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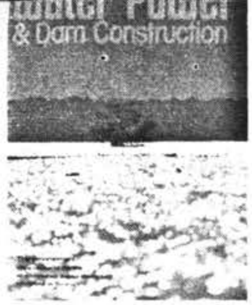

COVER: *Forest versus hydropower, one of the many problems raised in this issue on the environment.*
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NEXT MONTH: *the issue will coincide with the 51st Executive Meeting of the International Commission on Large Dams and will carry an updated and improved form of our Tables, "Major dams of the world". We shall also be looking at the Menkanshao dam in the People's Republic of China and the Asahan power complex and dam in Indonesia.*

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ENVIRONMENT

Degradation of the river Nile

By S. Shalash
Director*

PART ONE

One of the effects of construction of the High Aswan dam in Egypt was degradation of the river Nile. Theoretical studies which have been carried out over the last eighteen years are described, and the relationship between theory and actual effects is shown.

IT IS well known that the degradation problem of the river Nile in Egypt is a direct side effect of the construction of the High Aswan dam. The main affected reach of the river is located between points immediately downstream of the Low Aswan dam and upstream of the Delta barrage (river km 953). As the surface water levels of the river are subject to change, there will be a consequent effect on existing barrages across the river, and on the stability of the river banks and the river regime.

One of the main tasks of the Research Institute of Saad El Aali Side Effects (RISASE) is to monitor the annual effects of degradation on the river channel, particularly downstream of the existing hydraulic structures.

Between 1975 and the end of 1981, RISASE published an annual report about the results of the hydrological observations along the river reach between the Aswan dam and the Delta barrage. These reports consist of results of actual observations in the field, and the effects on barrages.

During the investigation work for the High Aswan dam project in 1954, an international panel of consultants drew attention, in their report, to the problem of degradation. They stated the following: "the major problem that requires further consideration and study is the potential degradation that may occur in the Nile river channel downstream from Aswan as a result of building the dam. Field observations on the Nile have been made for many decades so that much information is available, particularly on the suspended load in the river. These field data should be supplemented by further detailed observations specifically directed to obtaining a more comprehensive understanding of degradation processes in the Nile river channel. This will ensure proper design and construction of remedial measures in time before harmful effects can become particularly consequential and permanent."

Since this time many researchers have started to work on this problem.

In his paper "Some Consideration on the degradation problem in the Aswan High dam scheme" 1956, Fathy stated two points about the degradation behaviour that had to be settled. These were:

- the maximum extent of degradation; and
- the rate of the degradation process.

Fathy tried to clarify the first point by using several different methods. He stated that the slope of the river would be flattened because of a combination of four processes:

- deepening of the river bed in certain reaches;
- change in the slope of its channel;
- elongation of its passage; and,
- maintaining the river channel width.

Fathy then assumed that the final equilibrium of the river slope depended on three factors:

- formation of the river bed material;
- hydraulic characteristics of the stable canals; and,
- the highest discharge of the river.

In finding the maximum degradation which would occur in the Nile, Fathy used two main equations:

- the tractive shear stress equation

$$\tau = \gamma \, Y \, i$$

where: τ = the shear stress; Y = mean water depth, i = water slope; and, γ = specific weight of water; and

- the stable channel formula:

$$Q = K B i^{a} Y^{b}$$

where Q = discharge; and, K, a, and b, are constants.

In estimating the maximum degradation, Fathy made many complex assumptions, such as the maximum discharge and average river channel widths. Then he stated that the degradation would extend about 56 m below the Aswan and each following barrage. Fathy arrived at these results by using his own experience about the different parameters he considered.

In answering the second question concerning the rate of degradation, Fathy mentioned in his paper that the rate of degradation depended on three factors:

- the silt-carrying power of the channel at different gradients;
- the mean future discharges; and,
- the manner in which the discharges fluctuate about their mean values.

He used the following formula:

$$G = A(i - i_c)$$

where G is the silt discharge, A is a constant; and, i_c is the critical slope, for estimating rate of flow reduction.

By making certain assumptions of the value A, Fathy derived a timetable for the degradation process. He concluded that the process would stop after 86 years, that is, by the year 2058.

In his paper "River-Bed Degradation below large Capacity Dam", M. G. Mostafa tried the same method as Fathy to estimate the degradation, but used a different formula for a stable channel:

$$1 - V\sqrt{g^{R}} = \left[2.3 \log[12.27(R/K_s)]\right]/10/\sqrt{(R/K_s)}$$

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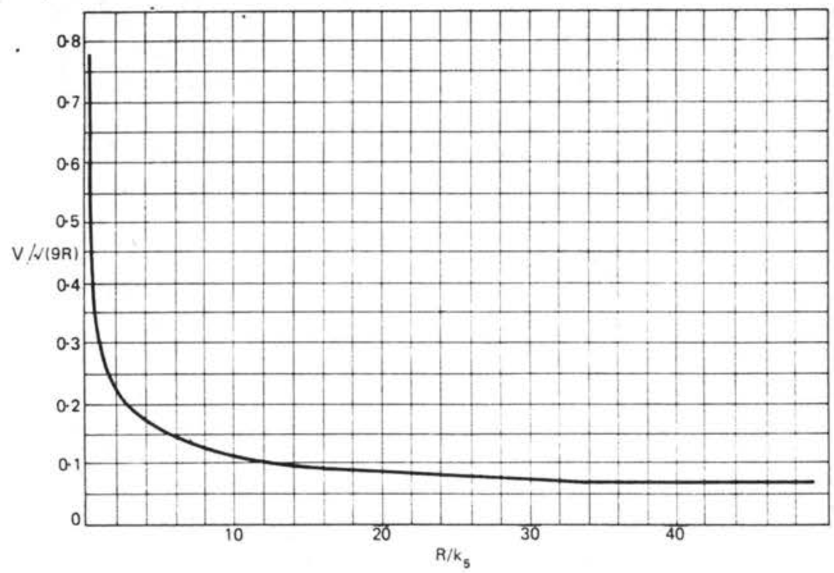

Fig. 1. Curve from Mostafa's formula to estimate degradation on the Nile.

where: V = mean average velocity; R = hydraulic radius; K_s = mean diameter at 75 per cent fines for the bed materials; and, g = gravitational acceleration.

