Chapter 1
General Characteristics

LOCATION

The Aswan Dam was built in 1902 and heightened twice in 1912 and 1934 to increase its storage capacity. Nevertheless, the stored water was not adequate for agricultural development and great amounts of flood water were released annually into the Mediterranean Sea. In 1959, the construction of a rock-filled dam started on the River Nile, 17 km south of Aswan, 900 km from Cairo, which created one of the largest man-made lakes in Africa - the High Dam Lake (Fig. 1). The Lake extends from the dam itself in the north to the Cataract at Dal, Sudan in the south. The major portion of the Lake lies in Egypt and is known as Lake Nasser, and Lake Nubia on the Sudanese side. Lake Nasser extends between latitudes 22° 00' - 23° 58' N and longitudes 31° 19' - 33° 19' E

The purpose of constructing the Aswan High Dam (**AHD**) was primarily to benefit the downstream side by controlling annual floods, provide irrigation to about two million feddans* and generate electricity. Indirectly, however, the upstream side has also benefited because of the formation of the lake, which has created great possibilities for fisheries, navigation, agricultural production and even tourism. The region from Aswan to Adindan, which was previously an undeveloped desert, is already developed by controlled use of water from the reservoir.

MORPHOMETRY

The whole reservoir extends about 496 km, 292 km for Lake Nasser and 204 km for Lake Nubia. The area of the reservoir at 180 m level is about 6275 km^2 of which Lake Nasser occupies about 5248 km^2. The mean depth of Lake Nasser at 160 m level is 21.5 m as compared with about 25.2 m at 180 m level.

* Hectare = 2.4 feddans = 2.471 acres.

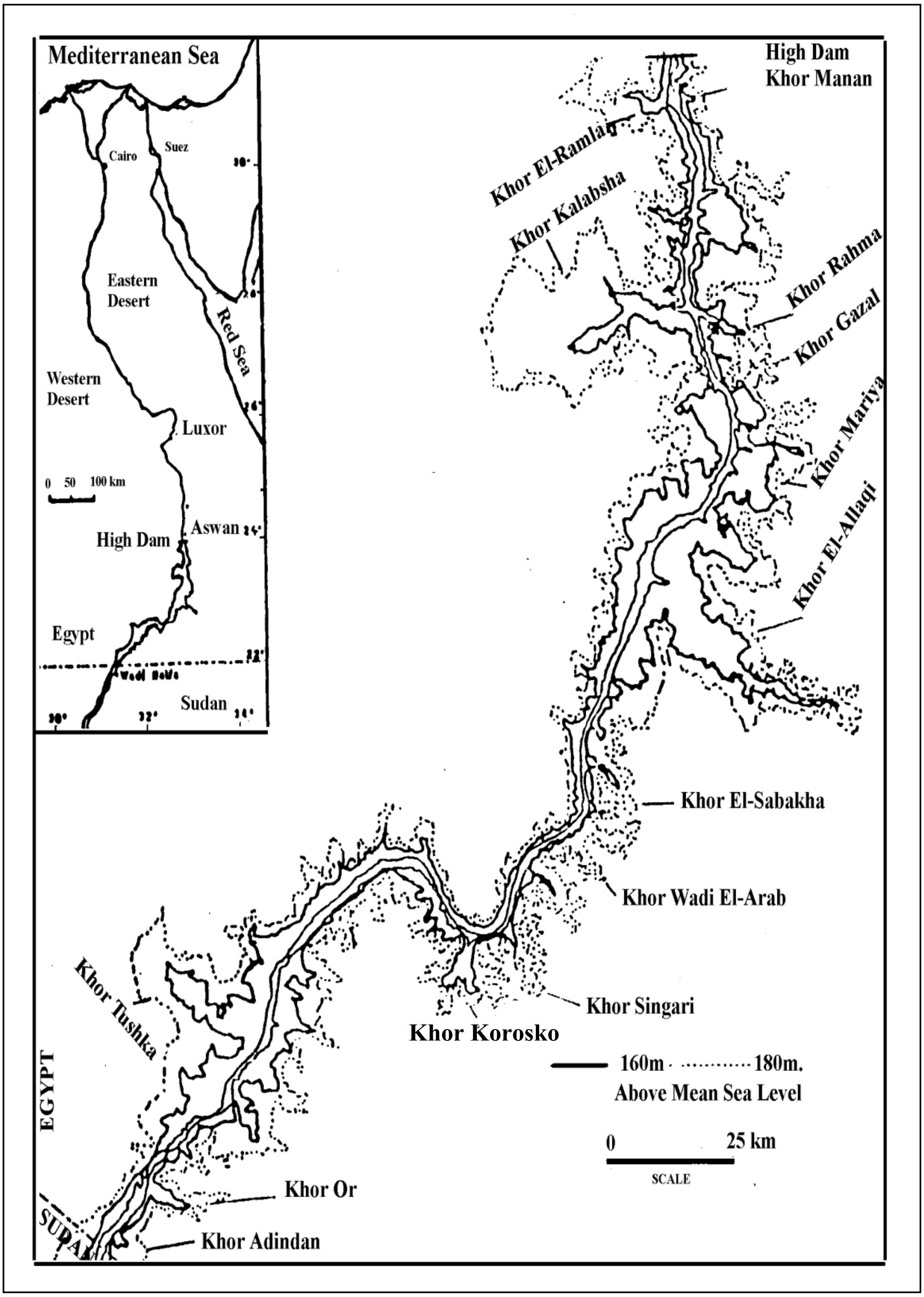

Fig. 1 **Map showing Lake Nasser with its major khors. The inset shows its location in Egypt.**

The mean width of the Lake at 160 m level is 8.9 km, and 18.0 km when the water level reaches 180 m. Morphometric data of Lake Nasser at water levels of 160 and 180 m are presented in Tables 1 and 2.

The deepest part of the Lake is the ancient river bed south the adjacent strips of cultivated land forming together the original river valley, called the central area of the Lake with its bottom elevation between 85 and 150 m above sea level. The side areas lie between 150 and 180 m A S L. The central part is considered as a flowing river-lake where the speed of the current is fast at the southern end of the Nubian gorge region (100-150 cm/sec). This speed is gradually reduced within a few kms to 10-20 cm/sec and in Lake Nasser to 0-3 cm/sec. The mean depth of this central part is gradually increasing from 10 m at the southern end to 70 m in the north. The bulk of the water masses coming from the south is passing through the central part, which forms about half of the total volume of the Lake (Entz 1976).

The flood, which arrived at Aswan from Khartoum within one month before the High Dam was built, covers now the same distance in not less than 5 months but sometimes probably more than 12 months depending on Lake level and the strength of the flood.

Comparing Lake Nasser with Lake Volta on Volta River, which was constructed in the same month and year of the Aswan High Dam (May 1964), shows that Lake Volta has a larger surface area (8700 km^2) than that of Lake Nasser. Also, Lake Volta has a greater volume (165 km^3) than Lake Nasser (153 km^3). Lake Nasser has a much more irregular shoreline (7,844 km), so its perimeter is much longer than that of Volta Lake (5,300 km). So, "Shoreline Index" values for Lake Nasser are greater than those for Volta Lake. The shoreline development value (DL according to Hutchinson) of Lake Nasser is extremely high (33.1) as compared with usual values of lakes ranging between 1.8 and 6 (Entz 1976). The mean depth of both lakes is almost similar (Lake Nasser 25 m, Volta Lake 19 m) as are their maximal depths (90 and 78 m respectively). But there is an important difference between their central areas, or main valleys. This area is much deeper and narrower in Lake Nasser than in Volta Lake, so it might play a much more important role in determining the flow of river water masses through the lake. In Lake Nasser the main valley might also be important for its relatively large area of muddy bottom and large quantities of original bottom fauna.

Lake Nasser has many embayments locally called khors (Fig. 2). The total number of important khors is 85 (48 on the eastern side and 37 on the western). Some khors as Kalabsha, Tushka and Allaqi are wide, with a sandy bottom and slope gently; others as Singari, El-Sabakha and Korosko are steep, relatively narrow with a rocky bottom. The total surface area of khors, as areas outside the main valley covered by water, is about 4,900 km^2 = 79 % of the total surface area, but in volume they contain only 86.4 km^3 water (= 55% of the total lake volume).

