7	6
		Financial Negotiation and close			1			1			1			1
Environment	Length of water recession (km)		33		4	40		6	30		5	30		5
	Rate of recession (%)				3			4			2			2
	Impact on Protected area				7			8			7			7
	Impact on wetland				3			4			2			2
	Impact on protected species				7			8			7			7
	Degradation of underground water				4			4			2			2
	CO_2 emission from the reservoir				5			6			5			5
Social	Land acquisition		33		4	30		2	40		4	30		2
	Flooding area				2			2			4			2
	Number of affected people				4			3			4			3
	Impact on ethnic minority and indigenous people				1			2			2			2
	Impact on fish breading and/or fishing				1			2			2			2
	Impact on Agriculture				1			2			2			2
	Impact on cultural property				2			2			2			2
	Impact on tourism potential				6			5			7			5
	Impact on current tourisum				7			6			5			6
	Impact on existing infrastructure				1			1			2			1
	Impact on landscape				3			2			4			2
	Human health hazard				1			1			2			1

6.11.2 General evaluation of the Candidate Projects

The outline of each candidate projects is mentioned below.

1) Kalagala

The Economic and technological aspects of the Kalagala project are relatively better because the construction cost is as low as 638 MUS$ while the generation cost is 3.3 cents/kWh. The environmental aspects are also better because the impact on the protected area and important species is not so serious. On the other hand social implications are not so good because the submerged farmland would be as large as 55 km^2. Impacts on cultural resources such as Kalagala shrine and Itanda Falls are anticipated and rafting business as well as existing lodges may also be affected.

2) Isimba

The Economic and technological aspects of Isimba project are relatively better because the construction cost is low (601 MUS$) and excavation volume is small (824 m3). Environmental aspects are also good because there is no recession area and the impact on protected species is smaller. On the other hand, social aspects are not so good because the farmland within 1km from the project site is relatively large (78 km^2) and population within 1km from the project site is estimated to be big (50,000).

3) Karuma

The Economic and Technical aspects of Karuma project are better because generation cost is low (4.2 cent/kWh), and access to road is good. Environmental aspects are better because part of the project site is out of National Park although recession are is 14.5 km and 23 IUCN red list species will be affected. On the other hand, social aspects are not so good because agricultural land of 1km within the project site is relatively large (140 km^2) and the population within 1km from the project site is estimated to be approximately 30,000.

4) Oriang

The Economic and Technical aspects of Oriang project are not so good because the penstock is long (12 km) and generation cost is high (5.8 cent/kWh). In addition, environmental aspects are also bad because of the long recession area (13km), the fact that 19 IUCN Red List species might be affected and that the whole project site is in the National Park. On the other hand, social aspects are better because farmland within 1km from the project area is relatively small (21 km^2) and the impact on cultural resources is also small.

5) Ayago

The Economic and technical conditions of Ayago project are good because the head is 83m and transmission loss is relatively low (56%). On the other hand, the environmental conditions are not good because of long recession area (8.8km), possible impact on 20 IUCN Red List species and impact on the National Park. Social conditions are good because of limited impact on existing infrastructure, agriculture and fishery.

6) Kiba

The economic and technical conditions of Kiba are bad because the generation cost is high (9.5 cent/kWh) and the penstock is long (14km). Environmental conditions are also bad because recession area is long (16.7 km), 22 IUCN Red List species might be affected and whole project site is in the National Park. Social conditions are good because of limited impact on existing infrastructure, agriculture and fishery.

7) Murchison

The Economic and technical conditions of Murchison are good because maximum power is big (655 MW) and construction materials are available. But environmental conditions are bad because 26 IUCN Red List species might be affected and both National Park and Ramsal area will be affected. Social conditions are also bad because of the impact on existing tourism such as that in Murchison Falls and Parra lodge, Safari tours, boat riding, and sports fishing.

As a result of weighting and summing up all items by the projects, the general evaluations showed that Ayago, Isimba, and Karuma have relatively higher score than the other projects. The evaluations do not mean absolute results but relative results. High evaluation does not mean no problems on all items but means relatively higher than the other projects. The remained problems are shown in the section 6.10.

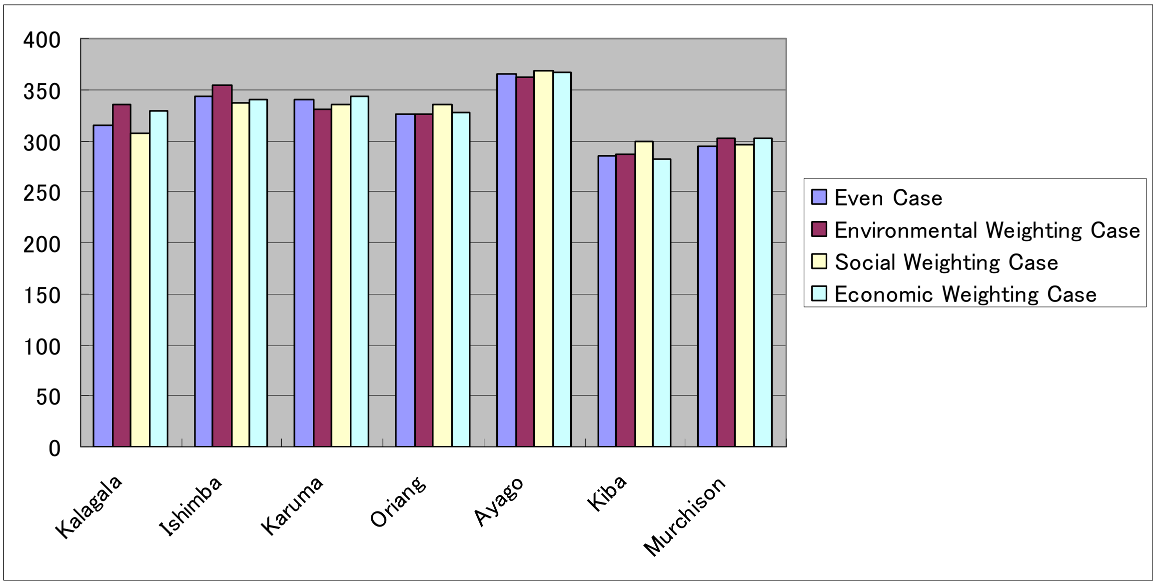


Figure 6.11.2-1 Evaluation of each site

General evaluation of candidate hydropower projects by evaluation items and by features are shown in Table 6.11.2-1 and Figure 6.11.2-2,3.

Table 6.11.2-1 General Evaluation of Candidate Hydropower Projects

Evaluation items			Kalagala		Isimba		Karuma		Oriang		Ayago		Kiba		Murchison	
				Rate		Rate		Rate		Rate		Rate		Rate		Rate
Economic and technical	Cost	Construction Cost (MUS$)	638	5	601	5	1,911	3	1,696	3	1,565	3	2,190	2	1,106	4
		Generation Cost (cent/kWh)	3.3	5	7.3	2	4.2	4	5.8	3	3.3	5	9.5	1	4.4	4
	Effectiveness	Maximum Power (MW)	330	3	138	1	587	4	392	3	616	5	292	2	655	5
		Construction time (year)	4	5	4	5	5	4	5	4	5	4	5	4	4	5
		Head (m)	28	1	13	1	79	4	53	3	83	5	40	2	88	5
		Distance to load center or existing grid (km)	28	4	47	2	1	5	34	3	46	2	56	2	122	1
		Length of Waterway (km)	0	5	0	5	12	2	12	2	8	3	14	1	2	4
		Geological Condition	sound	4	sound	4	moderate	3	moderate	3	moderate	3	moderate	3	moderate	3
		Excavation Volume	1,036	4	824	5	6,008	2	5,424	3	4,164	3	7,152	1	1,684	4
		Construction material availability (Concrete Volume: $1000m^3$)	356	5	560	5	1,520	4	1,262	4	1,059	4	1,794	3	822	5
		Accessibility (AccessRoad :km)	3	5	15	5	1	5	30	4	45	3	55	2	30	4
		Loss of transmission (%)	168	5	100	5	-	5	36	4	56	5	60	4	131	4
	Development progress	Lead Time (year)	6	2	6	2	5	5	5	3	5	4	5	3	5	3
		Financial Negotiation and close	To be determined	3	To be determined	3	To be determined	3	To be determined	3	To be determined	3	To be determined	3	To be determined	3
Environment	Length of water recession (km)		0	5	0	5	14.5	2	13.4	2	8.8	3	16.7	1	4.4	4
	Rate of recession (%)		0	5	0	5	89	2	89	2	89	2	89	2	89	2
	Impact on Protected area		Central Forest Reserve, IBA Moderate Impacts	3	Central Forest Reserve, IBA Moderate Impacts	3	Wildlife Reserve Minor impacts	4	National Park, Wildlife Reserve, IBA Major Impacts	2	National Park, Wildlife Reserve, IBA Major Impacts	2	National Park, Wildlife Reserve, IBA Major Impacts	2	National Park, Ramsar, IBA Serious Impacts	1
	Impact on wetland (km^2)		0	5	0.16	5	63.28	3	0.06	5	0.04	5	0.02	5	0.05	5
	Impact on protected species		EN:0, VU:0, NT:0, LC:0Negligible impacts	5	EN:0, VU:0, NT:0, LC:0Negligible impacts	5	EN:0, VU:2, NT:3, LC:18Major Impacts	12	EN:0, VU:1, NT:2, LC:16Major Impacts	12	EN:0, VU:1, NT:3, LC:16Major Impacts	12	EN:1, VU:2, NT:3, LC:16Major Impacts	12	EN:1, VU:2, NT:3, LC:20Serious Impacts	1
	Degradation of underground water (Length of tunnel: km)		0	5	0	5	11	2	11	2	7	3	14	1	2	4
	CO_2 emission from the reservoir (CO_2 t/day)		37.6	2	47.2	1	0.12	5	0.12	5	0.12	5	0.12	5	13.2	3