He used this to develop a curve (see Fig. 1) suitable for the river Nile.

He then applied a tractive stress formula to this procedure, to find out the maximum magnitude of degradation and its timetable.

Mostafa took for granted maximum degradation and assumed the following points:

- all the sediment load would be deposited in the reservoir and the flow which passed downstream of the dam would be clear;
- the flow in the river channel after completion of the degradation process would be uniform;
- the effect of meanders and change in the cross-section were not considered;
- there was no limit for the water surface slope except that which corresponded to the critical tractive shear stress;
- the High dam reservoir would reach its full capacity two years after its construction;
- the released discharge would be 350×10^6 m^3/day; and,
- the ripples and dunes would be diminished.

Also, Mostafa assumed that Lu's equation:

$$v = C_a R^x S^x$$

Table I—Rate and ultimate magnitude of degradation of the structures downstream of Aswan

Year	Aswan dam		Esna barrage		Naga-Hammadi barrage		Asiut barrage	
	D* (m)	WL* (m)	D (m)	WL (m)	D (m)	WL (m)	D (m)	WL (m)
1966	22.00	1.20						
1967	3.50	2.20						
1968	6.00	4.00						
1972	6.50	4.50	1.00	0.75				
1974	7.00	5.60	2.50	2.00				
1976	7.50	6.00	5.00	4.50				
1978	7.80	6.80	7.00	5.80	1.00	0.75		
1981	8.40	8.30	8.00	6.50	1.50	1.00		
1986	8.50	8.50	8.50	7.50	3.00	2.10		
1991			9.00	9.00	4.00	4.00	0.50	0.25
1996					6.00	5.70	1.00	0.75
2006					7.00	7.00	4.00	2.50
2016							5.50	3.50
2026							6.00	4.50
2036							6.50	6.50

*D = degradation WL = drop in water levels

was applicable for the river Nile with the same constants found by Lu.

Using all these assumptions together with the data of the Nile, Mostafa drew up a table for the maximum degradation, its rate of progress, and the time required for equilibrium.

From Table I one can see that the ultimate drop in surface water equals the ultimate bed degradation. Mostafa also mentioned in his paper that 40 per cent of the ultimate magnitude of degradation and drop in water levels would occur during the first two years after diversion of the river Nile upstream of the cofferdam of the Aswan High dam.

In a report submitted in 1960 to the Egyptian ministry of Irrigation by the Swedish Consultants VBB, it was noted that the maximum magnitude of degradation below the Aswan dam and the other barrages was in the order of 3-4 m. VBB did not mention the method used to establish the magnitude of degradation up to the point where it gained its equilibrium condition (see Fig. 2) at Esna Barrage; also the report did not mention the rate of degradation or the ultimate period of time it took.

In 1965 the author published a paper entitled "A study on Degradation on Nile Bed after Ṣaad El-Aali". In this article it was stated that most of the suspended load would be deposited in the reservoir. The fairly clear released flow, downstream of the dam, would carry some load from the river bed and from its banks until it regained its equilibrium condition. The paper contained a sediment concentration formula for the river Nile which was based on actual sediment observation in the river.

This formula is:

$$C = 0.375\,(Q-20)^{1.15}$$

where: C denotes sediment concentration (p.p.m) and, Q = flow discharge ($\times 10^6$ m^3/day).

The author estimated that the annual rate of river bed degradation would be a few centimetres per year downstream of each hydraulic structure, but he did not estimate the ultimate magnitude of degradation at the time this was expected to occur.

He also stated that the silt concentration generally increased gradually along the passage of flow from Aswan to the Delta barrage.

Simons presented a report to the MOI in Egypt in 1965 entitled "Evaluation of degradation and related hydraulic problems downstream of Aswan dam". During research work on rivers with similar boundary conditions to that of

