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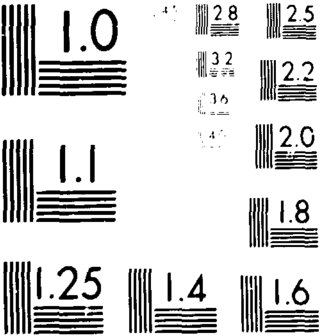

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HYDRO-ELECTRIC ENERGY IN EGYPT*

by

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INTRODUCTION

Hydro-Electrical Energy in Egypt can be derived from three main sources:

a) The Nile, its branches and the irrigation canals thereof.

b) The Mediterranean Sea connected to the Quattara Depression.

c) The Gulf of Suez and Red Sea water by pump storage on the hills on the Eastern side of Egypt, bordering the Gulf and Read Sea.

Over many centuries great efforts were exerted to control the Nile water for the purpose of irrigation. Studies for generating Hydro-Power started about 60 years ago with the Qattara Project. About 45 years ago two mini-hydro power stations were installed in the Fayoum area of a capacity of 600 KW and 300 KW each. A third mini-hydro power station of 700 KW capacity was installed in Nag-Hamadi in 1942. The construction of the first big hydro-power station with 350 MW capacity on the Aswan Barrage started in 1947 and was commissioned in 1961.

The biggest hydro power station in Egypt is that constructed on the High Dam at Aswan and it has a capacity of 2100 MW. It was installed between 1964 and 1970.

After 1973 with the increase of oil prices, it was decided to study all available Hydro Energy resources and for this purpose the "Qattara, Hydro-Electric and Renewable Energy Resources Projects Authority" was established in 1976. In the following paragraphs a description of the main existing Hydro-Power installations and the studies to utilize the Hydro-Energy resources shall be detailed.

Power Demand

Several studies have been carried out to forecast the energy and power demands for the country. The summary of the latest forecast based on 9% increase is given as follows:

Year	Consumption GWH	Maximum load MW
1980	18000	3250
1985	35000	5900
1990	51000	9000
1995	75000	13000
2000	105000	18000

During the period from 1970 to 1980 about 70% (which decreased to 65% in 1980) of the total consumption and the maximum load was supplied by the Hydro electric power station in Aswan. The load factor decreased from 68% in 1970 to 65% in 1980. The rate of increase of consumption and peak load was above 10% and reached 13% in some years in the period between 1970 and 1980. From these estimates it was clear that it was very necessary to develop every possible resource of hydro electric energy available to economise on fuel consumption.

1. The Nile Hydro-Energy Resources

1. General

After the construction of the High Dam it has been possible to harness the hydro-power resources upstream from Aswan. According to the International Agreement with Sudan, the total quantity of water allocated for Egypt is 55.5 km^3 (milliards of cubic meters). This quantity will reach 57.43 km^3 after Jonglei I Canal Project in Sudan is completed in 1985. There are further projects in Sudan to be developed after 1985 and Egypt will share in costs and benefits. The requirement for irrigation which controls the water release varies between an average minimum of 80Mm^3/day in January and reaches a maximum of 240 Mm^3/day in July, as indicated in Table No.1. The above-mentioned quantity of water is discharged completely from the High Dam and Aswan Barrage but decreases at Esna, Nag-Hammadi, Assiut and Delta Barrages. The average difference of level at the High Dam is 65 m being 175 m above sea level in front of Aswan Barrage and the downstream level is 87 m, i.e. the average difference of head at Aswan Barrage is 23 m. After the installation of Aswan II power station on Aswan Barrage, the full utilization of the water passing from the High Dam will be reached. This means that at Aswan 50% of the Nile hydro energy will be giving about 11 TWH (8 from the High Dam and 3 from Aswan I plus Aswan II).

The difference of level at Esna, Nag Hammadi and Assiut is about 5 to 6 m between upstream and downstream each and discharges are as shown in Table 2.

From the general study carried out in 1979 an estimate of capacity, energy production, benefit and cost is tabulated in Table No. 3.

The discharges at other sites on the Nile in the Delta and Fayoum are less and the difference of level ranges between 1 meter and 5 meters.

