Nile River Flood Control: Egyptian Experiences

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Area:

1000,000 Km2

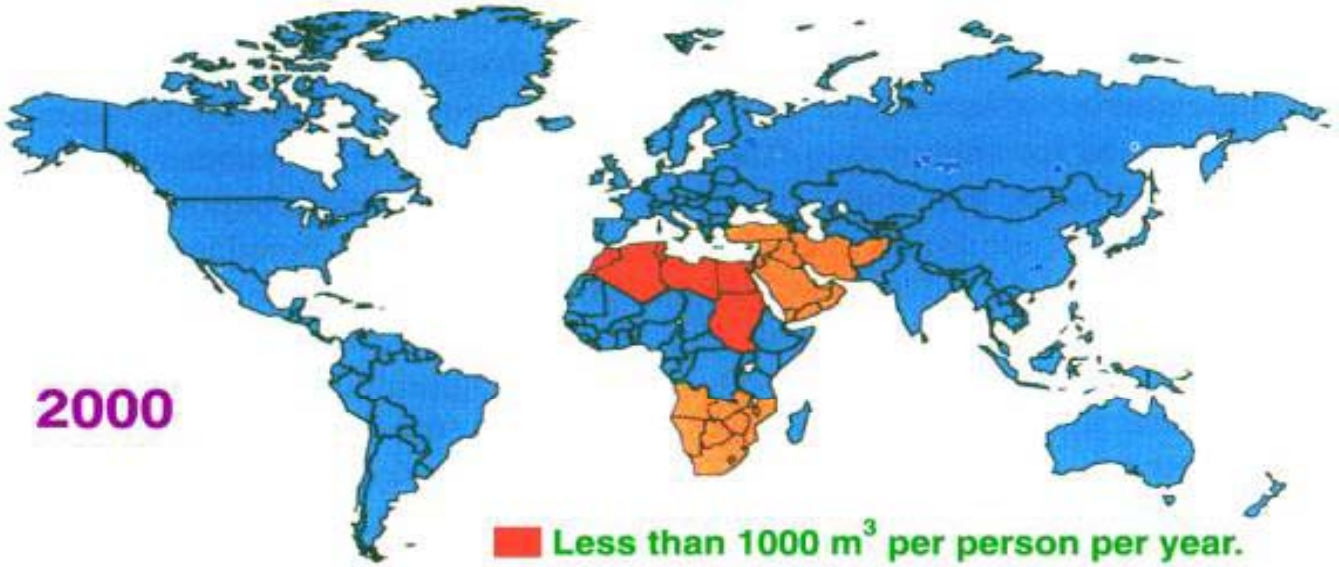
Population:

79 Million Capita

Total Cultivated Area:

8 Million Acres

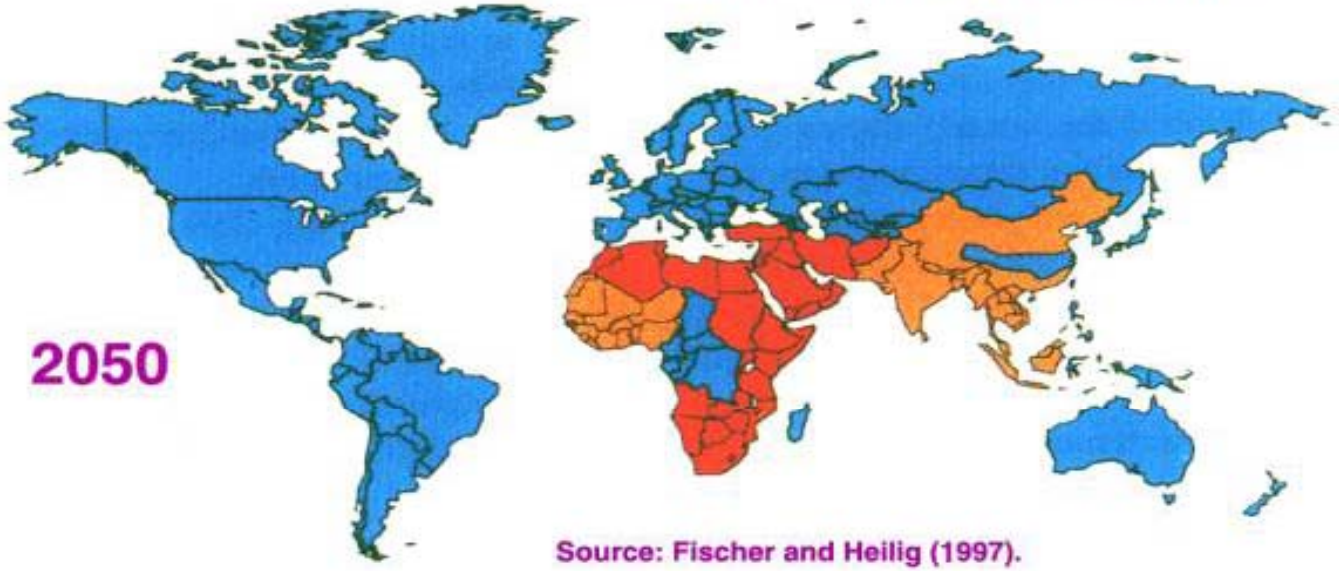
Global Water Scarcity



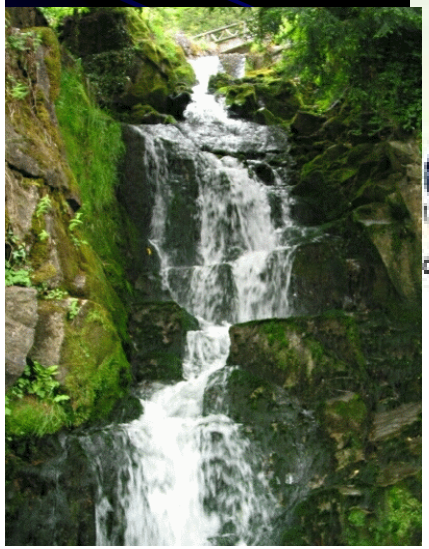
Less than 1000 m^3 per person per year.

Between 1000 and 2000 m^3 per person per year.

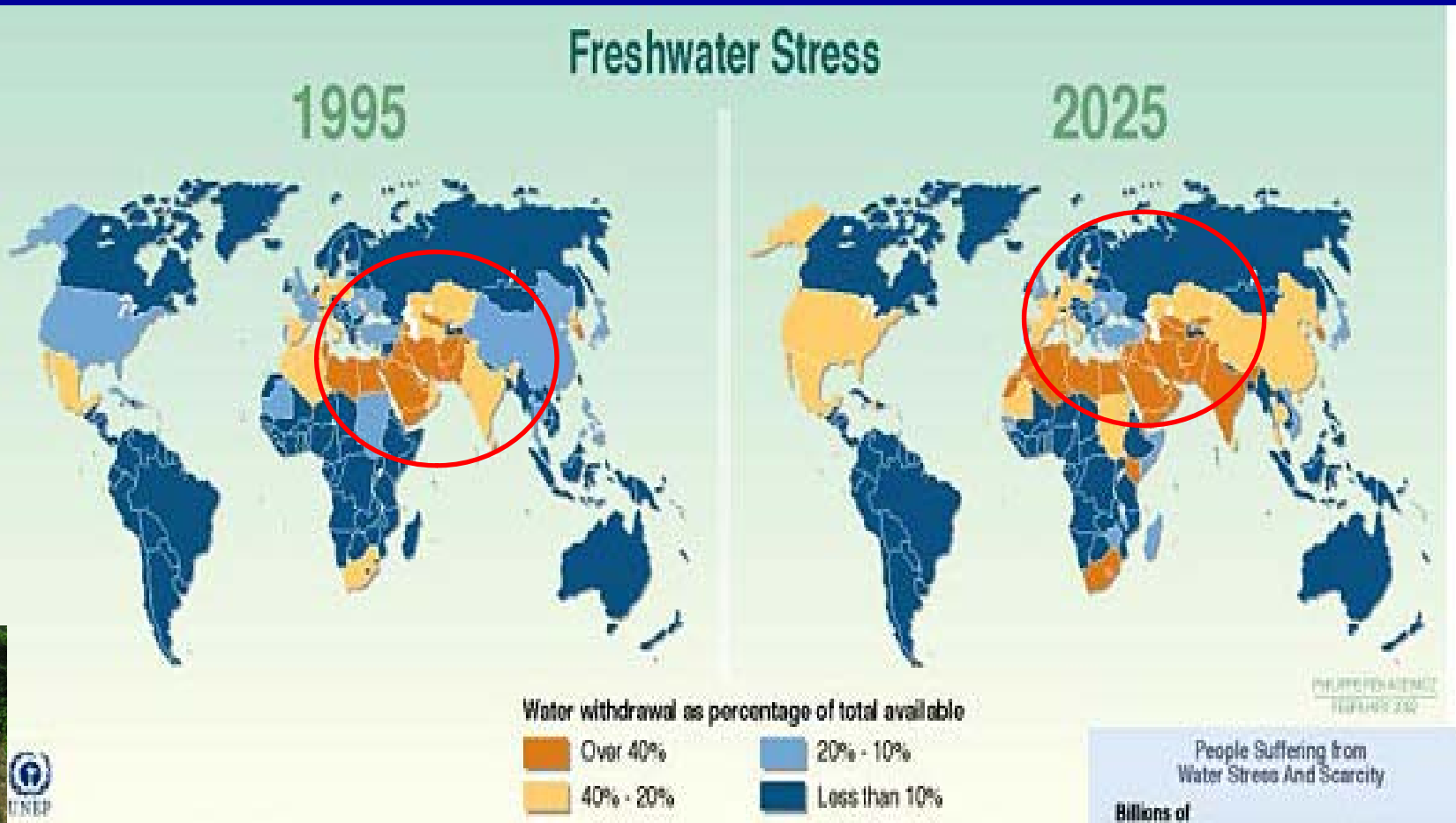
Greater than 2000 m^3 per person per year.