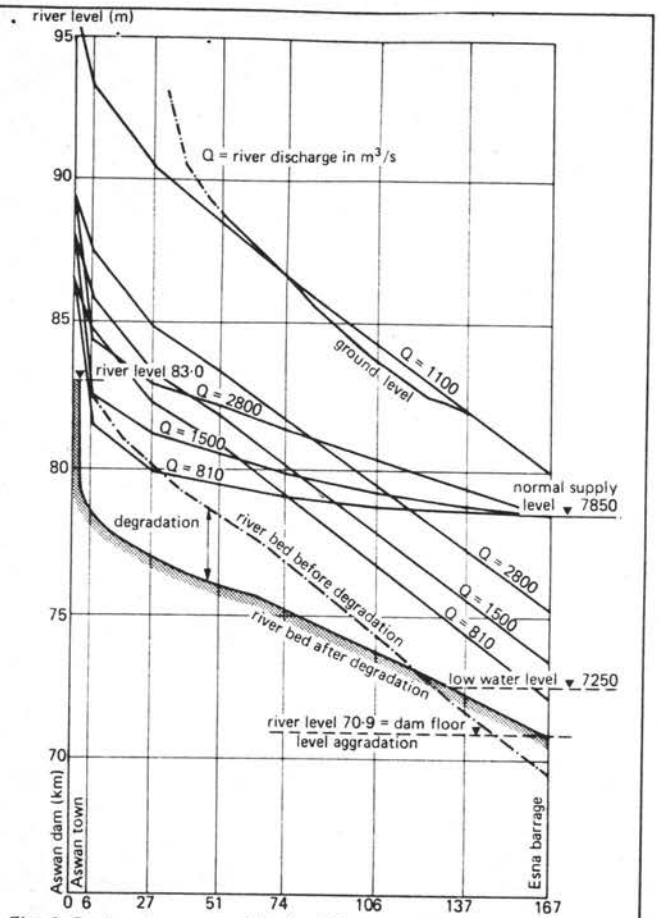

Fig. 2. Backwater curves for the Nile upstream of Esna barrage after degradation.

the Nile, he had found a formula for calculating the slope of surface water for stable channels. This is:

$$S \times 10^3 = 2.09\, d^{0.48}/Q^{0.21} \text{ (foot system)}$$

where: S = slope of energy gradient; d = mean diameter of bed material; and, Q = design discharge.

Using this formula, Simons gave the stable slope to the river, using a discharge of 250×10^6 m³/day and a mean diameter of bed material of 0.25 mm, of the order of 5.8 cm/km. He then estimated that the maximum extent of degradation would be 3.5 m downstream of Esna.

In addition, Simons carried out experimental studies at Colorado State University, USA, in 1961 on sand similar to the sand which forms the bed of the Nile, which has a diameter of 0.28 mm. This study showed that the sand started to move when the boundary shear was about 0.04 lb/ft². From this study Simons evaluated the corresponding stable slope to equal 3.8 cm/km, but he added in his report that this slope was small.

Ismail and co-authors, in their study of degradation based on experiments at the Hydraulic Research and Experiment Station of the Delta barrage in Egypt, estimated the reduction in the surface water slope of the Nile. Using their study as a kind of a model for the Nile, it can be seen that the degradation experiments which ran for 600 h reduced the initial channel slope by 40 per cent, but Ismail gave no value for the magnitude of degradation, its rate or the time it took.

A report on the study of degradation published in 1970 by V/O Technopromexport, Hydroproject, Moscow, USSR, was presented to the MOI in Egypt. This report is entitled "Comprehensive scheme utilization and designing three low head dams". It gives an estimate for the drop in water levels and the maxima below the hydraulic structures up to the year 2015. These are shown in Table II.

Table II—Discharge and fall in level from 9 km to 550 km downstream of Aswan

Rated discharge ($\times 10^6$ m³/day)	Lowering of water levels compared with 1964 levels (m)				Maximum water lowering (m)
	1970	1975	1985	2015	
225	0.4	0.7	1.3	2.3	2.5
80	0.5	0.8	1.5	2.6	3.0
225	0.4	0.6	1.1	2.1	2.5
80	0.5	0.9	1.3	2.5	3.0
225	0.3	0.5	0.9	1.7	2.5
80	0.4	0.6	1.1	2.1	3.0
225	0.2	0.4	0.4	0.3	1.0
80	0.3	0.5	0.6	0.5	1.5
207	0.4	0.8	1.1	2.5	3.0
80	0.5	1.0	1.3	2.8	3.5
207	0.3	0.4	0.8	1.9	2.6
80	0.5	0.7	1.1	2.3	3.0
177	0.4	0.9	1.3	2.6	3.0
80	0.5	1.1	1.5	2.8	3.5
177	0.3	0.6	0.9	1.9	2.5
80	0.4	0.8	1.1	2.3	3.0
148	0.3	0.8	1.2	2.2	2.5
80	0.5	1.1	1.4	2.5	3.0

Hydroproject calculated the drop in water levels downstream of the structure by plotting the corresponding water levels to fixed discharges of 225 and 80×10^6 m³/day between 1964 and 1969, and extrapolating the line on semi-logarithmic paper, (Fig. 3 to 6), to 2015.

In 1974 a paper entitled "Facts about degradation and its related problems downstream of Aswan dam" was published by the author in four parts. This paper reviewed the actual degradation in the river bed and the drop in water levels which occurred downstream of the existing hydraulic structures during the period 1963 to 1973. He used three methods based on the actual hydrological observations as follows:

- sediment discharge measurements of the released flow downstream of the existing structures and the upstream of backwater curve of the Delta barrage;

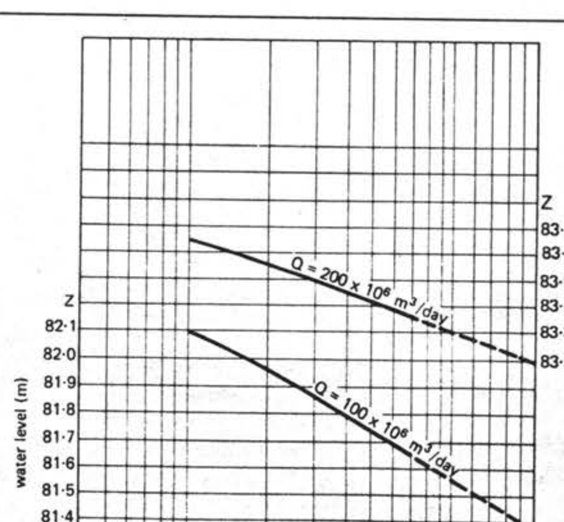

Fig. 3. Curve of water levels to show fluctuation downstream of Aswan for different years.