2. High Dam Power Station

(a) Particulars of the High Dam

The High Dam is a sand and rockfill structure having a total volume of 44 million cubic meters of fill and rises 111 meters above the river bed and is 3600 meters long. The reservoir level can reach 182 m and can be drained to 150 m and the live storage volume between these two limits amounts to 120 km^3 of water. The dead storage below 150 m level is 44 km^3 of water. Silt desposits in Lake Nasser are estimated to be 80 Mm^3 per year and therefore several hundred years are required to fill the reservoir. Some of the benefits of the High Dam are the storage of water, the guarantee of water required for irrigation for Egypt and Sudan in dry years and the generation of electricity.

(b) Description and Operation of the Power Station

The power house which is situated on the East side of the Dam, comprises a headrace canal which supplies six tunnels. Downstream each tunnel feeds two penstocks each of which supplies one 175 MW turbo-generator set. The turbines are Francis type having 6.3 m runner diameter cabable of discharging 350 cumecs to give 180,000 KW at 57.5 m head. The power station therefore consists of 12 units each 175 MW with a total capacity of 2100 MW. The power generated at 16 KV is stepped up to 500 KV and transmitted 900 km to Cairo where it is stepped down to 220 KV and interconnected to lower Egypt grid. Two substations at Nag-Hammadi and Samalut step down the voltage from 500 KV to 132 KV to feed Upper Egypt grid. The maximum dependable capacity of the High Dam Power Station is 1750 MW with one unit in maintenance and one as spin reserve. The maximum monthly production at 240 Mm^3/day is 1.25 TWH in summer but the total annual production is 8.0 TWH.

3. Aswan I Hydro-Powerstation

(a) Particulars of Aswan Barrage

The Aswan Barrage, 6 km downstream from the High Dam was constructed between 1899 and 1902 and was heightened twice during the years 1908-1912 and 1929-1933 to increase stored capacity from one milliard cubic meters of water to five milliards. The crest level of the Barrage is 123 and can hold water to 121 m, but after the construction of the High Dam the level should not exceed 113 m and should not fall below 107 m. This gives a storage capacity of 75 Mm^3 and the average reservoir level is 110.

(b) Decription and Operation of the Power Station

The power station is constructed in a natural bay on the West side upstream of the Barrage. There are seven Main Kaplan units to drive generators of capacity 47 MW each at 23 m head and two house units Kaplan units 10 MW each. The generators are solidly connected to step up transformers from 11 KV to 132 KV switchyard which is connected to the main grid. The discharged water is conveyed by four unlined tunnels running underneath the navigation lock to the western channel of the Nile. Aswan I is producing 1900 GWH per annum and the discharge varies between 1350 m^3/sec and 1480 m^3/sec. As the requirements of irrigation exceed this value during some months, the water is spilled through the sluices. Therefore it was decided to construct a new powerstation, Aswan II with 4 units each 67.5 MW, i.e. 270 MW fed from a forebay on the west side of the Barrage east of the navigation lock. The new powerstation which is under construction, will help to carry out maintenance of Aswan I without loss of energy. Both powerstations shall be capable of producing 3000 GWH per annum.

4. Esna, Nag-Hammadi and Assiut Barrages

These three barrages were built at the beginning of this century and subsequently heightened for control and supply of water to canals branching from the Nile upstream from these barrages. The reservoir level in front of these barrages is 78.5 m, 65.1 m and 50.6 m for Esna, Hag-Hammadi and Assiut respectively. The gross head varies from 6.8 to 3.9 m at Esna, from 5.8 to 2.8 m at Nag-Hammadi and from 6.8 m to 3.2 m at Assiut. Low head powerstations will be installed on these barrages. A thorough study has been carried out for electrification of Esna Barrage either by digging a diversion canal on the eastern side and constructing the powerstation on this diversion or building a new barrage with the powerstation on it. When investigations on the existing barrage are finished a decision will be taken as to which method to adopt.

A general study for electrification of Nag-Hammadi and Assiut necessitates more investigations on existing installations. The project for generating electricity from these existing barrages is competitive with alternative generation in modern oilfired steam power plants.

5. Mini-Hydro Power Plants

Three small installations in Fayoum area were constructed about forty years ago. The head varies between 5 and 6 meters and the discharge is 8 to 17 m^3/sec. Due to lack of spare parts and their old condition, none of these units is working nowadays.