Evaluation items		Kalagala	Rate	Isimba	Rate	Karuma	Rate	Oriang	Rate	Ayago	Rate	Kiba	Rate	Murchison	Rate
Social	Land acquisition (1000 m^2)Land acquisition	3,534Serious Impacts	1	6,730Serious Impacts	1	787Negligible impacts	4	706Minor impacts	3	589Minor impacts	3	958Minor impacts	3	2,698Major Impacts	2
Social	Flooding area (km^2)Flooding area	6.00Major Impacts	2	5.20Serious Impacts	1	0.00Negligible impacts	5	0.00Negligible impacts	5	0.00Negligible impacts	5	0.00Negligible impacts	5	0.90Moderate Impacts	3
Social	Number of affected people (Population within 1km)Number of affected people	36,145Major Impacts	2	49,744Serious Impacts	1	33,015Major Impacts	2	4,854Negligible impacts	5	5,049Negligible impacts	5	5,434Negligible impacts	5	1,890Negligible impacts	5
Social	Impact on ethnic minority and indigenous people Impact on ethnic minority and indigenous people	Settlement, Farm land Moderate Impacts	3	Settlement, Farm land Moderate Impacts	3	Settlement, Farm land Major Impacts	2	Fishing in the NP Minor impacts	4	Fishing in the NP Minor impacts	4	Fishing in the NP Minor impacts	4	Fishing in the NP Minor impacts	4
Social	Impact on fish breading and/or fishing Impact on fish breading and/or fishing	Negligible impacts Negligible impacts	5	Negligible impacts Negligible impacts	5	Minor impacts Minor impacts	4	Negligible impacts Negligible impacts	5	Negligible impacts Negligible impacts	5	Negligible impacts Negligible impacts	5	Negligible impacts Negligible impacts	5
Social	Impact on Agriculture (Farm land, km^2)Impact on Agriculture	55Moderate Impacts	3	78Major Impacts	2	140Serious Impacts	1	21Negligible impacts	5	21Negligible impacts	5	22Negligible impacts	5	27Negligible impacts	5
Social	Impact on cultural property Impact on cultural property	Kalagala shrine, Itanda Falls Serious Impacts	1	Mbuiamuti Landing Site Negligible impacts	5	Karuma Falls Major Impacts	2	-Negligible impacts	5	-Negligible impacts	5	-Negligible impacts	5	Murchison Falls Moderate Impacts	3
Social	Impact on tourism potential Impact on tourism potential	Itanda falls, Rafting Serious Impacts	1	-Negligible impacts	5	Karuma Falls Moderate Impacts	3	National Park Major Impacts	2	National Park Major Impacts	2	National Park Major Impacts	2	National Park, Murchison Falls, Sports Fishing Serious Impacts	1
Social	Impact on current tourism Impact on current tourism	Rafting business, Lodge Serious Impacts	1	-Negligible impacts	5	Karuma Falls Minor impacts	4	Safari Tour, Chobe LodgeMinor impacts	4	Safari Tour, Chobe LodgeMinor impacts	4	Safari Tour, Chobe LodgeMinor impacts	4	Safari Tour, Parra Lodge Serious Impacts	1
Social	Impact on existing infrastructure (Number of affected road)Impact on existing infrastructure	3Moderate Impacts	3	4Moderate Impacts	3	7Major Impacts	2	0Negligible impacts	5	0Negligible impacts	5	0Negligible impacts	5	1Minor impacts	4
Social	Impact on landscape Impact on landscape	Kalagara Falls Serious Impacts	1	-Negligible impacts	5	Karuma Falls Major Impacts	2	Natural Landscape Moderate Impacts	3	Natural Landscape Moderate Impacts	3	Natural Landscape Moderate Impacts	3	Murchison Falls, Natural landscape Serious Impacts	1
Social	Human health hazard (Dependence rate of rain water for drinking, %)Human health hazard	1.5Moderate Impacts	3	1.4Moderate Impacts	3	3.2Major Impacts	2	0.9Negligible impacts	5	0.8Negligible impacts	5	0.8Negligible impacts	5	1.0Negligible impacts	5
General Evaluation	Even Case	315315		343343		329340		315326		354365		274285		291291	
General Evaluation	Even Case	**B**		**A**		**A**		**B**		**A**		**C**		**C**	
General Evaluation	Environmental Weighting Case	335335		355355		320330		316326		352362		276286		298298	
General Evaluation	Environmental Weighting Case	**B**		**A**		**B**		**B**		**A**		**C**		**C**	
General Evaluation	Social Weighting Case	307307		337337		324335		325336		358369		288299		294294	
General Evaluation	Social Weighting Case	**C**		**B**		**B**		**B**		**A**		**C**		**C**	
General Evaluation	Economic Weighting Case	329329		340340		335344		319328		358367		273282		301301	
General Evaluation	Economic Weighting Case	**B**		**B**		**BA**		**B**		**A**		**C**		**C**	