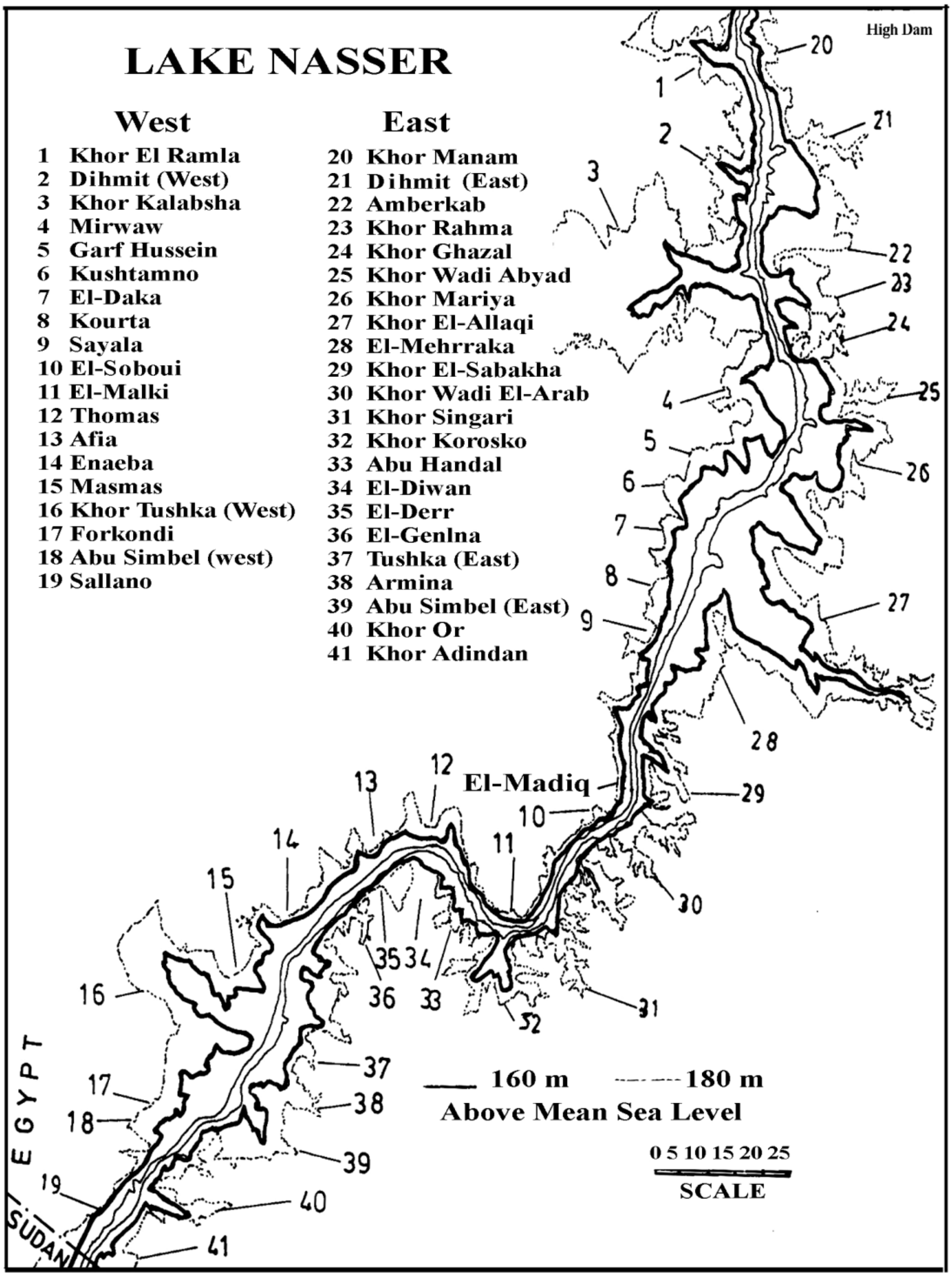

Fig. 2 **Important fishing sites and khors of Lake Nasser (Latif 1974a).**

ABIOTIC ENVIRONMENT

The water temperature fluctuates with air temperature, being high in summer and low in winter. In winter (i.e. November and December) the water temperature is usually uniform from the surface to the bottom at about 20 °C. In summer and early autumn the water temperature is different from the surface waters to the bottom ranging from 26-34 °C for the surface waters as compared with 15 - 21 °C in the bottom waters.

The transparency of the Lake water is affected by turbidity due to the presence of silt and clay (allochtonic inorganic materials) of riverine origin which are particularly strong in the flood season of the Nile, and the autochtonic suspended organic material (plankton and detritus), which flourish mainly in spring. Transparency in khors is normally less than in the main channel due to the abundant plankton populations.

Table 1 **Morphometric measurements of Lake Nasser at 160 and 180 m level (Entz 1976).**

	Lake Nasser	
	160 m	**180 m**
Length (km)	**291.8**	**291.8**
Shoreline (km)	**5380**	**7844**
Surface area (km^2)	**2585**	**5248**
Volume (km^3)	**55.6**	**132.5**
Mean width (km)	**8.9**	**18.0**
Depth (m):		
Mean	**21.5**	**25.2**
Maximum	**110**	**130**

The lake's water is completely oxygenated during winter and spring due to water circulation and the increase of phytoplankton, so it reaches 18 - 19 mg O_2/l (Aly 1992). In summer the oxygen concentration of the upper layer ranges from 6.0 to 11.2 mg O_2/l. Destruction of stratification takes place with the incoming flood water, particularly in the southern region of the reservoir. Then it extends to cover the northern region with the cooling of water.

The pH values of Lake Nasser are always on the alkaline side, the minimum value was recorded in summer, being 6.8 for the bottom water, and the maximum value was recorded in spring being 9.6 for the surface water.

As to the salt content of the water of Lake Nasser, N^+, K^+, HCO_3^-, Ca^{++}, SO_4^{2-}, PO_4^{3-} and available N_2 are higher than in Lake Volta (Entz 1970a). The concentration of sodium varies between 0.89 and 27.8 mg/l. Potassium range was 0.6 - 8 mg/l while the magnesium level ranged from 2.88 to 19.5 mg/l. The phosphate phosphorous ranged from 29.34 to 163 µg/l (0.074 - 0.522 mg/l dissolved phosphates). The silicate range was 8-35 mg/l (Elewa 1985b). Nitrate nitrogen, ammonia-nitrogen, nitrite-nitrogen and total organic nitrogen in the Lake ranged from 0.5 to 3.0 mg/l, 0.078 to 0.273 mg/l, and 9.44 to 14.45 mg/l respectively.

BIOLOGICAL DIVERSITY

Eleven macrophytic aquatic plants are recorded from the Egyptian Nubia pre- and post completion of Aswan High Dam. Two euhydrophytic species disappeared after Lake Nasser filling. Of the other 9 species, three *Potamogeton* spp. (i.e. *P. crispus, P. trichoides, P. pectinatus*) which were recorded during the seventies and early eighties are no longer observed in recent years. The most common species are *Najas marina* subsp. *armata, N. horrida, Zannichellia palustris, Potamogeton lucens* and the macroalga *Nitella hyalina.* Recently *Myriophyllum spicatum* appeared in the Lake.

***Table* 2 Morphometric data of various sections of Lake Nasser.**

	Length of section	Mean width (km) at levels		Mean depth (m) at levels		Surface area (km^2) at levels		Volume (km^3) at levels		Shoreline (km) at levels	
	(km)	160	180	160	180	160	180	160	180	160	180m
High Dam to Bab Kalabsha	61.94	6.79	13.92	22.17	25.05	422.8	864.5	9.38	21.69	1330	1829
Wadi Kalabsha (Bab Kalabsha) to Khor Mansour	--	---	---	12.90	9.88	442.3	553.9	0.27	5.47	113	464
Khor Mansour to Wadi El Allaqi	67.40	14.40	25.36	19.95	26.97	966.1	1707.2	19.29	46.06	1411	1774
Wadi El Allaqi to Ibrim (Khor Sabakha)	89.27	5.57	9.50	24.27	29.97	493.9	839.0	12.28	25.51	1651	2748
Ibrim to Abu Simbel	52.84	10.34	20.36	17.64	24.10	564.4	1075.7	9.60	25.89	732	846
Abu Simbel to Adindan	20.71	5.33	9.51	24.00	28.90	110.4	196.9	2.66	6.75	143	183

Lake Nasser is highly eutrophic and its primary productivity ranges from 4.32 to 128.15 mgC/m^3/h during 1990 (Abdel-Monem 1995). The community of planktonic algae is diverse including 135 species constituting 54, 34, 33, 13 and 1 species, of Chlorophyceae, Bacillariophyceae, Cyanophyceae, Dinophyceae and Euglenophyceae respectively. The blue-green algae mainly: *Oscillatoria, Phormidium, Anabaenopsis* and *Microcystis* spp., constitute the main phytoplankton in Lake Nasser. Diatoms, *Synedra, Nitzschia, Melosira, Navicula* spp. are common. Green algae are poorly represented, and *Chlorococcum agyptiacum, Legerheimia ciliata, Oocystis parva* and *Pediastrum simplex* (Abdel-Mageed 1995) are the dominant species in the Lake.

Twenty five identified and four unidentified species belonging to eleven genera of aquatic fungi are recorded in Lake Nasser. The fungal population of the Lake showed marked vertical variations. Of the mesophilic fungi, a total of 60 species and one variety belonging to 22 genera from both water (48 species, 1 variety and 16 genera) and bottom mud samples (40 species, 1 variety and 17 genera) have been recorded in the Lake. Moreover, 13 species and 1 variety belonging to 7 genera of thermophilic and thermotolerant fungi have been isolated from water (8 species, 1 variety and 3 genera) as well as from bottom mud (9 species, 1 variety and 6 genera) of Lake Nasser.

Microbiological studies of Lake Nasser show a remarkable increase of the total bacterial counts (TBCs) during the last two decades at all sites for both bacteria developed at 22 and 37 °C, amounting to more than 1000 folds. There is a gradual increase in TBCs from south to north with highest values near the

HD. Furthermore, four different genera with eight species of non-sulfur bacteria are recorded from the lake. The highest number of coliform and faecal coliform bacteria is recorded near the High Dam during winter.

The zooplankton population is mainly represented by typical limnoplankton forms, including 79 species dominated by Copepoda (10 species), Cladocera (10 species) and Rotifera (48 species). The zooplankton biomass (g/m^3) increases southward being the highest at Adindan, and decreases northward, being lowest in the vicinity of the High Dam (Latif 1983). At different localities, the zooplankton shows highest frequency in March, followed by August, while the least frequency prevails in June in the vicinity of the High Dam and in October at Amada and Adindan.

