Alexandria University
Faculty of Engineering

Power Trade Assessment in Eastern Nile Basin Countries

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THU 28 May 2015

XVth IWRA World Water Congress, Edinburgh, Scotland

Historical View

1. April 15, 1891 – Anglo-Italian Protocol.
2. May 15, 1902 – Treaty between GB and Ethiopia.
3. Dec 13, 1906 – Tripartite Treaty (Britain-France-Italy).
4. The 1925 exchange of notes between Britain and Italy.
5. May 7, 1929 – Agreement Egypt (48 KM^3) and Sudan (4 KM^3).
6. 1959 Agreement - Sudan (18.5 KM^3) and Egypt (55.5 KM^3).
7. 1993 Nile accord - Meles-Mubarak
8. Nile Basin Initiative (Feb 1999).
9. 1996: Helsinki Rules - Uses of the Waters of International Rivers.
10. 1995: Protocol on Shared Watercourse Systems.
11. 1997: UN Convention - Uses of International Watercourses.
12. April 2011 – GERD project (14 – 50 – 64 – 74 KM^3) + IPoE report
13. Mar 2015 – Declaration of Principles.
14. Consultant Firm (BRL and Deltares) (Quantity – Env. – Social).

Declaration of Principles

23/3/2015

1. Principle of cooperation.
2. Principle of development, regional integration and sustainability.
3. Principle of not causing significant damage.
4. Principle of fair and appropriate use.
5. The principle of the dam's storage reservoir first filling, and dam operation policies.
6. The principle of building trust.
7. The principle of exchange of information and data.
8. The principle of dam security.
9. The principle of the sovereignty, unity and territorial integrity of the State.
10. The principle of the peaceful settlement of disputes.

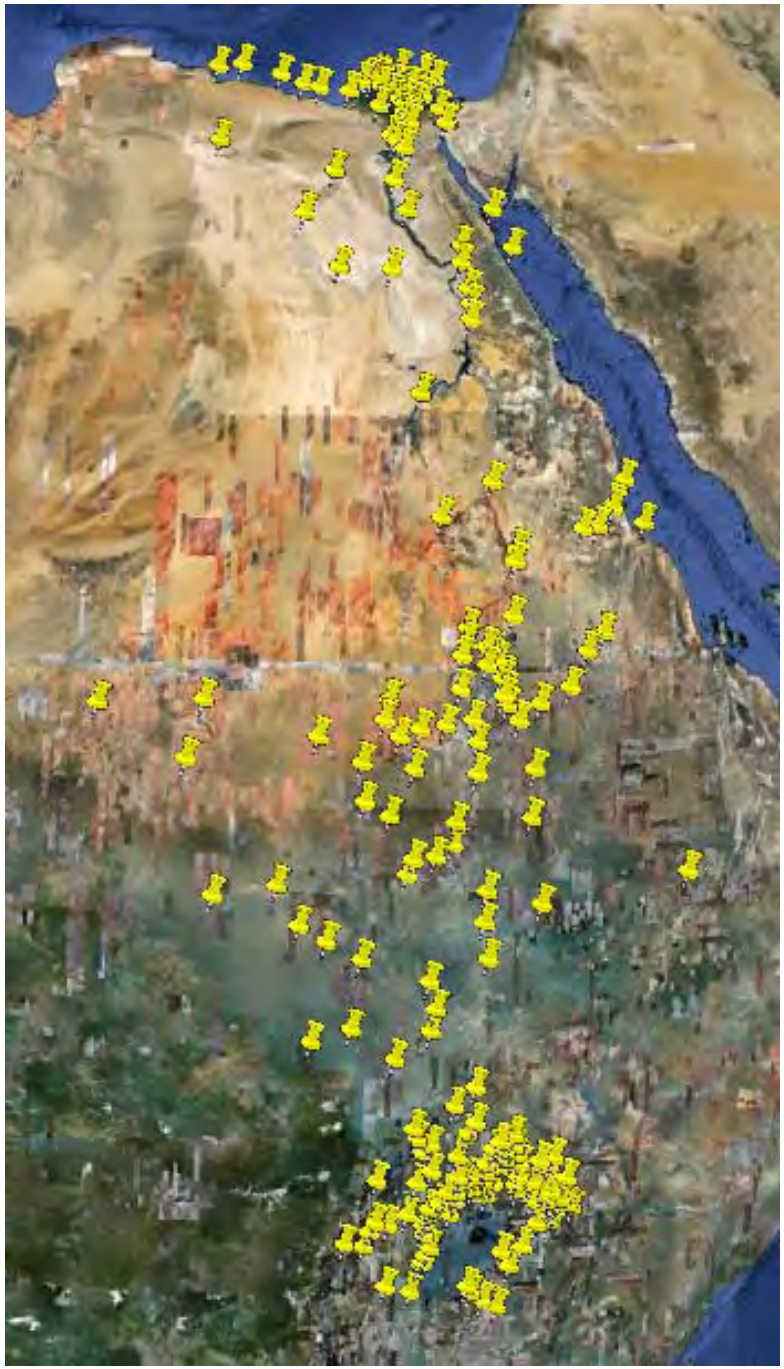
Facts and Figures

- Egypt Water Resources: 81 KM^3
  55.5 Nile – 22.0 Reuse – 2.0 GW – 1.0 Reuse of WW – 0.5 other
- Water usage
  71.5 Agr. – 5.5 Domestic – 3.0 Ind. – 1.0 Nav.
- 87% from Ethiopia (Blue Nile 56% - Atbara 14% – Sobat 16%).
- Blue and Green Water.
- Ethiopia (Droughts – Energy Crisis – Development needs).
- Sudan (Floods – Sedimentation – Irrigation – Energy).
- *Equitable, Reasonable and Sustainable.*
- *Power Plants (Egypt 32 GW – Sudan 3 GW – Ethiopia 1 GW).*

