Chapter 2
Sedimentation

BEFORE CONSTRUCTION OF ASWAN HIGH DAM (AHD)

At the beginning of the twentieth century, geologists were interested in the Nile Delta (Zaghloul 1976). Surface geologic work shows that the delta area is covered by recent alluvium of several meters thickness, This is underlain by coarse sand and gravels with occasional clay lenses of Pleistocene. Their total thickness ranges from 200 to 500 m. It generally increases towards the north and thins on both east and west. On top and towards the sea, the section changes to silt and clay.

According to information given by Herodotus and Strabo (fifth century B.C., first century A.D.), the Nile Delta has six or seven tributaries (Fig. 12A) during Pharaonic times. Thus, the suspended load of the Nile was discharged over a much wider geographic area than in recent years. Between the fourth and ninth centuries A.D., the discharge of the Canopic and Sebennitic Branches gradually decreased and finally ceased. At present, the Delta has only two branches, namely the Rosetta and Damietta Branches which are equivalent respectively to the old Bolbitinic and Bucolic Branches (Fig. 12B). Concentration of discharge at Rosetta and Damietta locally changed the discharge/wave-power index, leading to a pattern of river-dominated sedimentation. The deltaic mud tended therefore: (1) to prograde further seaward across the shelf than in earlier times, and (2) to be more concentrated around the river mouths. Thus, before the closure of the Aswan High Dam (AHD), a substantial quantity of sediment was regularly brought down by the Nile to the Delta coast through the Rosetta and Damietta estuaries (Summerhayes & Marks 1976).

Quelennec & Kruk (1976) pointed out that 98% of the annual sediment load occurred during the flood season, with the following distribution:

July	August	September	October	November
2%	45%	38%	12%	1.5%

It was noted that 10 - 15 % of the annual suspended load was deposited in irrigation areas in Upper Egypt, and in the Nile bed upstream of Cairo. Not less than this amount, or may be more, should be presumably spread over agriculture lands of the Delta downstream of Cairo. Quelennec & Kruk (1976) pointed out, on the basis of comparison with known average rates of sedimentation at sea and with the volumes involved in some of the Nile Delta coastal changes, that the Nile load was deposited also outside the continental shelf before 1964.

The construction of the Aswan High Dam, combined with, more or less, complete damming of the river near Rosetta and Damietta, have turned the lower reaches of the Nile into tidal bodies of saline water. Cessation of sediment discharge means that the sands and prodeltic mud of the delta front are no longer being nourished by the river. The immediate effect will be a deepening of the sea bed in shallow water within a few kilometers of the Nile mouths. Deepening, in turn, will decrease wave attenuation, causing a gradual increase in the flux of wave energy at the coastline, thereby leading to a gradual increase in the rate of coastal erosion (Sumerhayes & Marks 1976).

AFTER CONSTRUCTION OF ASWAN HIGH DAM

The Nile flood usually carries a heavy load of mud - on the average 134 million tons annually (Aboul-Ata 1978). The Lake's area within the reach of this turbid water shows usually decreased transparency, varying through the years especially in the first decade of impoundment. In the early years of filling of the reservoir, for instance 1966, the turbid water reached as far north as the Aswan High Dam (Latif 1976a). In the following years, with the rise in water level, the range covered by turbid water receded southwards and it appears to be confined to the southern portion of the reservoir whereby this turbid water appeared only in Lake Nubia and southernmost part of Lake Nasser in the seventies. However, due to the low flood of 1972, the turbid water appeared only in Lake Nubia (Fig. 13).

In general the total load of suspended solids decreases from south to north due to the sedimentation of different components (sand, silt and clay), along the Nile's course as it moves across the reservoir. Sedimentological studies on Lake Nasser were carried out by many investigators (Entz 1974b, 1976 and 1980a, Philip *et al*. 1977, Aboul-Haggag 1977, Scott *et al*. 1978, Sherif *et al*. 1981, High Dam Authority 1982, El-Otify 1985, El-Dardir 1984 and 1987, Elewa *et al*. 1988, Sadiek 1987, El-Dardir *et al*. 1988 and Nour El-Din 1990).

Before the construction of the AHD the Nile used to discharge its sediments into the Mediterranean Sea. Since 1964, this amount of sediments has been held in the AHD reservoir. Hurst (1957) pointed out that about 100 million tons of suspended sediments (30, 40 and 30% fine sand, fine silt and clay) are carried annually with the Nile on entering Egypt. The quantity of these sediments increases greatly at the beginning of Nile flood. Elster & Vollenweider (1961) estimated the average value of suspended matter in the Nile at the Egyptian borders during the flood period (August to October), to 1.6

kg/m^3. However, after the construction of AHD and creating the High Dam Lake these features changed basically. According to Entz (1976) the amount of mud reaching Lake Nasser is about 0.1 kg/m^3/year. Entz (1980a) points out that the suspended material in Lake Nasser does not exceed a few milligrams per litre and it is mostly organic matter of planktonic origin. It seems that the center of sedimentation is located in the area of the pervious Second Cataract near Wadi Halfa, in which a new Delta started to grow. Thus, no clay reaches the Egyptian water, only with high turbidity in the southern region of the Lake. El-Otify (1985) and Habib *et al*. (1996) found that the total suspended matter fluctuated between a minimum of 10 mg/l and a maximum of 132 mg/l. A gradual increase in the total suspended matter was recorded along the main body of Lake Nasser from north to south in autumn and summer.