In Lake Nasser, the benthic fauna include 59 species dominated by insects (28 spp.), followed by molluscs (19 spp.), annelids (5 spp.), crustaceans (4 spp.) and cnidarians (coelenterates) and Bryozoa each is represented by one species. The benthos biomass is estimated as 44, 13.8, 8.2 and 6.0 gm/m^2 for Amada and 13.2, 16.1, 9.7 and 5.6 gm/m^2 for Adindan during March, June, August and October respectively (Latif, 1983).

Although 75 fish species (Bishai & Khalil 1997) known from the Nile system have been recorded, the fisheries of Lake Nasser depend upon only a limited number of species, viz., (in order of importance) *Sarotherodon galilaeus, Oreochromis niloticus, Hydrocynus forskalii, Alestes nurse, A. dentex, A. baremoze, Lates niloticus, Bagrus bajad, B. docmak, Synodontis serratus, Barbus bynni, Labeo horie, L. coubie, L. niloticus. Eutropius niloticus. Sarotherodon galilaeus, Oreochromis niloticus, Lates niloticus* and *Hydrocynus* spp. are adapted well to the new conditions and indeed have become the main specis in the Lake.

The mean water level increased from 130.17 m (above MSL) in 1966 to 174.49 m in 1979. Thus, the Lake's area expanded and the fish landings increased from 751 ton in 1966 to 27,021 ton in 1979, followed by another increase to a maximum of 34,206 ton in 1981, when the mean water level was about 174 m. Then, the mean water level decreased to 158.08 m in 1987, coinciding with a decrease in the total catch to 16, 815 ton in 1987. The fish landings resumed their increase to 30,838 ton in 1991, which coincides with an increase in the mean water level to 165.79 m in 1991. Another picture was observed during the period 1991- 1999. Thus, the mean water level increased progressively to a maximum of 178.92 m in 1999, accompanied with a sharp decrease in the total catch from 30,838 ton in 1991 to 13,983 ton in 1999 (Table 103). This is mainly attributed to that during the last 10 years, a large portion of the fish catch is sold illegally in the black market with high prices, and hence not recorded in the official catches.

GEOLOGY

Geological and stratigraphical studies dealing with the area surrounding the Lake were carried out by different authors (Ball 1902, El-Shazly 1954, Gindy

1954, Attia 1955, El-Ramly & Akkad 1960, Shata 1962, Said & Issawy 1964, El-Ramly 1973, Klitzch & Lejal-Nicol 1984, Latif 1984a, Hendriks *et al*. 1987, Gindy 1991 etc). The geological map of Lake Nasser and its surroundings is shown in Fig. 3. El-Ramly (1973) gave the following succession of the exposed and subsurface lithostratigraphic sedimentary units from bottom to top:

1. Lower Cretaceous Nubia Sandstone Formation (Aptian-Albian).
2. Upper Cretaceous Variegated Shells (Cenomanian-Santonian).
3. Upper Cretaceous phosphatic bed (Companion).
4. Upper Cretaceous Dakhla Shales (Maestrichtian-Danian).
5. Paleocene Kurkur Formation.
6. Upper Paleocene-Lower Eocene Garra Formation.
7. Lower Eocene Dungul Formation
8. Plio-Pleistocene gravel sheets.
9. Plio-Pleistocene Tufa deposits.
10. Pleistocene freshwater limestone.
11. Pleistocene calcite deposits.
12. Pleistocene Holocene playas.
13. Holocene sand dunes.

Klitzsch & Lejal-Nicol (1984) classified the sediments in Aswan area into the following rock formations arranged from bottom to top:

1. Aswan Formation.
2. Abu Aggag Formation.
3. Taref Formation.

Hendriks *et al*. (1987) studied the sediments in Aswan-Abu Simbel area and classified them into three formations arranged from bottom to top as follows:

1. Abu Aggag Formation.
2. Timsah Formation.
3. Umm Barmil Formation.

The Red Sea ranges, which are related to earth movements, form the backbone on the eastern side of the Lake region. The region is underlaid by a considerable thickness of sedimentary rocks, that lie on igneous and metamorphic rocks of Precambrian and later ages. The northeastern, southwestern and western parts of the Lake are covered by crystalline basement. Some volcanic exposures occur on the western side of the Lake associated with the crystalline basement.

The oldest sedimentary rocks exposed in this region are of the Early Cretaceous age (Aptian - Albian), and they crop out in nearly the entire southern Lake region. In the northern Lake region, they crop out in-between the crystalline bergs. Sedimentary rocks of Late Cretaceous and of Tertiary age are exposed on the northwestern side the Lake. In some areas, the older sedimentary rocks and the volcanics are mantled by scree and detritus (desert pavement) or by recent alluvia in depressions and wadis.

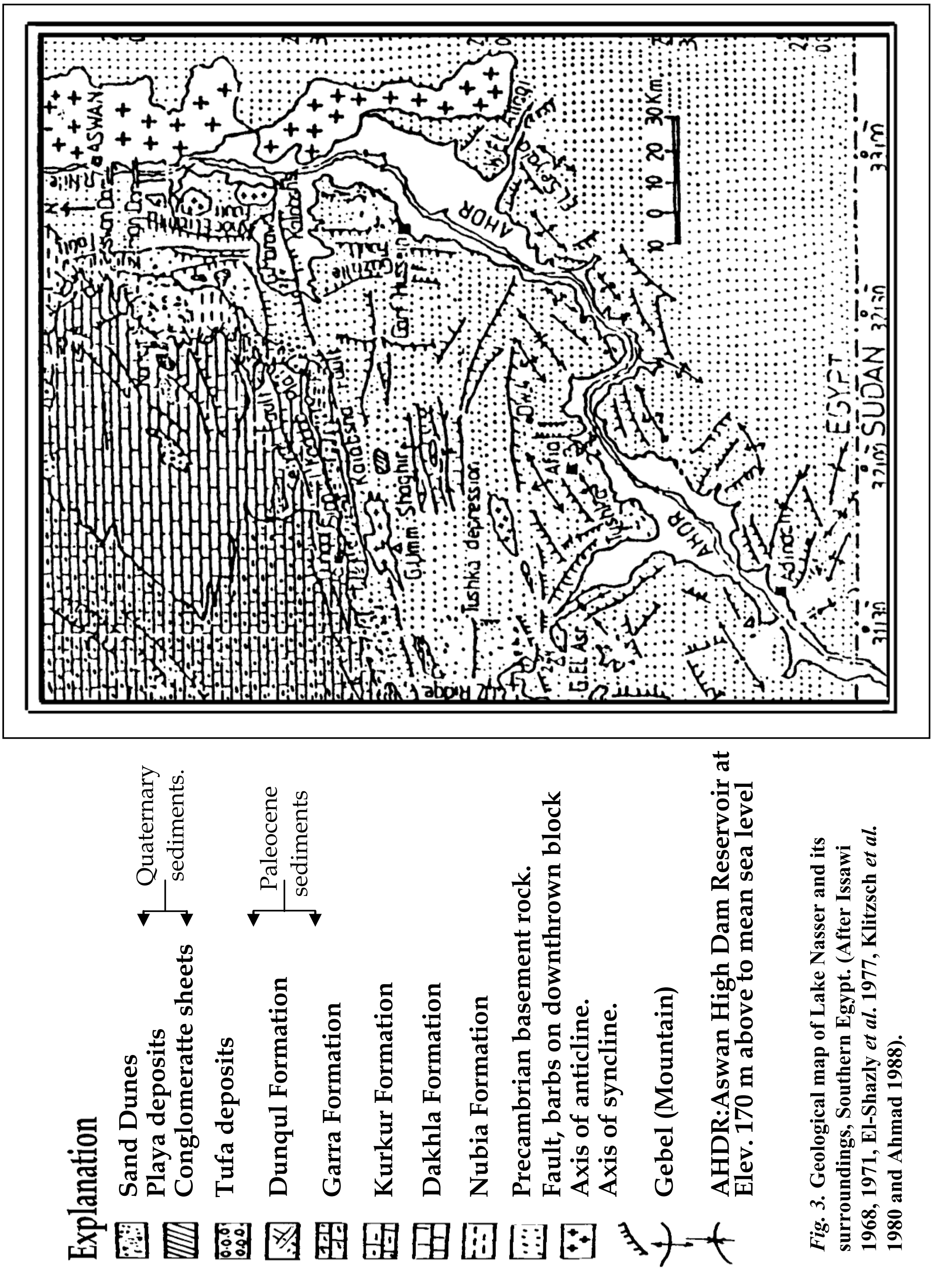

***Fig. 3*. Geological map of Lake Nasser and its surroundings, Southern Egypt. (After Issawi 1968, 1971, El-Shazly *et al.* 1977, Klitzsch *et al.* 1980 and Ahmad 1988).**

The Nubian sandstone formation is mainly composed of sandstones, siltstones and clays. It varies in thickness from one locality to another in the lake region and ranges from 10 to 65 m along the stretch between the High Dam and Kalabsha to 592 m at the Sinn El-Kaddab graben on the northwestern side of Lake Nasser. In the Lake region, the majority of the topographic features date back to the Pliocene, and the present deep gorges and khors (wadis) together with the relief are probably of Pleistocene or Recent age. In this aspect, reference should be given to the direction of the old River Nile channel. The River Nile course followed different directions starting southward from Wadi Halfa until Aswan northward. In the sector, from Wadi Halfa until Thomas, it followed a SW -NE direction, between Thomas and El-Diwan, it followed a NW - SE direction, then a W - E direction from El-Diwan to Korosko. From Korosko northward, the old River Nile channel followed two directions, one SW-NE and the other SE - NW direction, following the main regional fracture lines in this sector of the channel. From Kalabsha northward until the High Dam site, it followed nearly one main trend of a S - N direction. It appears that the igneous and metamorphic rock exposures on both sides of the old Nile channel control the direction of this channel in this sector. The area at El-Madiq forms a deep canyon where the rocks are highly slicken-sided.