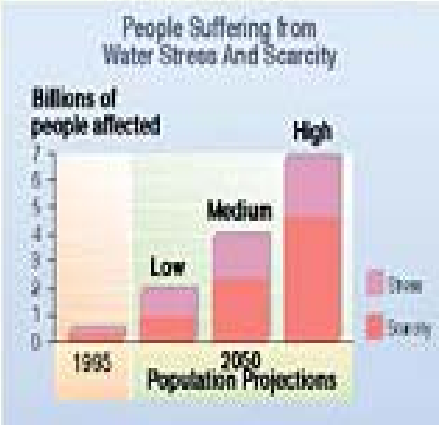
Source: Fischer and Heilig (1997).



Egypt water withdrawal more than 40% of the available fresh water



ource: World Meteorological Organisation (WMO), Geneva, 1996; Global Environment Outlook 2000 (GEO), UNEP; Earthscan, London, 1999.



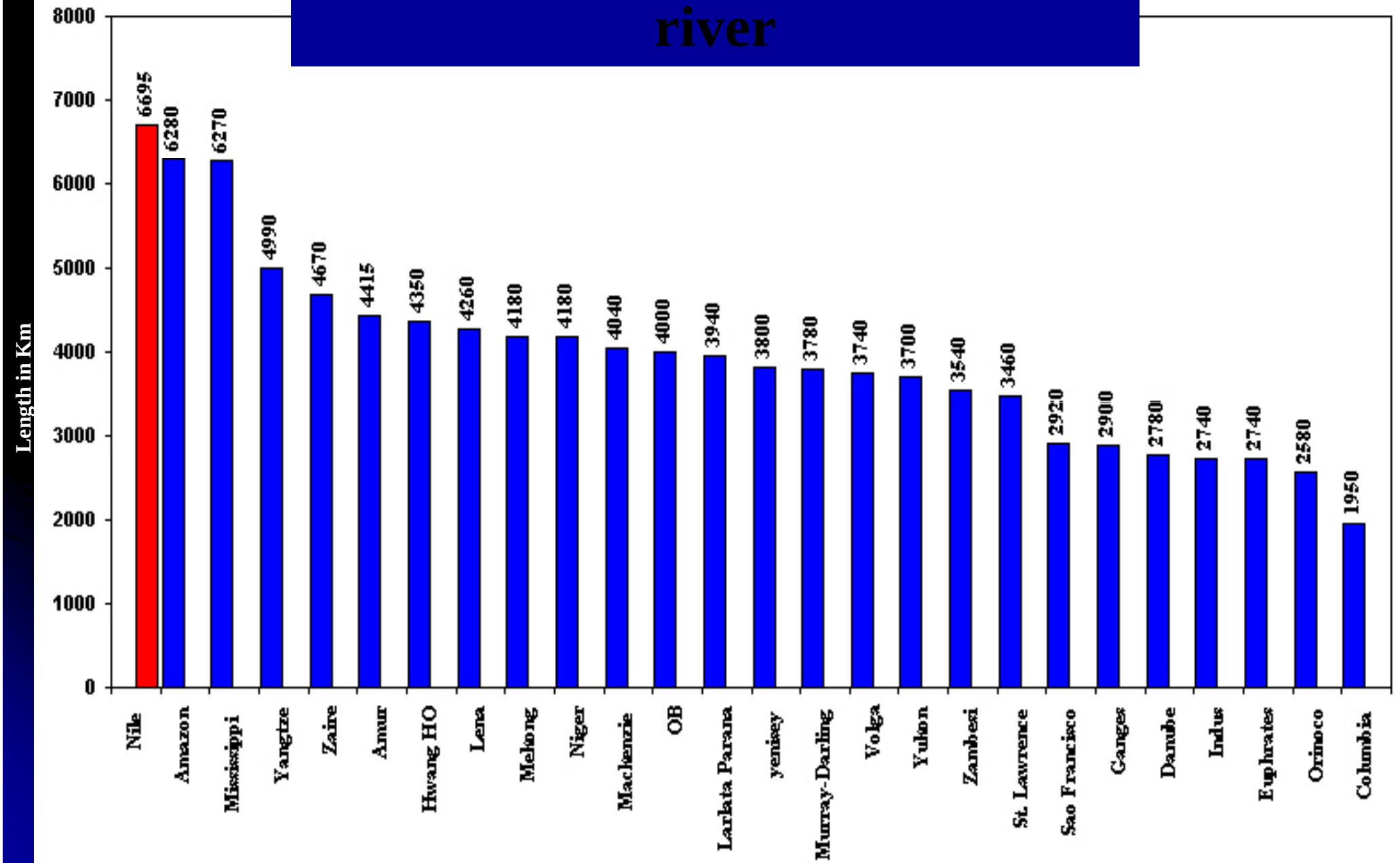
1. Introduction

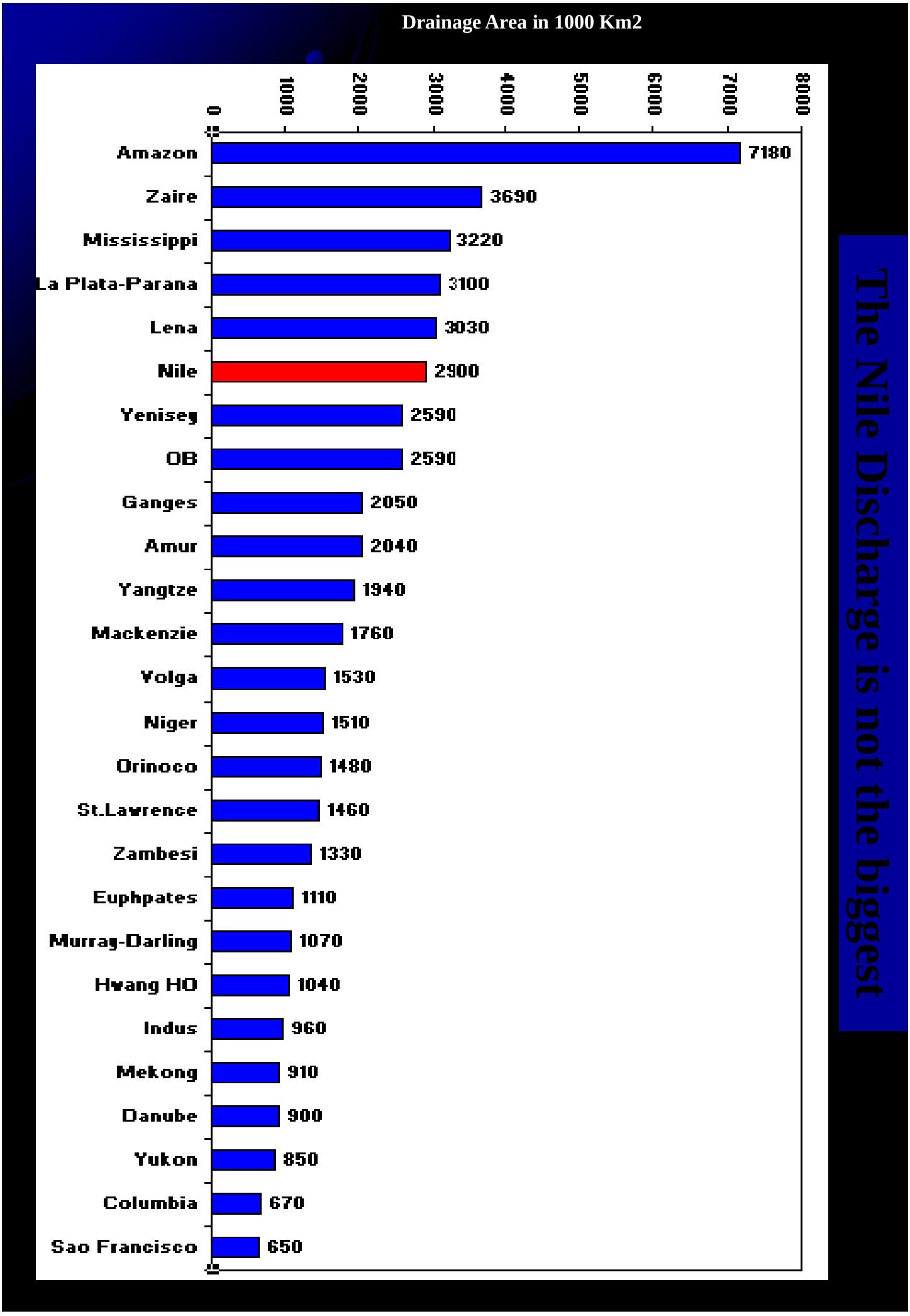
1.1 The Hydrological Features of The Nile River Before and After the High Aswan Dam

*The Nile is **the longest river in the world** and extends for approximately 6800 km.