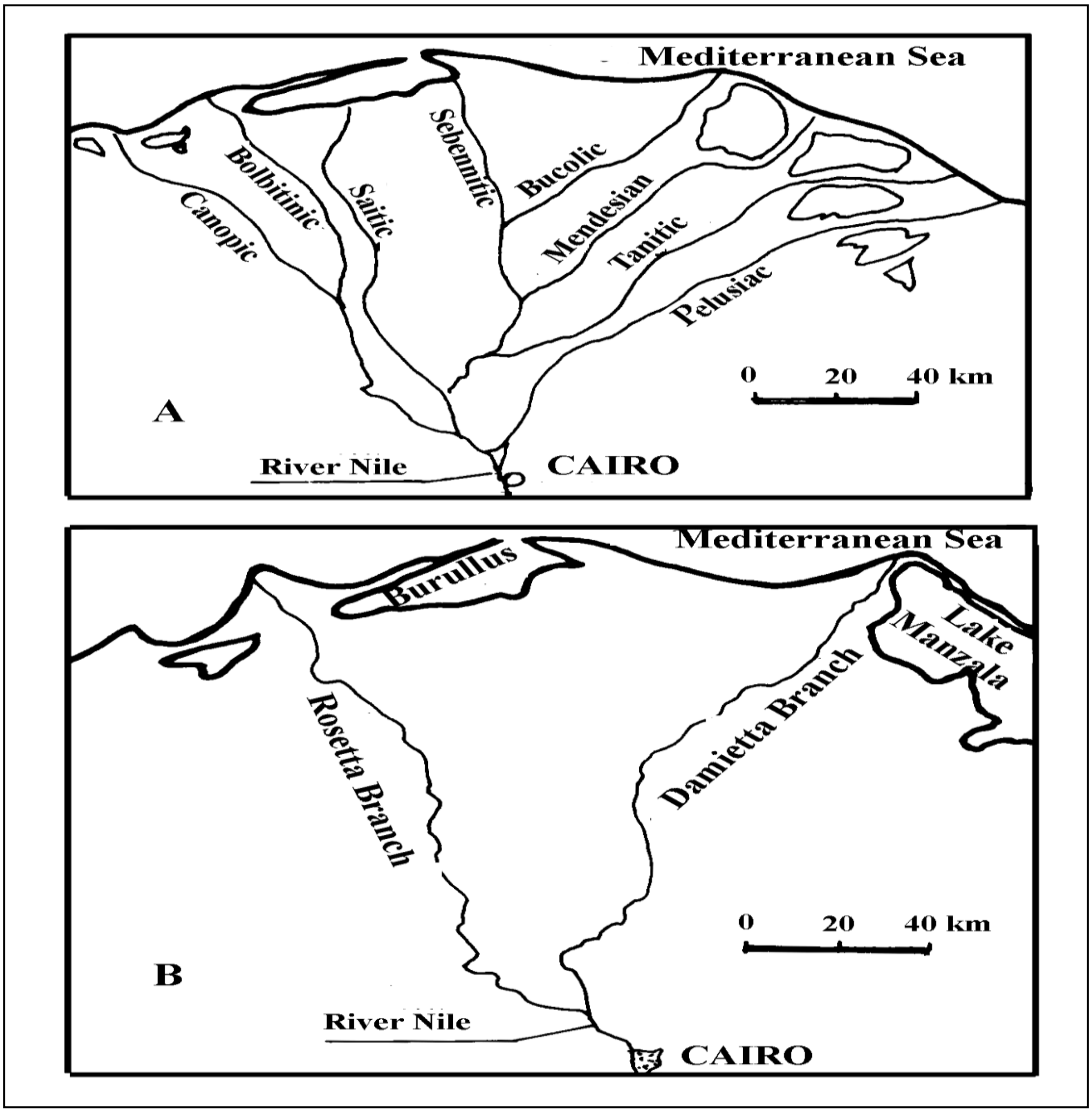

Fig. 12 A : Old Pharaonic branches of the Nile Delta.
B: Recent branches (Rosetta and Damietta) of the Nile Delta.
(Source: Latif, 1984a)

Rizkana & Aboul-Ezz (1964) pointed out that since the process of silting up of the reservoir will proceed year by year, the stored water reaching Egypt proper downstream of the Lake will be devoid of suspended material. This will also lead to a downvalley decrease in load relative to discharge with consequent increase in the erosive power of the water. Such change will decrease slope requirements of the down valley direction, thus preventing the Nile from attaining a slope of transportation or in other words a graded profile.

Aboul-Haggag (1977) showed that sedimentation in the High Dam Lake is controlled by many factors including the annual effective base level for each flood, the changes during hydrological year, the distribution and characteristics of rocky islands, the valley Lake bends, the old river terraces, the plankton induced deposition and certain man-made features. The maximum silt thickness (Fig. 14), that is, the area of most intense deposition, recorded in Lake Nubia until 1975 was at Gomi and the Second Cataract (Abca) where this layer was 17 and 20 m respectively, compared to 2 m at Adindan and 1 m at Abu-Simbel within Lake Nasser (Aboul-Haggag 1977).

Philip *et al.* (1977) describe most of the lake bottom sediments as clayey sediments. Scott *et al*. (1978) explain that the distribution of sedimentation in AHD reservoir is governed by the water level in the Lake, the volume of flood water and the distribution of the flood period at a given water level. El-Dardir (1984, 1987) reports that most of the sedimentation in the Lake takes place at the area north of El-Daweishat and south of Wadi Halfa in the Lake Nubia.

Entz (1980a) recorded the average rate of sedimentation as 90.480 million m^3 per year. The exact site and quantity of sedimentation depends on the total amount of sediments, its size distribution, velocity of water masses and the Lake water level. Sherif *et al.* (1981) studied the sedimentation processes in the High Dam Reservoir. They pointed out that the suspended silt load of the Nile flood (about 0.1 km^3 per year) was sedimented from 1968 to 1974 between Attiry (415 km south of the High Dam) and Abu Simbel (280 km south of the High Dam) and the bulk was deposited around the Second Cataract near Wadi Halfa. The latter authors pointed out that the suspended material in Lake Nasser did not exceed a few milligrams per litre and even that was mostly of planktonic origin. The High Dam Authority (1982) recorded a maximum sedimentation in the Lake between Amka and El-Daweishat 364 km and 431 km south of the High Dam respectively.

Estimates of the thickness of sediments, based on echosounding profiles and from the bottom level, have shown that the maximum sedimentation seems to occur in Lake Nubia (the Sudanese part of the reservoir) at Atteri, Murshid and Kingarti (400, 380 and 385 km from the High Dam respectively). The maximum sedimentation takes place at Adindan and Abu Simbel (in the southern part of the Egyptian sector of the reservoir) (El-Dardir 1984). The latter author concluded that undoubtedly, because of the sedimentation in the Lake, many of the channel islands and hills have been buried. Elewa and Latif (1988) reported that the