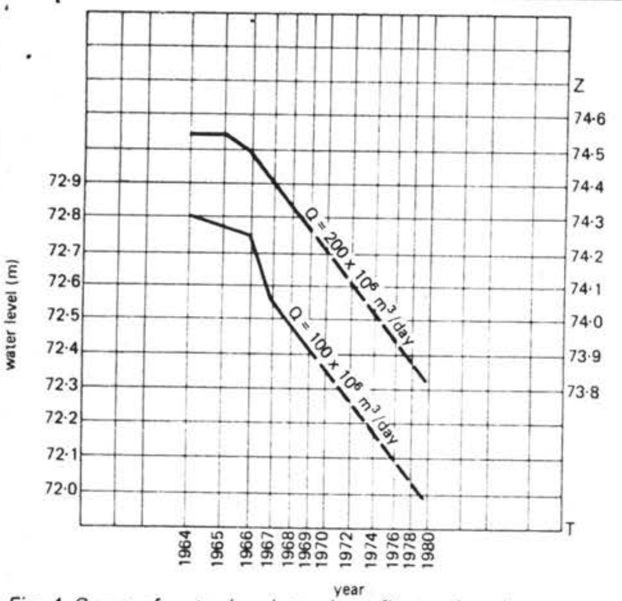

Fig. 4. Curve of water levels to show fluctuation downstream of Esna barrage for different years.

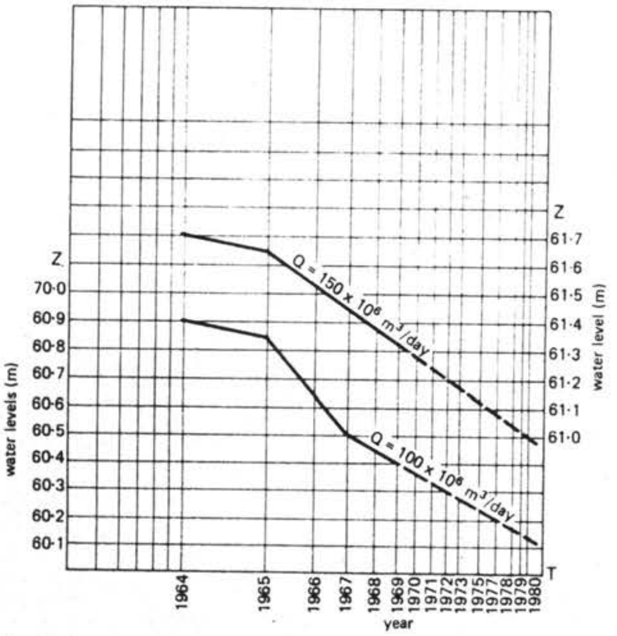

Fig. 5. Curve of water levels to show fluctuation downstream of N. Hammadi barrage for different years.

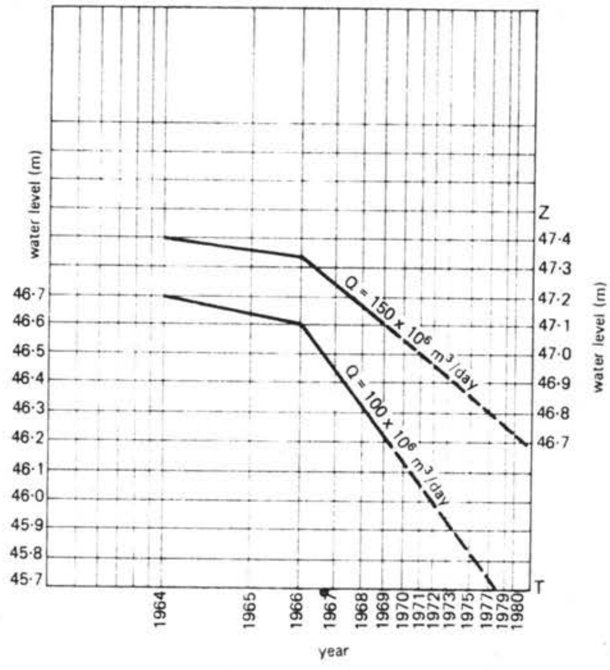

Fig. 6. Curve of water levels to show fluctuation downstream of Asiut barrage for different years.

- variation of the slope of surface water downstream of each structure up to the beginning of the backwater curve of the next structure; and,
- annual observation of the change in water levels directly downstream of every structure, relating this to different discharges.

The author used the recorded data from 1964 to 1973 with the year 1963 as a comparison datum year. Results of these actual observations are summarized in Table III.

In Part Four of his paper, the author used Simons' stable channel formula and estimated the ultimate magnitude of degradation and the period required for degradation to reach its final stage. The results are:

- downstream of Aswan dam the maximum drop in levels and the bed would be 1 m, and 1.37 m for discharges of 250 and 350×10^6 m^3/day respectively;
- downstream of Esna barrage, the maximum degradations were 0.9 m, and 1.08 m, for the same discharge.
- downstream of the Naga Hammadi barrage, the maximum estimated figures were 1.01 m and 1.37 m for both discharges; and,
- downstream of the Asiut barrage, the maximum estimated figures were 1.7 m and 2.9 m for both discharges.

Table III—Maximum drop in water levels calculated by various methods

Downstream of:	Suspended solids method	Gauge height discharge method	Surface water slope method	Maximum drop in water level (cm)
Aswan dam	12	21	22	58
Esna barrage	26	29	41	76
Naga-Hammadi	25	23	24	57
Asiut barrage	8	3	27	50

The author also estimated that the period needed for the river to reach its equilibrium would be 50 years downstream of Aswan to 200 years downstream of Asiut.