The increase in water level causes the inundation of new lands on both sides of the Lake, and their extent depends on the slope. Thus, extensive areas of the wadis having gentle slopes are covered with water with increased storage. Under these circumstances, the water causes leaching of salts especially the first time the lands are inundated. In turn, the Lake's soils had originated from the weathering of the geological formations within the Lake's area or from water drainage since ancient times. The salt composition of the soils shows that the predominant anions are sulphate and chloride; carbonate may be in traces but bicarbonate may also be encountered. The predominant cations are sodium and calcium, but potassium and magnesium may occur to a less extent. The possible salt forms are NaCl, Na_2SO_4, $NaHSO_4$, $CaCl_2$ and $CaCO_3$ (Abdel-Salam *et al*. 1974a, b).

The Nubian sandstone aquifer reflects the presence of these salts, but to different degrees in the different water samples according to the interpretations of El-Ramly (1973). Na^+ and Cl^- are predominating in some samples while, Ca^{2+}, CO_3^{2-}, and HCO_3^- show an increase in other samples. Mg^{+2}, CO_3^{2-}, HCO_3^- and SO_4^{2-} are evident in some other samples. According to Shata (1979), the initial salinity on some of the production wells in Wadi Kurkur (along the northwestern bank of the reservoir) is of the order of 1500 mg/l.

CLIMATE

Air Temperature. Lake Nasser is situated on the eastern side of the great Saharan belt, bordered on the north by the Mediterranean belt (winter rainfall) and on the south by the tropical belt (mostly summer rainfall). The area, including Lake Nasser, receives no rainfall except for occasional thunderstorms which sporadically penetrate the area in winter.

During the period 1974 - 1975 the mean annual air temperature was 25.7 °C (Table 3), means of summer (June to August) and winter (December to February) temperatures were 32.6 and 16.8 °C (Table 6). January is the coldest month and July is the hottest (Table 4). The annual amplitude is from 8.1 °C to 46.2 °C (Table 3).

In 1985 the air temperature fluctuated between a minimum value of 11.5 °C at stn. 3 in January and a maximum value of 35.5 °C at stn. 6 in July (Fig. 4 and Table 4). In 1997 the monthly average values of air temperature ranged from 15.1 °C in February to 34.9 °C in July (Table 5) The mean annual values ranged from 22.1 °C at stn. 5 to 25.2 °C at stn. 6 (Fig. 4 and Table 4). The mean annual value of six stations in the Lake was 23.1 °C (Fig. 4 and Table 4).

The average seasonal values of air temperature for the region, examplified by Aswan during 5 periods (1974/1975; 1976/1978; 1983, 1984 and 1997) are shown in Table 6. Generally, the mean air temperature increases from February to July and remains almost constant till September, with a progressive decrease till the end of the year. The mean annual air temperature was almost the same (i.e. 25.7 and 25.6 °C) during the periods 1974/75 and 1976/78 respectively. Then, the mean annual air temperature decreased to 23.3 °C in 1983. Afterwards, it increased to 25.3°C in 1984 and 26.3 in 1997 (Tables 5 & 6).

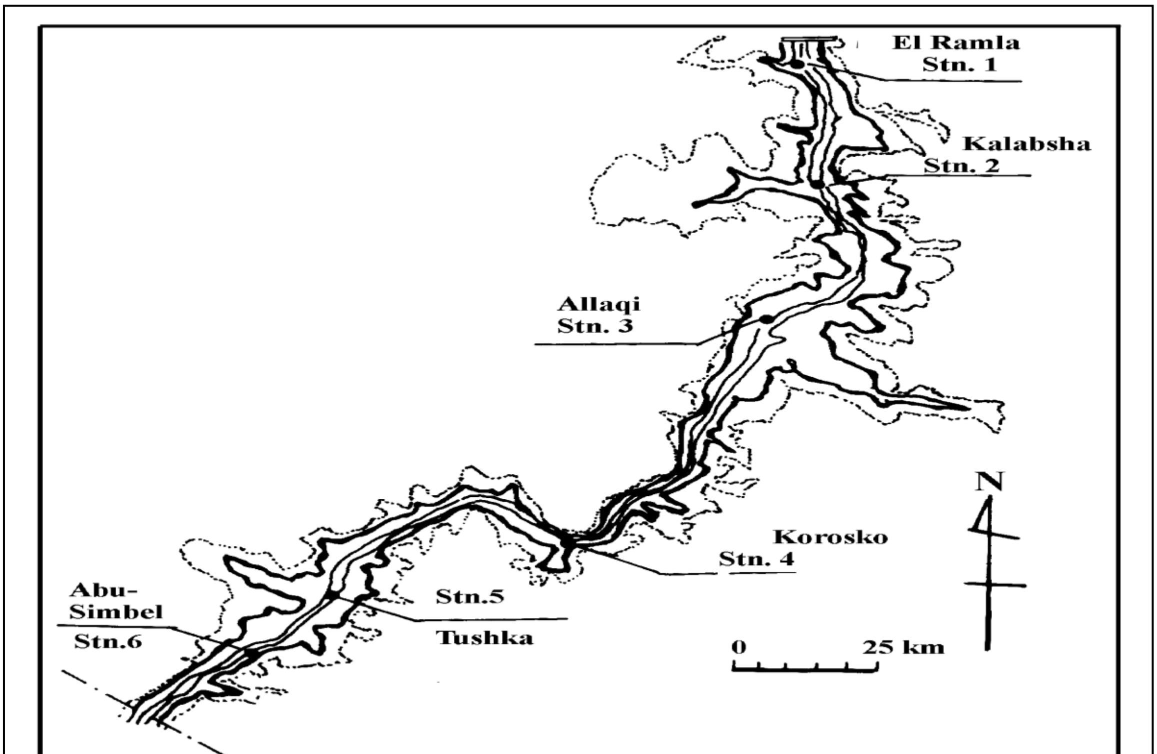

Fig. 4 **Location of stations in the main channel of the High Dam Lake.**

Table 3 **Air temperature of Aswan during (1974 - 1975) and 1997 (in parentheses).**

Month	Air temperature °C					
	Max.		min.		mean	
Jan.	23.5	(25.0)	**8.1**	(11.5)	**15.5**	(18.0)
Feb.	26.2	(21.9)	9.6	**(8.6)**	17.8	(15.1)
Mar.	30.5	(26.9)	13.0	(13.6)	22.0	(20.4)
Apr.	35.3	(34.6)	17.9	(18.6)	26.9	(26.9)
May	38.7	(39.2)	21.4	(24.3)	30.4	(31.7)
June	37.0	(41.5)	20.3	(26.4)	28.7	(34.7)
July	**41.1**	**(42.2)**	24.8	(27.3)	35.5	**(34.9)**
Aug.	41.0	(41.0)	24.8	(26.7)	33.5	(34.1)
Sept.	39.5	(39.5)	22.6	(24.4)	31.1	(31.9)
Oct.	36.4	(35.3)	19.6	(21.6)	27.7	(28.4)
Nov.	29.8	(29.9)	14.6	(15.8)	21.8	(22.6)
Dec.	25.0	(24.1)	9.7	(10.9)	17.0	(17.2)
Mean annual					25.7	(26.3)

In spring, summer and autumn the average values of air temperature decreased progressively during the periods 1974/75, 1976/78 and 1983 as shown in Table 6. Another picture was observed in winter, when the mean air temperature increased from 16.8 °C in 1974/75 to 19.0 °C in 1984 (Table 6).

Latif (1984a) reported that the Lake's microclimate shows an air temperature lower than Aswan, especially during summer months, the daily range for Aswan being 6 to 10 °C as compared with a range over the Lake of 0.5 to 4.5 °C. The seasonal variation of air temperature in 1985 (Fig. 5) shows that the daily minimum air temperature was about 5 °C (between 4 and 6 am) from January to February, while the daily maximum air temperature was about 25 °C between 2 - 4 pm during these months. The temperature began to rise considerably in March and its range was between 15 °C and 33 °C. The air temperature was between 21 °C and 44 °C from June to August, and was between 15 °C and 30 °C in autumn.

Belal *et al.* (1992) mentioned that the mean annual air temperature is 25.9 °C. Mean for summer is 31.9 °C, and for winter is 17.1 °C. Thus, the mean annual air temperature increased progressively from 1983 to 1993, being 23.1; 25.3 and 25.9 °C in 1983, 1984 and 1993 respectively.