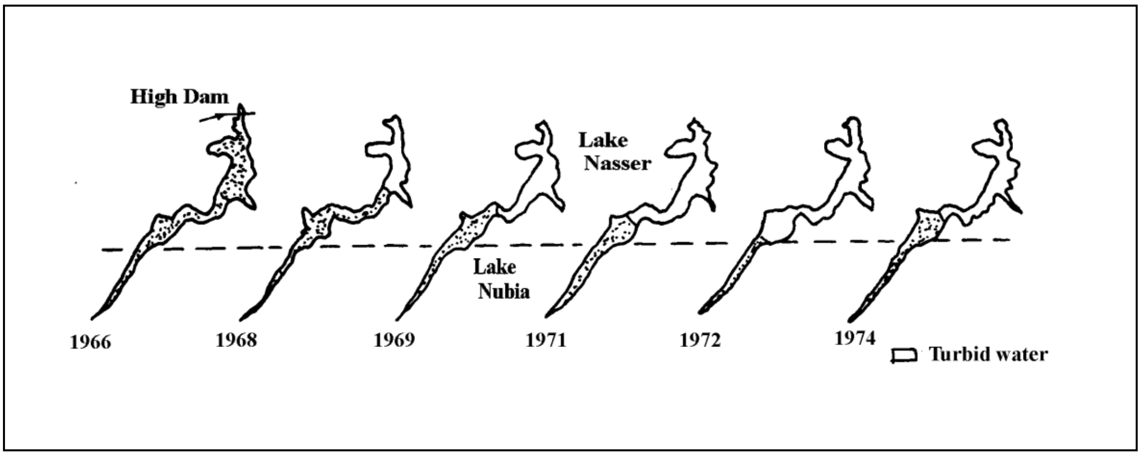

Fig. 13 **Extent of flood turbid water in some selected years (Latif 1984a).**

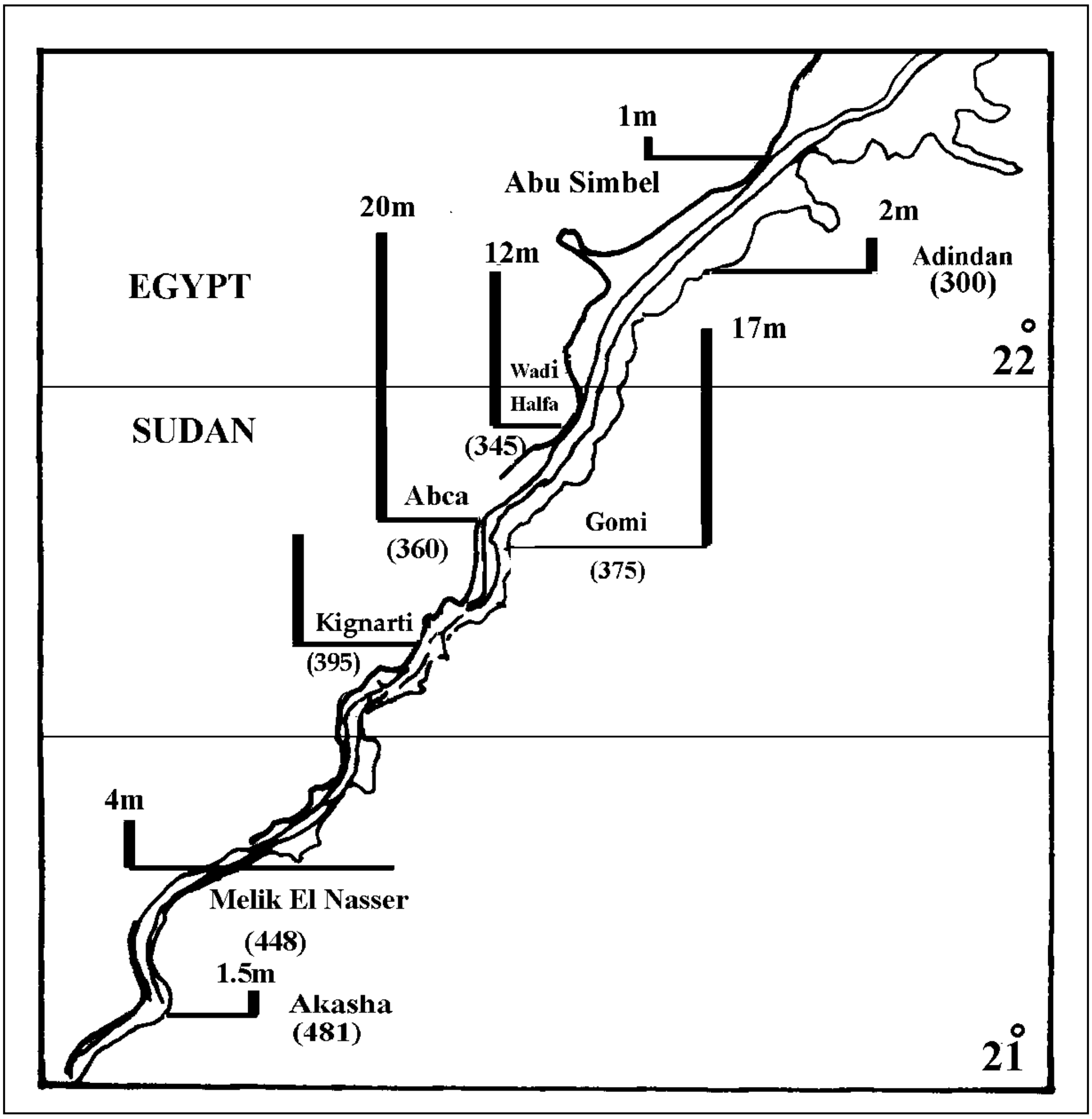

Fig. 14 **Distribution of siltation in the Aswan High Dam Reservoir. Figures in parentheses indicate distance (km) from the High Dam (Latif 1984a).**

bottom of the lake received its sediments mechanically from the flood and country rocks and chemically from solution, due to action of several physico-chemical parameters controlling the deposition of the chemical components. Sadiek (1987) showed that the lake sediments were deposited by tractive currents suspension load and tranquil water.

El-Dardir (1987) studied the sedimentation processes in Lake Nubia and concluded that the highest load value of suspended matter prevailed in the southern part and the lowest value in the northern region. This, in his opinion, goes parallel with the current speed, except at Kignarti and Gomi where this part is characterized by an abrupt increase in velocity. El-Dardir *et al.* (1988) report that the bottom sediments of the southern khors are composed of silt, clay and sand arranged in a decreasing order of abundance. Geochemical, minerological and sedimentological studies on some khors sediments of Lake Nasser were carried out by Gindy (1991).

Latif (1984a) pointed out that $30 \times 10^9 m^3$ have been considered as dead storage, to account for the expected sedimentation during the expected 500 years life of the reservoir.

Nature of Sediments

The sediments were estimated to about 125 million tons/year, while other estimation of the total amount of sediment deposited since 1964 was about 1 km^3/year (Entz 1974b). The exact site and quantity of sedimentation depends on the total amount and its grain size distribution and the Lake level (Raheja 1970).

The darkest colour of sediment was observed near Aswan (Entz & Latif 1974). The latter authors related the dark grey colour to the relatively old sediments and the anoxic conditions during the summer stagnation period which lasts longest near the High Dam and has a decreasing duration towards the south. The light colour, on the other hand, was attributed to freshly sedimented silt with fairly low organic matter content.

Some microorganisms (Cladocera, Copepoda, ... etc.) behave as filtering organisms in the reservoir as they feed on finer materials suspended in the water. After digesting the organic content in the fine materials, these microorganisms coagulate the suspended particles to bigger droplets (Hafez 1977). These filtering organisms are believed by Entz (1974b) to be the main reason for the turbid water not reaching the northern section of the reservoir.

Deposition in Lake Nubia (Sudanese part) of the reservoir differs from that of the Egyptian part. At the entrance of Lake Nubia, where the Nile velocity and its related transporting power are decreased to the extent that the Nile becomes unable to hold the relatively large and heavy suspended materials, the river begins to put down its suspended load as sediment. So, the Nile is building up a new delta at the southern part of Lake Nubia by the sedimentation of the relatively heavier and coarser parts of the material in suspension while the finer fractions settle down further north in the Egyptian part of the reservoir.

The environmental conditions such as, parent material, chemical composition, pH, Eh (electromotive force), temperature and water circulation are the controlling factors affecting the formation of clay minerals (Degens, *et al*. 1957).

Effect of Environmental Factors on Nature of Sediments

Higazy *et al.* (1986) studied the environmental influence on the clay mineral formation and deposition in the High Dam Reservoir and concluded the following:

The clay deposit in the reservoir is detrital and authigenic, but the authigenic clay minerals reflect the chemistry of the environment more closely. It is believed that these clay minerals are mainly authigenic due to the abundance of montmorillonite. Chemical and physical properties of elements control their deposition. The pH values of the bottom sediment, as well as, the pH values of the overlying water are in harmony with the montmorillonite/kaolinite (M/R). Also, the seasonal variation in temperature of the water controls the thermal stratification of this water and hence affects its oxygenation which is responsible for the oxidation-reduction conditions, as well as, the life of plants, animals and organisms that affect the rate of deposition. Since slight acidic media favour the formation of kaolinite, while slightly basic media favour the formation of montmorillonite, the X-ray analysis data show that kaolinite is inversely proportional to montmorillonite for compensation between pH and Eh. Heavier and coarser parts of the suspended materials are deposited in the Sudanese part of the reservoir (Lake Nubia) especially at its entrance, while the final fraction settles down in the Egyptian part of the Aswan High Dam Reservoir. The spatial variation in the reservoir sediment indicates that the water is slightly more basic upstream, while the spatial variation in the trace elements of the clay fractions shows that manganese increases southwards, while magnesium displays maximum decrease at Allaqi and reaches maximum increase at Adindan. Generally, the spatial variation of the trace elements in the clay fraction is conformable with the spatial variation of the pH.