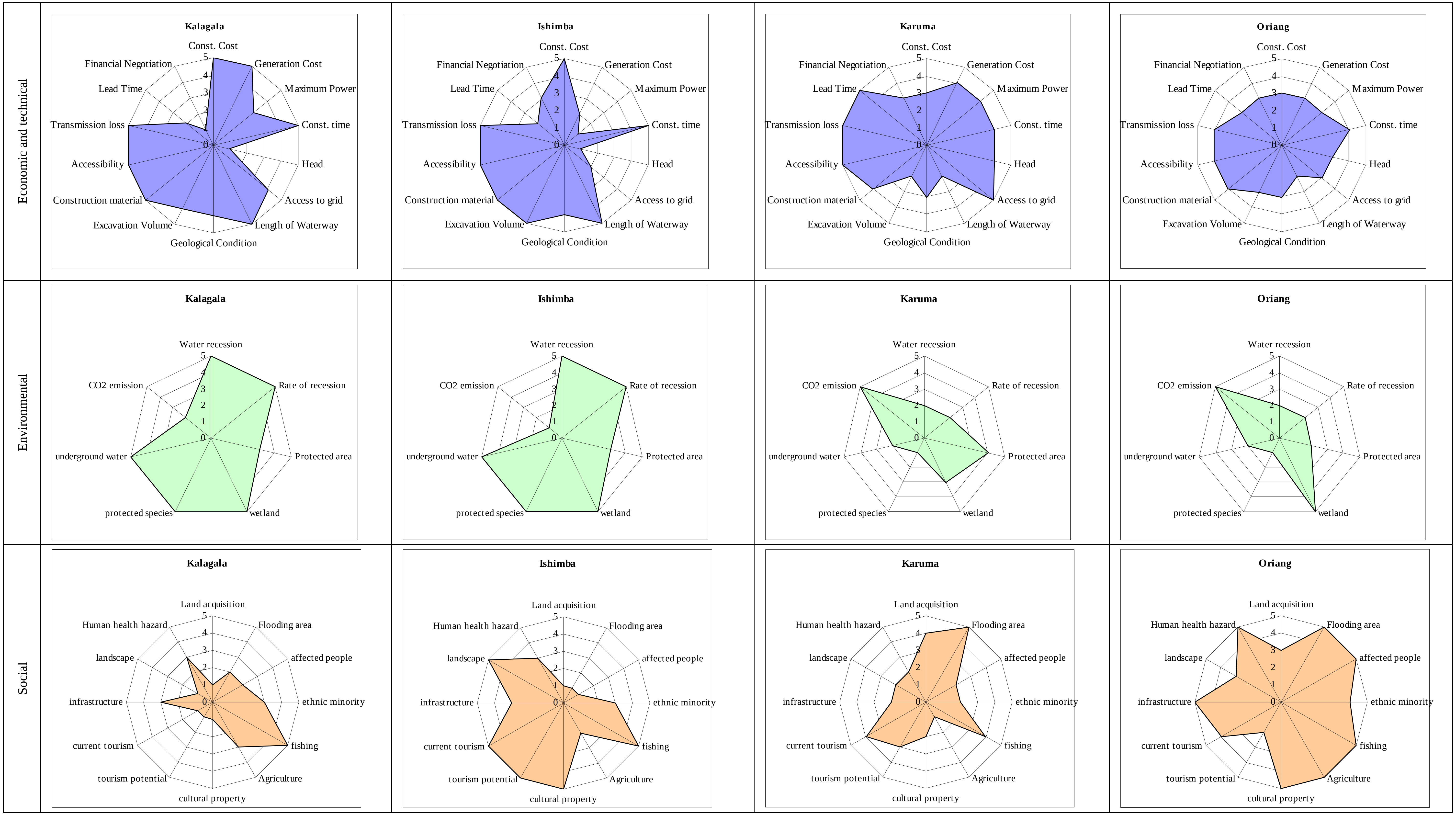


Figure 6.11.2-2 General Evaluation of Candidate Hydropower Projects-1

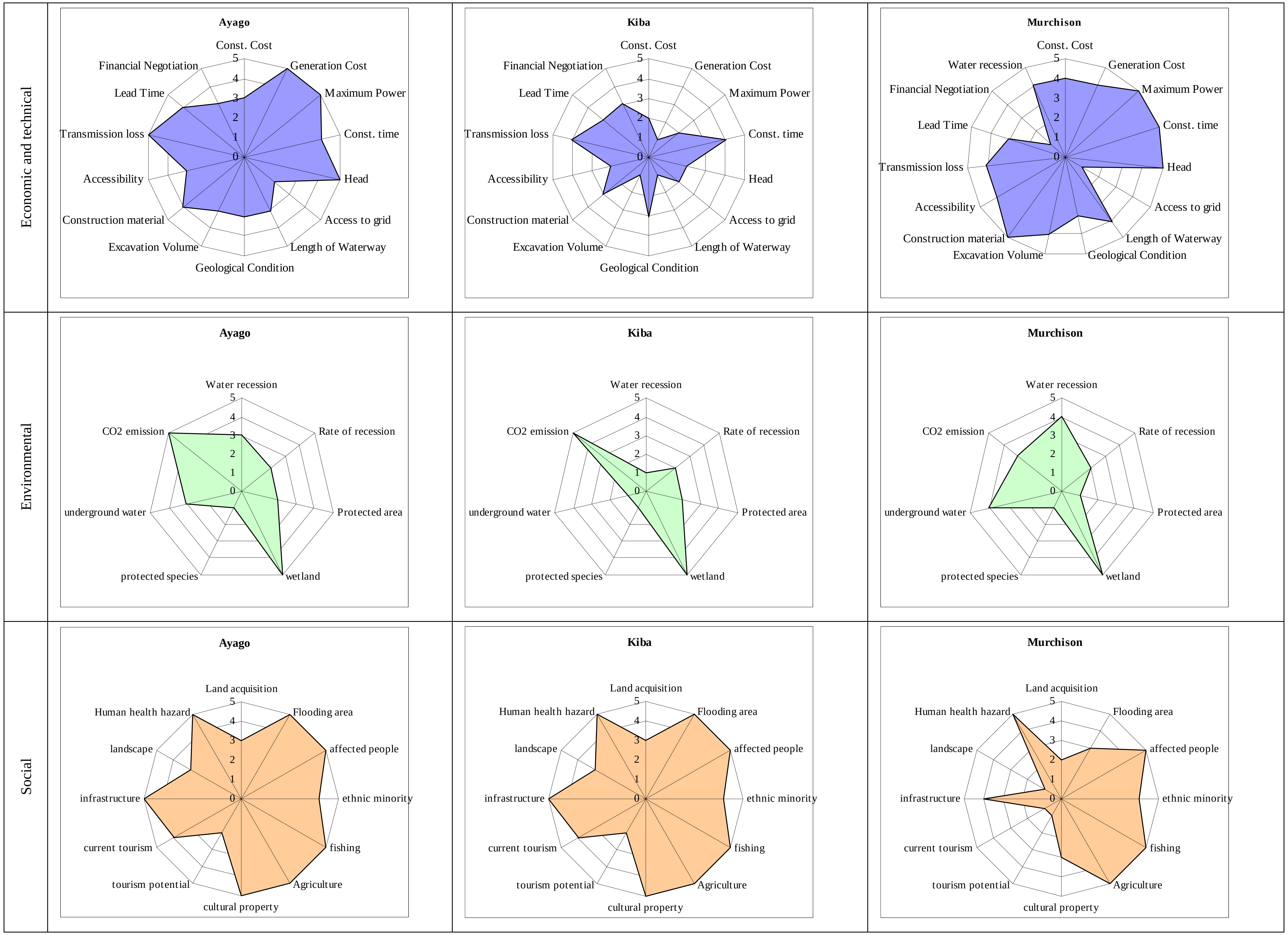


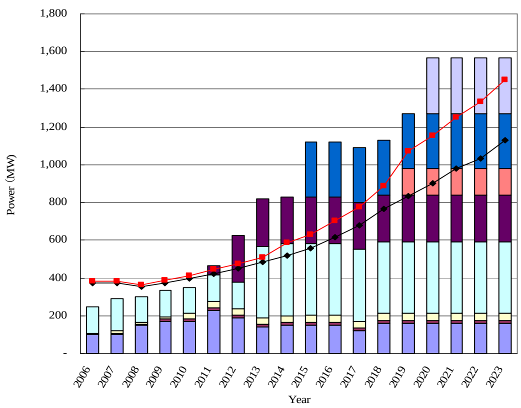
Figure 6.11.2-3 General Evaluation of Candidate Hydropower Projects-2

6.11.3 Selection of Prospective Site

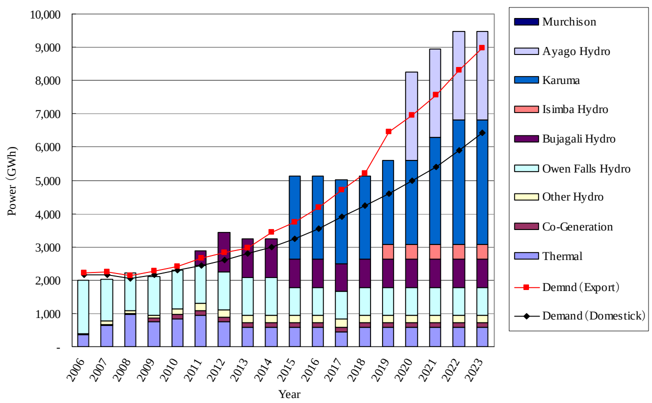
Review of GDP 2008-2023 was carried out for selection of prospective sites from among the 7 sites. According to the demand forecast in GDP 2009-2025 as shown in Figure 6.11.3-1, by 2023 expansion of 1,129 MW of peak power and 6,458 GWh of firm energy will be needed without considering power export and expansion of 1,449 MW of peak power and 8,967 GWh of firm energy will be needed in case power export is considered. This power expansion will be possible by 2 or 3 prospective sites that are the Ayago Site, Karuma Site and Isimba Site evaluated to A rank by comparison study of the 7 candidate sites.

Among these 3 sites the Karuma Site and Isimba Site are under feasibility study by an Indian and German Consultant.

Therefore the Study Team determined the Ayago Site as the selected prospective site. For the further investigation of Ayago site, it will be required to consider environmental conservations because Ayago site is located in the Natural Park.



MW Balance



GWh Balance

Figure 6.11.3-1 Demand and Supply Balance up to 2023

6.12 Scenario of Power Development Plan

This Study made an examination of the 6 scenarios of power development plan shown in the table below: Scenarios I, II, III, IV, V and VI corresponding to Middle case of power demand forecast, High case, Low case, Middle case plus export to Kenya, the targeted power demand of Vision 2035 and National Development Plan 2011/12-2014/15 (NDP), respectively.

Table 6.12-1 Scenarios of Power Development Plan

	Demand Forecast	Data Source
Scenario I	Medium Case	Study Team
Scenario II	High Case	Study Team
Scenario III	Low Case	Study Team
Scenario IV	Medium + Export to Kenya	Study Team
Scenario V	Vision 2035	PSIP Draft Report Dec.8,2009
Scenario VI	NDP	NDP

（Source: Study Team）

It should be noted that the coverage of power development plan in this Study is nationwide, so that the power sources considered were those of over 50MW that can contribute to meet the nationwide power demand as main power supplier.

6.12.1 Basic Assumptions

The basic assumptions of the study of Power Development Plan were set as follows.

1) Time horizon for the Plan is from 2010 through to 2023.

2) The Power Development Plan basically uses the data from GDP2009-2025 and incorporates the large hydropower projects. Both Isimba and Karuma hydropower projects, have a feasibility study in progress, and the schedule for the Isimba Hydropower Project and the Karuma Hydropower Project given to the study team by MEMD are as follows:

   / Operation of Isimba Hydropower Project commences in 2019; and,

   / Operation of Karuma Hydropower commences with 192MW in 2015 and, additionally, 96MW in 2017.

3) In the Plan, the order of hydropower development is firstly Karuma and then Ayago, followed by Isimba Hydropower Project and then Oriang Hydropower Project, A-ranked and B-ranked respectively as the result of 6.11.2. Kalagala Hydropower Project is checked off because of Kalagala Offset.

4) The Plan uses firm power and energy.

5) Target reserve margin is 15%.

6) Diesel thermal power plants, because of high cost and large environmental impact, will be retired as early as possible upon commencement of operation of major hydropower projects.

7) Assuming the power demand based on Vision 2035 and NDP, Scenario V and VI incorporates the targeted power supply including the planned power developments, respectively.

8) Being able to be developed in phases, Ayago Hydropower Project could be developed in phases of 100MW in each phase.

6.12.2 Power Development Plans Considered

(1) Major Hydropower Projects

In preparing the Power Development Plan, the hydropower projects selected in this Study and the project under construction were considered. Development priority was given based on the result of this Study. The installed capacity of those hydropower projects are shown in Table 6.12.2-1.

Table 6.12.2-1 Large Hydropower Projects

Project	Installed Capacity(MW)	Annual Energy (GWh)		Stage	Rank
		Total	Firm		
Owen Falls	380	1,354	830	Existing	-
Bujagali	250 (50-5 unit)	1,365	844	Construction	-
Kalagala	330 (33-10 unit)	1,801	1,114	n/a	-
Isimba	138 (23-6 unit)	752	465	F/S	A
Karuma	576 (48-12 unit)	4,145	2,514	F/S	A
Oriang	392 (49-8 unit)	2,768	1,679	n/a	B
Ayago	612 (51-12 unit)	4,357	2,641	n/a	A
Kiba	288 (48-6 unit)	2,066	1,253	n/a	C
Murchison	648 (54-12 unit)	2,314	1,403	n/a	C
Total	3,578	20,922	12,743	n/a	

(2) Small Hydropower Projects

As for small hydropower projects, those shown in GDP2009-2025 were incorporated and shown in Table 6.12.2-2.