Another mini-hydro powerstation at Nag-Hammadi fitted with 3 units of 800 KW each is in a better condition but it is only used in emergencies.

Our new policy is to develop mini-hydro resources and it concentrates on the study and construction of mini-hydro power stations in Fayoum and Delta regions.

Qattara Project

1. General

The Qattara Depression, which is located about 80 kms south of Egypt's coast with the Mediterranean Sea, reaches a depth of 145 m below sea level and the area at 60 m below sea level for the generation of electricity. The water will form a lake 12600 sq.km. in about ten years and generate 600 MW peak load or 4500 GWH yearly. After the formation of the lake, evaporation due to the heat of the sun will take place from its surface. The estimated evaporation will range between 1.7 m and 2 meters per year and it is estimated that the water to replace the evaporation will produce approximately 350 MW or 2000 GWH yearly. This run of the river power station can be used as base load or peak load. It can be also combined with pump storage to a nearby hill of 250 meters.

2. Studies of the Project

These studies were started as long ago as 1916 and another study was made in 1933. The most comprehensive study, however, was started in 1964 in collaboration with Germany by a team headed by Dr. Bassler. These studies included site investigations, borings, climatic conditions, geology etc.

The report on the results of these studies was submitted in 1973 and gave details of four routes for the canal from the Mediterranean to the Depression. This report recommended the use of the shortest route which runs through a mountainous area and therefore requires excavation of about 5000 million cubic meters of earth. During 1975 there was great hope of using nuclear energy to dig the canal and therefore Lahmeyer, the German Consultants, started a detailed study on this alternative of shortest distance with nuclear energy. For comparison an alternative with 2 tunnels of 14 m diameter was studied. Also another alternative called one way pump storage by pumping water to + 140 m and dropping it to - 60 m at the other end of the elevated canal was also proposed. The conclusions reached from this study show that using nuclear energy for digging the canal represents the cheapest method costing 1700 million U.S. dollars. The execution would take 14 years but due to the Secondary effects of using nuclear energy a delay in developing the surrounding area was estimated to cost over one thousand million U.S. dollars. This solution has become remote due to the difficulties in obtaining nuclear technology and due to the great public objection to this method. The second alternative using two tunnels will cost 8000 million U.S. dollars and limits the generated power to 350 MW and is therefore very expensive.

The third alternative using an elevated open canal dug by conventional methods would cost 6000 million U.S. dollars and it is also expensive. The two latter alternatives can be carried out in ten years.

The final report submitted by the consultants shall be reviewed by the Board of Advisors soon. The recommendations of the Board of Advisors shall be submitted to the Board of Directors of the Authority to decide about the next steps. Meanwhile, the Authority has been investigating using conventional methods of digging a route on the eastern side of the Depression running through a less hilly area. The maximum height on this route will be about 100 m compared with 270 m on the shorter route. This eastern route will reach 90 km compared with 76 km for the shortest route. This project has many challenges but is rather interesting and if executed it will be the biggest hydro-project depending on solar energy.

II. Gulf of Suez and Red Sea Water

1. General

The load factor of the grid has decreased from 68% in 1970 to 65% in 1980 and it is expected to reach 61% in 1990. A pump storage powerstation is one of the best methods of improving the load factor and meeting peak and emergency loads. During the past five years a general survey to chose the best sites for pump storage stations has been carried out. The sites studied were located near the Nile at Qena and Mokkatem and would involve the use of Nile water. The hills in these regions are about 250 m high and the difficulties which would arise through the use of Nile water, which is required for irrigation, showed the unsuitability of such sites.

A second possible pump storage site is that linked with the Qattara Project and this is still under study.