Elewa & Latif (1988) investigated the effect of physico-chemical conditions on the deposition of some elements of Aswan High Dam Reservoir water and concluded the following:

1. The water of the reservoir may be divided into two media:
   a- Oxidized (the oxygenated layer) alkaline layer.
   b- Reduced with free H_2S, slightly alkaline layer (the non-oxygenated layer).
2. Temperature, oxidizable organic matter and free oxygen play an important role to form the two media.
3. Deposition of the carbonate is related partly, to the alkaline medium,

however, the carbonate secreting or encrusting organisms play the major role at some parts of the reservoir.

4. Al_2O_3 and Fe_2O_3 are deposited simultaneously as hydrolysates, however, the distribution of Na_2O and K_2O favours the presence of sodic and potash feldspars.
5. Iron, manganese and heavy metals were deposited in the form of colloidal sulphides in the reduced, slightly alkaline medium.
6. Copper and zinc were deposited adsorbed onto the colloidal manganese.

Mechanical Analysis of Sediments

Fishar (1995) studied the bottom sediments of Lake Nasser during 1993 at 10 stations (Fig. 15 and Table 11), his results are presented in Table 12.The latter author showed that the bottom sediments of the Lake are heterogeneous, and in the main channel they are mainly silty clay and clayey silt, while the samples representing the eastern and western sides include more sand. The highest percentage of mud (silt and clay) was recorded in the main channel of the southern stations (Tushka, Abu Simbel and Adindan), while the western side of Singari and Abu Simbel sections have established muddy sandy bottom (Fishar 1995 - Table 12).

Relation between sediment, calcium carbonate, organic matter and productivity

Latif *et al*. (1989) determined the calcium carbonate and organic matter in the bottom sediments of the northern, middle and southern sectors of Lake Nasser, and their effects on the productivity of the Lake (Table 13). The highest values of $CaCO_3$ were recorded at Amada (middle area) (9.99 - 11.27%) compared with 1.71 - 2.61% and 2.81 - 3.37% at Adindan and El-Birba respectively. Plants and planktonic algae are well known for their ability to extract CO_2, raise pH and thus promote precipitation of carbonate. Phytoplankton production can be a major factor in the precipitation of calcium carbonate.

The highest productivity is recorded in the middle area of the Lake (Table 13). A significant correlation between calcium carbonate concentration in the bottom sediments with the productivity of the Lake (Table 13) is observed. Fishar (1995) calculated the percentage of organic matter in the bottom sediments of Lake Nasser and found that it ranged from 0.93% in the western station of Adindan section to 2.99% in the main channel of Maryia section. Fig. 16 clearly shows a seasonal pattern of organic matter in Lake Nasser. The highest percentages of organic matter were recorded during winter, with average values of 1.91, 2.67 and 2.36% in the eastern side, main channel and western side respectively. This was followed by a decrease in the value at the two sides during spring. In summer, a slight increase in the percentage of organic matter was observed in the main channel attaining 1.93%, in contrast to another decrease at both sides reducing the values to be 1.18 and 1.43% in the eastern and western sides respectively. In autumn, an increase in percentage of organic matter was recorded in the eastern side and main channel, while a decrease in percentage was observed in the western side to attain an average value of 1.03%.

Table 11 **Latitudes, longitudes and distance from the High Dam (km) of selected sections in Lake Nasser during 1993 (Fishar 1995).**

Site	Latitudes		Longitudes		Distance from the HD
Upstream	23°	56.24´	32°	51.89´	29
Dihmit	23°	51.1´	32°	53.78´	21
Kalabsha	23°	33.41´	32°	52.04´	47.7
Mariya	23°	20.08´	32°	56.12´	74.3
El-Madiq	22°	6.47´	32°	37.68´	130.1
Singari	22°	37.65´	32°	24.14´	167.2
Amada	22°	43.97´	32°	5.45´	199.
Tushka	22°	36.32´	31°	55.21´	240.
Abu Simbel	22°	19.71´	31°	37.14´	268.8
Adindan	22°	14.71´	31°	31.81´	299.7

Table 12 **Calculated percentages of sand, silt and clay fractions at different localities of Lake Nasser during 1993 (Fishar 1995).**

Site	Locality	Sand (%)	Silt (%)	Clay (%)	Type of sediments
	E	20	41	39	sandy muddy
Upstream	M	5	22	73	black mud
	W	29	39	32	sandy
	E	3	56	41	muddy
Dihmit	M	7	26	67	black mud
	W	15	33	52	sandy mud
	E	16	51	33	sandy muddy
Kalabsha	M	4	26	70	black mud
	W	9	47	44	sandy muddy
	E	22.1	39	38.9	sandy muddy
Maryia	M	3.8	33	63.2	black mud
	W	28	22.5	49.5	muddy sand
	E	36	41	21	muddy
El-Madiq	M	2.4	30.1	67.5	black mud
	W	34	41	25	muddy sand
	E	7	70	23	muddy
Singari	M	7.8	22	70.2	black mud
	W	62	22	16	sandy
	E	40	31	29	muddy sand
Amada	M	5.1	67	27.7	black mud
	W	43	29	28	muddy sand
	E	30	29	41	sandy mud
Tushka	M	2	66	32	black mud
	W	42	17	41	muddy sandy
	E	12	30	58	sandy mud
Abu Simbel	M	2	26	72	black mud
	W	62	17	21	muddy sand
	E	33	46	21	sandy muddy
Adindan	M	1.9	32.1	66	black mud
	W	37	46	17	sandy muddy

E: Eastern side; M: Main channel; W: Western side [For stations refer to Fig. 15 and Table 11].

Table 13 **Relation between sediment, calcium carbonate, organic matter and productivity in Lake Nasser during 1981 – 1983 (Latif *et al.* 1989).**

	Spring			Summer			Autumn			Winter		
	El-Birba	Amada	Adindan	El-Birba	Amada	Adindan	El-Birba	Amada	Adindan	El-Birba	Amada	Adindan
$CaCO_3$ (%)	2.81	11.26	2.22	3.28	11.27	2.61	2.97	9.99	2.23	3.37	10.44	1.71
Organic matter (%)	2.23	2.22	1.96	3.11	2.68	2.85	3.62	3.39	3.03	2.36	2.18	2.87
Chlorophyll *a* concentration (μg/l)	3.8	11.7	2.8	0.95	6.1	3.5	4.7	6.7	3.3	5.5	11.1	2.0
Zooplankton biomass (g/m^3)	6.1	13.3	16.4	1.5	5.9	8.3	4.1	9.7	11.8	3.2	4.8	5.5
Benthos biomass (g/m^2)	139.5	44.0	13.2	25.2	13.8	16.1	1.0	2.1	9.7	3.5	6.0	5.6

Habib *et al.* (1996) pointed out that the levels of particulate organic matter in the northern region of Lake Nasser (stns. 1 - 3) were comparatively low as compared with the southern region. The average amount of particulate organic matter ranged from 0.4 to 7.5 g/m^3. Similar seasonal patterns were observed with the maximum in July - September and minimum in December - February at the southern stations (4 - 6). Peaks of particulate organic matter appeared a little earlier at the northern stations (April-July) than at the southern stations (July-August). The seasonal patterns of particulate organic matter (Fig. 17) were similar to those of suspended solids (Fig. 18) at station 6.