Table 6.12.2-2 Power Supply Plan of Small Hydro Projects

Firm Capacity (MW)

Name of Project	Installed Capacity	2010	2011	2012	2013	2014	2015	2016
Mubuk 1 (KML)	5	3	3	3	3	3	3	3
Mubuku 3 (KCCL)	9.5	1	1	1	1	1	1	1
Maziba	1	-	1	1	1	1	1	1
Ishasha	6.5	3	3	3	3	3	3	3
Paidha	3	-	-	-	-	-	1.5	1.5
Kikagati	10	-	5	5	5	5	5	5
Bugoye	13	7	10	10	10	10	10	10
Waki	5	-	-	-	-	-	-	
Muzizi	10	-	-	-	-	-	-	
Mpanga	18	8	8	8	8	8	8	8
Kyambura	5.2	-	-	-	-	-	-	
Buseuka	9	6	6	6	6	6	6	6
Muyembe	10	-	-	-	-	-	-	-
Sub Total	105.2	28	37	37	37	37	38.5	38.5

(MW)

Name of Project	Installed Capacity	2017	2018	2019	2020	2021	2022	2023
Mubuk 1 (KML)	5	3	3	3	3	3	3	3
Mubuku 3 (KCCL)	9.5	1	1	1	1	1	1	1
Maziba	1	1	1	1	1	1	1	1
Ishasha	6.5	3	3	3	3	3	3	3
Paidha	3	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Kikagati	10	5	5	5	5	5	5	5
Bugoye	13	10	10	10	10	10	10	10
Waki	5	-	-	-	-	-	-	-
Muzizi	10	-	-	-	-	-	-	-
Mpanga	18	8	8	8	8	8	8	8
Kyambura	5.2	-	-	-	-	-	-	-
Buseuka	9	6	6	6	6	6	6	6
Muyembe	10	-	-	-	-	-	-	-
Sub Total	105.2	38.5	38.5	38.5	38.5	38.5	38.5	38.5

(3) Thermal Power and Other Power Sources

The power sources shown in GDP2009-2025 were adopted and shown in Table 6.12.2-3.

Table 6.12.2-3 Power Supply Plan of Other Power Projects

(Unit: MW)

Name of Project	Installed Capacity	2010	2011	2012	2013	2014	2015	2016
Thermal								
Aggreko 1, Lugogo	50							
Aggreko 2, Kiira	50							
Mutundwe	50	50	50					
Namanve	50	50	50	50	50	50	50	50
Invespro, Nalubaale	50	50	50	50				
Electromaxx	20	18	18	18				
Mputa	85		50	50	50	50	50	50
Kabale Peat	30				20	20	20	20
Thermal Subtotal	385	168	218	168	120	120	120	120
Namugoga Solar	50		10	20	20	30	30	30
Co-generation								
Kinyara Sugar Work	5	5	5	5	5	5	5	5
Kakira Sugar Work	12	12	12	12	12	12	12	12
SCOUL Lugas	6							
Co-gene Subtotal	68	17	17	17	17	17	17	17
Other Thermal Total	503	185	245	205	157	167	167	167

Name of Project	Installed Capacity	2017	2018	2019	2020	2021	2022	2023
Thermal								
Aggreko 1, Lugogo	50							
Aggreko 2, Kiira	50							
Mutundwe	50							
Namanve	50	50	50	50	50	50	50	50
Invespro, Nalubaale	50							
Electromaxx	20							
Mputa	85	50	50	50	50	50	50	50
Kabale Peat	30	20	20	20	20	20	20	20
Thermal Subtotal	385	120	120	120	120	120	120	120
Namugoga Solar	50	30	40	40	40	40	40	40
Co-generaion								
Kinyara Sugar Work	5	5	5	5	5	5	5	5
Kakira Sugar Work	12	12	12	12	12	12	12	12
SCOUL Lugas	6							
Co-gene Subtotal	68	17	17	17	17	17	17	17
Other Thermal Total	503	167	177	177	177	177	177	177

6.12 3 Power Development Plan for Each Scenario

(1) Scenario I

Scenario I of the Power Development Plan was prepared as shown in Table 6.12.3-1 to meet the Medium case power demand.

1) Major Hydropower Development Plan

Table 6.12.3-1 Hydropower Development Plan (Scenario I)

year	Project	Unit	Installed Capacity	Annual Firm Energy
2015	Karuma	4	192 MW	1,682 GWh
2017	Karuma	2	96 MW	832 GWh
2019	Isimba	10	138 MW	465 GWh
2020	Ayago	2	102 MW	894 GWh
2023	Ayago	2	102 MW	893 GWh

2) Demand-Supply Balance

Table 6.12.3-2 Demand - Supply Balance (Scenario I)

year	Power Demand (MW)	Demand With Margin	Supply(MW)		Energy Demand (GWh)	Firm Energy (GWh)	
			Total	Suspend Thermal		Total	Suspend Thermal
2010	406	467	360		2,346	2,007	
2011	439	505	469		2,535	2,290	
2012	474	545	852		2,740	2,663	
2013	512	589	804		2,961	2,771	
2014	553	636	804		3,199	2,985	
2015	598	688	998	120	3,457	4,679	756
2016	646	743	998	120	3,736	4,679	756
2017	698	803	1,094	120	4,037	5,511	756
2018	755	868	1,094	120	4,363	5,552	756
2019	815	937	1,232	120	4,714	6,017	756
2020	881	1,013	1,334	120	5,049	6,464	756
2021	952	1,095	1,334	120	5,505	6,911	756
2022	1,029	1,183	1,334	120	5,949	6,911	756
2023	1,112	1,279	1,439	120	6,428	7,804	756

Peak power and supply balance is shown in Figure 6.12.3.1

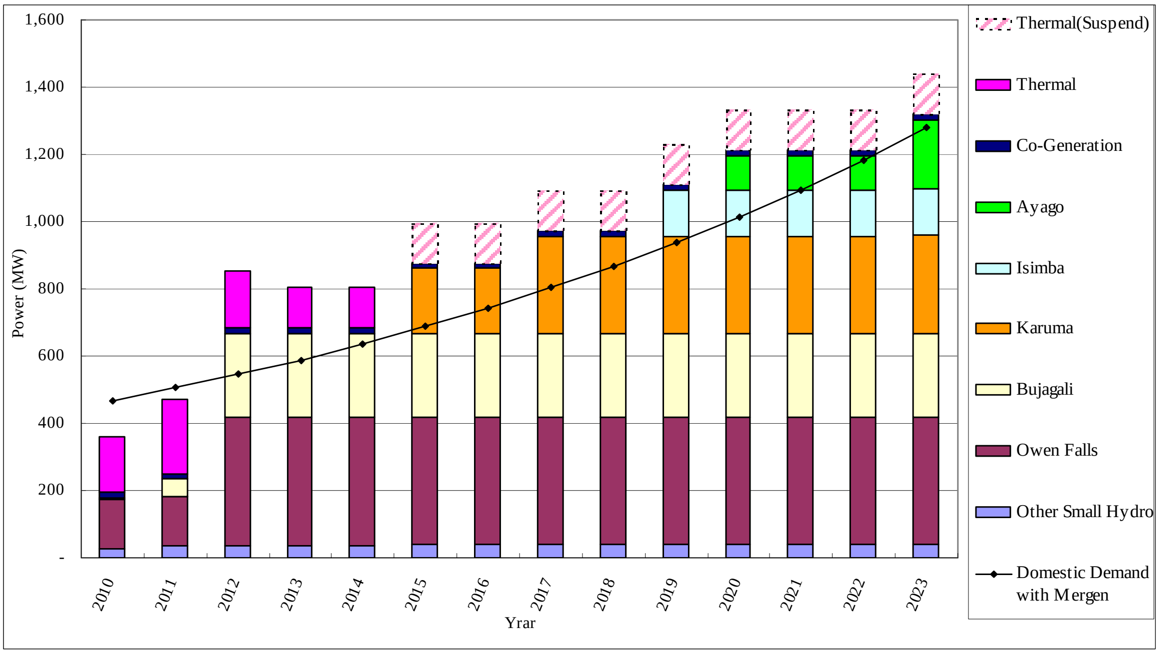


Figure 6.12.3-1 Power Demand and Supply Balance (Scenario I)

Energy and supply balance is shown in Figure 6.12.3-1.

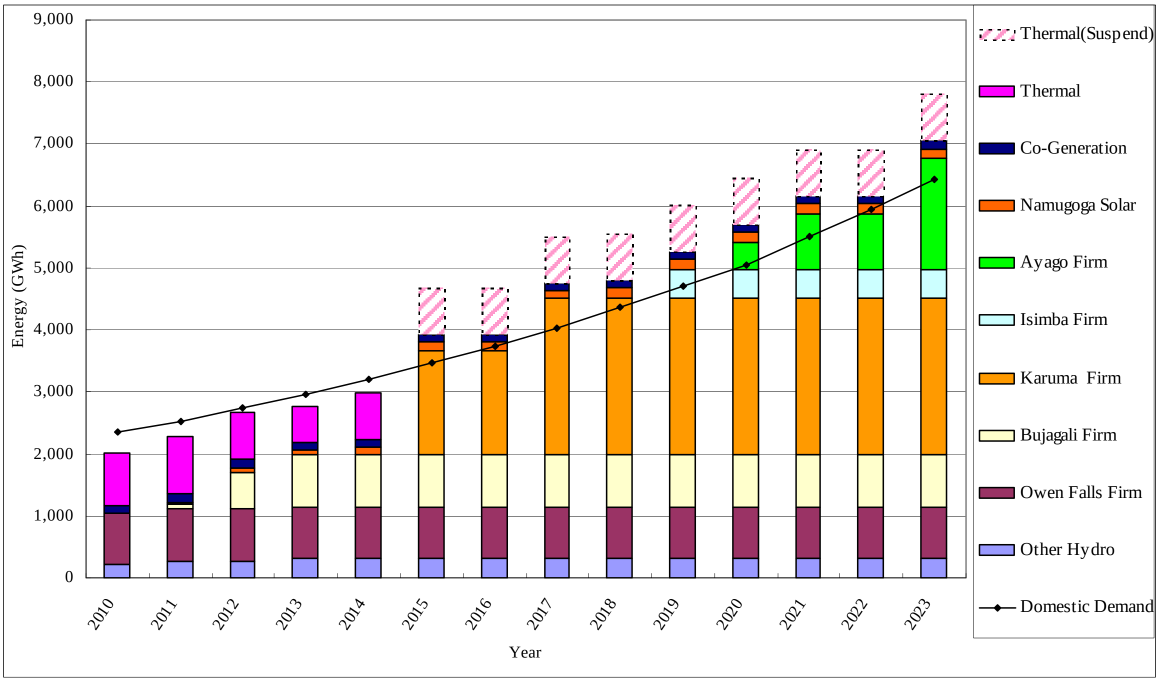


Figure 6.12.3-2 Energy Demand and Supply Balance (Scenario I)

Scenario I shows that Ayago Hydropower Project will be developed in stages as follows:

1) First stage: 102MW (51MW-2unit) in 2020

2) Second stage: 102MW (51MW-2unit) in 2023

3) Further stages: Capacity additions according to demand increase thereafter.