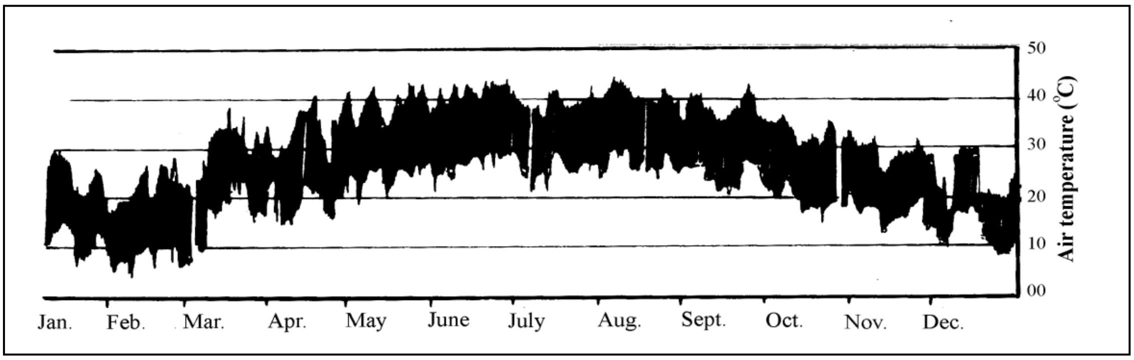

Fig. 5 **Seasonal variation of air temperature (°C) at the Fishery Management Center in 1985 (Abdel-Rahman & Goma 1992b).**

Table 4 **Monthly and mean annual variations of air temperature (°C) at six stations of Lake Nasser in 1985 (Abdel-Rahman & Goma 1992b).**

Month	Station						
	1	2	3	4	5	6	Monthly average
Jan.	18.5	14.5	11.5*	15.5	13.4	18.9	15.4
Feb.	11.8	18.8	22.4	14.5	17.5	18.1	17.2
Mar.	18.6	15.6	12.6	15.5	12.5	16.4	15.2*
Apr.	26.3	23.4	21.5	22.2	24.0	31.0	27.7
May	25.0	29.5	23.6	25.3	23.5	25.5	25.4
June	24.6	25.4	31.1	29.5	25.5	30.0	27.7
July	26.7	27.0	33.0	30.4	27.0	35.5**	29.9**
Aug.	24.4	27.5	27.5	28.5	30.5	29.3	28.0
Sept.	29.4	25.8	30.0	30.8	26.8	31.0	29.0
Oct.	24.5	22.5	21.1	25.6	22.4	23.0	23.1
Nov.	22.1	22.3	19.5	22.9	21.3	21.5	21.6
Dec.	19.5	17.3	15.5	23.4	21.1	22.4	19.9
Mean	22.6	22.5	22.4	23.7	22.1*	25.2**	23.1

* and ** designate minimum and maximum values, respectively. For stations refer to Fig. 4.

Relative Humidity. The relative humidity is highest (i.e. 40 - 41%) in December and January, and lowest in May and June, being 13 - 15 % and in turn is slightly higher over the lake than in Aswan (Latif 1984a).

Table 5 **Average monthly values of air temperature (°C) of Lake Nasser Area.**

Month	Year				
	1974 - 1975	1976 - 1978	1983	1984	1997
Jan.	15.5	14.8	15.4	22.1	18.0
Feb.	17.8	17.7	17.2	16.5	15.1
Mar.	22.0	21.0	15.2	23.5	20.4
Apr.	26.9	26.8	27.7	24.8	26.9
May	30.4	31.0	25.4	30.2	31.7
June	28.7	32.7	27.7	27.3	34.7
July	35.5	33.3	29.9	31.4	34.9
Aug.	33.5	32.1	28.0	29.2	34.1
Sept.	31.1	30.7	29.0	28.2	31.9
Oct.	27.7	28.5	23.1	28.5	28.4
Nov.	21.8	21.0	21.6	23.7	22.6
Dec.	17.0	17.1	19.9	18.5	17.2
Mean annual	**25.7**	**25.6**	**23.3**	**25.3**	**26.3**

Table 6 **Average seasonal values of air temperature (°C) of Lake Nasser Area.**

Season	Year				
	1974 - 1975	1976 - 1978	1983	1984	1997
Winter	16.8	16.5	17.5	19.0	16.8
Spring	26.4	26.3	22.8	26.2	26.3
Summer	32.6	32.7	28.5	29.3	34.6
Autumn	26.9	26.7	24.6	26.8	27.6
Mean	**25.7**	**25.6**	**23.3**	**25.3**	**26.3**

Wind Speed and Direction. Data based on regular meterological observations in Aswan and in Wadi Halfa (Omar & El-Bakry 1970), Entz (1976) during 1969 - 1974 and those of Latif (1984a and b) show the following :

1. All the year round the wind speed does not vary greatly, as the mean value ranges from 8 - 10 knots (15-19 kmh^{-1}), while the mean value for the whole year is around 9 knots (17 kmh^{-1}).

2. The prevailing wind is mostly NW-NE, blowing along the main channel or towards the lake center in the khors of the western side and towards the shore in the opposite eastern khors, causing leeward surface currents in different areas.

3. Between March and June strong easterly winds may blow usually reaching 10-15 m/sec (36-54 kmh^{-1}) or sometimes 18 - 20 m/sec (64.8 - 72 kmh^{-1}) accompanied with increased temperatures and followed by hot southerly winds. Sandstorms may occur in June and July or sometimes earlier (Latif 1984a). Stronger winds during winter causes complete water circulation.

4. During summer months moderate winds are common, interrupted frequently by shorter or longer calm periods especially in July and August which promotes a stable stratification of the Lake. In July an average of 46.4% of the days are calm. In winter under cooling weather conditions the wind is helping to destroy the lake stratification.

Moderate but sometimes remarkable wind induced surface currents are detectable in the Lake down to 3 - 5 m depth. Their direction in the central channel is from north to south, i.e. just opposite the main south-north current of the Lake, with a massive flow of water following the Nile valley towards the High Dam.

In special localities wind induced upwelling movements are recorded replacing the surface water masses blown away by the wind pressure. Such areas with upwelling currents are characterized by reduced water temperatures and oxygen saturation, low pH values and sometimes remarkable high transparency up to 600 or probably 800 cm Secchi values. Such conditions are frequently recorded near the High Dam, and sometimes at the southern end of the valley near Amada (200 km from HD), and almost regularly at the end of khors on the western shores. Entz (1976) points out that wind induced sinking water movements are present in other localities resulting in the accumulation of warmer water masses rich in oxygen with high algal turbidity and high primary production. This phenomenon could be observed in erosion littorals e.g. in khors of the eastern shore of Lake Nasser (Singari and Korosko, 180 km from HD), as also in Gorge region of Lake Nubia, near the previous Second Cataract (360 km from HD). Such peculiar conditions diminish the depth of the metalimnion under upwelling and increases it under descending water movement.

The speed of wind induced currents could reach 10 to 35 cm/sec. The above scheduled system of currents covering practically the whole surface of the reservoir may be an effective way to avoid any gradual increase of salinity despite the extremely high rate of evaporation.

Another action of wind or even a slight breeze is its remarkable direct cooling effect on the surface water temperature. Wind is enhancing already high rate of evaporation, under conditions of extremely low relative humidity (of $\pm$ 35 % in winter and only 13 - 21 % in summer) to about 3,000 mm/year. These phenomena may explain the relatively low surface water temperature (16.0 - 33.0 °C) under extremely high ambient temperature of the surrounding desert (40.0 - 52.0 °C) in summer time (Table 15).

Evaporation. Because Lake Nasser is located in an arid region, evaporation results in a significant water loss. Several methods were used to determine the evaporation in Lake Nasser. Sharf El Din & El-Shahawy (1980) estimate evaporation from Lake Nasser by the mass transfer method (Sverdrup 1937 and Penman 1962 equations). The monthly evaporation has the maximum value of 40.95 cm (13.7 mm/day) in September and minimum value in January: 16.21 cm (5.2 mm/day). The total annual evaporation is about 359 cm. Adopting the Dalton, combination and Pan approaches Omar & El-Bakry (1970) calculated the daily minimum, maximum and average evaporation as 8.0, 8.3 and 8.1 mm/day respectively. They mentioned that maximum monthly evaporation values occur in September and minimum in February. The High Dam Authority estimates the evaporation from the Lake as 10 km^3 annually at 180 m level, thus representing a decrease in water level by 2 m at the surface area of 5000 km^2. A model of impoundment evaporation processes estimates a loss of 12.5 km^3 per annum, assuming unchanging surface area of 5000 km^2 for impoundment (Gishler 1976) (Table 7a).

Table 7a **Evaporation in Lake Nasser.**

	Max.	Min.	Average	Author
Daily evaporation (mm/day)	8.3	8.0	8.1	Omar & El-Bakry (1970)
	13.7	5.42	--	El-Shahawy (1975)
	13.7	5.2	--	Sharaf El-Din & El-Shahawy (1980)
Monthly evaporation (cm/month)	40.95		16.21	Sharaf El-Din & El Shahawy (1980)
Annual evaporation (cm/year)		359		Sharaf El-Din & El Shahawy (1980)
Annual water losses km^3	10			High Dam Authority
	12.5			Gishler (1976)
	14			Harb & El-Bakry (1979)
	16.4 (Actual)			Aboul-Ata (1978)

21.6 (Calculated)	Aboul-Ata (1978)

El-Shahawy (1975) figured that the maximum evaporation from the Lake is 13.7 mm/day in September and a minimum of 5.42 mm/day in January (Table 7a). Harb & El-Bakry (1979) pointed out that the annual lake evaporation is around 7.3 mm/day. At the Lake water level of 175 m, the total water loss by evaporation will not be more than 14 milliard m^3, which is about 11% of the Lake content. Aboul-Ata (1978) concluded that the values of actual water losses from the Lake were lower than the calculated theoretical values and estimated as 16.4 (actual) and 21.6 km^3 (calculated) for 1975 respectively (Table 7a).