In 1975 a comprehensive study was submitted to the MOI, Egypt, by Hydroproject about estimating degradation downstream of existing barrages. This report gave an estimation for river bed degradation and related drop in water levels. The results are shown in Table IV.

Hydroproject used formulae based on its observations and experiences with similar rivers.

In 1979 Chow and co-authors designed a mathematical model based on a combination of actual field measurements and selected sediment formulae to estimate the

Table IV—Decrease in water level and bed elevation in time

Site	Adopted decrease in water level (m)	Adopted decrease of mean river bed elevations (m)	Period of time (months)
km 10, downstream of Aswan dam	3.0	2.5	
Gafra (35 km downstream of Low Aswan)	2.5	3.5	120
Downstream of Esna barrage	3.5	4.5	300
Downstream of Naga-Hammadi barrage	4.0	4.0	480
Downstream of Asuit Barrage	8.0	11.0	700

Table V—Details of structures in Fig. 7				
Name of structure	Location from Low Aswan (km)	Foundation	Date of construction	
High Aswan	6.5	Sandy	1969	100 m
Low Aswan	0	Rock	1902	40 m
Esna barrage	167	Sandy	1908	5
N. Hammadi barrage	360	Sandy	1908	5
Asiut barrage	545	Sandy	1902	5
Delta barrage	954	Sandy	1936	3.5 m

maximum degradation of the river bed which would occur in the future, but there were no definite results. By using this mathematical model to establish the magnitude of degradation downstream of Esna barrage over 50 years, it showed a result of 90 cm more in addition to the amount of degradation which had occurred up until the year 1981.

In 1982 the Hydraulics Research Station (HRS), Wallingford, UK, published a report about the Esna barrage under the title "Degradation of the river Nile—A preliminary assessment of flow conditions downstream of Esna barrage". In it HRS stated that the ultimate degradation downstream of the Esna barrage would not exceed 20 cm; this was more than the amount that had been reached in 1981, and the estimation assumed a discharge rate of 605×10^6 m^3/day.

HRS used a mathematical model which was fed by actual field data collected until the end of 1981 and various sediment formulae.

Research work

Background. The reach of the river under investigation starts from downstream of the low Aswan dam and ends upstream of the Delta barrage. The length of this reach is 953 km.

There are five main control structures. The locations of these structures together with dates of construction are summarized in Table V (see also Fig. 7).

The low Aswan dam has been reinforced twice since its initial completion, and Esna and N. Hammadi and Asiut have been reinforced once. The reinforcements were done to increase the heads for irrigation purposes.

All these structures were built to a hydraulic design which did not affect the hydrological regime of the river before the construction of the High Aswan dam.

The river bed and its banks are formed of fine alluvial soil which is a mixture of fine sand, silt and clay in varying ratios, but mainly fine sand.

The sinuosity of the river channel from Aswan to the Delta barrage varies between 1.01 and 1.30, and its waterway generally has a normal gradient.

Part of the river forms just one channel, while in other places it divided into two, with oval-shaped islands in the middle. More details are available in documents on the characteristics and the hydrological regime in the Nile Basin and MOI documents.

For hydrological data collection, five gauging stations have been constructed upstream of the Delta barrage.

Details of these stations are as follows:

Aswan: 7 km downstream of the Low Aswan dam,

El-Hanadi: 12 km downstream of Esna barrage,

El-Samata: 24 km downstream of Naga Hammadi barrage,

Sallam: 10 km downstream of the Asiut barrage (see Fig. 4),

El-Ekhsas: 68 km upstream of the Delta barrage.

Main hydrological parameters which were recorded are summarized as follows:

- suspended load measurements;
- water level records;
- discharge measurements, and,
- hydrographic survey.

Records of data collection started before construction of High Aswan and have continued systematically by the same method until now. 1963 was selected as the comparison datum year.