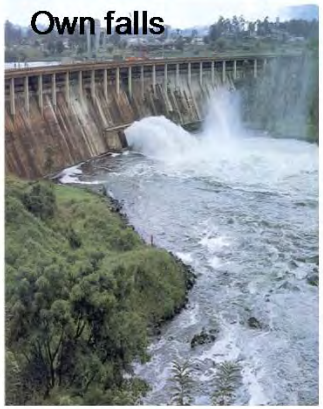

THE NILE BASIN VOL. XI – HURST BLACK & SIKA

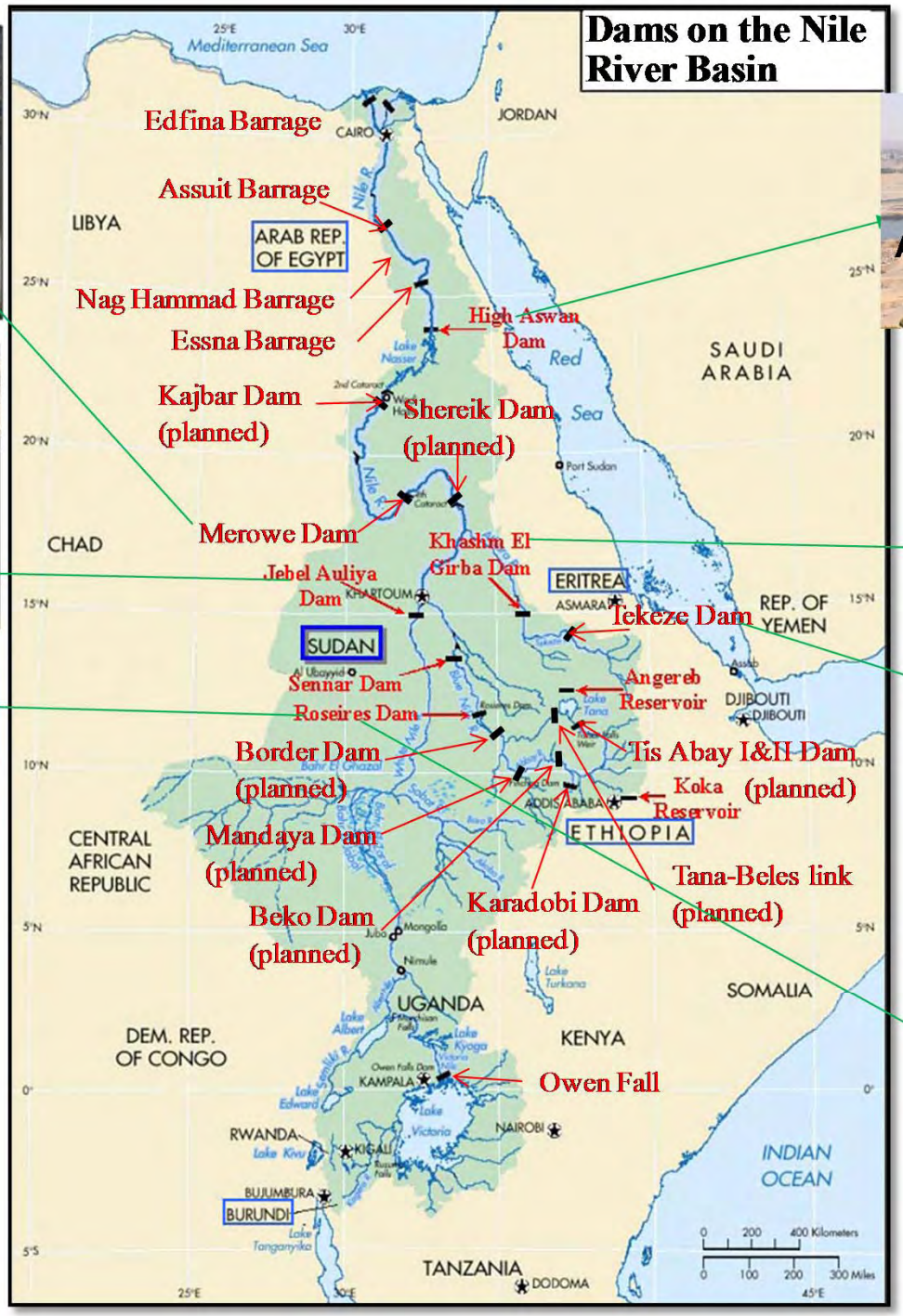
Nile Basin Data

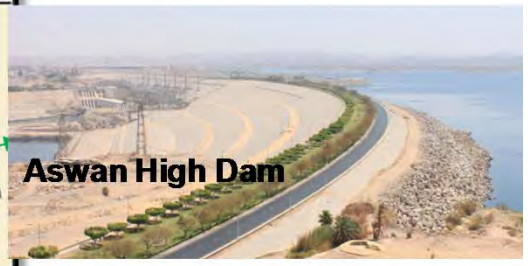
- 195 stations, 10 days average, since 1903, and available data:
  - Calculated and measured discharges
  - Water levels
  - Rainfall
- Database has been created with the assistance of 80 students during Summer training.