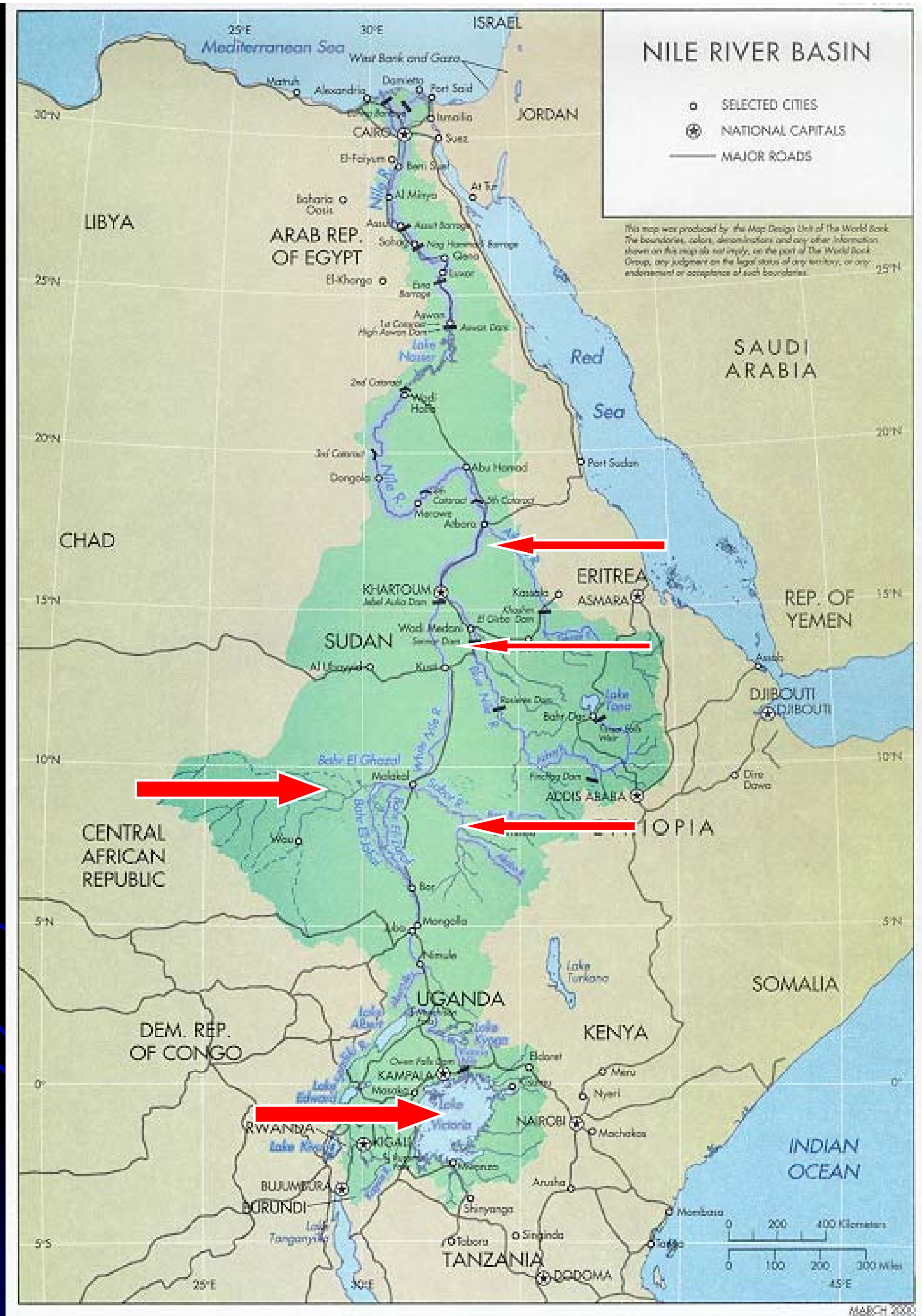
***The maximum discharge** for the Nile *before* the construction of the High Aswan Dam (HAD) was 14000 m^3/s which occurred in the year 1878/79,
*Meanwhile **the minimum discharge** was 274 m^3/s which occurred in the year 1913/14.

The River Nile is the longest river

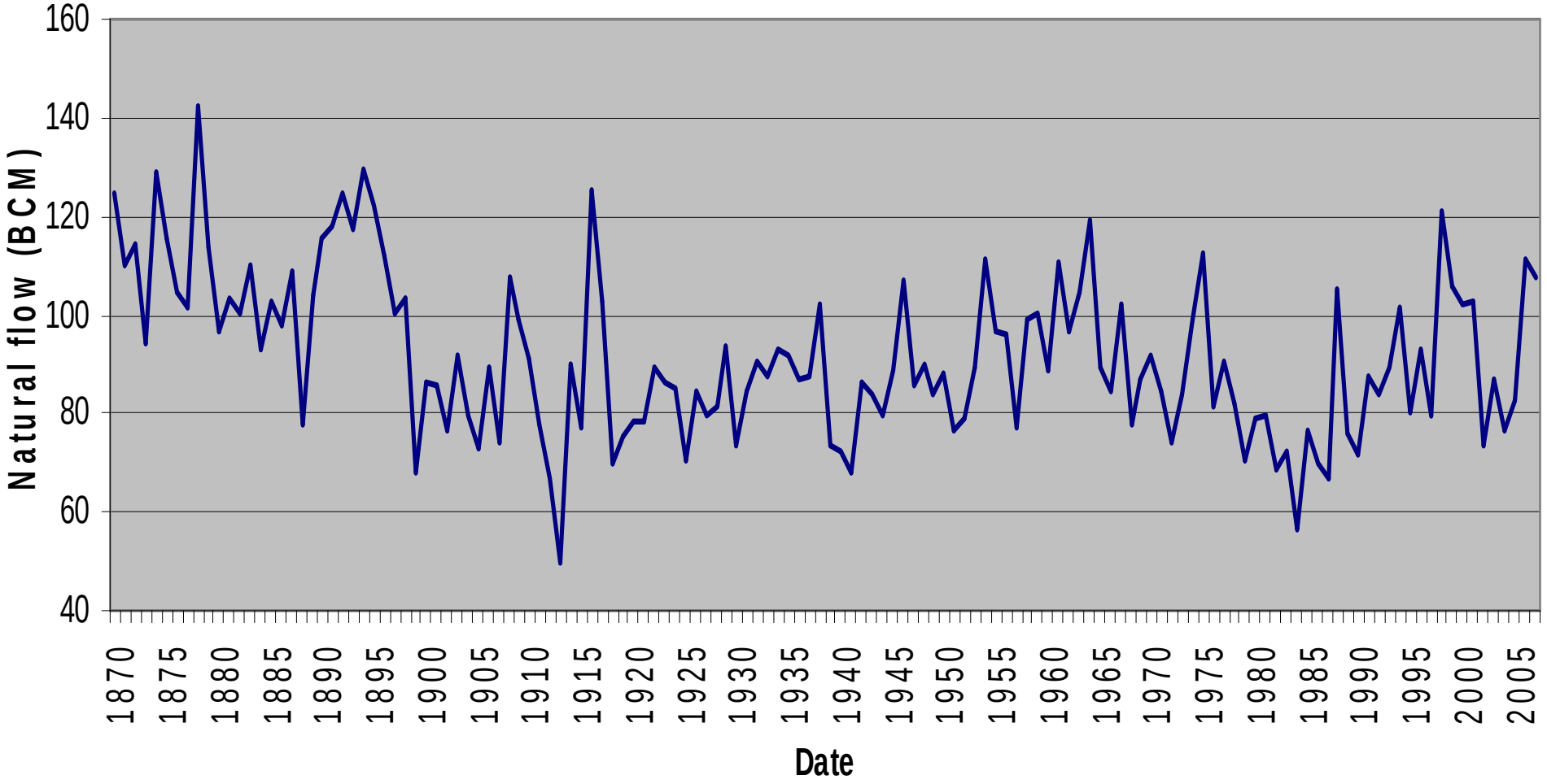




The Nile Discharge is not the biggest

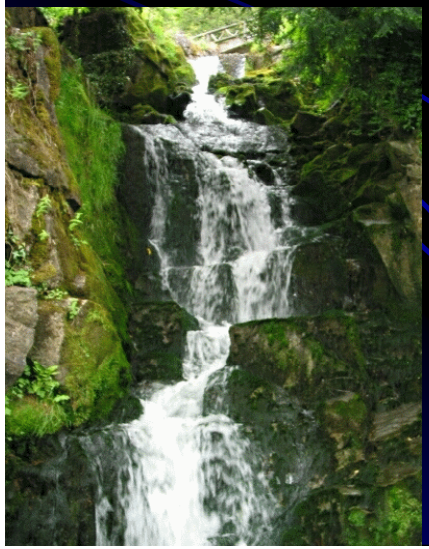

NILE RIVER BASIN
SELECTED CITIES
NATIONAL CAPITALS
MAJOR ROADS
Mediterranean Sea
ISRAEL
West Bank and Gaza
JORDAN
LIBYA
ARAB REP. OF EGYPT
CAIRO
Alexandria
Port Said
Suez
Luxor
Aswan
Lake Nasser
Red Sea
SAUDI ARABIA
CHAD
SUDAN
KHARTOUM
Port Sudan
Abu Hamad
Dongola
ERITREA
ASMARA
REP. OF YEMEN
DJIBOUTI
ETHIOPIA
ADDIS ABABA
Lake Tana
Malakal
Juba
CENTRAL AFRICAN REPUBLIC
DEM. REP. OF CONGO
UGANDA
KAMPALA
Lake Albert
Lake Kyoga
Lake Edward
Lake Victoria
Lake Turkana
KENYA
NAIROBI
SOMALIA
RWANDA
KIGALI
BUJUMBURA
BURUNDI
Lake Tanganyika
TANZANIA
DODOMA
Mombasa
INDIAN OCEAN
MARCH 2000