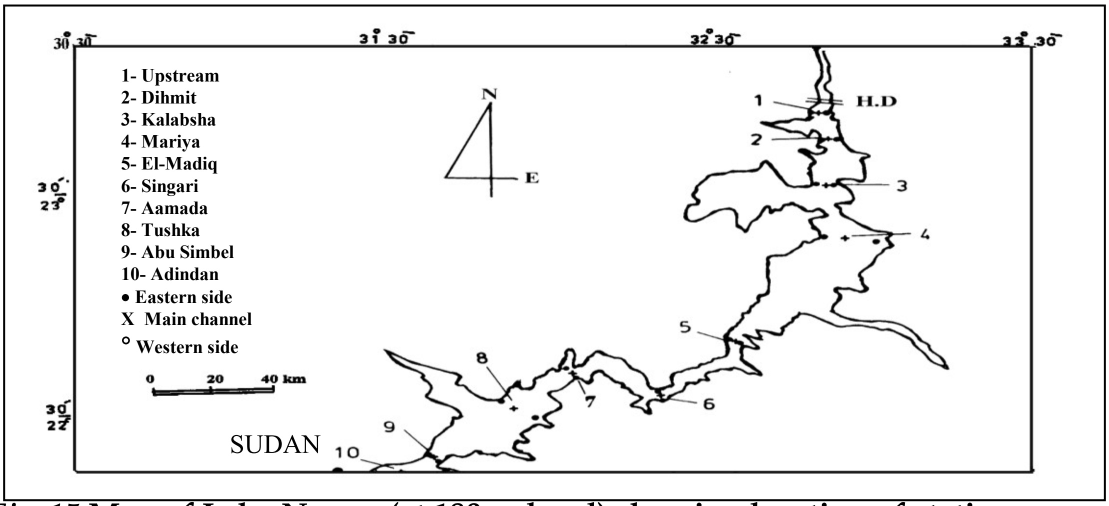

Fig. 15 **Map of Lake Nasser (at 180 m level) showing location of stations. (Fishar 1995).**

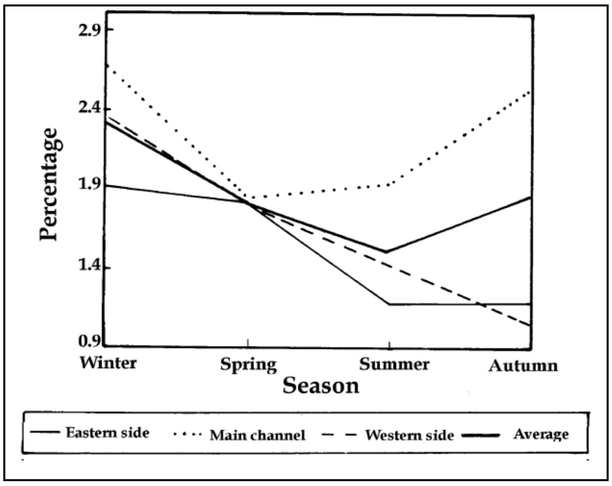

Fig. 16 **Seasonal variations of percentage of total organic matter in the sediment of Lake Nasser (Fishar 1995).**

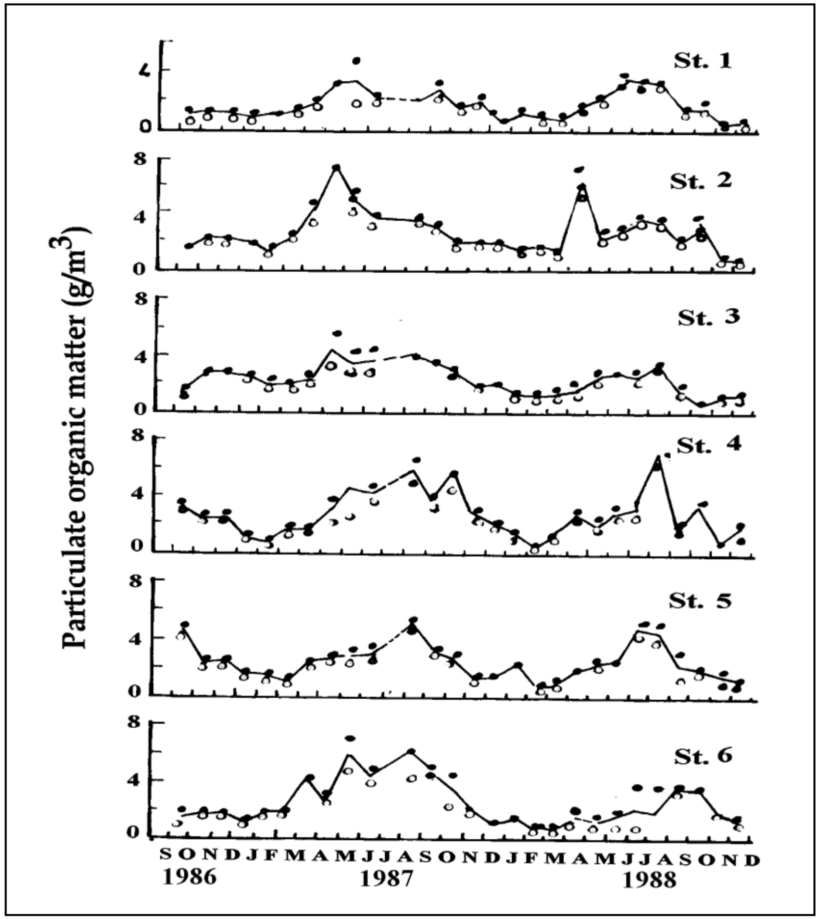

Fig. 17 Seasonal changes of the particulate organic matter at stns. 1-6 in the main channel of Lake Nasser. Lines are for averages of the surface (◦) and 2m (•) samples (Habib *et al.*1996) [For stations refer to Fig. 4].