As shown by the areas framed by dotted line in Figure 6.12.3-1 and Figure 6.12.3-2 above, diesel thermal plants will be able to be retired.

This scenario was prepared so as to meet the predicted demand as much as possible but, until 2014, the supplying capacity cannot meet the increasing demand making the reserve margin negative, leading to such a situation that supply reliability cannot be secured. The drop in Power and Energy supply over the 2012-2013 period is due to the cancellation of planned thermal power plants earlier scheduled for commissioning in 2013.

(2) Scenario II

Scenario II of Power Development Plan was prepared as shown in Table 6.12.3-3 based on the high case demand forecast, This scenario requires the development of another plant i.e. Oriang hydropower project, with the commissioning of 102MW of Ayago in 2020 and 2022 and 102MW of Oriang in 2023.

1) Major Hydropower Development Plan

Table 6.12.3-3 Hydropower Development Plan (Scenario II)

Year	Project	Unit	Installed Capacity	Annual Firm Energy
2015	Karuma	4	192 MW	1,682 GWh
2017	Karuma	2	96 MW	832 GWh
2019	Isimba	10	138 MW	465 GWh
2020	Ayago	2	102 MW	894 GWh
2022	Ayago	2	102 MW	893 GWh
2023	Ayago	2	102 MW	854 GWh

2) Demand Supply Balance

Table 6.12.3-4 Demand－ Supply Balance (Scenario II)

Year	Power Demand (MW)	Demand With Margin	Supply(MW)		Energy Demand (GWh)	Firm Energy(GWh)	
			Total	Suspend Thermal		Total	Suspend Thermal
2010	410	472	360		2,368	2,007	
2011	447	514	469		2,582	2,290	
2012	487	560	852		2,816	2,663	
2013	531	611	804		3,072	2,771	
2014	579	666	804		3,350	2,985	
2015	632	727	998		3,654	4,679	
2016	689	792	998		3,985	4,679	
2017	752	865	1,094	120	4,346	5,511	756
2018	820	943	1,094	120	4,740	5,552	756
2019	894	1,028	1,232	120	5,169	6,017	756
2020	975	1,121	1,334	120	5,637	6,911	756
2021	1,063	1,222	1,334	120	6,148	6,911	756
2022	1,160	1,334	1,436	120	6,706	7,804	756
2023	1,265	1,455	1,636	120	7,317	9,517	756

Peak power supply and demand balance is shown below.

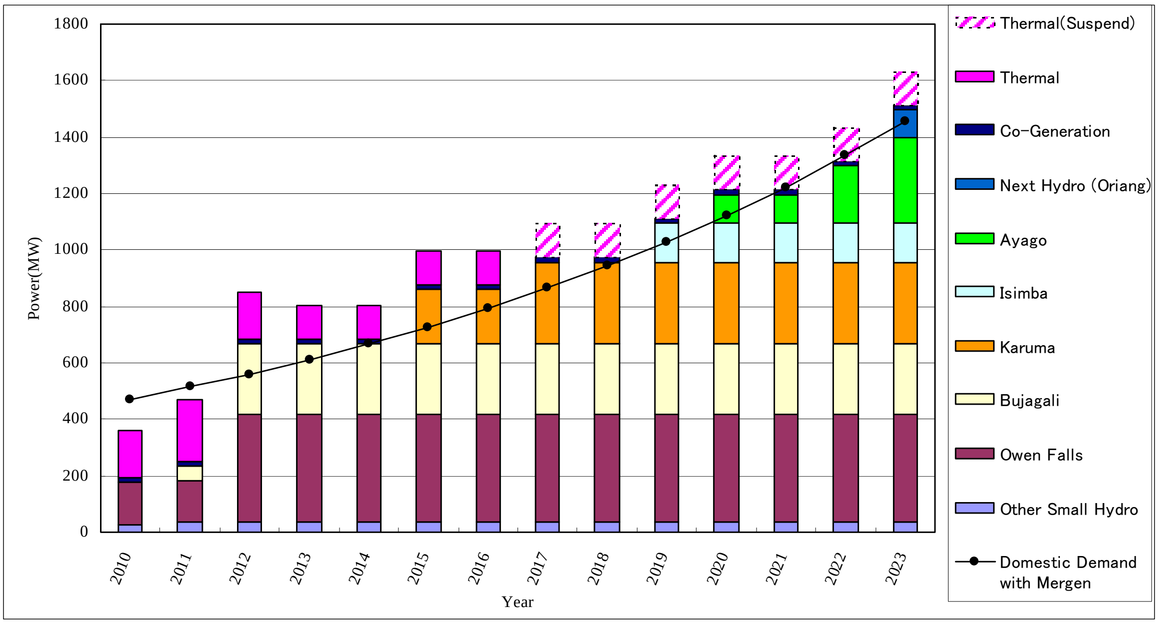


Figure 6.12.3-3　Power Demand and Supply Balance (Scenario II)

Energy supply and demand balance is shown below.

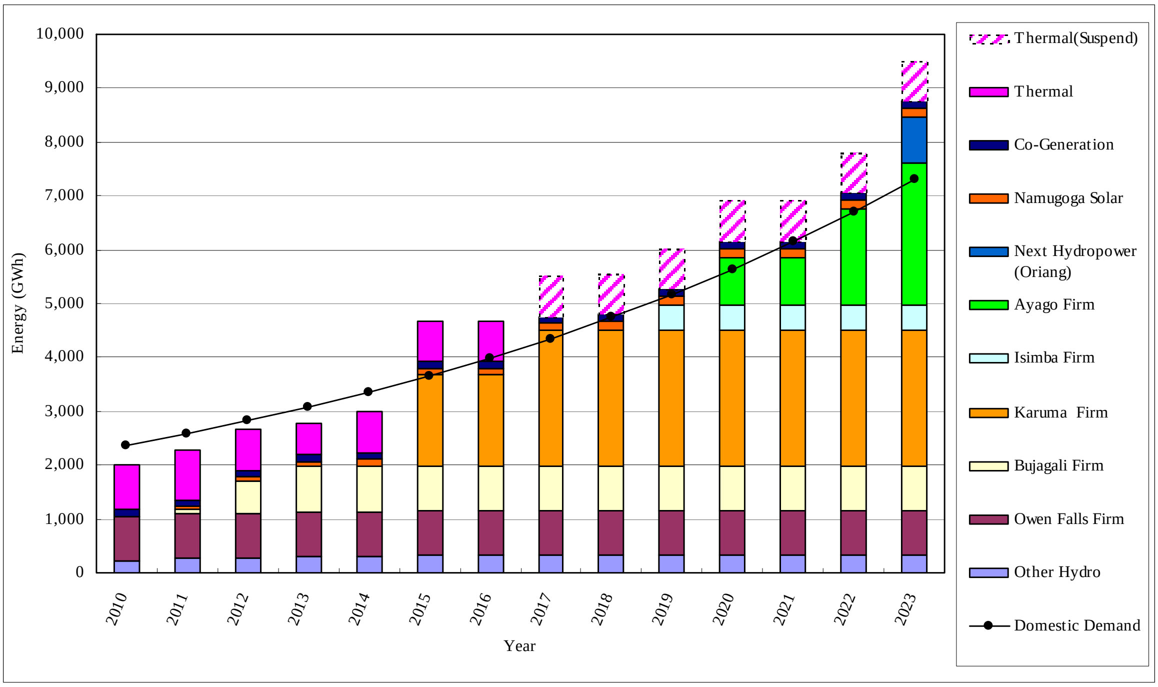


Figure 6.12.3-4　Energy Demand and Supply Balance (Scenario II)

(3) Scenario III

Scenario III was based on low case demand forecast, revealing that, as for Ayago Hydropower project, it is enough to develop 102MW in 2022 because of low demand growth. The result of study as is shown below.

1) Major Hydropower Development Plan

Table 6.12.3-5 Hydropower Development Plan (Scenario III)

year	Project	Unit	Installed Capacity	Annual Firm Energy
2015	Karuma	4	192 MW	1,682 GWh
2017	Karuma	2	96 MW	832 GWh
2019	Isimba	10	138 MW	465 GWh
2022	Ayago	2	102 MW	894 GWh

2) Supply Demand Balance

Table 6.12.3-6 Supply Demand Balance (Scenario III, Low Case)

year	Power Demand (MW)	Demand With Margin	Supply(MW)		Energy Demand (GWh)	Firm Energy(GWh)	
			Total	Suspend Thermal		Total	Suspend Thermal
2010	402	462	360		2,324	2,007	
2011	430	495	469		2,489	2,290	
2012	461	530	852		2,664	2,663	
2013	493	567	804		2,852	2,771	
2014	528	607	804		3,054	2,985	
2015	566	651	998	120	3,270	4,679	756
2016	605	696	998	120	3,500	4,679	756
2017	648	745	1,094	120	3,748	5,511	756
2018	694	798	1,094	120	4,012	5,552	756
2019	743	854	1,232	120	4,296	6,017	756
2020	795	914	1,232	120	4,599	6,017	756
2021	852	980	1,232	120	4,924	6,017	756
2022	912	1,049	1,334	120	5,272	6,911	756
2023	976	1,122	1,334	120	5,644	6,911	756

Peak power supply demand balance is shown below.