Natural Yield of the Nile River for Years Through 1870 to 2007



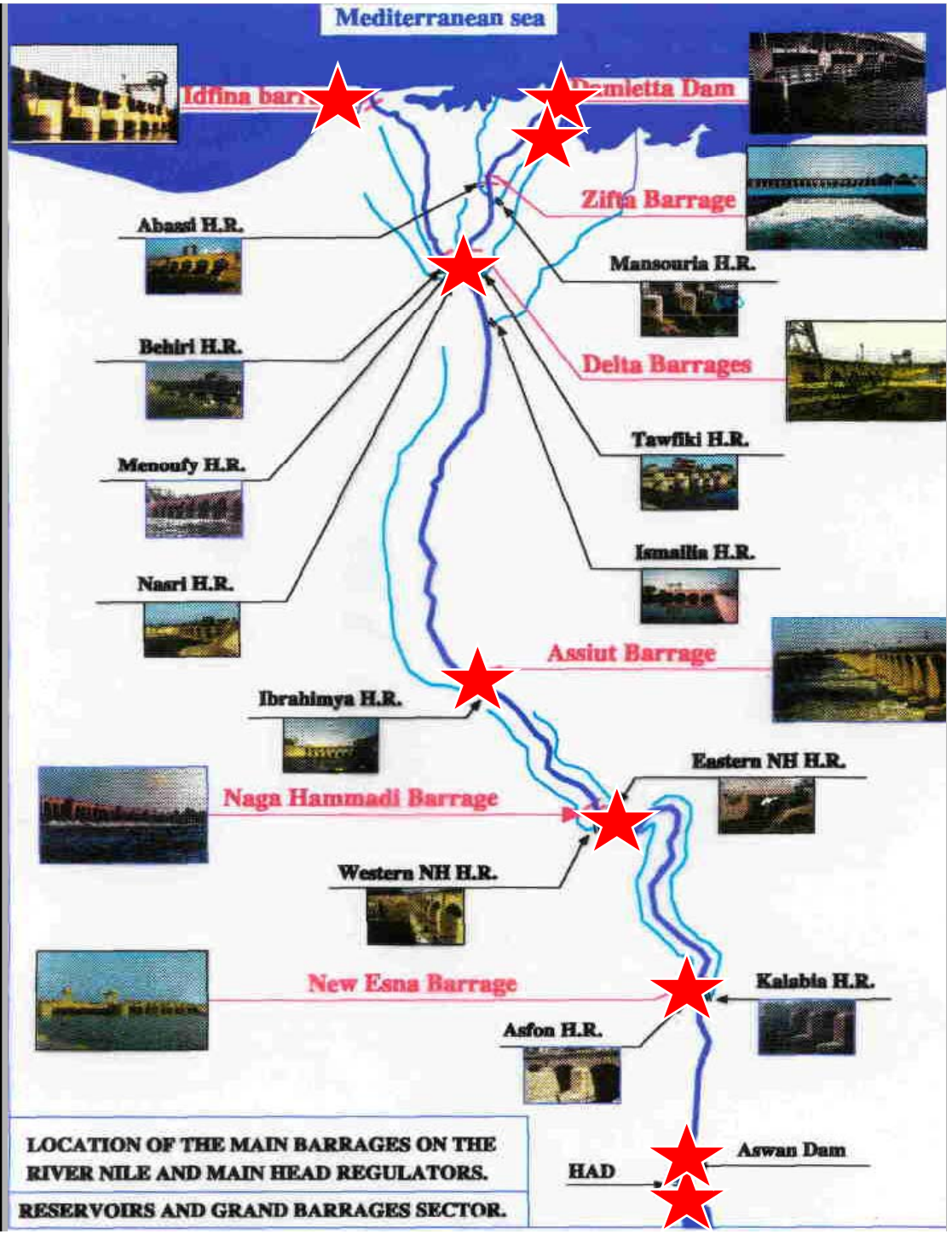
*In high water years, **catastrophic floods** inflicted disastrous harm on agriculture, industry, and dwellings of lower Egypt, while in **low water years**, some lands were exposed to severe droughts.

*The regulation of these varying natural flows had been carried out in steps: the ***construction of levees*** along the river course to prevent flooding,
building of barrages across the river to raise the water to command levels, and later on, *some annual storage projects were executed in the river basin*.



Major control

Hydraulic structures across the Nile in Egypt



*The first of these storage projects was the **old Aswan Dam**. This did not offer complete control of the Nile waters. *The amount of flood water discharging to the sea between August and October in a normal-flow year was 32 km^3*, a little above one third of the total average yearly supply.

1.2 Need for the High Aswan Dam (HAD)

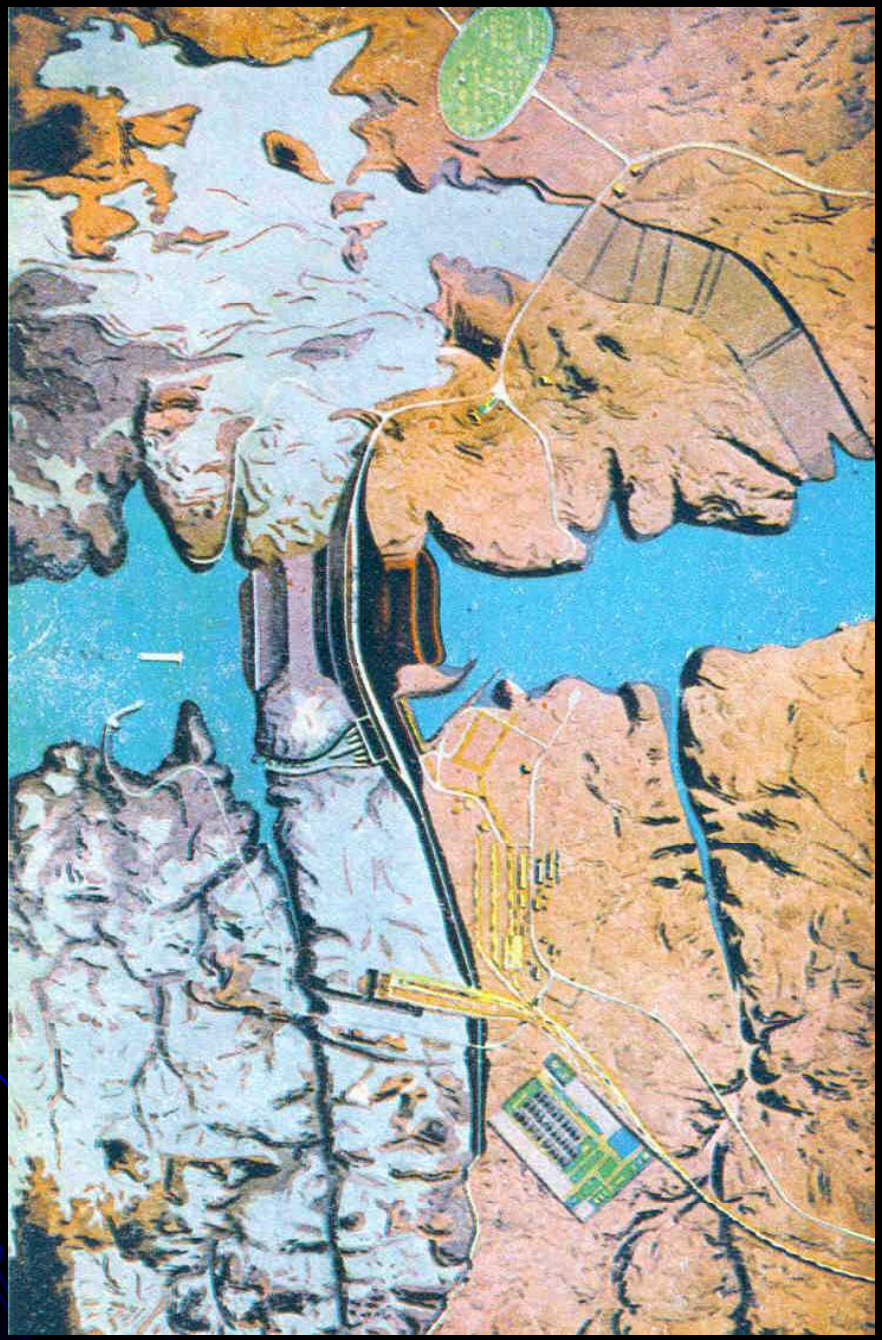
In 1968 the High Aswan Dam was constructed *to save the excess water from high-flood years to be consumed in the years of low floods.*