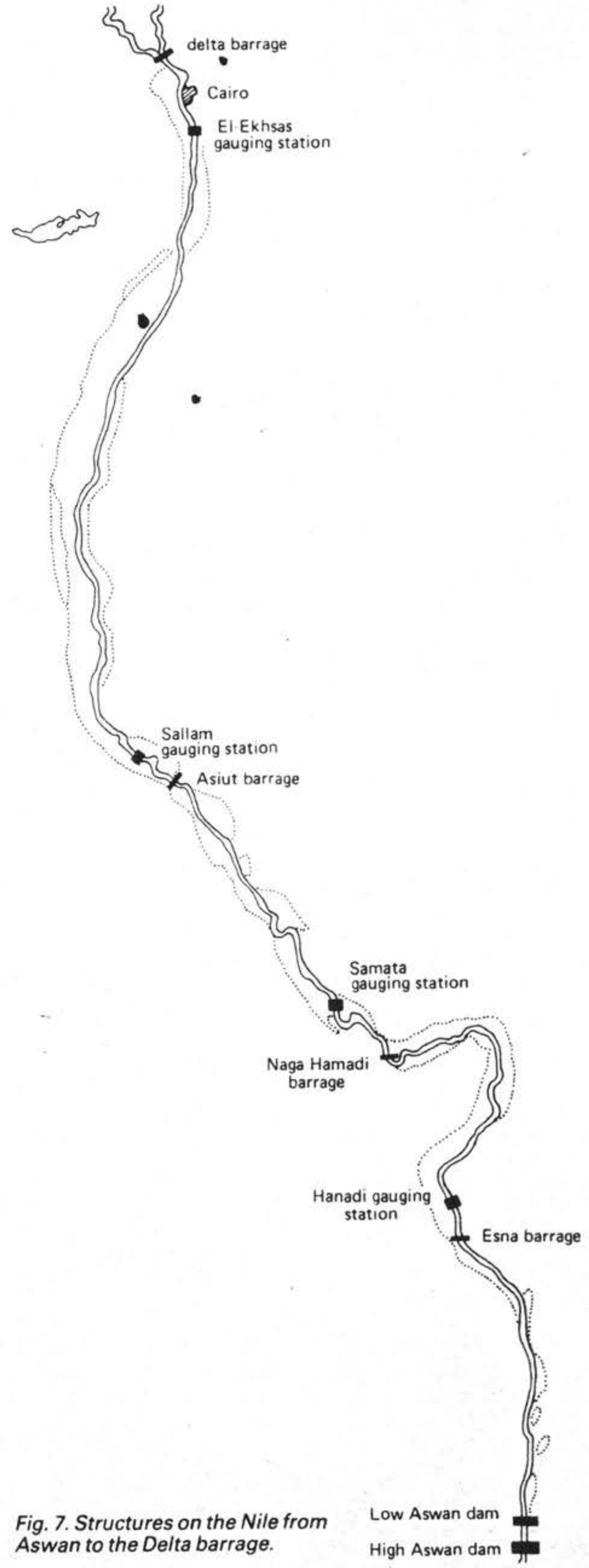

Fig. 7. Structures on the Nile from Aswan to the Delta barrage.

Field results. All the data which were collected from field observations and their analysis can be summarized as follows.

Results of suspended load measurements. Table VI

Table VI—Total suspended load passing structures ($\times 10^6$ t)

Year	Low Aswan	Esna	N. Hammadi	Asiut	Delta barrage
1964	26.27	29.42	36.43	38.67	51.76
65	5.68	6.71	7.33	13.83	10.46
66	3.78	4.02	4.72	6.25	9.04
67	3.14	4.09	6.62	9.00	14.43
68	2.30	2.58	2.60	2.69	3.22
69	1.91	2.30	2.69	3.23	3.15
1970	2.67	2.97	3.47	3.88	4.44
71	2.46	2.66	3.16	3.56	4.50
72	2.71	3.01	3.51	3.91	4.40
73	2.78	3.20	3.65	4.20	5.06
74	2.83	3.20	3.65	4.20	5.08
75	1.82	2.20	2.70	3.30	5.93
76	1.61	1.95	2.45	3.05	3.90
77	1.61	1.95	2.45	3.10	4.02
78	2.20	2.70	3.20	3.20	4.70
79	2.10	2.50	2.90	3.30	4.11
1980	1.79	2.10	2.40	2.70	3.32
81	1.56	1.90	2.20	2.50	3.10
82	1.92	2.10	2.25	2.40	2.60
Total	71.14	81.56	98.38	116.97	147.22

shows the total weight of the suspended load, which was measured downstream of each hydraulic structure at gauging stations during the period 1964-1982. Table VI shows the amount of suspended solids which were discharged with the released flow downstream of High Aswan, and it also shows the increase in the suspended sediment load along the reach between Low Aswan and the Delta barrage, which was lifted from the river bed, and its banks.

The maximum degradation downstream of each hydraulic structure was calculated on the basis of the following data:

- the affected reaches of the river by degradation are the reaches extending from downstream of each barrage and the beginning of the backwater curve of the next structure.
- the lengths of these affected reaches and data of other parameters which are as follows:

Downstream of Low Aswan—Esna barrage
—Length of affected reach = 85 km
—Average width of river reach = 611 m
Downstream of Esna—Naga Hammadi barrage
—Length of affected reach = 103 km
—Average width of the river reach = 574 m
Downstream of Naga Hammadi—Asiut barrage
—Length of affected reach = 90 km
—Average width of the river reach = 567 m
Downstream of Asiut—Delta barrage
—Length of affected reach = 340 km
—Average width of river reach = 577 m

- The specific weight of the river bed material was found, after experiments, to equal 1.55 t/m^3.

As the degradation boundary takes the shape of a wedge, in general, the maximum magnitude downstream of the structure would be double the average magnitude of degradation. The maximum degradation downstream of the various structures is as follows: Low Aswan = 25.9 cm; Esna barrage = 38.5 cm; N. Hammadi barrage = 40 cm; and, Asiut barrage = 70 cm.

This magnitude of degradation occurred during the period 1964-1982.

Results of the change in water levels. The rate of change in water levels along the river was observed during the period 1960-1982, with special attention to the drop in levels downstream of the barrages. An actual relationship between the discharge and gauge levels curves on an annual basis was established as a result of measurements in field at the gauging stations. The period 1960-1963 represents the condition of the river before the construc-

Table VII—Water levels (m) downstream of Aswan dam which correspond to certain discharges

Year	Discharges ($\times 10^6$ m^3/day)						
	80	90	100	120	150	200	250
1960	82.96	83.16	83.35	83.73	84.27	85.12	85.91
61	82.91	83.10	83.27	83.63	84.17	84.99	85.70
62	82.77	82.99	83.20	83.60	84.12	84.92	85.62
63	82.78	82.99	83.18	83.57	84.12	84.90	85.59
1964	82.78	82.98	83.14	83.50	84.01	84.79	85.48
65	82.78	82.96	83.13	83.47	83.95	84.78	85.50
66	82.59	82.78	82.95	83.30	83.79	84.56	85.28
67	82.48	82.66	82.85	83.23	83.77	84.63	85.42
68	82.43	82.63	82.83	83.21	83.76	84.61	85.39
69	82.39	82.58	82.77	83.14	83.70	84.57	85.39
70	82.24	82.46	82.67	83.08	83.67	84.53	85.26
71		82.53	82.73	83.11	83.66	84.52	85.26
72		82.45	82.68	83.10	83.68	84.53	85.28
73	82.24	82.46	82.68	83.10	83.69	84.55	85.28
74		82.38	82.61	83.04	83.66	84.54	85.26
75		82.41	82.65	83.09	83.68	84.56	85.30
76		82.44	82.65	83.12	83.74	84.60	85.36
77		82.44	82.68	83.14	83.75	84.64	85.39
78		92.50	82.71	83.12	83.74	84.63	85.40
79		82.52	82.74	83.15	83.79	84.65	85.42
1980		82.52	82.71	83.10	83.63	84.60	85.38
81				83.05	83.68	84.60	85.24
82				83.05	84.74	84.65	85.37