In a later study (Abu-Zeid 1987), the average monthly evaporation is estimated by the heat budget method (E_B) and bulk aerodynamic method (E_H), using monthly estimations of different meteorological elements over the Lake based on more recent measurements (Table 7b). The results indicate that the mean daily evaporation maximum is in June (about 10.9 mm/day), and the minimum in January (about 3.8 mm/day). The mean daily value of evaporation for the year as a whole is 7.35 mm/day. The highest evaporation occurs between June-September, when evaporation is 45 percent of the total yearly value.

Table 7b **Mean daily values (mm) of evaporation calculated by the heat budget method (E_H) and by the bulk aerodynamic method (E_B). (Abu-Zeid 1987).**

Month	E_H	E_B
Jan.	3.59	3.93
Feb.	4.95	4.08
Mar.	5.40	4.77
Apr.	5.52	7.32
May	8.95	9.31
June	11.66	10.11
July	10.42	10.01
Aug.	8.39	10.68
Sept.	8.61	10.47
Oct.	6.98	7.83
Nov.	4.87	5.17
Dec.	4.90	4.52
Mean	**7.35**	**7.35**

ORIGIN OF WATER

The River Nile is the creator of fertile land in Egypt. It has sustained the existence of the fertile land and supported man's early civilization. In view of the increasing population from 20 millions in 1952 to 38 millions in 1977 to 61.4525 millions in 1996 (about 63 millions in 1999), the availability of water has been a determining factor between prosperity and famine in Egypt when the Nile yield has been subjected to dramatic changes from one year to another.

During the pre-damming period (from 1869 to 1961) the mean annual flow of the River Nile at Aswan was 90.9 km^3. Aboul-Ata (1978) reported that the annual water supply varied from one year to another between about 42 km^3 in 1913-1914 to about 151 km^3 in 1878 - 1879. The average flow rate at Aswan for this period ranged from 14,000 m^3s^{-1} in 1878 to 275 m^3s^{-1} in 1922. It was difficult to maintain sufficient agricultural production, due to the extreme variations in the Nile flow. Low floods were below agricultural requirements and high floods inundated the land and caused property damage. Hence, the Aswan Dam was built in 1902 for regulating the flood and water storage for subsequent use. It was heightened twice in 1912 and 1934. Previously, about 40% of the Nile's average annual yield was lost in the Mediterranean Sea.

For Egypt, there are different origins of the Nile water. Out of an annual average yield of $84x10^9m^3$, the highly turbid flood water from the Ethiopian Plateau catchment region contributes 84% of the total supply. The annual Nile flood during the period from July to September used to be directly discharged to the sea prior to the construction of the AHD. The remaining 16 % consists of clearly distinct non-turbid water originating from the equatorial lakes region of Africa.

Table 8 **Hydraulic projects of the Nile (Mancy 1978).**

	Distance from AHD (km)	Year of completion	Reservoir capacity (10^9m^3)
Owen Falls Dam (White Nile)	4431	1954	120
Gebel El Aulia (White Nile)	1879	1937	5.5
Rosaries Dam (Blue Nile)	2459	1967	3.0
Sennar Dam (Blue Nile)	2193	1925	1.0
Khashm El Girba Dam (Atbara)	1513	1966	1.3
Old Aswan Dam	65	1902	5.2
Aswan High Dam (AHD)	0	1964	168.9
Jonglei Canal	--	--	--

Table 9 **Annual maximum, minimum and average water levels (m above MSL) of Lake Nasser during the period 1964 - 1999.**

Year	Water level (m)			Year	Water level (m)		
	Max.	Min.	Aver.		Max.	Min.	Aver.
1964	126.80	105.94	116.37	**1982**	172.63	170.18	171.41
1965	132.66	115.74	124.20	**1983**	169.86	165.64	167.75
1966	141.32	119.20	130.17	**1984**	169.42	162.97	166.20
1967	151.08	133.48	142.28	**1985**	164.34	156.16	160.25
1968	156.55	145.29	150.92	**1986**	163.61	156.14	160.38
1969	161.29	150.80	156.05	**1987**	161.66	154.50	158.08
1970	164.88	153.81	159.35	**1988**	168.82	150.62	159.72
1971	167.64	159.65	163.65	**1989**	169.79	164.30	167.05
1972	165.30	162.49	163.90	**1990**	169.50	163.72	166.61
1973	166.32	158.20	162.26	**1991**	169.35	162.23	165.79
1974	170.64	161.00	165.82	**1992**	170.75	163.84	167.30
1975	175.71	165.60	170.66	**1993**	174.32	167.24	170.78
1976	176.55	172.42	174.49	**1994**	177.28	169.51	173.40
1977	177.21	171.69	174.45	**1995**	176.93	172.32	174.62

1978	177.49	172.44	174.97	**1996**	178.55	172.28	175.76
1979	175.95	173.03	174.49	**1997**	178.52	175.40	177.38
1980	176.22	171.18	173.70	**1998**	181.30	174.66	178.13
1981	175.96	171.13	173.55	**1999**	181.60	175.66	178.92

The Nile is at present the only major river in the world which is totally controlled and fully utilized. This was achieved by an extensive Egyptian-Sudanese River Programme, which included six dams, the Jonglei Canal, seven barrages, and the Aswan High Dam (Table 8). Under the present flow control programmes, at present less than ½ billion m^3 is discharged directly to the sea. The Egypt's share from the Nile is 55.5 billion m^3/year, which is supposed to increase by 4 billion m^3/year after the construction of Jonglei Canal, southern Sudan.

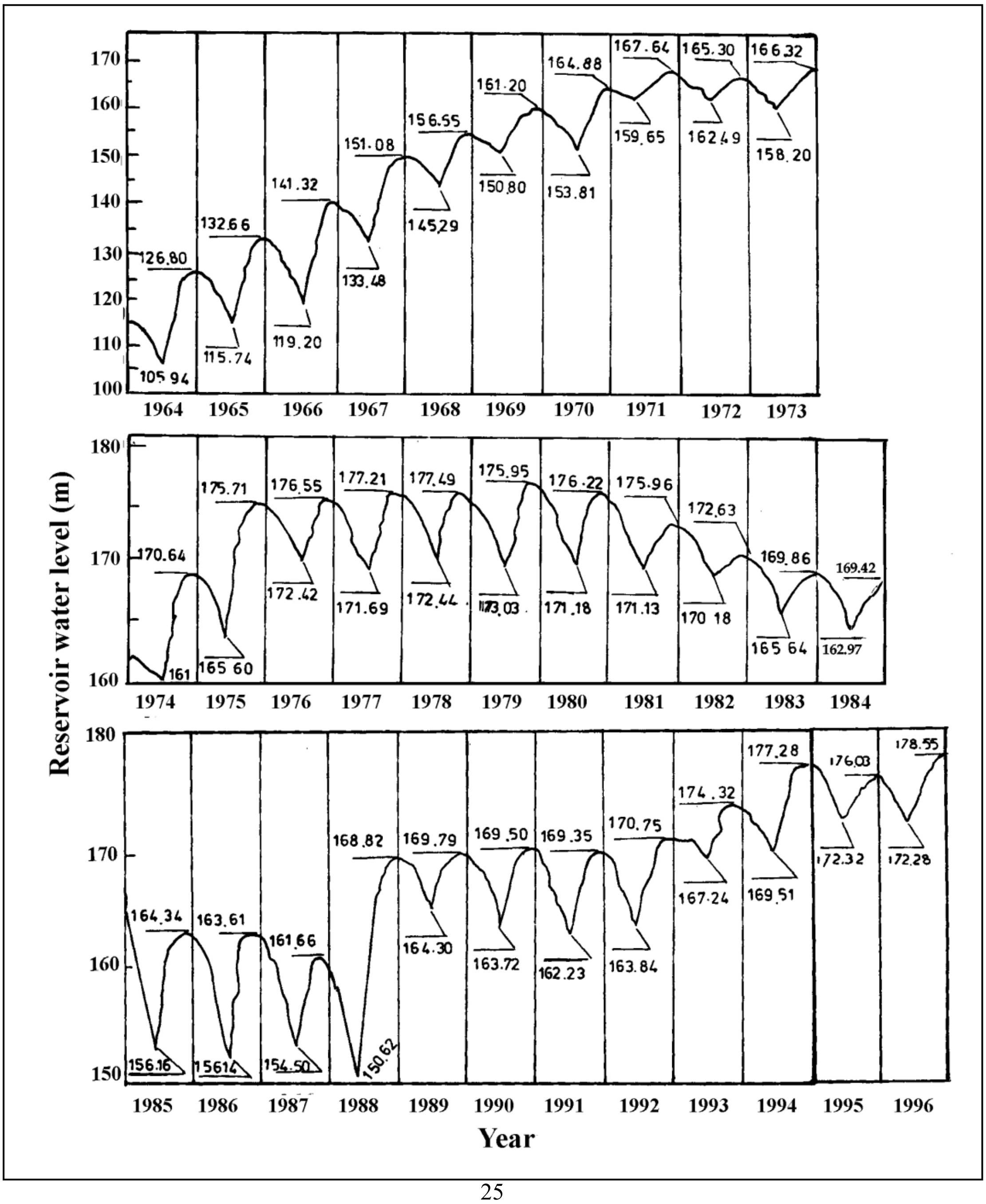

Fig. 6 **Water level of Lake Nasser (1964 - 1996).**

HYDROLOGY AND SEASONAL FLOWS

The river channel was diverted to its new path on May 15, 1964, after the completion of the first stage of AHD construction. The water level in the reservoir increased progressively through successive years (with the exception of 1972) (Table 9 and Fig. 6). The maximum operation level of 175 m above MSL was reached on October 13, 1975 and 175.63 by the end of the year (El-Darwish 1979). The final storage level is 183 m and, to safeguard the dam against exceptionally high floods, an important rule for the operation of the AHD is not to exceed 175 m level by the end of July (before the arrival of the new flood), thereby allowing for sufficient reservoir capacity to receive high floods. At the live storage of 175 m above MSL, the reservoir holds about 140.5 km^3, while the size of impoundment at 183 m above MSL is approximately 171.9 km^3.