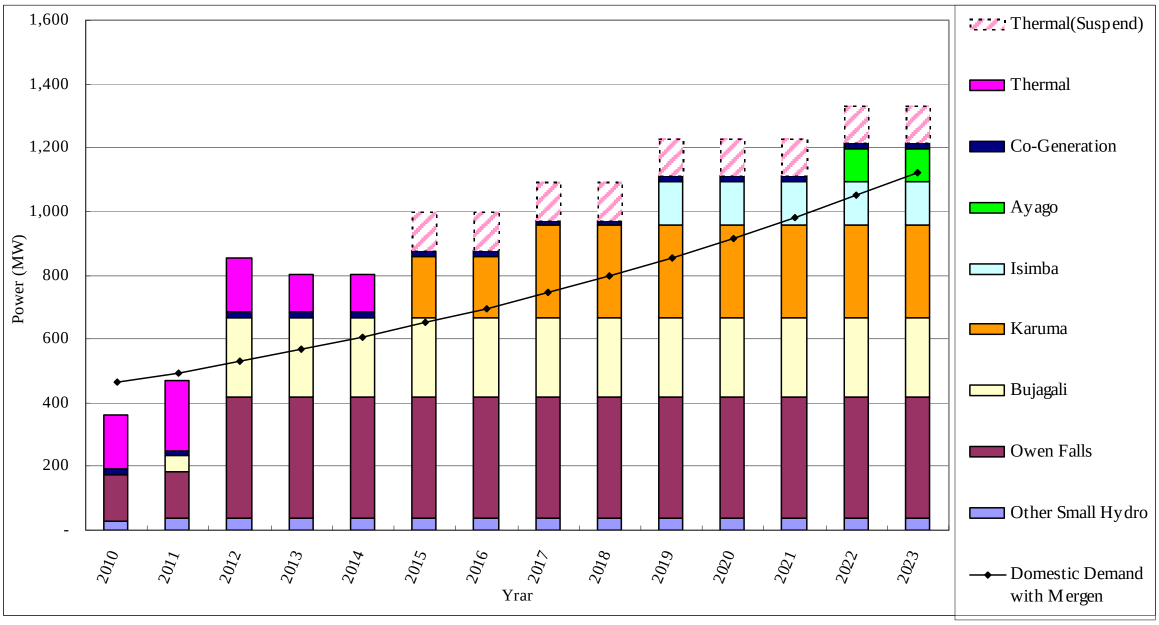


Figure 6.12.3-5 Power Demand and Supply Balance (Scenario III)

Annual energy supply demand supply balance is shown below.

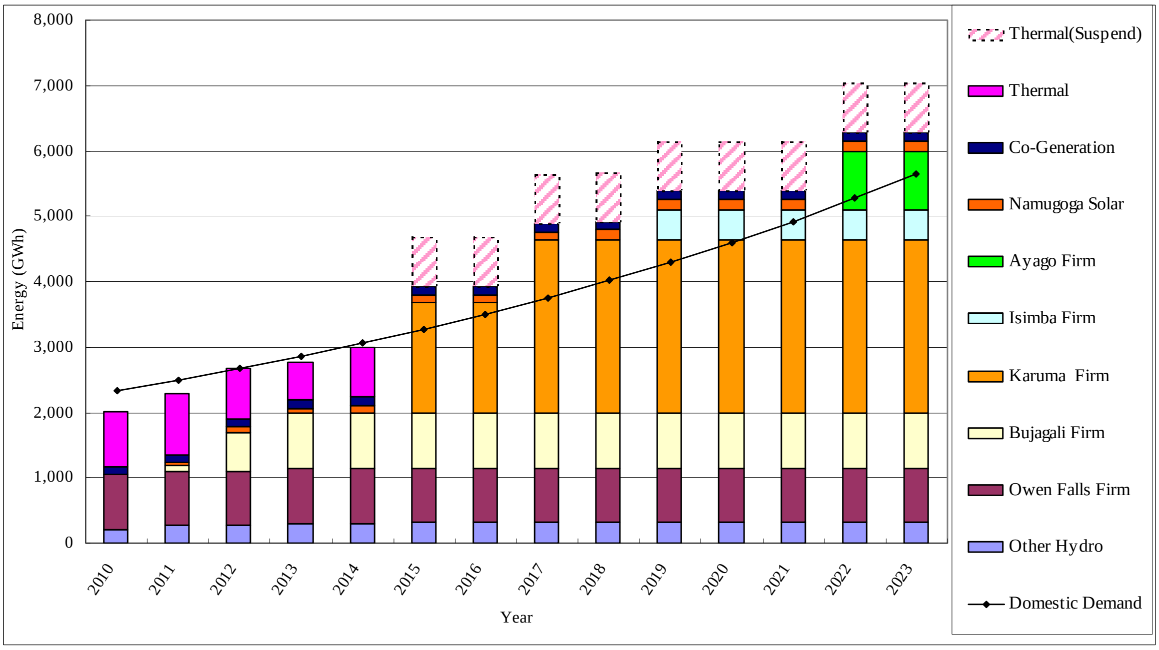


Figure 6.12.3-6 Energy Demand and Supply Balance (Scenario III)

(4) Scenario IV

Scenario IV considers demand forecast of Middle case plus export demand to Kenya.

Kenya was chosen as the most likely power importer from the Ayago project from amongst the neighbouring countries because because of the prevailing electric power situation and the size of electric power industry as well as the contacts already in place between both countries for power exchange.

In Scenario IV of Power Development Plan, as shown in Table 6.12.3-7, Ayago Hydropower Project will be developed in three stages with 102MW each in 2019, 2021 and 2023.

Regarding the power supply source for export, thermal power is not suitable as it bring negative margin to Uganda in view of acceptable level of power tariff to Kenya. It will therefore be realistic to export power only from 2015 in this scenario.

1) Major Hydropower Development Plan

Table 6.12.3-7 Hydropower Development Plan (Scenario IV)

Year	Project	Unit	Installed Capacity	Annual Firm Energy
2015	Karuma	4	192 MW	1,682 GWh
2017	Karuma	2	96 MW	832 GWh
2019	Isimba	5	138 MW	465 GWh
	Ayago	2	102 MW	894 GWh
2021	Ayago	2	102 MW	893 GWh
2023	Ayago	2	102 MW	854 GWh

2) Supply Demand Balance

Table6.12.3-8 Supply Demand Balance (Scenario IV)

Year	Power Demand (MW)	Supply(MW)		Energy Demand (GWh)	Firm Energy(GWh)	
		Total	Suspend Thermal		Total	Suspend Thermal
2010	468	360		2,356	2,007	
2011	515	469		2,623	2,290	
2012	555	852		2,828	2,663	
2013	599	804		2,974	2,771	
2014	656	804		3,225	2,985	
2015	708	998		3,559	4,679	
2016	763	998		3,838	4,679	
2017	823	1,094	120	4,300	5,638	756
2018	918	1,094	120	4,801	5,679	756
2019	1,073	1,334	120	5,415	6,368	756
2020	1,113	1,334	120	5,794	7,038	756
2021	1,195	1,436	120	6,250	7,931	756
2022	1,283	1,436	120	6,694	7,931	756
2023	1,379	1,538	120	7,129	8,785	756

For peak power, supply and demand balance is shown in Figure 6.12.3-7.

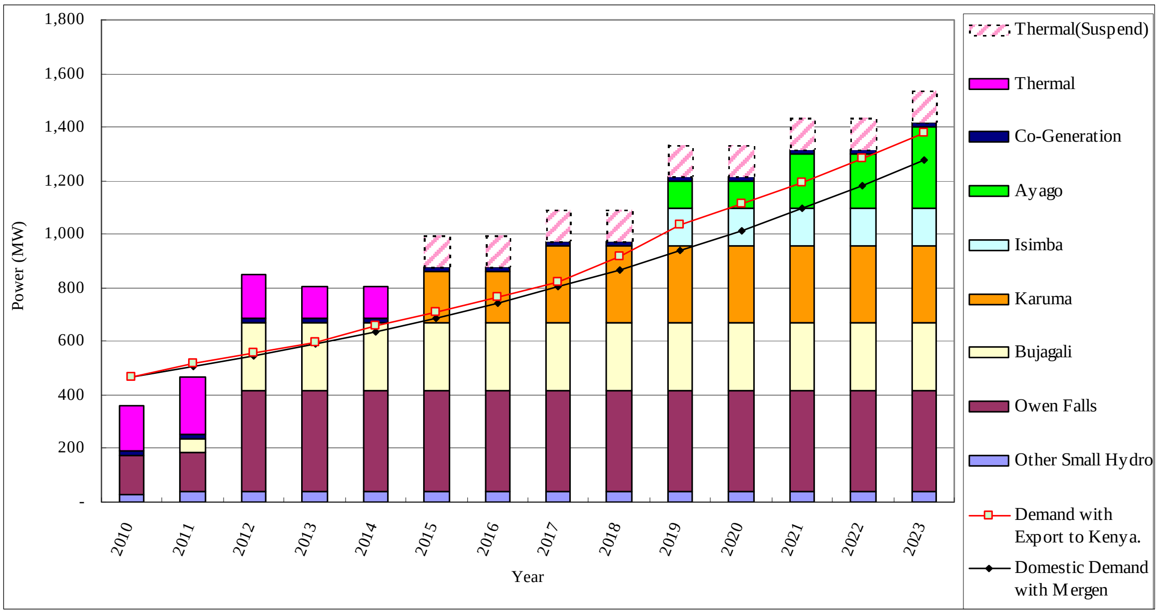


Figure 6.12.3-7 Power Demand and Supply Balance (Scenario IV)

Energy supply and demand balance is shown in Figure &.12.3-8.