Table VIII—Water levels (m) downstream of Esna barrage which correspond to certain discharges

Year	Discharges ($\times 10^6$ m^3/day)									
	80	90	100	120	150	200	250	300	400	500
1962	72.90	73.12	73.31	73.84	74.17	74.90	75.55	76.13	77.16	78.05
63	72.66	72.88	73.08	73.45	74.00	74.76	75.43	76.02	77.03	77.89
64	72.25	72.50	72.75	73.20	73.855	74.833	75.75	76.55	78.00	79.20
65		72.70	72.93	73.31	73.85	74.74	75.53	76.25	77.52	
66		72.50	72.73	73.16	73.75	74.70	75.55			
67	72.05	72.27	72.48	72.88	73.47	74.35	75.15	75.85	77.05	
68	72.07	72.30	72.49	72.88	73.44	74.32				
69	72.00	72.20	72.40	72.80	73.36	74.21				
1970	72.00	72.22	72.43	72.83	73.40	74.24				
71		72.00	72.30	72.82	73.46	74.22				
72	71.90	72.10	72.32	72.77	73.33	74.24				
73		72.12	72.30	72.66	73.20	74.11				
74										
75										
76				72.79	73.39	74.38				
77		72.21	72.39	72.75	73.34	74.29				
78		72.21	72.39	72.75	73.34	74.29				
79		72.18	72.39	72.80	73.38	74.29				
1980		72.19	72.40	72.79	73.34	74.28				
81			72.40	72.78	73.34	74.26				
82			72.40	72.79	73.37	74.34	75.31			

Table IX—Water levels (m) downstream of Naga-Hammadi which correspond to certain discharges

Year	Discharges ($\times 10^6$ m^3/day)									
	80	90	100	120	150	200	250	300	400	500
1960	60.26	60.51	60.74	61.06	61.42	62.05	62.05	63.19	64.18	65.50
61	60.15	60.40	60.46	61.04	61.60	62.40	63.07	63.67	64.71	65.59
62	60.24	60.52	60.77	61.22	61.78	62.55	63.08	63.54	64.55	65.59
63	60.44	60.70	60.92	61.28	61.76	62.42	63.03	63.56	64.48	65.24
64		60.60	60.81	61.20	61.70	62.44	63.03	63.51	64.41	65.22
65	60.38	60.59	60.79	61.16	61.67	62.41	63.02	63.35	64.47	
66	60.30	60.53	60.75	61.16	61.68	62.41	63.03	63.56		
67	59.95	60.20	60.45	60.90	61.49	62.26	62.30	63.43	64.28	65.05
68	60.00	60.23	60.46	60.88	61.46	62.24				
69	59.87	60.15	60.39	60.80	61.45					
1970	59.95	60.20	60.43	60.86	61.45					
71	60.00	60.19	60.37	60.76	61.43					
72	59.87	60.13	60.37	60.81	61.40					
73	59.86	60.08	60.29	60.72	61.32					
74	59.84	60.05	60.26	60.65	61.25					
75	59.84	60.07	60.25	60.65	61.25					
76		59.99	60.24	60.74	61.32					
77		59.99	60.24	60.74	61.32					
78		59.99	60.24	60.72	61.20					
79		59.95	60.17	60.58	61.16	62.02				
1980		59.95	60.16	60.54	61.11	62.01				
81		59.83	60.03	60.44	61.05	62.02				
82		59.74	59.97	60.42	61.05	62.02				

Table X—Water levels (m) downstream of Asiut barrage which correspond to certain discharges

Year	Discharges ($\times 10^6$ m^3/day)									
	80	90	100	120	150	200	250	300	400	500
1960	46.38	46.57	46.73	47.07	47.54	48.20	48.78	48.38	50.18	50.90
61	46.20	46.38	46.55	66.88	47.34	48.05	48.66	49.23	50.19	51.00
62	46.24	46.44	46.62	46.97	47.42	48.13	48.75	49.32	50.31	51.16
63	46.23	46.43	46.63	46.98	47.44	48.14	48.70	49.19	50.36	50.84
64	46.21	46.44	46.61	46.99	47.49	48.22	48.83	49.40	50.32	51.09
65	46.38	46.56	46.74	47.05	47.49	48.12	48.71	49.22		
66	46.38	46.56	46.73	47.05	47.48	48.13	48.70			
67	46.17	46.37	46.56	47.91	47.41	48.15	48.77	49.33		
68	45.91	46.12	46.32	46.64	47.11					
69	45.78	45.98	46.09	46.48	47.17					
1970	45.80	46.04	46.26	46.64	47.14					
71	45.73	45.96	46.20	46.59	47.12					
72	45.73	45.96	46.20	46.59	47.12					
73	45.62	45.88	46.12	46.57	47.17					
74	45.67	45.87	46.08	46.52	47.17					
75	45.67	45.87	46.08	46.50	47.12					
76	45.64	45.89	46.11	46.52	47.07					
77	45.61	45.85	46.08	46.49	47.05					
78				46.52	47.05					
79										
1980	45.77	45.95	46.13	46.48	46.98					
81	45.50	45.75	46.00	46.44	47.00					
82	45.50	45.76	46.00	46.44	47.00					