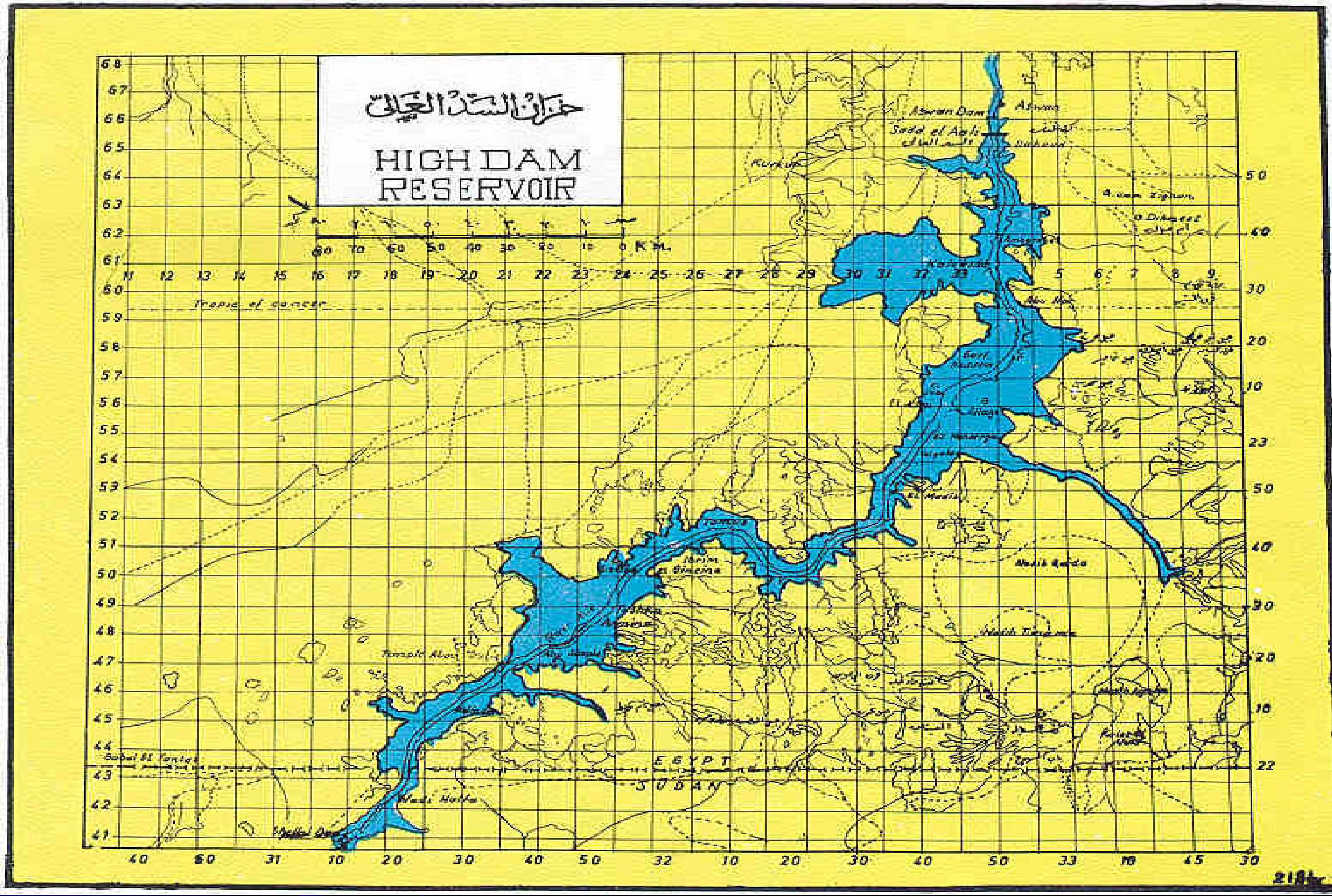
This guaranteed the annual average of 84 km^3 of water needed for the present use and the future arable land expansion.

In one of *the most severe droughts* which continued form year ***1979 to year 1988***, *water availability to Egypt* was **secured** from HAD reservoir. In addition, to protect Egypt from high floods.