SENNAR DAM (D.S. VIEW)







KHASHM EL GIRBA DAM (U.S. VIEW)

Rosseriers dam

Date	Water Arriving Aswan	Dongola
1973 – Aug (1-10)	278	387
1973 – Aug (11-20)	494	474
1973 – Aug (21-end)	**616**	452
1973 – Sep (1-10)	598	607
1973 – Sep (11-20)	491	556
1979 – Feb (1-10)	97.8	111
1979 – Feb (11-20)	73.6	75
1979 – Feb (21-end)	**13.1**	64.2
1979 – Mar (1-10)	53.2	78.5
1979 – Mar (11-20)	74.9	74
1997 – Jan (11-20)	48.2	89.8
1997 – Jan (21-end)	33.3	91.1
1997 – Feb (1-10)	**16.6**	86.4
1997 – Feb (11-20)	102	84.3
1997 – Feb (21-end)	28.5	79.3

	Dongola	Hudeiba & Hassanab	Atbara Km 3.0	Diff
1999 – Aug (1-10)	541	412	142	13
1999 – Aug (11-20)	680	546	189	55
1999 – Aug (21-end)	843	606	253	16
1999 – Sep (1-10)	890	644	341	95
1999 – Sep (11-20)	807	517	181	-109
1999 – Sep (21-end)	503	312	36	-155
1999 – Oct (1-10)	350	202	9	-139
1999 – Oct (11-20)	465	437	100	72
1999 – Oct (21-end)	550	453	119	22
1999 – Nov (1-10)	385	278	9	-98

Water Arriving at Aswan

Ten-days and Monthly means in millions of cubic metres per day, totals in millions of cubic metres , to 3 significant figure

52 instead of 0.25

49.2

1553

		Jan.	Feb.	Mar.	Apr.	May	June.	July.	Aug.	Sept.	Oct.	Nov.
	1 - 10	60.0	42.2	51.7	59.7	58.3	38.9	45.6	132	575	222	203
	11 - 20	59.0	54.0	36.8	59.3	54.2	51.3	49.2	311	508	162	151
	21 - end	25.4	0.250	43.4	92.7	40.1	46.9	80.8	493	309	201	91
1983		7.4	34.4	43.9	70.6	50.5	45.7	59.2	318	464	195	148
		470	**960**	**1360**	**2120**	**1570**	**1370**	**1840**	**9860**	**13900**	**6050**	**4450**
	1 - 10	20.0	102	37.9	23.9	72.0	34.1	38.4	276	284	146	54.4
	11 - 20	46.1	63.1	37.5	84.3	77.3	29.6	100	261	168	149	29.1
	21 - end	96.0	54.3	41.3	66.0	40.8	12.5	143	284	92.6	92.3	54.5
1984	Mean	55.4	73.8	39.0	58.1	62.6	25.4	95.2	274	182	128	46
	Total	**1720**	**2140**	**1210**	**1740**	**1940**	**760**	**2950**	**8500**	**5450**	**3960**	**1380**
	1 -10	32.4	36.1	39.2	40.0	63.5	49.6	71.4	239	683	244	109
	11 -20	50.6	44.4	61.2	79.3	63.5	40.6	152	486	788	232	86.5
	21 - end	39.7	23.4	69.7	53.1	70.1	56.1	265	515	496	137	98.4
1985	Mean	40.9	35.0	53.9	57.5	65.8	48.8	166	417	656	202	97.9
	Total	**1270**	**990**	**1670**	**1720**	**2040**	**1460**	**5150**	**12900**	**19700**	**6270**	**2940**
	1 - 10	90.8	59.4	32.6	51.9	83.5	86.5	59.7	231	470	205	128
	11 -20	49.8	30.4	32.6	55.0	80.5	0.600	158	562	454	159	87.8
	21 - end	56.8	51.6	36.3	61.2	51.7	22.8	222	434	330	188	42.4
1986	Mean	65.5	46.8	33.9	56.1	71.3	36.6	149	410	418	184	86.2
	Total	**2030**	**1310**	**1050**	**1680**	**2210**	**1100**	**4610**	**12700**	**12600**	**5700**	**2580**

Discharges of Water

Ten-days and monthly means in millions of cubic metres per day,

		January	February	March	April	May	June
1973	1—10	51.4	42.8	20.1	32.2	82.4	73.6
	11—20	59.1	62.5	41.6	73.2	73.0	67.0
	21-end	57.6	34.5	54.8	76.2	81.6	92.0
	Mean	56.4	47.5	39.4	60.5	79.1	77.6
	Total	**1740**	**1330**	**1220**	**1820**	**2450**	**2330**
1974	1—10	28.6	97.5	44.5	*31.0	87.5	87.9
	11—20	68.6	60.5	43.8	64.1	87.3	83.1
	21-end	90.0	52.8	50.9	73.0	84.1	76.6
	Mean	63.3	71.5	46.5	56.9	86.2	82.5
	Total	**1960**	**2000**	**1440**	**1650**	**2670**	**2430**
1975	1—10	55.6	74.5	44.9	69.8	92.1	66.0
	11—20	84.9	62.3	24.8	82.1	69.8	36.7
	21-end	84.0	47.5	37.5	82.6	72.4	38.1
	Mean	75.2	75.2	35.8	78.2	78.2	46.9
	Total	**2330**	**2110**	**1110**	**2350**	**2420**	**1410**
1976	1—10	105	86.6	75.2	29.2	39.7	126
	11—20	82.5	57.4	62.2	39.9	77.7	35.0
	21-end	89.7	53.4	33.0	85.4	90.5	71.4
	Mean	92.4	66.2	56.0	51.5	70.0	77.6
	Total	**2860**	**1920**	**1740**	**1540**	**2170**	**2330**
1977	1—10	50.8	57.2	1.1	28.3	48.5	56.0
	11—20	52.4	28.0	31.9	56.5	70.0	50.1
	21-end	71.9	33.1	46.9	79.2	89.1	41.6
	Mean	58.8	39.9	27.3	54.7	69.8	49.2
	Total	**1820**	**1120**	**846**	**1640**	**2160**	**1480**