The water level in the reservoir reaches its maximum in November and December of each year, then decreases gradually till the second half of July (dry period) (Figs. 7 and 8 and Table 10). When the flood water reaches the reservoir, the level starts to increase again. Recently, in 1999 the water level reached 181.60 m above sea level, which is considered as one of the highest records since the construction of AHD.

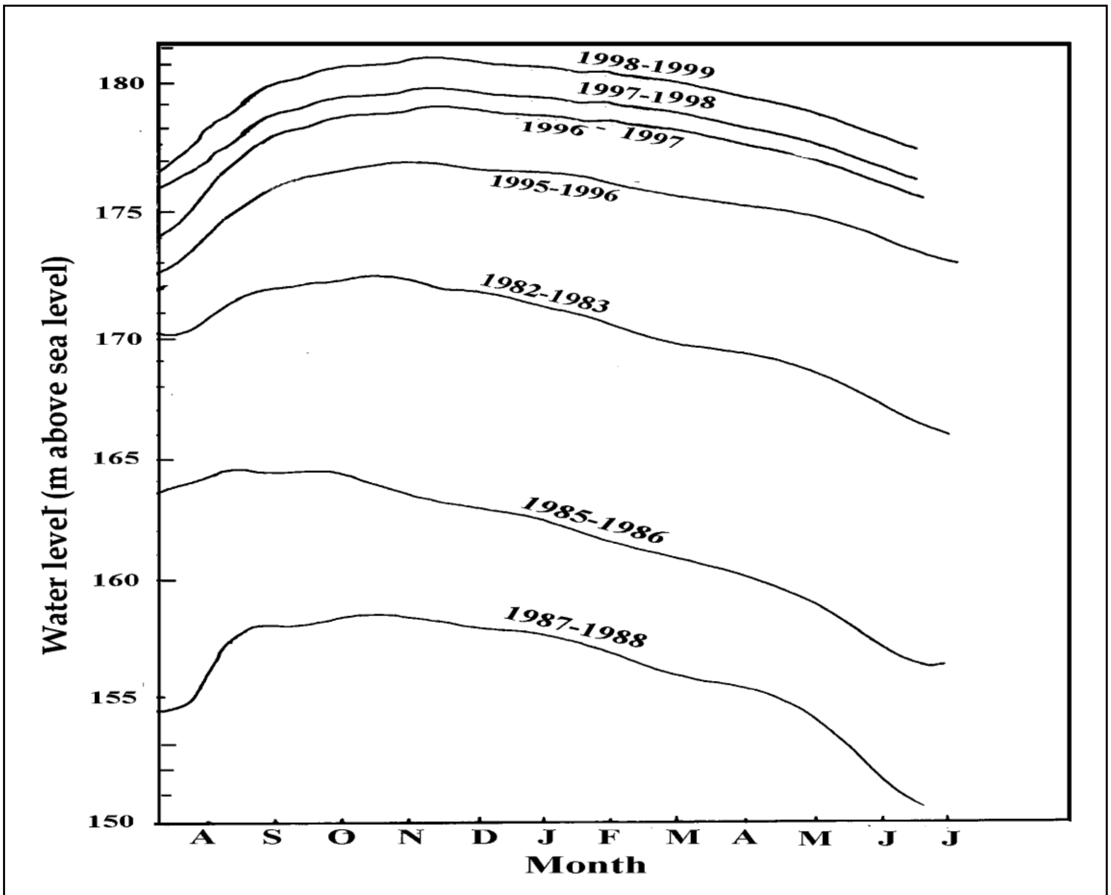

Fig. 7 **Level of Lake Nasser during the period 1982 - 1999.**

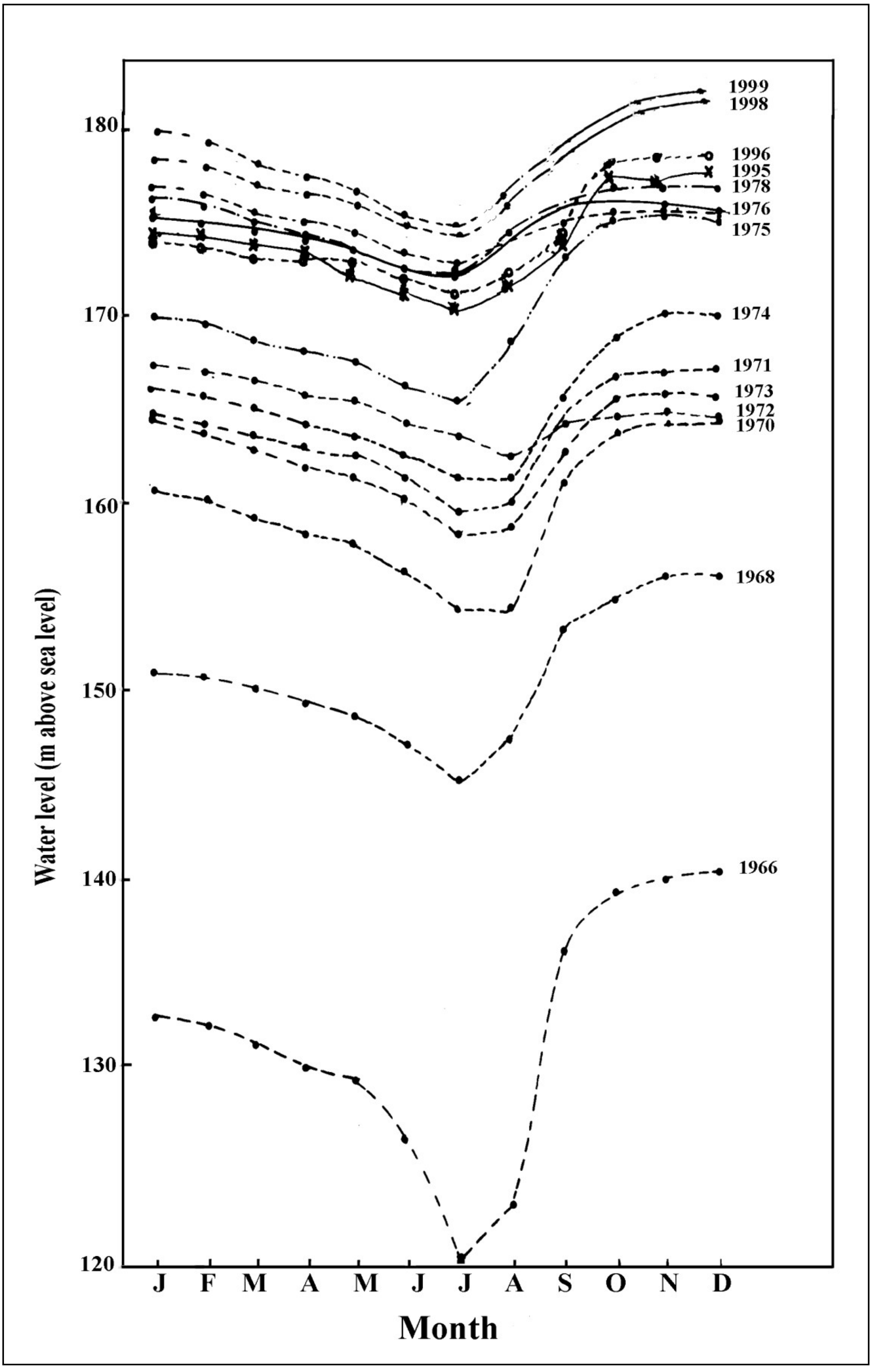

Fig. 8 **Monthly levels of Lake Nasser during 1966 - 1999.**

Table 10 **Monthly maximum and minimum water levels (m above MSL) in Lake Nasser during 1996 and 1997 (in parentheses) & 1999 (bold type).**

Month	Minimum		Maximum		Average		1999
Jan.	175.69	(178.52)	175.88	(178.32)	175.79	(178.45)	**180.23**
Feb.	175.27	(178.31)	175.69	(178.00)	175.48	(178.16)	**179.67**
March	174.60	(177.98)	175.26	(177.48)	174.93	(177.74)	**178.98**
April	174.04	(177.46)	174.58	(177.15)	174.32	(177.31)	**178.23**
May	173.34	(177.13)	174.03	(176.61)	173.69	(176.94)	**177.55**
June	172.35	(167.58)	173.33	(175.65)	172.84	(176.11)	**176.59**
July	172.28	(175.62)	172.69	(175.40)	172.49	(175.49)	**175.81**
Aug.	172.81	(177.11)	175.28	(175.51)	174.05	(176.14)	**176.83**
Sept.	175.39	(177.79)	177.79	(177.06)	176.59	(177.63)	**179.63**
Oct.	177.81	(178.00)	178.53	(177.72)	178.17	(177.88)	**180.78**
Nov.	178.50	(178.39)	178.55	(177.96)	178.53	(178.17)	**181.53**
Dec.	178.52	(178.52)	178.54	(178.40)	178.53	(178.51)	**181.19**

The High Dam provides complete control of the river flow. At present the river flow is maintained at a rather constant rate throughout the year. This is of the order 100 million m^3 day^{-1} (Figs. 9 - 11). Hence, downstream - north of the High Dam - the abnormally high turbidity of the Nile during the flood season before 1964 is now suppressed with control and storage of flood water in the reservoir whereby turbidity varies within narrow limits through the whole year (Figs. 9 and 10).