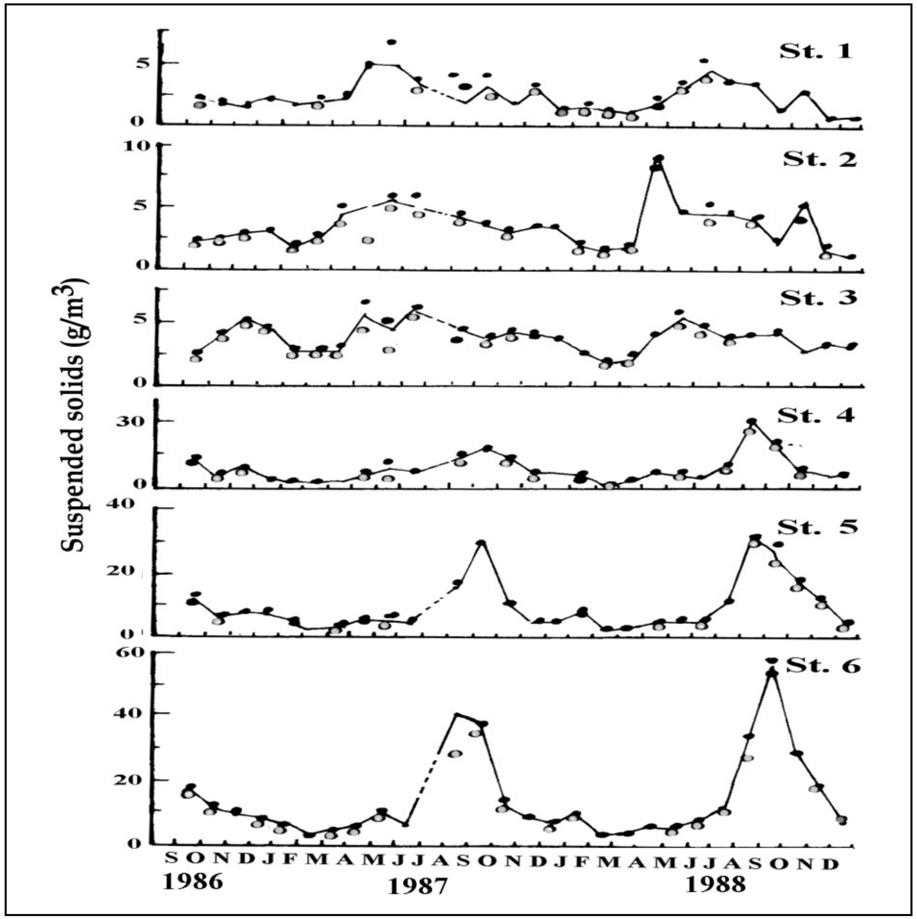

Fig. 18 Seasonal changes of the suspended solids at stns. 1-6 in the main channel of Lake Nasser. Lines are for averages of the surface (◦) and 2m (•) samples. (Habib *et al.* 1996).

Heavy Metal Concentrations in Relation to Lake Sediments

Pathways and distribution of metals in natural waters are necessary for assessing the current status of metals in the environment and for avoiding potential problems due to metals. Sediments and suspended particulate matter play an important role in the dynamics of organic and inorganic compounds in the aquatic environments (Felz 1980, Wakehom & Farrington 1980). Highly charged clay particles are responsible for the proportion of both cations and anions (Grobler *et al.* 1981). The organic matter associated with sediment particles is largely responsible for the ability of sediment to adsorb uncharged organic compounds (Karickhoff 1983). Therefore, pollutant concentrations in sediments usually increase with decreasing particle size (Dossis & Warren 1980). Elewa *et al.* (1990) assessed the levels of iron, manganese, copper and zinc in the surface sediment of Lake Nasser in summer and winter 1988 (Figs. 19-22). The results indicate that in Lake Nasser, copper content is high (56 - 81 ppm) as compared with that of Lake Nubia (38.3 - 42.9 ppm). There is a consistent correlation between copper content and depth of the collected samples, as well as the grain size and and organic matter contents (Glenn & Van Atta 1973, Schettle & Friedmann 1973).

In Lake Nasser, zinc content ranges between 77 - 432 ppm. Generally, zinc concentration in Lake Nasser increases rapidly southwards to reach its maximum value of 432 ppm at Abu Simbel, followed by an abrupt decrease to 166 ppm at Adindan, and further decrease to 63.1 ppm in the most southern region in Lake Nubia. Furthermore, the enrichment of zinc in Lake sediments in the area lying between Singari and Abu Simbel (Fig. 20) is associated with its accumulation with organic matter (Elewa 1980). In the sediments of Lake Nasser, Cu and Zn distribution is more related to the amount of clay. Meanwhile, Zn and Cu are chiefly adsorbed onto the clay minerals and hydrated iron and manganese oxides (El-Dardir 1984). On the other hand, the accumulation of Zn and Cu in the sediment may be the result of the deposition of metal rich planktonic debris and subsequent degradation of the debris (Takamatsu *et al.* 1985).

Robbins & Callender (1975) and Forstnar (1983) point out that the cycling of Mn within sediments is well known to vary with the redox condition of the sediment. Thus, Mn is precipitated primarily within inorganic and organic particles on the Lake bottom. Takamatsu *et al.* (1985) have shown that Mn concentration was very high in the oxidized uppermost layer of offshore sediment. This may result from the dissolution-deposition cycles of Mn within the water sediment interface of Lake Nasser (Elewa *et al.* 1990). The trend of Fe distribution in Lake Nasser was low in the northern region followed by an increase southward (Fig. 22).

Lake Nasser is a productive Lake with clinograde oxygen-curves, with the oxygen deficient part in the hypolimnion during the warm period in summer and early autumn. Fe and Mn are liberated from sediments as sulphides. Thus, several mechanisms are responsible for the remobilization of these metals e.g. desorption, dissolution, mineralization, ligend exchange and enzymatic hydrolysis. These processes are affected by environmental factors such as: redox potential, pH, temperature, turbulence and depend on the dynamic equilibrium between the concentrations of metals in the interstitial water and the sediment (Bostrom *et al*. 1982, Elewa 1976 , Grobler *et al*. 1987).