Table XI—Water levels (m) upstream of Delta barrage which correspond to certain discharges

Year	Discharges ($\times 10^6$ m^3/day)									
	80	90	100	120	150	200	250	300	400	500
1964	17.84	18.02	18.17	18.19	18.92	19.63	20.30	20.88	21.98	22.80
67	18.19	18.36	18.55	18.98	19.39	20.18	20.91	21.60		
68	18.00	18.18	18.34	18.61	19.13					
69	17.91	18.14	18.35	18.73	19.22					
1970	18.02	18.24	18.45	18.48	19.32					
71	18.43	18.59	18.78	19.19						
72	17.97	18.24	18.48	18.96	19.72					
73	18.12	18.30	18.49	18.87	19.43					
74	17.98	18.25	18.49	18.92						
75	18.03	18.25	18.46	18.84	19.42					
76	18.07	18.33	18.56	18.96	19.47					
77	18.12	18.37	18.60	18.99	19.49					
78			18.60	19.04	19.65					
79		18.32	18.57	19.01	19.56					
1980		18.56	18.83	19.21	19.67					
81		18.47	18.71	19.14	19.67					
82	10.20	18.47	18.70	19.13	19.66					

tion of High Aswan, but for comparison, the year 1963 was selected to be the datum year. The period 1964-1982 shows the actual changes in water levels downstream of the hydraulic structures after construction of High Aswan. Water levels which corresponded to selected discharges varying between 80 and 250×10^6 m^3/day were considered, as these corresponded to existing conditions. The results are shown in Tables VII to XI.

As a general remark from field observations, the maximum drop in water levels varies according to the discharge rate, and the drops in water levels are higher at low discharges.

A summary of the conclusions of the field results are as follows:

- *downstream of Low Aswan.* The drop in water levels varies between 42 and 40 cm for discharges of 100×10^6 m^3/day and 250×10^6 m^3/day respectively. This is the total drop in water during the period 1964-1982.
- *downstream of Esna barrage.* The total drop in water level varies between 72 cm and 15 cm for discharge 100×10^6 m^3/day and 200×10^6 m^3/day. For discharges of 80×10^6 m^3/day the drop in water levels was 76 cm for discharges of 80×10^6 m^3/day during the same period.
- *downstream of Naga Hammadi barrage.* The total drop in water levels are between 65 cm and 99 cm for discharges of 200×10^6 m^3/day and 80×10^6 m^3/day during the same period.
- *downstream of Asiut barrage.* The total drop in water levels downstream of the Asiut barrage are recorded as 49 cm and 78 cm for discharges of 150×10^6 m^3/day and 80×10^6 m^3/day during the same period.

(To be concluded.)

Malaysia abandons Tembeling

By S. S. Rachagan
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After 12 years of uncertainty, environmentalists in Malaysia believe that they have convinced the Malaysian government of the need to abandon the proposed Tembeling hydroelectric project in Malaysia's largest national park, Taman Negara.

THE URGENT need for rapid growth in developing societies, and the appeal that large and dramatic projects have for their leaders, more than anything else, has set the stage for a confrontation between economic growth and sound environmental management: it is a confrontation that the environment has far too often lost. Indeed, the basic forces at work in the development in such societies appear to obey criteria incompatible with ecological health and renewal. Hence, when environmental considerations played a significant role in the Malaysian government's decision to abandon the Tembeling dam project, environmentalists had cause for cheer.

The proposed Tembeling hydro project

The proposal to build a dam in Taman Negara for the Tembeling hydroelectric project was first mooted in October 1971 when the National Electricity Board (NEB) recommended a multipurpose dam across the Sungai Tembeling. The river is an upper tributary of Peninsula Malaysia's longest river, the Sungai Pahang, in central Pahang (see Fig. 1). The proposal followed the catastrophic floods of January 1971, which claimed 24 lives and necessitated the evacuation of some 150 000 people from their homes in the Pahang river basin. Less severe but nonetheless major flooding occurred again towards the end of 1971. The need for flood mitigation and the hydroelectric power potential of the basin were the principal considerations for the proposed dam.

According to the NEB's 26th Annual Report[1], the Tembeling project would have consisted of a main dam, saddle dams and associated works, including an intake feeding through a power tunnel to a conventional surface power station (see Fig. 2). With a total installed capacity of 110 MW comprising four units of 27.5 MW each, the average annual output of energy, it was estimated, would be 441 GWh. A gated shaft spillway with a capacity of 4800 m^3/s was planned for regulated flood discharges.

The main dam would have been a rockfill structure with a height of 67 m, (see Fig. 3) and the six saddle dams would have been of earthfill construction. The total volume of fill in the dam would have been 2.5×10^6 m^3 and the reservoir formed by the dams would have spanned 53 km, having a surface area of 250 km^2. According to the NEB's 27th Annual Report[2], the height of the dam could have been raised by 6 m.

Further details of the proposed Tembeling dam, estimated to cost in excess of M$300 million, remain shrouded by an unwillingness of the proposers to discuss it in public. Apart from the brief descriptions in the annual reports, much of the information remains hidden in files marked "confidential", "restricted" and "secret".

Since the initial proposal by the NEB in October 1971, the project has been the subject of three studies. An Australian team was appointed in June 1972 to undertake

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