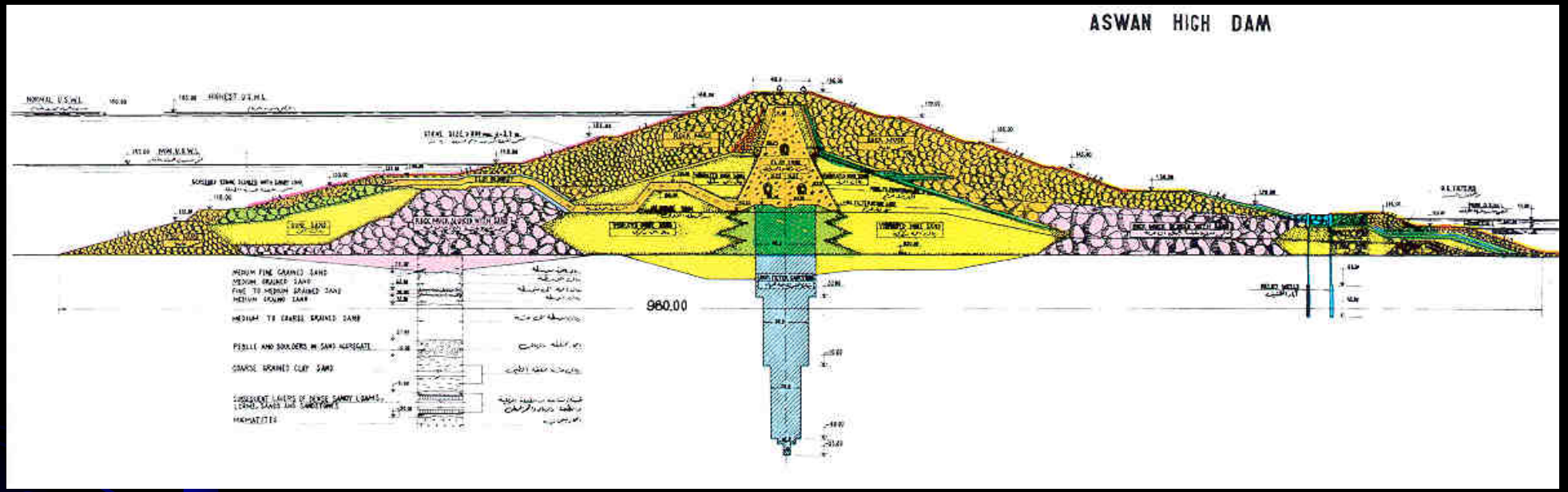
1.3 Description of HAD

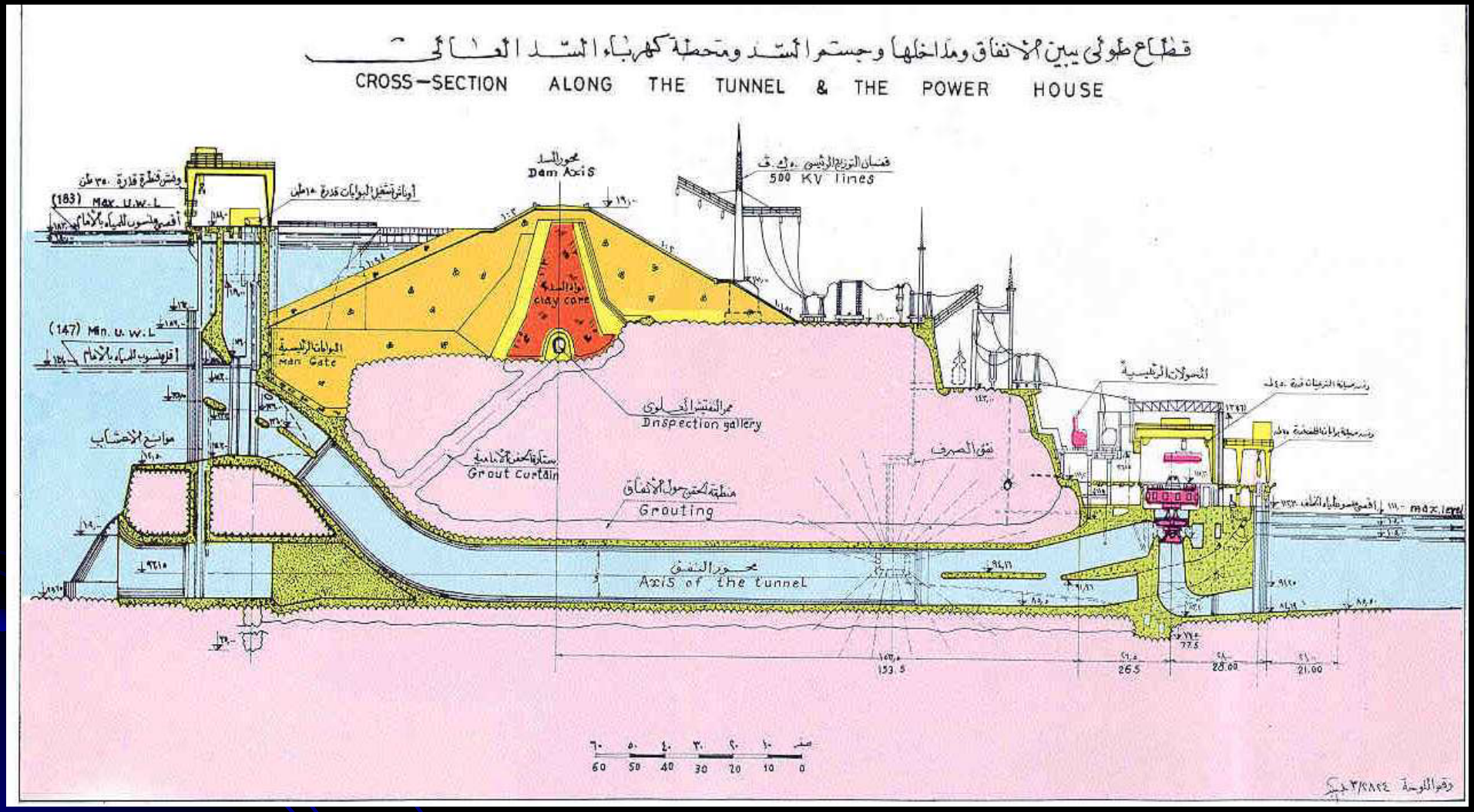
*HAD was completed in 1968. It's **height** is 111 m. between the bed level and the roadway level. The **length of HAD** is 3600 m including the two wings. It was constructed of *granite stone and sand with a core of puddle clay,* connected to a horizontal impervious layer in the upstream to prevent water seepage. A **vertical cut-off curtain** below the core having ***a depth of 210 m*** penetrated the sedimentary layer to the bedrock.





خزان السد العالى
HIGH DAM RESERVOIR
Aswan Dam
Aswan
Sadd el Aali
Kurkur
Tropic of cancer
EGYPT
SUDAN
Wadi Halfa
KM.

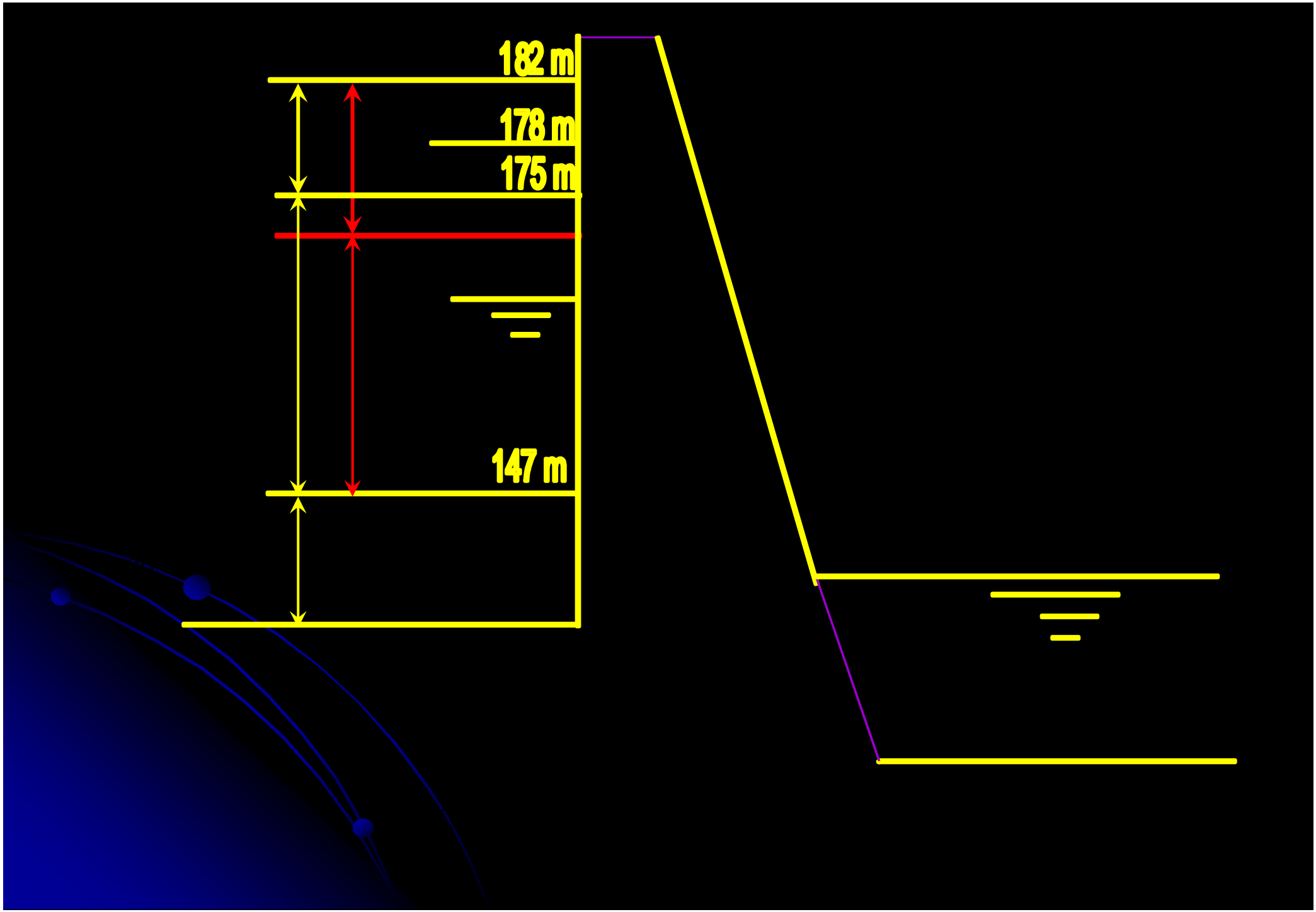

ASWAN HIGH DAM
960.00


قطاع طولى بين الانفاق وما خلفها وجسم السد ومحطة كهرباء السد العالى
CROSS-SECTION ALONG THE TUNNEL & THE POWER HOUSE
محور السد
Dam Axis
خطوط التوزيع الرئيسى ٥٠٠ ك.ف
500 KV lines
(183) Max. U.W.L
(147) Min. u. w. L
مواد السد
clay core
البوابات الرئيسية
Man Gate
مر التفتيش الداخلى
Dnspection gallery
ستارة الحقن
Grout Curtain
منطقة الحقن حول الانفاق
Grouting
محور النفق
Axis of the tunnel
نفق المصرف
المحولات الرئيسية
153.5
26.5
28.00
21.00
77.5
٦٠ ٥٠ ٤٠ ٣٠ ٢٠ ١٠ صفر
60 50 40 30 20 10 0

*A diversion channel was excavated on the eastern bank leading to the hydro-power main tunnels. The 6 tunnels deliver the water to the generating units, and there are bypasses which direct the surplus water out of the power station. The capacity of the power station is 2.10 million kW.

* An emergency gated spillway of crest of length 288m. is constructed on the left bank to pass the flow when it reaches its maximum level.

*The total reservoir storage capacity was estimated at ***162 km³ at water level of 182 amsl***, including: **90 km³ for live storage**, **31 km³ for sediment deposition, and 41 km³ for flood protection**.


182 m
178 m
175 m
147 m

1.4 System of Controlling Upstream Water Level of HAD

To control the water surface elevation upstream HAD during high floods to not exceed the maximum elevation of +182 amsl, the surplus water could be directed through the **bypasses out of the power station(**The total discharge of these tunnels is 11000 m^3/s.) **or (and) through the emergency gated spillway to the river downstream**.