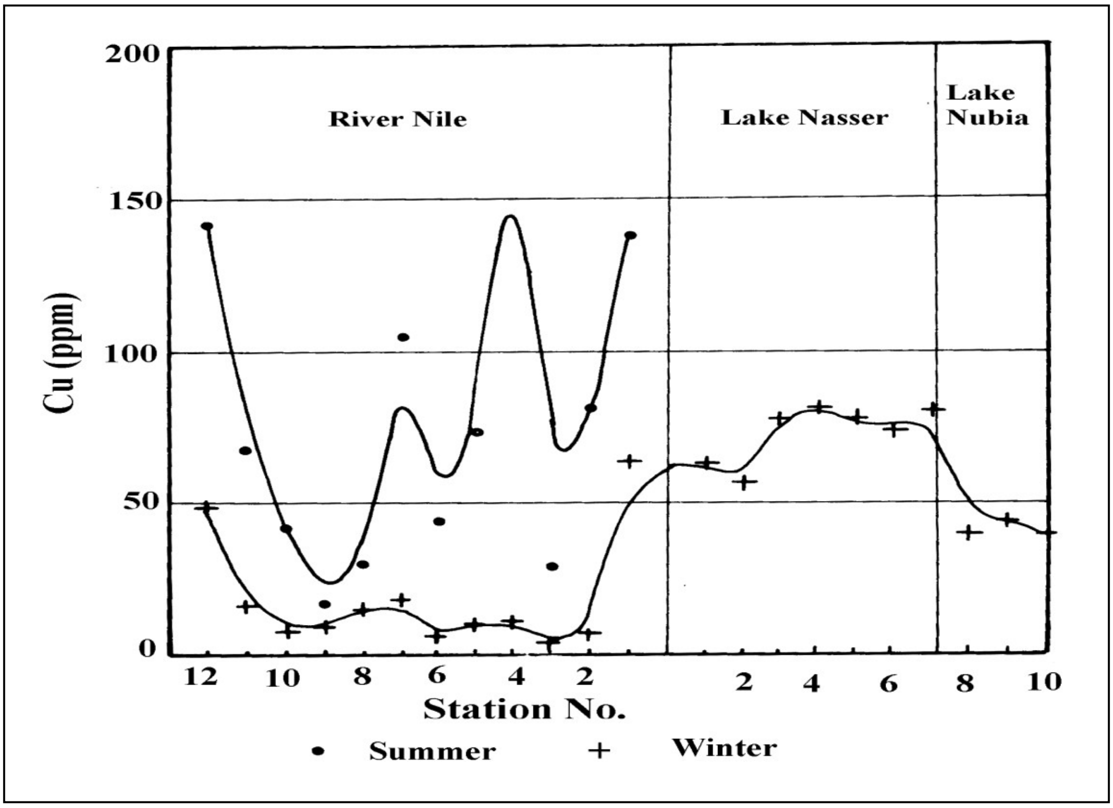

Fig. 19 **Copper distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

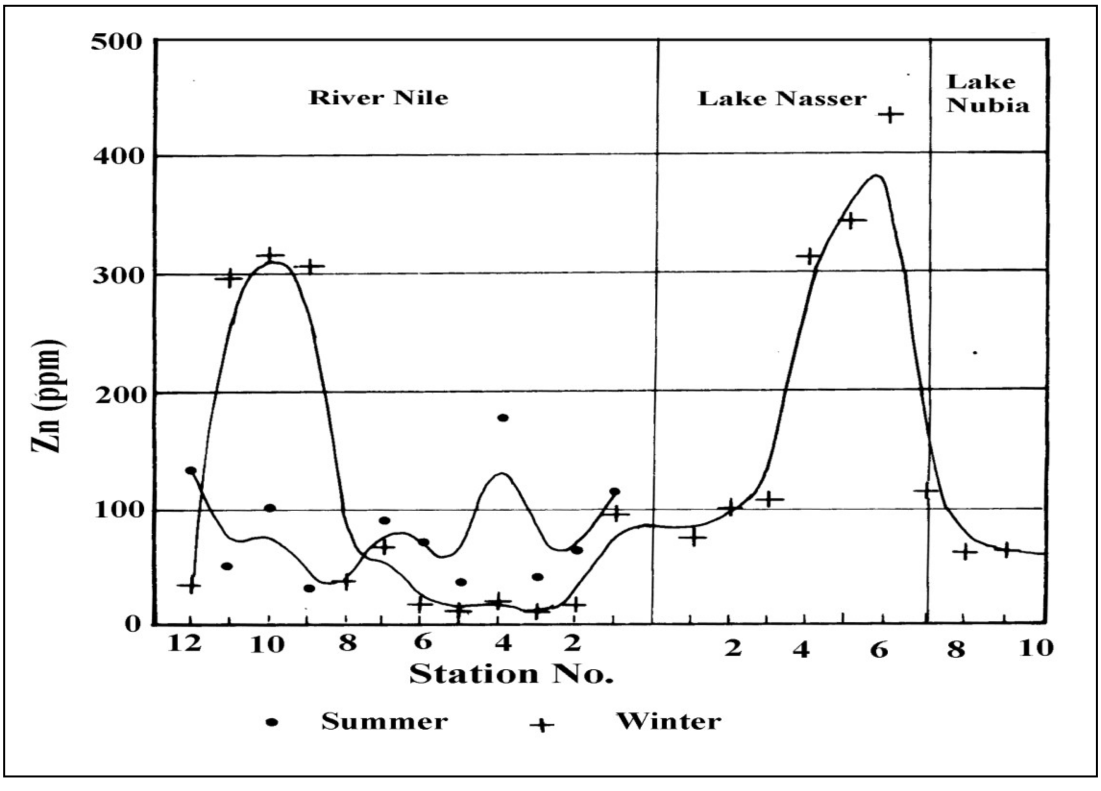

Fig. 20 **Zinc distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

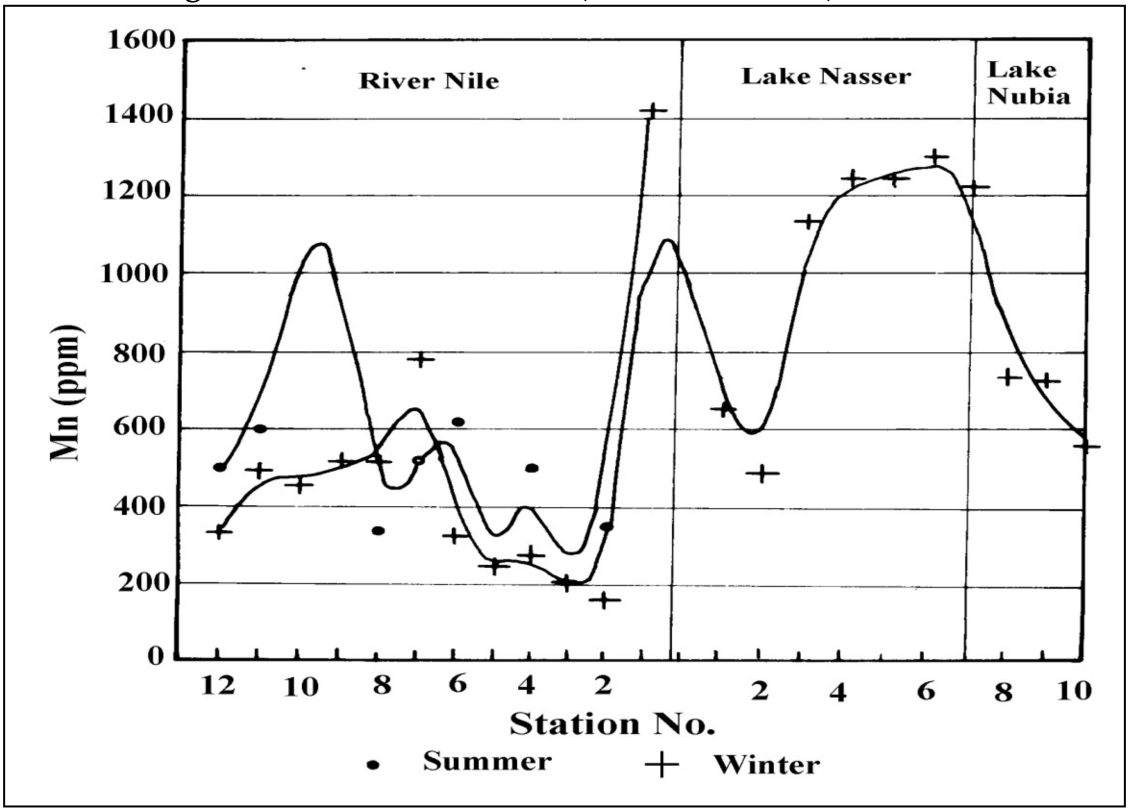

Fig. 21 **Manganese distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

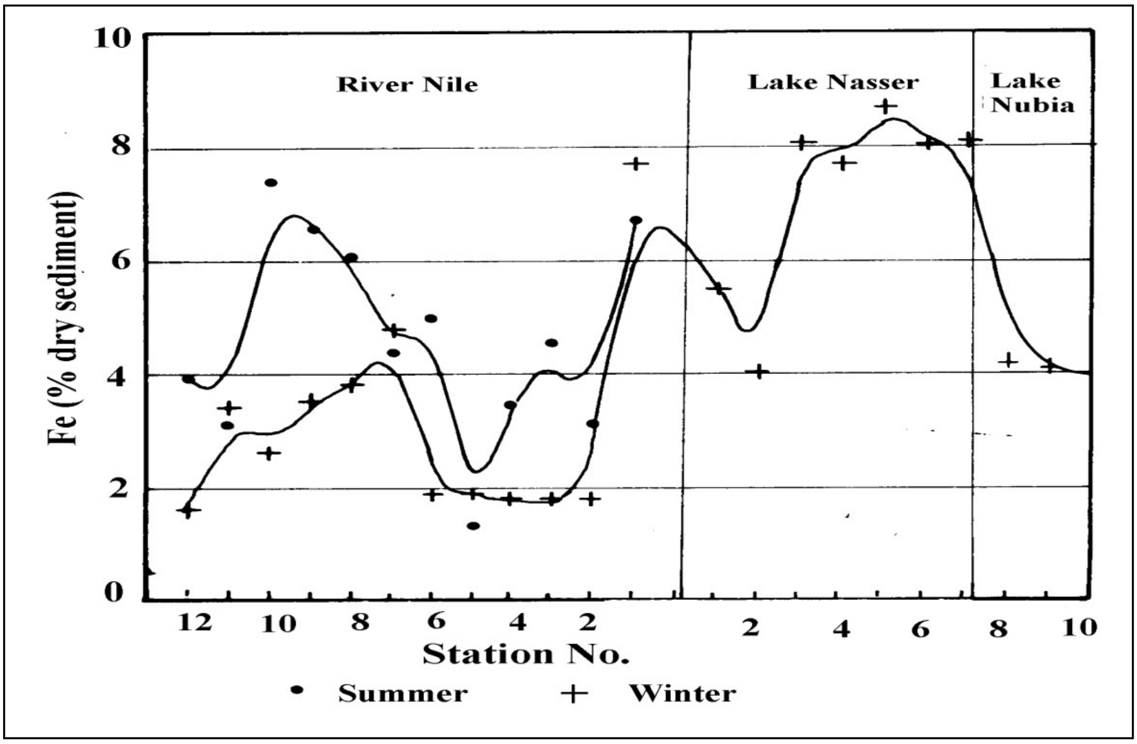

Fig. 22 **Iron distribution in the sediments of River Nile at Aswan and Lake Nasser during summer and winter 1988 (Elewa *et al.* 1990).**

Alsterberg (1927) and Hutchinson (1957) report the direction of transpiration of elements from sediments into free water being controlled by temperature and oxygen stratification and by the morphology of the Lake basin. In turn, the presence or absence of the oxidized microzone in the bottom sediment constitutes an immense difference to the amount and nature of substances leaving the mud and passing into the water (Gorham 1965). Elewa *et al.* (1990) mentioned that, the enrichment of a given element in Lake Nasser sediment may be affected by a variety of environmental factors. Few elements are more concentrated into the organic mud, e.g. Fe and Mn . Another factor affecting Fe distribution is the grain size. Krauskopf (1956) indicates that the depletion of Cu and Zn could be the result of precipitation as sulphides. On the other hand, the role of redox chemistry in controlling the distribution of Fe and Mn can be observed in the sediment of Lake Nasser (Elewa *et al.* 1990). The latter authors conclude that Fe, Mn, Zn and Cu are concentrated in the clay sediment rather in the silt and sand. On the other hand there is a positive correlation between these metals and the organic matter content. It is concluded that Lake Nasser sediments are more concentrated with these metals in comparison with downstream River Nile.

CONCLUSIONS

Before AHD construction an average of about 124 million tons of mud was brought annually with the flood, 10 - 15% was deposited in irrigation areas of Upper Egypt and in the Nile bed upstream Cairo. About the same amount or more was spread on agricultural land of the delta, in addition to paramount quantity brought down to the Delta coast through the Rosetta and Damietta estuaries, in addition to deposition outside the continental shelf.

After the construction of AHD and complete filling of Lake Nasser the amount of mud reaching the Lake is about 0.1 - 10 mg/l, and recently 10 - 132 mg/l (average 0.1 km^3/year) of suspended material mostly organic matter of planktonic origin. After damming the river near Rosetta and Damietta, the lower reaches of the river turned into tidal bodies of saline water. A gradual decrease of suspended matter was recorded from south to north of the Lake. Until 1977 the center of sedimentation was located in the area of Gomi and Second Cataract near Wadi Halfa where a layer of 17 - 20 m thickness was deposited compared to 2 and 1 m at Adindan and Abu Simbel within Lake Nasser where maximum sedimentation occurs. Dead storage has been estimated as $30x10^9m^3$, to account for the expected sedimentation during the expected 500 years life of the reservoir.