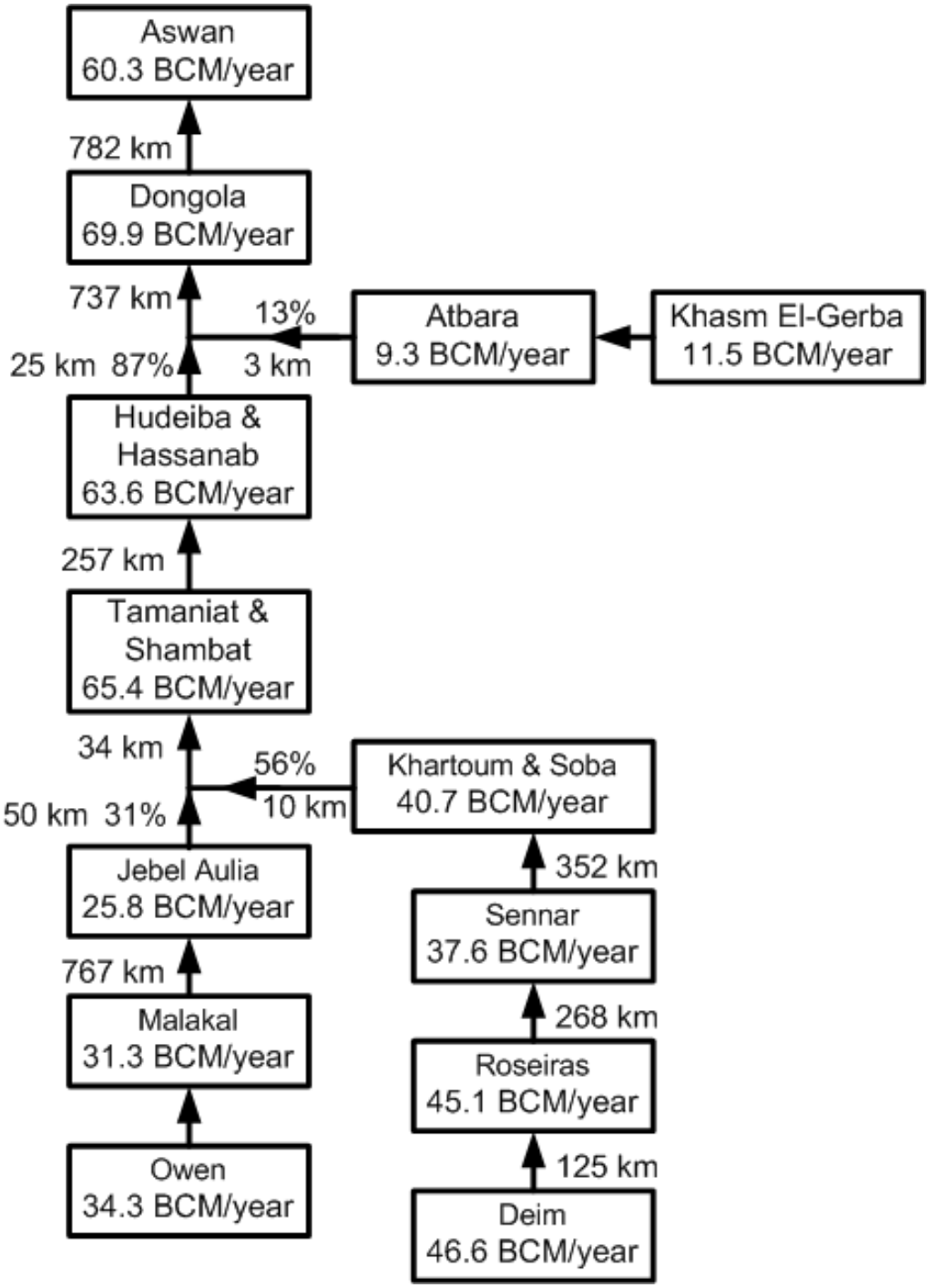
* N.B. The contents of Sudd Aali began at 2nd April 1974 according to the new instructions. So, the Monthly total and the Monthly Mean were calculated for 29 days only after cancelling the first of April 1974.

Arriving at Aswan

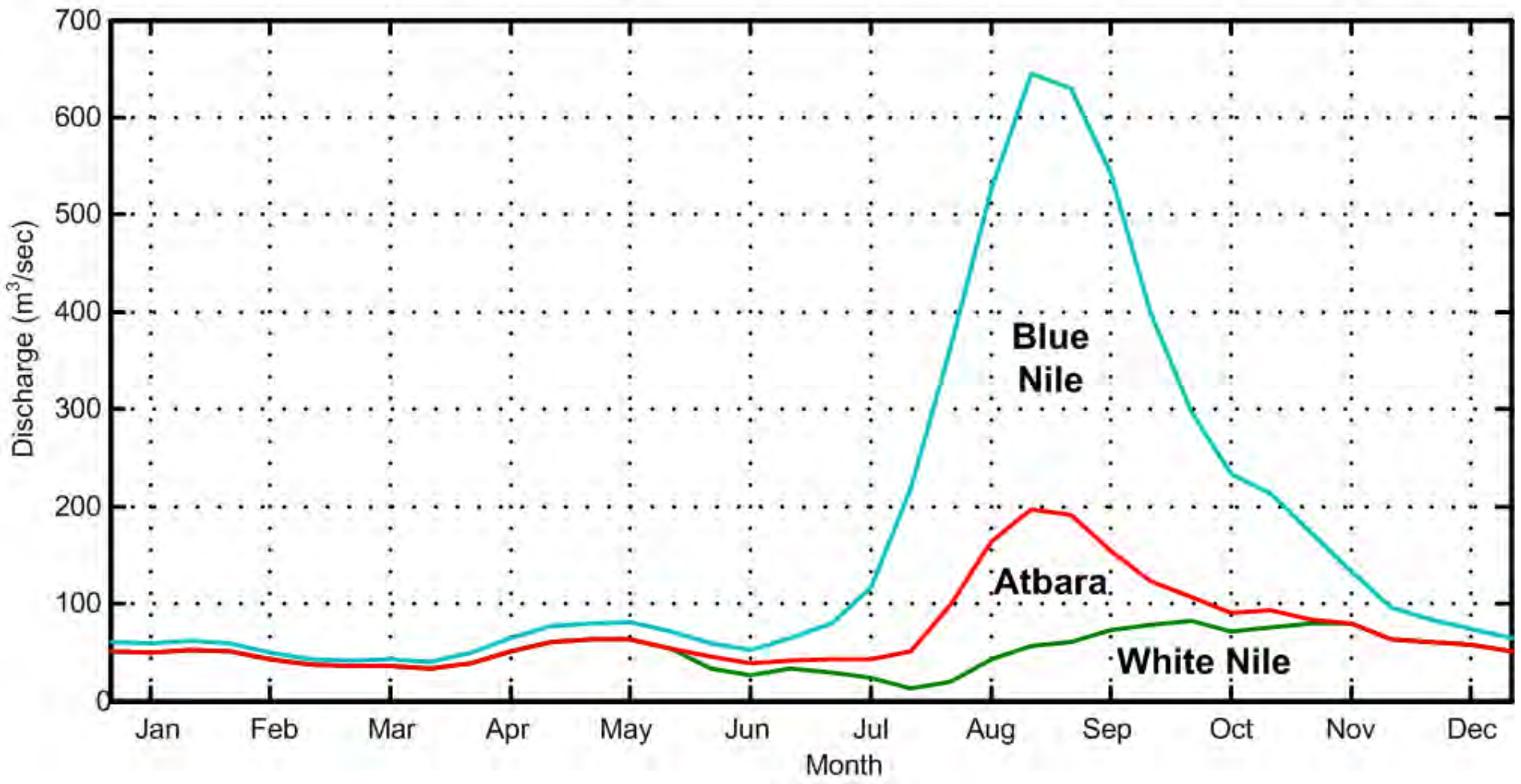
totals in millions of cubic metres, to 3 significant figures.