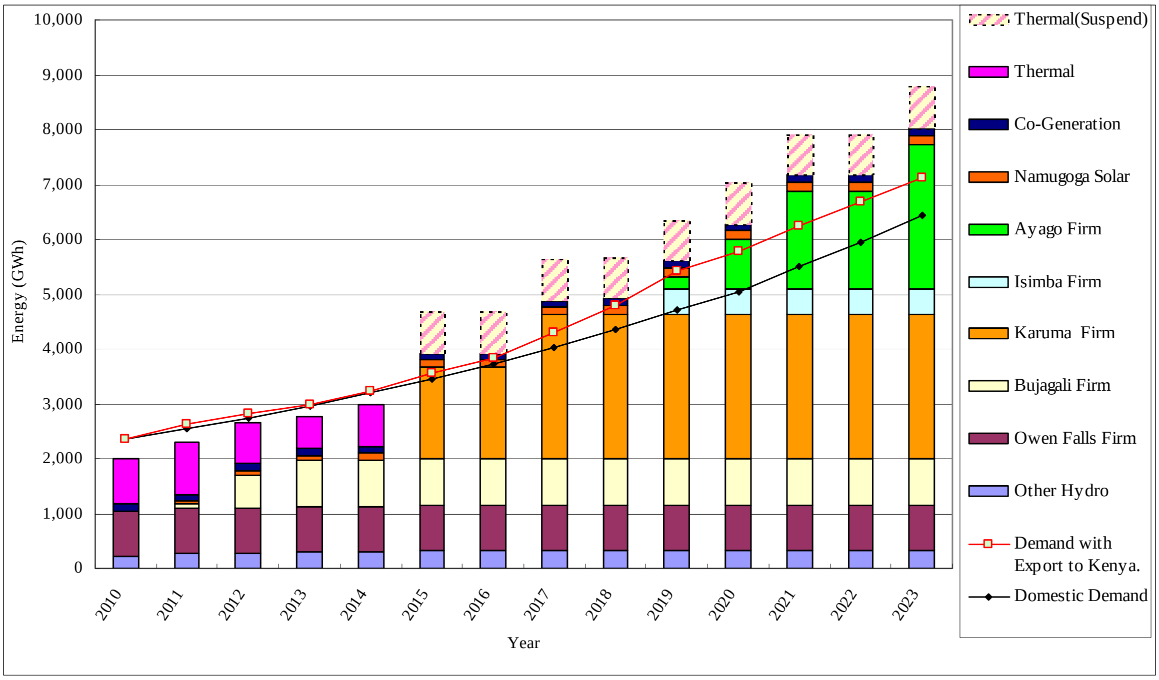


Figure 6.12.3-8 Energy Demand and Supply Balance (Scenario IV)

(5) Scenario V

Scenario V takes demand forecast from the power and energy supply target set in Vision 2035. On the side supply, besides the targeted power developments in Vision2035, Ayago and Oriang hydropower projects were added together with the planned thermal power plants using oil or gas from the Lake Albert exploration or using imported fuel. Thermal power generation capacity and production level in this report were only assumptive due to the uncertainty of oil production.

1) Development Plan

Table 6.12.3-9 Hydropower Development Plan (Scenario V)

Year	Project	Unit	Installed Capacity	Annual Firm Energy
2015	Karuma	4	192 MW	1,682 GWh
	Thermal to be considered	5	250 MW	1610 GWh
2016	Thermal to be considered	2	100 MW	644 GWh
2017	Karuma	2	96 MW	832 GWh
	Thermal to be considered	1	50 MW	322 GWh
2018	Thermal to be considered	2	100 MW	644 GWh
2019	Isimba	5	138 MW	465 GWh
	Ayago	2	102 MW	894 GWh
2020	Ayago	1	102 MW	893 GWh
	Thermal to be considered	2	100 MW	644 GWh
2021	Thermal to be considered	2	100 MW	644 GWh
2022	Ayago	2	103 MW	854 GWh
2023	Oriang	2	98 MW	858 GWh

2) Supply Demand Balance

Table 6.12.3-10 Supply Demand Balance (Scenario V)

Year	Power Demand (MW)	Supply(MW)		Energy Demand (GWh)	Firm Energy(GWh)	
		Thermal to be considered	Total		Planned to be considered	Total
2010	642		360	3,416		2,007
2011	717		469	3,837		2,290
2012	812		852	4,308		2,663
2013	908		804	4,838		2,771
2014	1,003		804	5,367		2,985
2015	1,115	250	1,248	5,989	1,610	6,289
2016	1,235	350	1,348	6,700	2,254	6,933
2017	1,381	400	1,497	7,498	2,576	8,087
2018	1,534	500	1,597	8,281	3,220	8,792
2019	1,691	600	1,837	9,230	3,220	9,461
2020	1,875	750	2,039	10,209	3,862	11,668
2021	2,057	750	2,189	11,315	4,830	12,634
2022	2,276	750	2,291	12,411	4,830	13,488
2023	2,482	750	2,485	13,546	4,830	15,167

(Source: PSIP Draft in December, 2009)

If the thermal power projects are developed as planned then , power and energy supply of Scenario V will attain the targets stated in Vision 2035 from 2015..

Power demand supply balance is shown in Figure 6.12.3-9

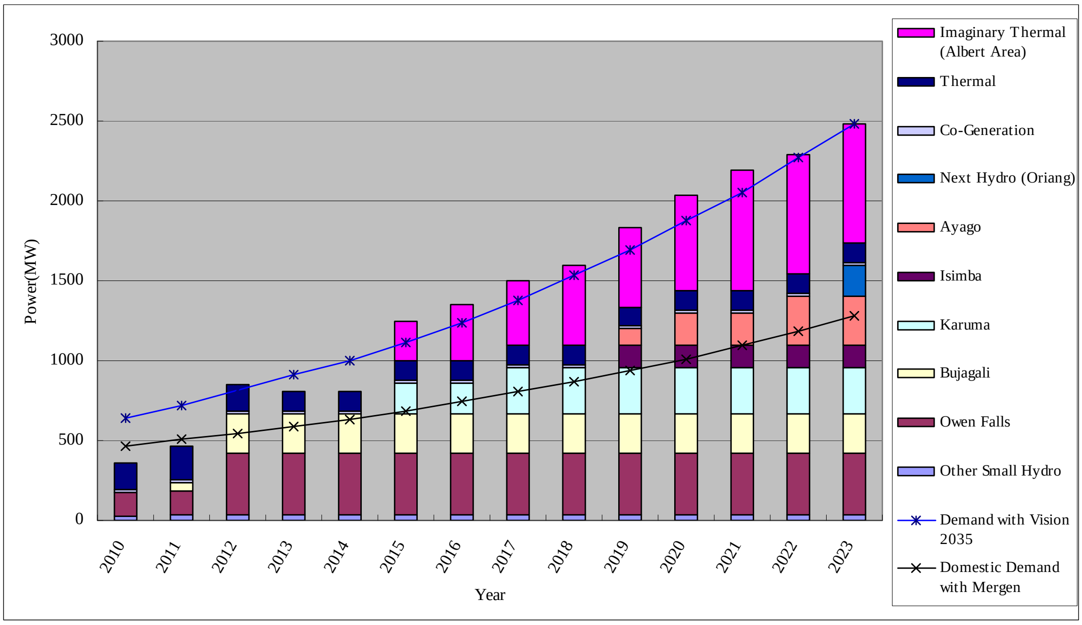


Figure 6.12.3-9 Power Demand and Supply Balance (Scenario V)

Energy supply and demand balance is shown in Figure 6.12.3-10.

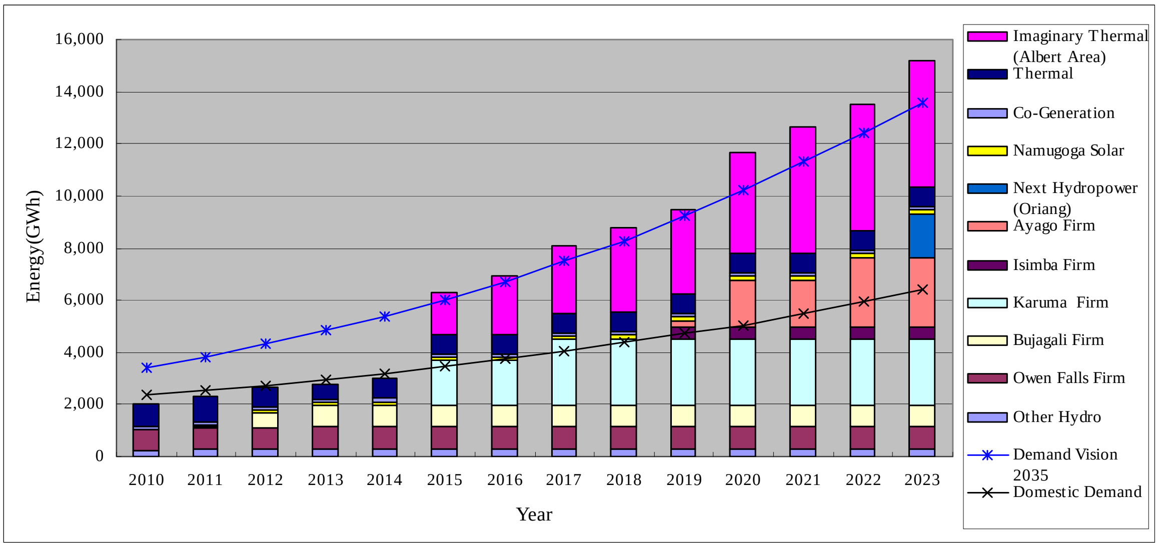


Figure 6.12.3-10 Energy Demand and Supply Balance (Scenario V)

(6) Scenario VI

Scenario VI takes demand forecast from the target supply power and energy stated in NDP. As for supply side, besides the targeted power developments in NDP, Ayago and Oriang hydropower projects were added together with the planned thermal power plant –burning oil explored at Albert Lake or imported fuel. As for that thermal power, its expected generation capacity was only considered because of uncertainty of oil production.