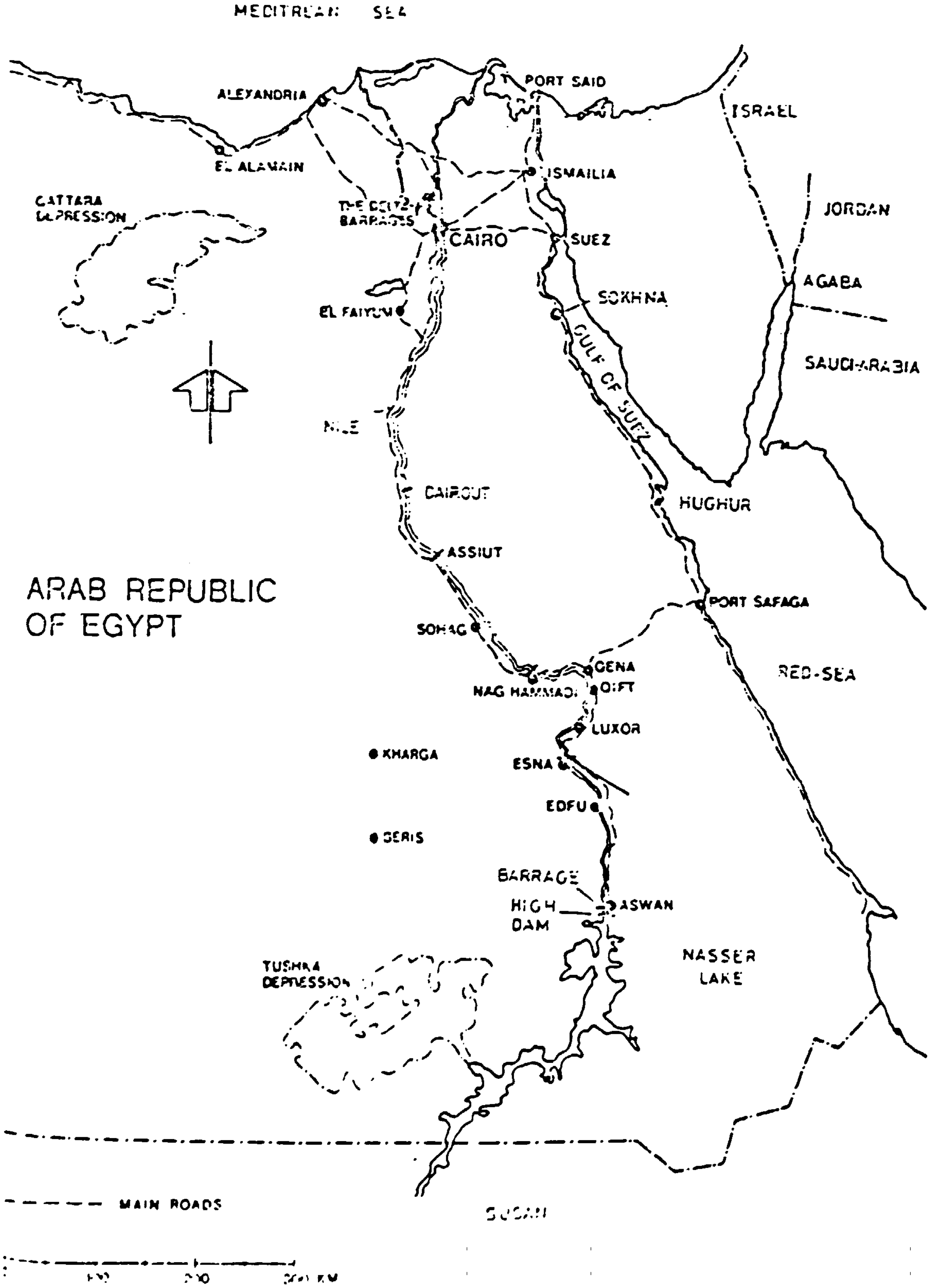
A third location on the Gulf of Suez and Red Sea has been investigated thoroughly. A study of Ataqa mountains near Suez, Alala mountains near Ein el Sukhna which is 60 km south of Suez and near the terminal of the 220 KV overhead line connected to Cairo.

2. Description of Ein el Sukhna Pump Storage Project

The site investigations, including a test tunnel 260 m long in the mountain and differenct borings, have been carried out. Investigations of sea water fouling and tide characteristics are also being carried out. It is expected that the feasibility report will be submitted to the Board of Directors of the Authority early in 1981. The plan requires the installation of 2 x 150 MW units to pump the water to the basin on top of the mountain which has a capacity of 8 million cubic meters of water. Due to the geology of the mountain and the expense of making a cavern in a zone with friable sand, it is suggested to have an outside shaft where the machines will be erected instead of making a cavern inside the mountain. It is suggested to build a steel penstock to the height of 350 meters and a pressure shaft to the top of the mountain. A second powerstation with a capacity of 600 MW can be built in the same area. Under the programme for building the Ain el Sukhna powerstation it is planned to have the first units running by 1986 followed by other stages. The first stage of 300 MW is expected to cost 150 m Egyptian pounds.