July	August	September	October	November	December	Year
73.0	278	598	348	236	105	
79.3	494	491	286	135	101	
96.8	616	509	290	117	76.5	
83.5	468	532	307	163	96.9	168
2590	**14500**	**16000**	**9520**	**4890**	**2910**	**61300**
90.5	470	579	396	151	106	
186	623	583	353	118	103	
442	864	526	222	102	71.4	
246	659	563	320	124	92.6	202
7640	**20400**	**16900**	**9930**	**3710**	**2870**	**73700**
64.9	410	848	655	164	115	
110	598	854	382	128	92.7	
161	933	719	244	127	94.7	
113	656	807	421	139	101	220
3510	**20300**	**24200**	**13100**	**4180**	**3120**	**80100**
79.0	280	601	233	104	86.8	
116	517	452	200	116	86.8	
195	663	332	130	70.6	76.0	
132	493	462	186	96.8	82.9	156
4100	**15300**	**13900**	**5760**	**2900**	**2570**	**57000**
50.8	540	623	324	190	105	
97.0	452	422	194	218	82.0	
173	893	352	179	151	86.4	
109	637	466	231	186	90.8	169
3380	**19700**	**14000**	**7150**	**5590**	**2820**	**61700**

- At Atbara:
  - 13% from Atbara River
  - 87% from Main Nile
- At Khartoum
  - 56 % from Blue Nile
  - 31 % from White Nile
- Water Losses or abstraction
  - Atbara – Dongola reach
    - 72.9 - 69.9 = 3 BCM
  - Dongola – Aswan reach
    - 69.9 – 60.3 = 9.6 BCM