1) Development Plan

Table 6.12.3-11 Hydropower Development Plan (Scenario VI)

Year	Hydro Project	Installed Capacity (MW)		
		Hydro	Thermal to be considered	Total
2013			1,700 MW	1,700 MW
2014			700 MW	700 MW
2015	Karuma	192 MW	500 MW	692 MW
2016			1,000 MW	1,000 MW
2017	Karuma	96 MW	800 MW	896 MW
2018			1,000 MW	100 MW
2019	Isimba	138 MW	700 MW	
	Ayago	102 MW		840 MW
2020	Ayago	204 MW	500 MW	
	Oriyang	194 MW		898 MW
2021			1,200 MW	1,200 MW
2022			1,200 MW	1,200MW
2023			1,300 MW	1,300MW

2) Supply Demand Balance

Table 6.12.3-12 Suply Demand Balance (Scenario VI)

Year	Power Demand (MW)	Supply(MW)		Construction Cost of Thermal to be considered (mil.US$)
		Total	Thermal to be considered	
2010	425	360		
2011	1,117	469		
2012	1,809	852		
2013	2,501	2,504	1,700	1,360
2014	3,193	3,204	700	560
2015	3,885	3,898	500	750
2016	4,828	4,898	1,000	1,150
2017	5,771	5,797	800	990
2018	6,715	6,797	1,000	1,150
2019	7,658	7,737	700	910
2020	8,601	8,635	500	750
2021	9,815	9,835	1,200	1,310
2022	11,029	11,035	1,200	1,310
2023	12,242	12,335	1,300	1,390

Note: Imaginary Thermal is a packaged power consisting of HFO, Coal thermal

Taking into consideration of energy security, two types, Heavy Fuel Oil and Coal thermal of Imaginary thermal power plant are applied. Estimated construction costs of HFO and Coal thermal are 580 $/kW (refer to Section 7) and 1,500$/kW (Source: IEA) respectively.

In this case, it is too difficult to satisfy this plan because of it is requested that huge construction cost is prepared in order to realize NDP target demand.

Power demand supply balance is shown in Figure 6.12.3-11

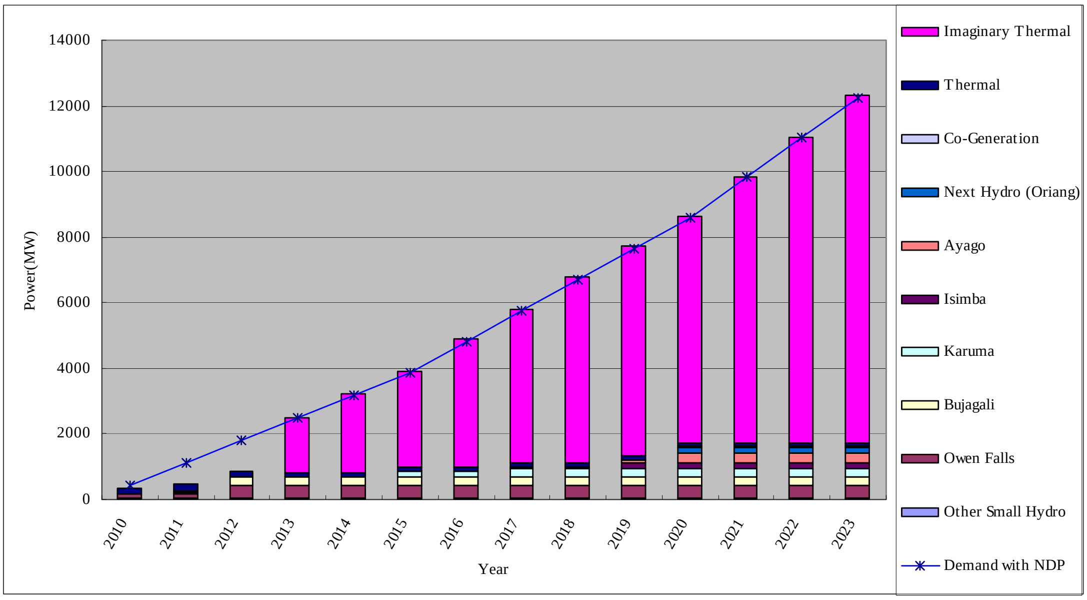


Figure 6.12.3-11 Power Demand and Supply Balance (Scenario VI)

6.12.4 Target Supply Reliability

Reserve margin for peak power demand is shown in Table 6.12.4-1.

Table 6.12.4-1 Reserve Margin (%) for Peak Power Demand

Year	2010	2011	2012	2013	2014	2015	2016
Scenario I	0	7	80	57	45	47	36
Scenario II	0	5	75	51	39	58	45
Scenario III	0	9	85	63	52	55	45
Scenario IV	0	4	76	54	40	42	32

Year	2017	2018	2019	2020	2021	2022	2023
Scenario I	39	29	36	38	27	18	19
Scenario II	29	19	24	24	14	13	20
Scenario III	50	40	50	40	30	32	24
Scenario IV	36	21	33	24	25	17	17

In 2011 and thereafter, all scenarios have enough reserve margin against the target 15%, except two years in Scenario II: 14% in 2021 and 13% at 2012.

Reserve margin for energy demand is shown in Table 6.12.4-2.

Table6.12.4-2 Reserve Margin(%) for Energy Demand

Year	2010	2011	2012	2013	2014	2015	2016
Scenario I	0	0	0	0	0	13	5
Scenario II	0	0	0	0	0	28	17
Scenario III	0	0	0	0	0	20	12
Scenario IV	0	0	0	0	0	10	2

Year	2017	2018	2019	2020	2021	2022	2023
Scenario I	18	10	12	13	12	3	10
Scenario II	9	1	2	9	0	5	20
Scenario III	27	20	22	14	7	17	9
Scenario IV	14	3	4	8	15	7	13

The Study shows that for the period 2013 -2014, the result are similar to GDP 2009-2025 indicating that the current energy supply cannot meet the annual energy demand. For the present, there will be no power addition in 2013 and 2014 and, if the actual demand increases as forecast, there may be power shortage. To cope with such a situation, emergency thermal power, e.g. diesel power, may have to be introduced; in that case it is necessary to consider fiscal conditions.

6.12.5 Summary of Power Development Plan

Power Development Plan of major hydropower projects -Bujagali, Karuma, Isimba, Ayago, and Oriang- for each scenario is shown in Table 6.12.5-1.

Table 6.12.5-1 Summary of Power Development Plan (For Large Hydro)

	Scenario I		Scenario II		Scenario III		Scenario IV	
	plant	power	plant	power	plant	power	plant	power
2010								
2011	Bujagali	50MW	Bujagali	50MW	Bujagali	50MW	Bujagali	50MW
2012	Bujagali	200MW	Bujagali	200MW	Bujagali	200MW	Bujagali	200MW
2013								
2014								
2015	Karuma	192MW	Karuma	192MW	Karuma	192MW	Karuma	192MW
2016								
2017	Karuma	96MW	Karuma	96MW	Karuma	96MW	Karuma	96MW
2018								
2019	Isimba	138MW	Isimba	138MW	Isimba	138MW	Isimba Ayago	138MW 102MW
2020	Ayago	102MW	Ayago	102MW				
2021							Ayago	102MW
2022			Ayago	102MW	Ayago	102MW		
2023	Ayago	102MW	Ayago Oriang	102MW 102MW			Ayago	102MW

In a run-of-river type hydropower development, surplus energy above the firm energy cannot be counted in the power supply plan, so that the power supply plan takes the maximum capacity of Karuma project at 300MW. Secondary energy, which is energy in excess of firm energy, is usually expected to contribute to save fuel of thermal power, so that it is desirable to give priority to development of firm capacity over secondary capacity in Uganda, where there is more deficiency in energy than in peak power. Therefore, it would appear more reasonable to develop the Karuma at 300MW together with Ayago at 300MW than to develop the Karuma at 600MW in one phase since the 600 MW is more expensive. Thermal power can be suspended or retired in 2015 and thereafter in Scenarios I, III and IV and in 2017 and thereafter in Scenario II. Table 6.12.5-2 shows fuel cost saving of the suspended/retired thermal power. The adopted price of fuel is 0.12 US$/kWh (refer to 7.11). As the result, the suspension of thermal power enabled by development of hydropower projects will contribute to improve financial situation.

Table 6.12.5-2 Cost Saving from Suspended Thermal (Until 2023)

Year		2015	2016	2017	2018	2019	2020	2021	2022	2023
Suspended Power (GWh)	Scenario I	881	881	977	977	1,217	1,217	1,320	1,320	1,421
	Scenario II			977	977	1,217	1,217	1,320	1,320	1,421
	Scenario III	881	881	977	977	1,217	1,217	1,320	1,320	1,421
	Scenario IV	881	881	977	977	1,217	1,217	1,320	1,320	1,421
Cost Saving (mil.US$)	Scenario I	106	106	117	117	146	146	158	158	171
	Scenario II	0	0	117	117	146	146	158	158	171
	Scenario III	106	106	117	117	146	146	158	158	171
	Scenario IV	106	106	117	117	146	146	158	158	171

In addition, annual reduction of CO_2 emission is estimated at 516,616 ~ 548,856 t eq.CO_2 by suspension of diesel thermal power. (Refer to Table 5.1.4-4).

In conclusion, it is recommendable to steadily develop the above-mentioned hydropower projects since hydropower development contributes not only to solve the chronicle power shortage but also to promote retirement of high-cost thermal power and to reduce CO_2 emission and, eventually, to contribute to stable power supply in East Africa region.