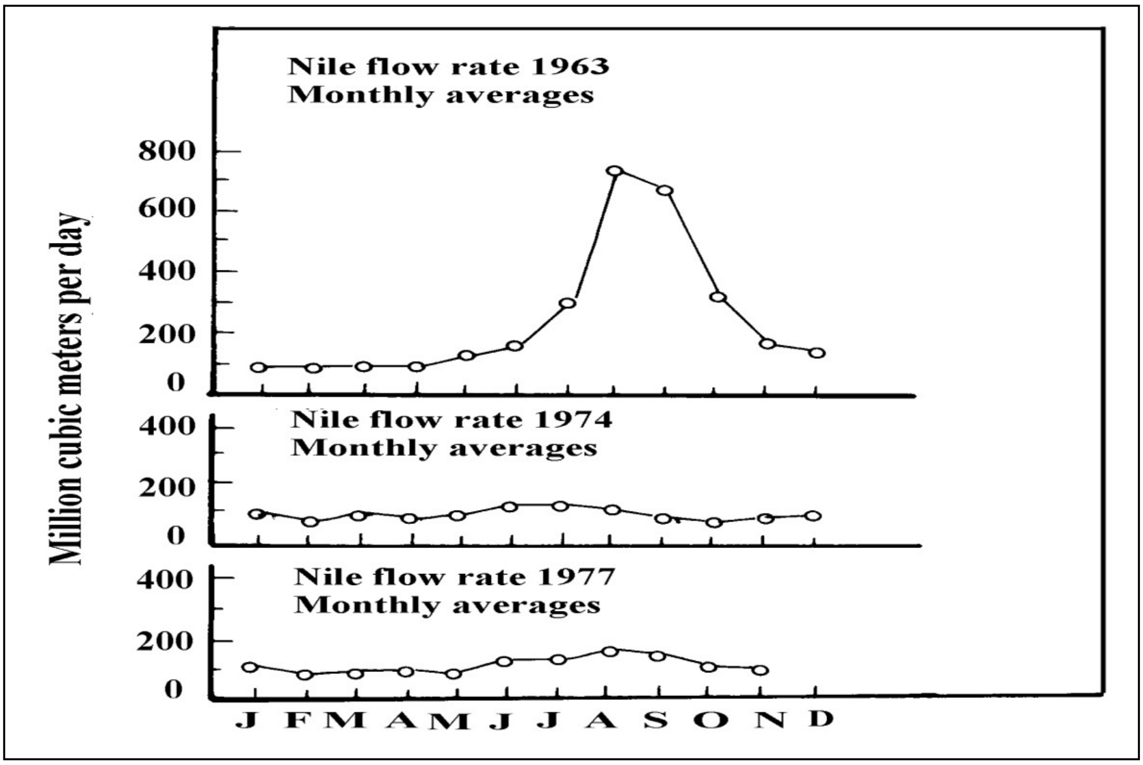

Fig. 9 **Comparison between average flow rates in the Nile before and after the High Dam construction (Ramadan 1978).**

Water discharge and storage. Since 1968, all excess water has been stored in the reservoir. The volume of water accumulated increased from 13.4 km^3 in 1968, to 87.3 km^3 in 1971, but decreased due to low flood to 76.7 km^3 in 1972 (Fig. 11). Then followed a continuous increase (Fig. 11). The pattern in total storage and outflow along the period from 1966 to 1978 could be followed from Fig. 11 (Elewa 1980).

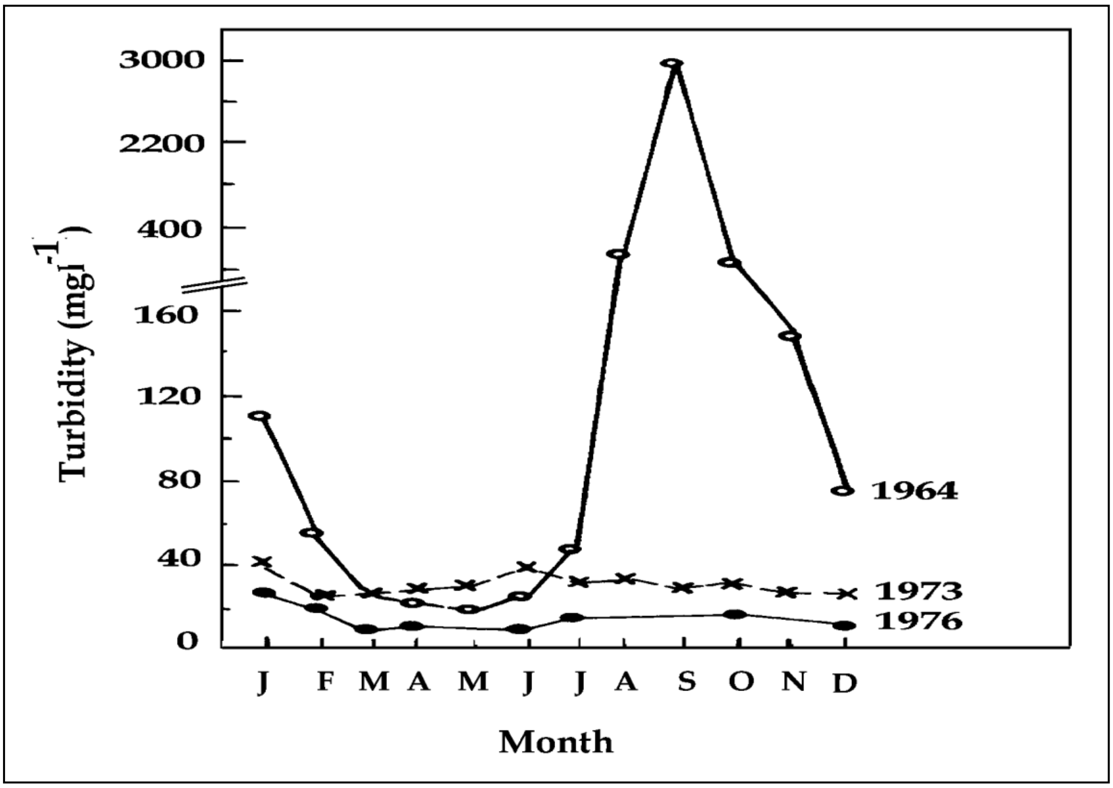

Fig. 10 **Average variations of turbidity in Nile waters (Ramadan 1978).**

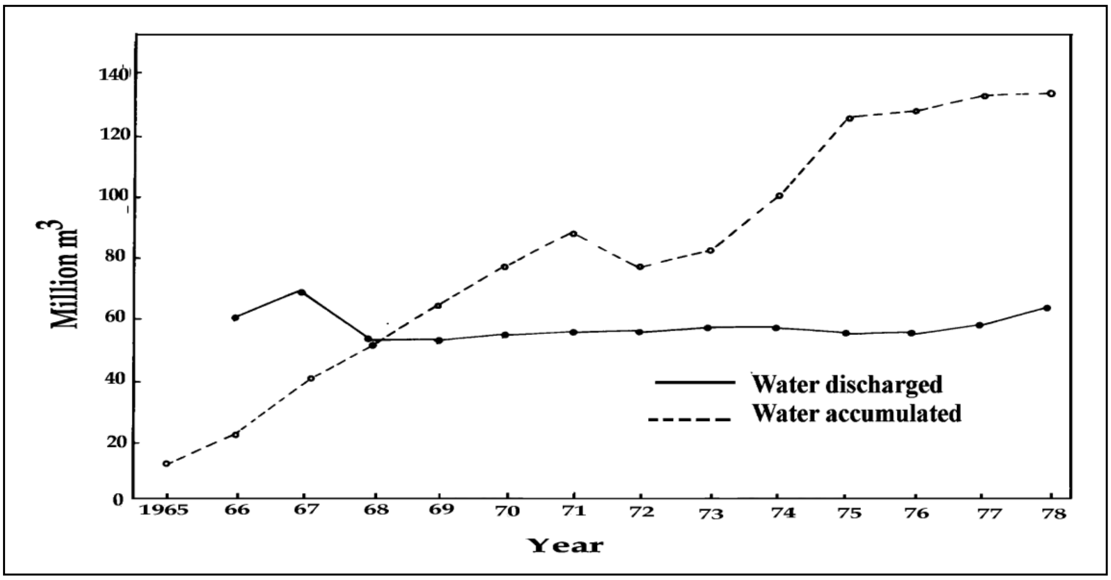

Fig. 11 **Water discharged and accumulated in Lake Nasser during 1965 - 1978 (Elewa 1980).**