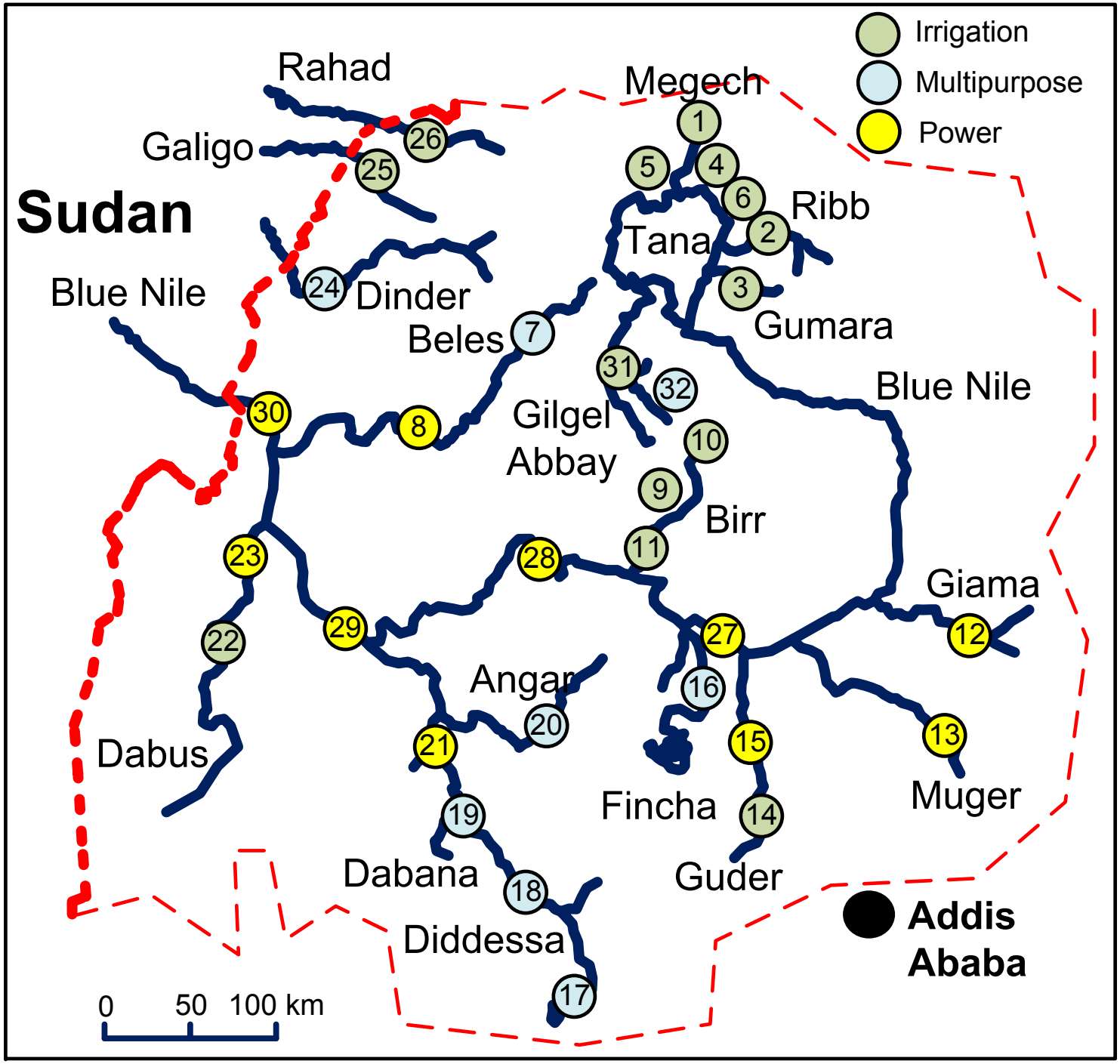


10 Days Average – Water Arriving Aswan From Blue Nile, White Nile, and Atbara



Ethiopia

- 1,104,300 Km^2
- 10 Basins
- Population:
  - 79 millions (2009)
  - 278 millions (2050)


Irrigation
Multipurpose
Power
Rahad
Galigo
Sudan
Blue Nile
Dinder
Megech
Tana
Ribb
Gumara
Beles
Blue Nile
Gilgel
Abbay
Birr
Giama
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Dabus
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	Benefit projects (Ethiopia)	Non-benefit projects (Ethiopia)
Benefit projects (Egypt and Sudan)	12 projects (8, 12, 13, 15, 16, 17, 18, 19, 21, 23, 27, 28, 29, and 30)	2 projects (12, and 19)
Non-benefit projects (Egypt and Sudan)	10 projects (4, 5, 6, 7, 11, 14, 20, 22, 24, and 26)	6 projects (1, 2, 3, 9, 10, and 25)


Saddle dam
Spillway
Main dam
2250 MW (#6)
Right of way (# 8 line)
3750 MW (#10)
Switchyard 500 Kv
SP studio pietrangeli
consulting engineers
www.pietrangeli.it

Main Dam	
Type	Roller compacted concrete (RCC) dam
Max. Height above foundation	145 m
Crest length	1,780 m
Reservoir Data	
Full Supply Level (FSL)	640 m asl
Minimum operating level (MOL)	590 m asl
Total Storage volume	74.01 Bm^3
Dead storage volume	14.79 Bm^3
Surface area at (FSL)	1,874 km^2
Mean annual sediment yield	207 Mm^3/y
Saddle Dam	
Type	Rock Fill with Bituminous Surface Sealing
Height	45m
Crest length	4,800m
Power and Energy	
Total Installed Capacity	6,000 MW
Average annual energy generation	15,692 GWh/yr
Plant factor	0.31

Critical Points

- Reservoir (size, filling time, operation rules, and water usage).
- Dam break analysis.
- Environmental and social impacts (Water quality, sediment transport, marine, ecology, salinity, water borne disease, reservoir land, industry).
- Quantity (Floods in Sudan – Peak time – Spillage – White Nile – Irrigation Expansion – Evaporation – Leakage).
- Power trade.

THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

MINISTRY OF WATER AND ENERGY

ALTERNATIVES TO THE MANDAYA PROJECT CASCADING OPTIONS

July 2011

NORPLAN Norconsult Scott Wilson EDF JV

In association with

SHEBELLE CONSULT PLC TROPICS CONSULTING ENGINEERS P.L.C

Background

In March 2011 the Government announced that a contract was signed with the Italian contractor Salini to develop the Millennium Dam later renamed Renaissance Dam. The Consultant immediately informed MoWE that all study work with Mandaya was at once stopped if not otherwise instructed as this project was strongly impacted by the Renaissance project. MoWE in letter dated 28.04,2011 confirmed that any ongoing studies and site investigations at Mandaya should be stopped until further notice was given and the Consultant instructed to study upstream options to replace the Mandaya project in the cascade.

This memo is a response to the instruction from the Client MoWE, to highlight the cascade development taking into account ongoing project construction. And further to enhance that systematic development of the hydropower potential in the main Abay river course through many years to come would have minimum negative influence to its preceding and any other earlier developed project. The different options have been recommended and prioritize /ranked according to their technical, construction cost per unit energy and assessed environmental and social-economic impact merits.

The Consultant learned in September 2010 that a study of a project was under development downstream of Mandaya. A presentation of the cascade development options to be presented in the Beko-Abo Draft Prefeasibility Report recommending developments to start at the top of the cascade was made to MoWE in late October. Technical information on the ongoing downstream project now named Renaissance Dam (earlier named Border) was only received late March 2011 and all study work with Mandaya was immediately stopped as this project was strongly impacted. MoWE in letter dated 28.04,2011 confirmed that any ongoing studies and site investigations at Mandaya should be stopped until further notice was given.

In the same letter the Consultant was instructed to study upstream options to replace the Mandaya project in the cascade. This memorandum is a response to that instruction.