QATTARA HYDRO AND RENEWABLE
ENERGY PROJECTS AUTHORITY

KEY MAP



Water Release for Irrigation at Aswan

		Mm^3/day			Mm^3/day
Jan	1	80	Jul	1	240
	2	80		2	240
	3	120		3	225
Feb	1	135	Aug	1	235
	2	155		2	215
	3	135		3	210
Mar	1	140	Sep	1	190
	2	140		2	165
	3	135		3	150
Apr	1	140	Oct	1	130
	2	135		2	125
	3	135		3	130
May	1	150	Nov	1	135
	2	185		2	130
	3	220		3	115
June	1	225	Dec	1	115
	2	225		2	115
	3	235		3	80

Water release Mm^3/day

		Esna	Nag Hammadi	Assiut
Jan	1	73.3	67.8	56.1
	2	73.3	67.8	51.1
	3	110.0	101.7	84.2
Feb	1	124.8	108.4	82.5
	2	143.2	124.3	82.5
	3	124.8	108.4	82.5
Mar	1	127.5	111.2	99.9
	2	127.5	111.2	99.9
	3	122.8	107.0	96.6
Apr	1	123.6	106.7	80.0
	2	128.4	110.8	82.2
	3	128.4	110.8	82.2
May	1	138.2	123.3	97.8
	2	169.9	151.6	120.3
	3	202.4	180.7	143.3
June	1	207.4	185.8	150.4
	2	207.4	185.8	150.4
	3	217.0	194.4	157.3
July	1	228.1	204.0	162.7
	2	228.1	204.0	162.7
	3	213.1	190.8	152.2
Aug	1	199.9	175.8	133.1
	2	195.2	171.6	129.9
	3	176.7	155.3	117.6
Sep	1	151.5	129.3	93.5
	2	138.0	117.8	85.2
	3	119.8	102.2	74.0
Oct	1	115.7	99.4	92.0
	2	111.1	95.4	88.4
	3	115.7	99.4	92.0

Water release Mm^3/day

		Esna	Nag Hammadi	Assiut
Nov	1	124.0	105.3	76.1
	2	120.0	101.9	73.6
	3	105.7	89.8	64.9
Dec	1	102.3	88.3	64.4
	2	102.3	88.3	64.4
	3	71.3	61.5	44.8
Annual Release, Km^3		52.4	46.1	35.8

	Number of Units	Capacity MW	Energy Firm	Production Sec	GWH Total	Benefit ₤E M	Cost ₤E M
Esna + 78.5	7	88.2	437	138	575	148.4	09.6
Nag Hammadi + 65.1	5	52.5	163	156	319	75.4	51.2
Assiut + 50.6	5	52.5	214	103	317	79.4	61.2
Total		193.2	814	397	1211	303.2	212.0
Esna + 79.5	7	99.5	511	188	698	172.7	94.9
Nag Hammadi + 66.1	6	75.6	308	145	456	101.5	78.7
Assiut + 51.6	5	63.0	313	82	395	103.2	67.8
Total		238.1	1132	415	1549	377.4	241.4

Qattara Project Characteristics

Natural Resources of the Qattara Depression:

1.	Surface at El. ± 0	20 000 km^2
2.	Surface at El. - 60 m	11 600 km^2
3.	Deepest point of Qattara Depression at El.	- 145 m
4.	Future Qattara Lake operation water level at El.	- 60 m
5.	Volume of Qattara Lake at El. - 60 m	197 km^3
6.	Evaporation rate (fresh salt water)	1 722 mm/a
7.	Balanced inflow evaporation at El. - 60 m	
	fresh salt water	615 m^3/s
	saturated salt water	506 m^3/s
	long-range average (8% salinity)	600 m^3/s

8. Filling time of the Qattara Lake up to El. - 60 m

permanent inflow (m^3/s)	filling time (years)
700	29.6
800	18.7
900	14.1
1 000	11.3
1 100	9.5
1 200	8.2