PLATE NO 12

ملحق رقم ١٢

ROUGHNESS COEFFICIENT N = 0.035

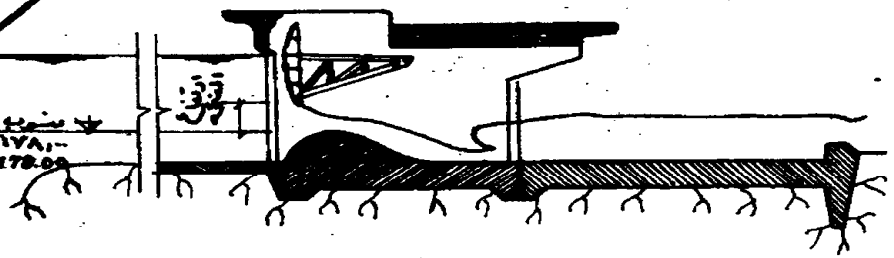
معامل الخشونة ن = ٠,٠٣٥

ROUGHNESS COEFFICIENT N=0.02

معامل الخشونة ن = ٠,٠٢

منحنى تصرف مفيض الطوارئ

IMMERGENCY SPILLWAY DISCHARGE CURVE



CROSS SECTION IMMERGENCY SPILLWAY

قطاع مفيض الطوارئ

منسوب أمام الخزان بالمتر

UP STREAM LEVEL

OPENING HIGHT 0.50 m — ارتفاع الفتحات ٠,٥٠ متر

OPENING HIGHT 1.00 m — ارتفاع الفتحات ١,٠٠ متر

OPENING HIGHT 1.50 m — ارتفاع الفتحات ١,٥٠ متر

OPENING HIGHT 2.00 m — ارتفاع الفتحات ٢,٠٠ متر

OPENING HIGHT 2.50 m — ارتفاع الفتحات ٢,٥٠ متر

3.00 m — ٣,٠٠ متر

3.50 m — ٣,٥٠ متر

GATES TOTALLY OPENED — البوابات مفتوحة على آخرها

182 / ١٨٢

181 / ١٨١

180 / ١٨٠

179 / ١٧٩

178 / ١٧٨

DISCHARGE OF SPILLWAY M³/Sec — تصرف المفيض م٣/ث

0-00 صفر

1000 ١٠٠٠

2000 ٢٠٠٠

3000 ٣٠٠٠

4000 ٤٠٠٠

5000 ٥٠٠٠

2.Reasons for Toshka Project

Practical experience showed that degradation occurs at low rates and causes no great danger as long as the discharges flowing downstream HAD **are kept within the limits of the actual requirements**.

Discharges exceed the actual requirements should be released in the river course, *the downstream reaches of the barrages would be subjected to tangible increase in degradation rates of the river channel*. This can be **avoided** if the extra discharges could be released upstream of HAD, *into Toshka Depression*. Studies about Toshka Project demonstrated its *efficiency in fulfilling the required purpose.*

3. Toshka Project Description

The excess flood water passes out of lake Nasser via Khor Toshka to the Toshka depression. **Three hydraulic structures a**re constructed within the project *to control the water level in the lake*, *to measure the discharge spilled to the Toshka Depression and to maintain the channel stability*. These works are: **Uncontrolled Spillway, Toshka Channel, and an Ogee Weir**.

3.1. Khor Toshka

It is a *natural waterway* leading to the Nile. It extends in the north west towards Lake Nasser. *Its length is* **72 km** form the axis of the River, *but its width is* considerably variable, ranging from **1.0 km to 10.0 km.** The area of Khor Toshka covers about **132 km^2**, confined by contour line 185 m amsl.

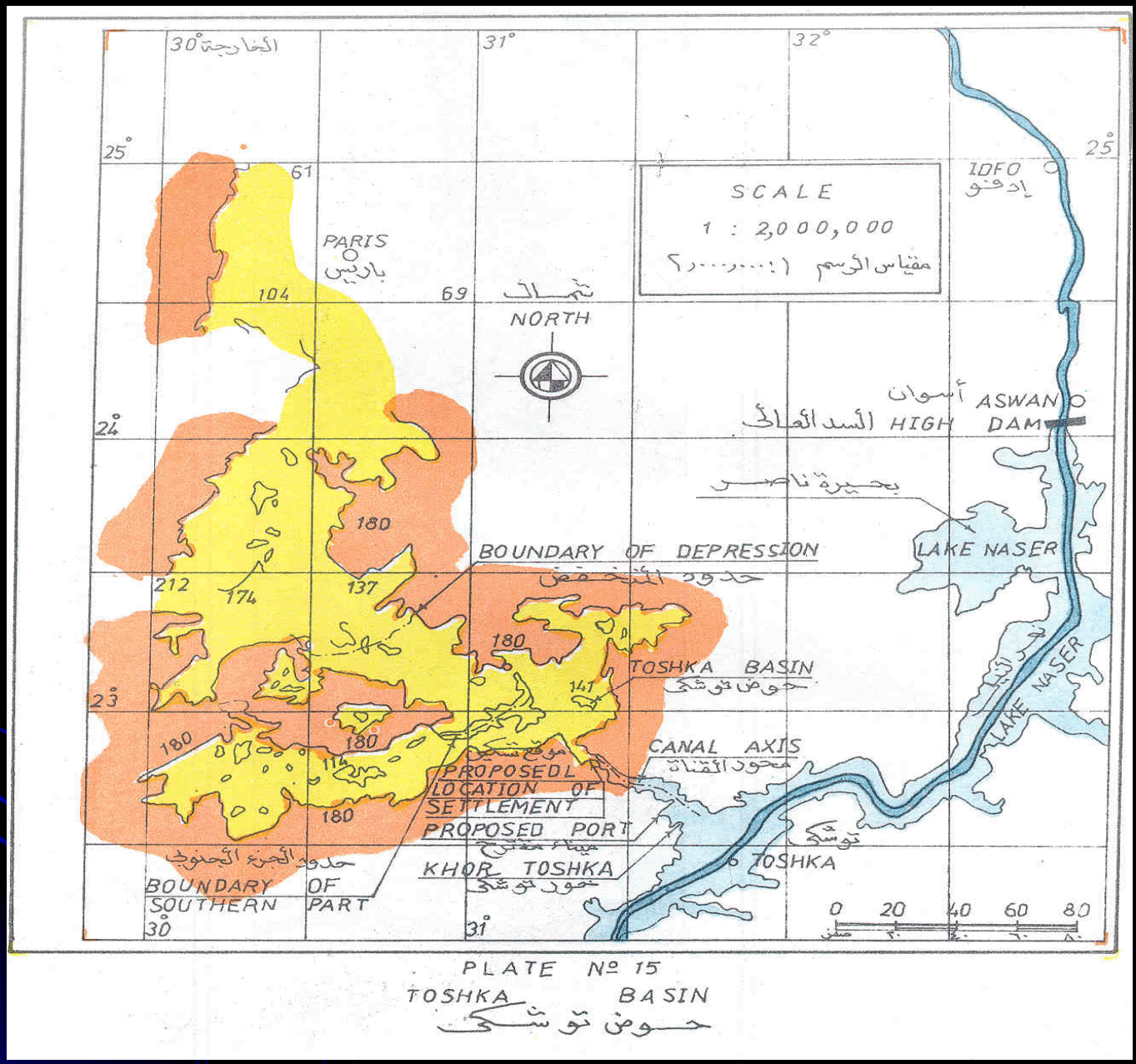
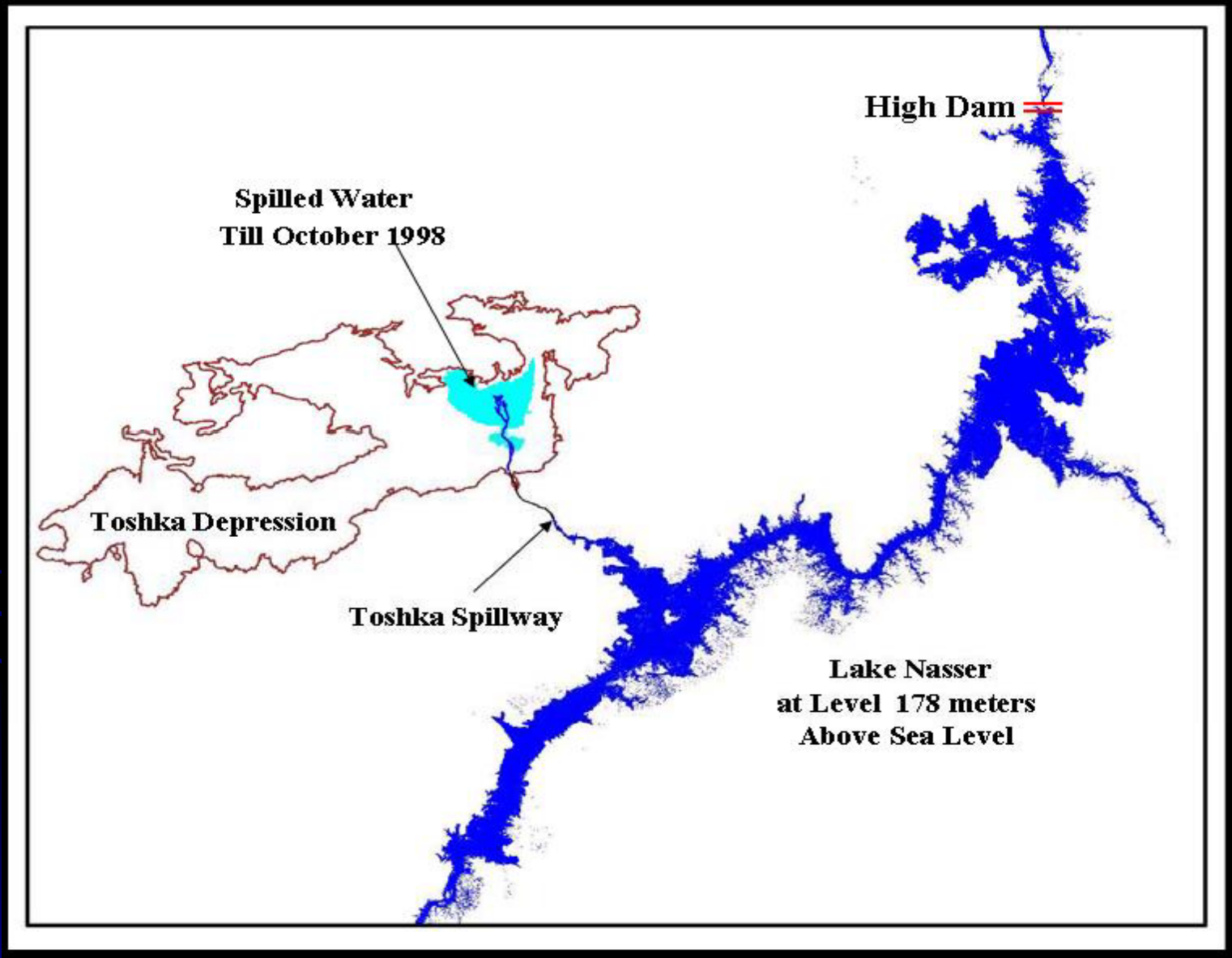