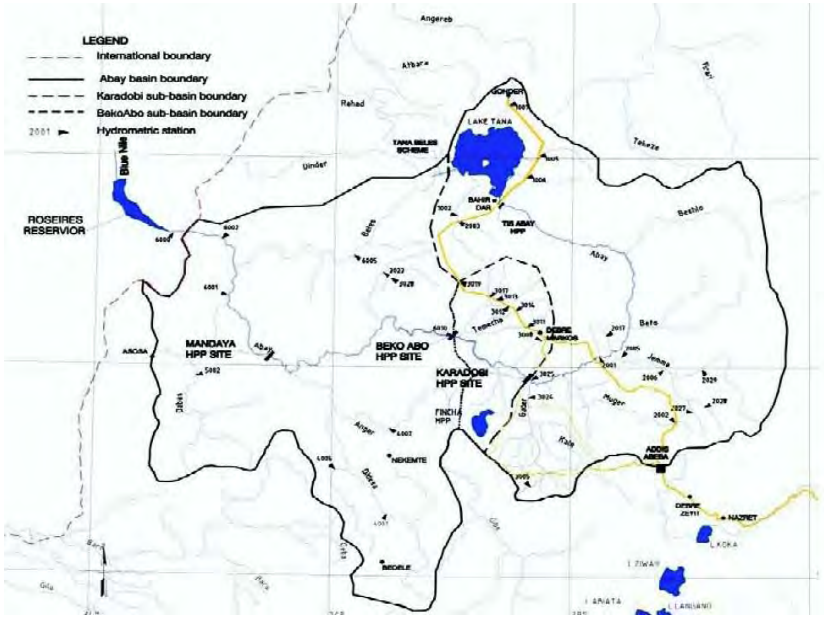
Four cascading options have been studied and analysed, ref Table S3 below:

A: Karadobi – Beko Abo Low – Mandaya – Renaissance FSL 620

B: Karadobi – Beko Abo Low – Upper Mandaya – Renaissance FSL 640 (Lower Didesa excluded as deemed not to be economic in the cascade)

C: Beko Abo High – Mandaya – Renaissance FSL 620

D: Beko Abo High – Upper Mandaya – Renaissance FSL 640 (Lower Didesa excluded as deemed not to be economic in the cascade)



The Upper Mandaya and Lower Didesa dam sites are located about 39 km and 45 km North West respectively from the newly constructed road bridge over the Didesa River situated 30 km north east of the Kamashi town. Currently, there is no access to these sites except walking through a remote and challenging topography or by helicopter. Upper Mandaya is about 7.5 km and Lower Didesa about 8.5 km upstream of the Abay-Didesa confluence. The distance between the two dam locations is about 9 km.

The sites were inspected on 8 May 2011. Access was by helicopter from Bahir Dar. The sites were just within the range of the helicopter and there was insufficient fuel for multiple fly-pasts of the sites. However, adequate aerial photographs were taken to show the sites. A number of photographs were also taken from the ground of both sites.

Cascade A consisting of Karadobi – Beko Abo Low – Mandaya – Renaissance FSL 620 m gives the highest energy output of the cascade options studied at the lowest construction cost (unit energy basis) per kWh and with the least environmental and socio-economic impacts.

	Potential Irrigated Area	Irrigation Water Requirements	
Area	**Ha.**	**Mm^3/a**	**Average flow (m^3/s)**
Lake Tana	7500	614.4	19.48
Upper Beles	75000	1 024.0	32.47
Didesa River	45500	435.0	13.79
Finchaa Sugar	22000	307.8	9.75
Totals	**210000**	**2 381.2**	**75.49**