There are many physico-chemical conditions affecting deposition of elements in the reservoir including: media of reservoir (oxidized or reduced), temperature, deposition of carbonate, Al_2O_3, Fe_2O, Na_2O, K_2O as well as heavy metals (Fe, Mn, Cu, Zn etc.). The bottom deposits of the reservoir are heterogenous mainly silty clay and clayey silt in the main channel containing more sand on the sides of the Lake.

There is a relationship among calcium carbonate, organic matter and productivity. The highest $CaCO_3$ content of the sediment was recorded at Amada (middle area) with the highest productivity, as phytoplankton can be a major factor in $CaCO_3$ precipitation. The seasonal pattern of organic matter in the Lake shows the highest values in winter in the main channel and both sides of the Lake followed by a decrease coinciding with the fluctuation of phytoplankton being highest in winter.

The particulate organic matter is higher in the southern region compared with that in the northern region. The southern region is richer in both phyto- and zooplankton compared with the northern region. The seasonal pattern of particulate organic matter is similar to that of suspended solids at the southernmost stations. Maximum particulate organic matter is recorded in summer.

Regarding heavy metals in the sediment in Lake Nasser, they are more concentrated in the Lake than downstream the Nile. Copper concentration in Lake Nasser is higher than in Lake Nubia. There is a consistent correlation between copper content, depth, grain size and organic content. Zinc concentration ranges between 77 - 432 ppm showing an increase southwards to reach its maximum at Abu Simbel, followed by an abrupt decrease to 166 ppm at Adindan, and further decrease (63.1 ppm) in the southernmost region of the Lake. Enrichment of zinc in Lake sediment between Singari and Abu Simbel is associated with its accumulation with organic matter. Zn and Cu are merely adsorbed onto the clay minerals and hydrated iron and manganese oxides. Accumulation of Zn and Cu in sediment may be the result of the deposition of metal rich planktonic debris and subsequent degradation of debris.

Manganese concentration is very high in the oxidized uppermost layer of offshore sediment which may result from dissolution, deposition cycles of manganese with the water sediment interface in the lake.

Iron is low in the northern region followed by an increase southwards. In summer stagnation Fe and Mn are liberated from the sediment as sulphides. This process is affected by many factors as redox potential, pH, turbulence, temperature and dynamic equilibria between metal concentrations in the interstitial water and the sediment. Thus several mechanisms are responsible for the remobilization of these metals, i.e. hydrolysis, dissolution, mineralization, ligend exchange and enzymatic hydrolysis. Furthermore the presence or absence of the oxidized microzone in the bottom sediment constitutes an immense difference in the amount and nature of substances leaving the mud and passing onto the water. Grain size is another factor in distribution of iron, the rate of redox chemistry seems to play a role in controlling distribution of Fe and Cu in the Lake. It seems that Fe, Mn, Zn and Cu are concentrated in the clay sediment rather than in the silt and sand.