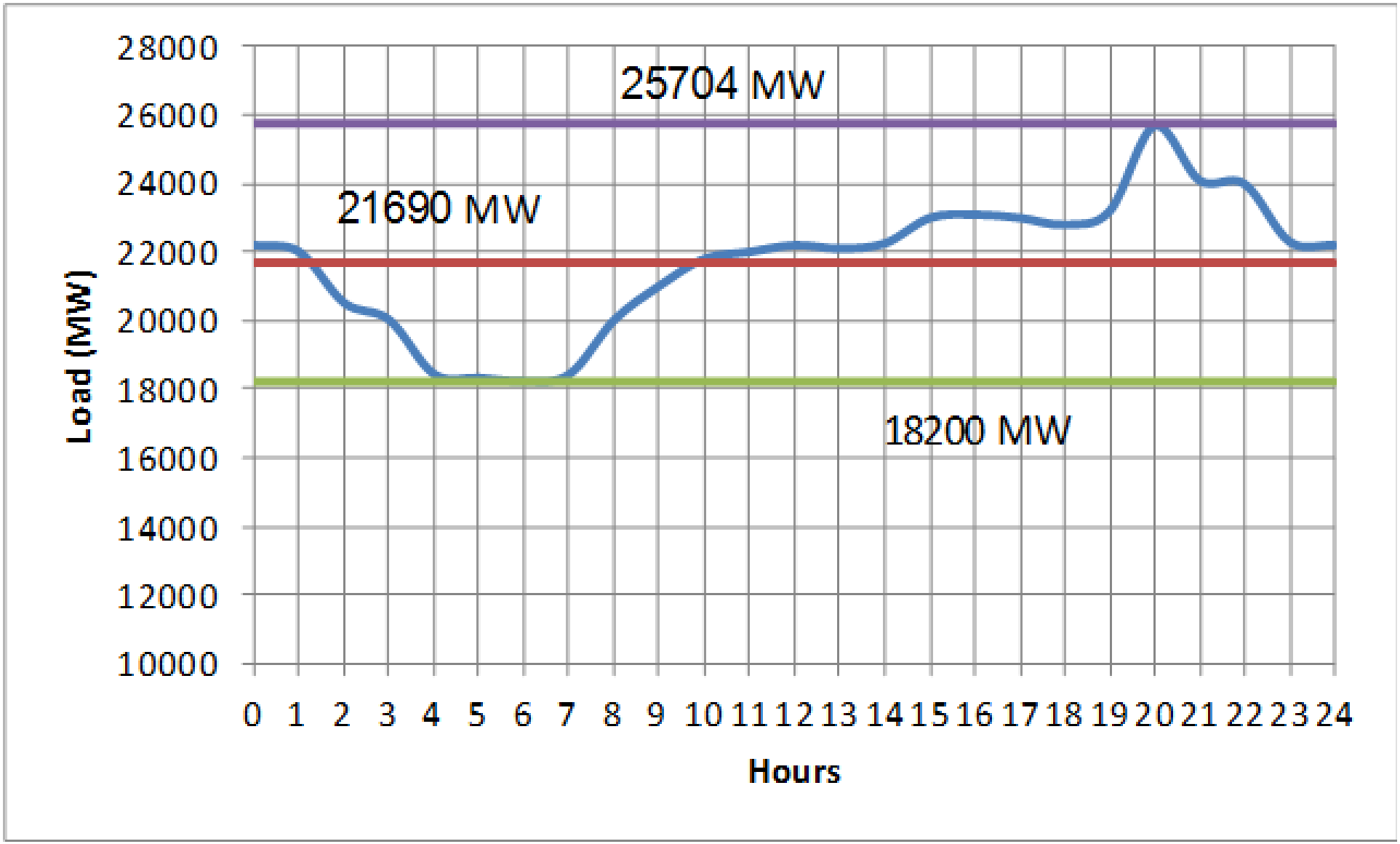
Power and Energy Production

Option	Project	** Inflow		Reservoir					Cascading Performance and Output							Stand Alone
		Average Annual	Additional Inflow	FSL	MOL	Gross Storage Volume	Live Storage Volume	Accumulated Live Storage	Gross head	Capacity	50-year average					Production
				Nat. Ref. level	Nat. Ref. level						Inflow*	Turb. Disch.	Spill	Evaporation	Production	
		Bill. m^3	Bill. m3	m	m	Bill. m3	Bill. m3	Bill. m3	m	MW	m^3/s	m^3/s	m^3/s	m^3/s	GWh/a	GWh/a
A	**Karadobi/Beko-Abo Low/Mandaya/Renaissance 620**															
	Karadobi	17,8		1 146	1 100	40,2	17,3	17,3	236	1 600	565	532	24	10	8 764	**8 761**
	Beko-Abo Low	21,4	3,6	910	870	2,0	1,2	18,5	110	935	671	634	35	1	5 209	
	Mandaya	35,0	13,6	800	770	48,1	18,9	37,4	180	2 750	1 098	1 074	8	18	14 099	
	Renaissance 620	48,8	13,8	620	590	35,0	23,4	60,8	125	2 400	1 524	1 480	10	34	13 623	**12 600**
	Beles														2 208	
Cas. 1	**Sum Ethiopia**					**125,3**			**651**	**7 685**	-	-	-	**63**	**43 903**	
B	**Karadobi/Beko-Abo Low/Mandaya Upper/Reenaissance 640**															
	Karadobi	17,8		1 146	1 100	40,0	17,3	17,3	236	1 600	565	532	24	10	8 764	
	Beko-Abo Low	21,4	3,6	910	870	2,0	1,2	18,5	110	935	671	634	35	1	5 209	
	Mandaya Upper	26,0	4,6	800	770	27,7	10,3	28,7	160	1 700	816	774	26	16	9 485	
	Renaissance 640	48,8	22,8	640	610	62,9	37,8	#REF!	145	2 800	1 523	1 420	75	50	15 207	**15 122**
	Beles														2 208	
Cas. 2	**Sum Ethiopia**					**132,6**			**651**	**7 035**	-	-	-	**77**	**40 873**	
C	**Beko-Abo High/Mandaya/Renaissance 620**															
	Beko-Abo High	21,3		1 062	1 010	31,7	17,5	17,5	262	2 423	679	649	23	9	12 815	**12 815**
	Mandaya	35,0	13,7	800	770	49,1	18,9	36,4	180	2 750	1 100	1 074	8	18	14 334	**13 967**
	Renaissance 620	48,8	13,8	620	590	35,0	23,4	59,8	125	2 400	1 525	1 477	15	34	13 577	**12600**
	Beles														2 208	
	Chemoga Yeda Stage II														*-568*	
Cas. 3	**Sum Ethiopia**					**115,8**			**567**	**7 573**	-	-	-	**61**	**42 366**	
D	**Beko-Abo High/Mandaya Upper/Renaissance 640**															
	Beko-Abo High	21,4		1 062	1 010	31,7	17,5	17,5	262	2 423	679	649	23	9	12 815	
	Mandaya Upper	26,0	4,6	800	770	27,7	10,3	27,8	160	1 700	817	773	29	16	9 560	**8 597**
	Renaissance 640	48,8	22,8	640	610	62,9	37,8	#REF!	145	2 800	1 524	1 444	36	34	15 314	**15122**
	Beles														2 208	
	Chemoga Yeda Stage II														*-568*	
Cas. 4	**Sum Ethiopia**					**122,3**			**567**	**6 923**	-	-	-	**59**	**39 329**	
	Lower Didesa Outside Cascade	9	9	800	770	8	4	4	160	550	277	247	27	4	**2 843**	**2843**

* Natural inflow before regulations and evaporation losses

** After deduction of upstream evaporations

Plant factor around 0,6 for all projects


28000
26000
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22000
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Load (MW)
25704 MW
21690 MW
18200 MW
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hours

	GERD	AHD	Comments
Installed Power (MW)	6000 (375×16)	2100 (175×12)	2.86
Annual mean discharge (10^9 m^3/year)	60	55.5	
Design USWL (m)	590	165	
DSWL (m)	500	110	
Effective Head (m)	90	55	
Mechanical Efficiency	0.85	0.8	
Available Power (MW)	1427	949	1.5
Plant load factor	%24	%45	Compare
Energy (GWhr/year)	12500	8313	1.5