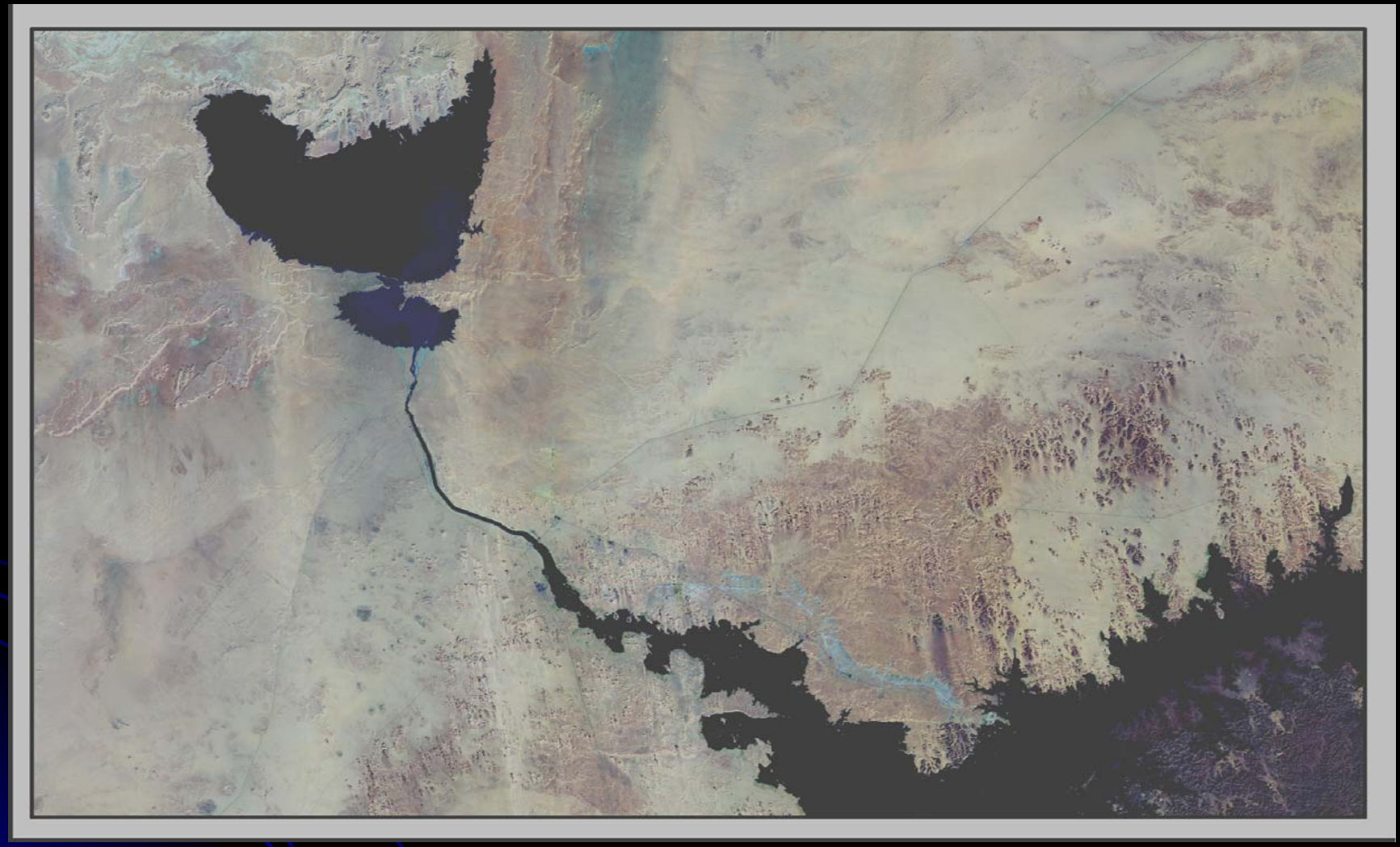
PLATE Nº 15

TOSHKA BASIN

حوض توشكى

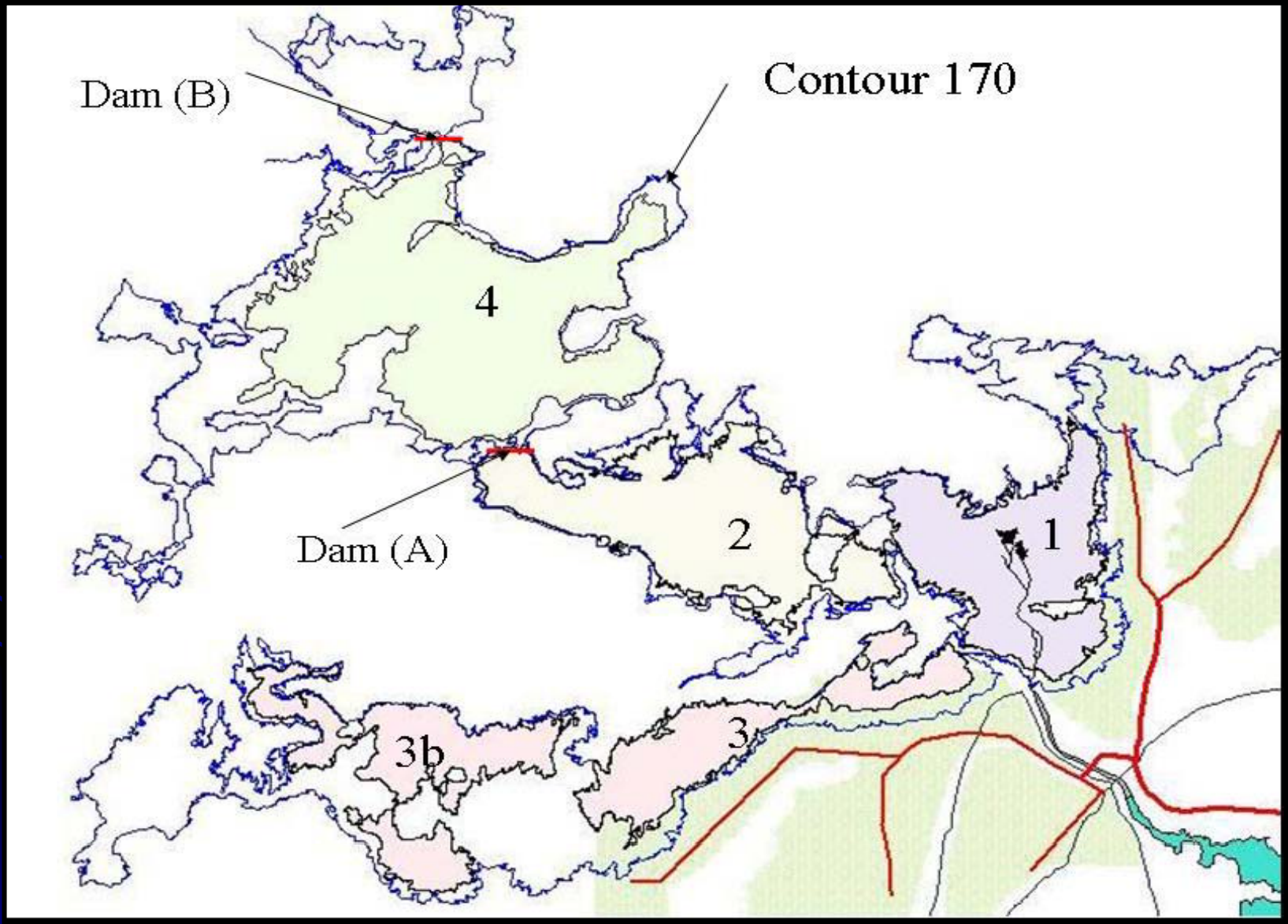
Lake Nasser & Toshka Depression





Landsat Image in April 2001

Main Basins in Toshka Depression



3.2 The Uncontrolled Spillway

It is a sill made of plain concrete with downstream dry pitching. The level of the **sill** is 178 m. amsl, and its **length is 750 m.** It allows the excess flood water to flow **freely** when its level exceeds 178 m. amsl.

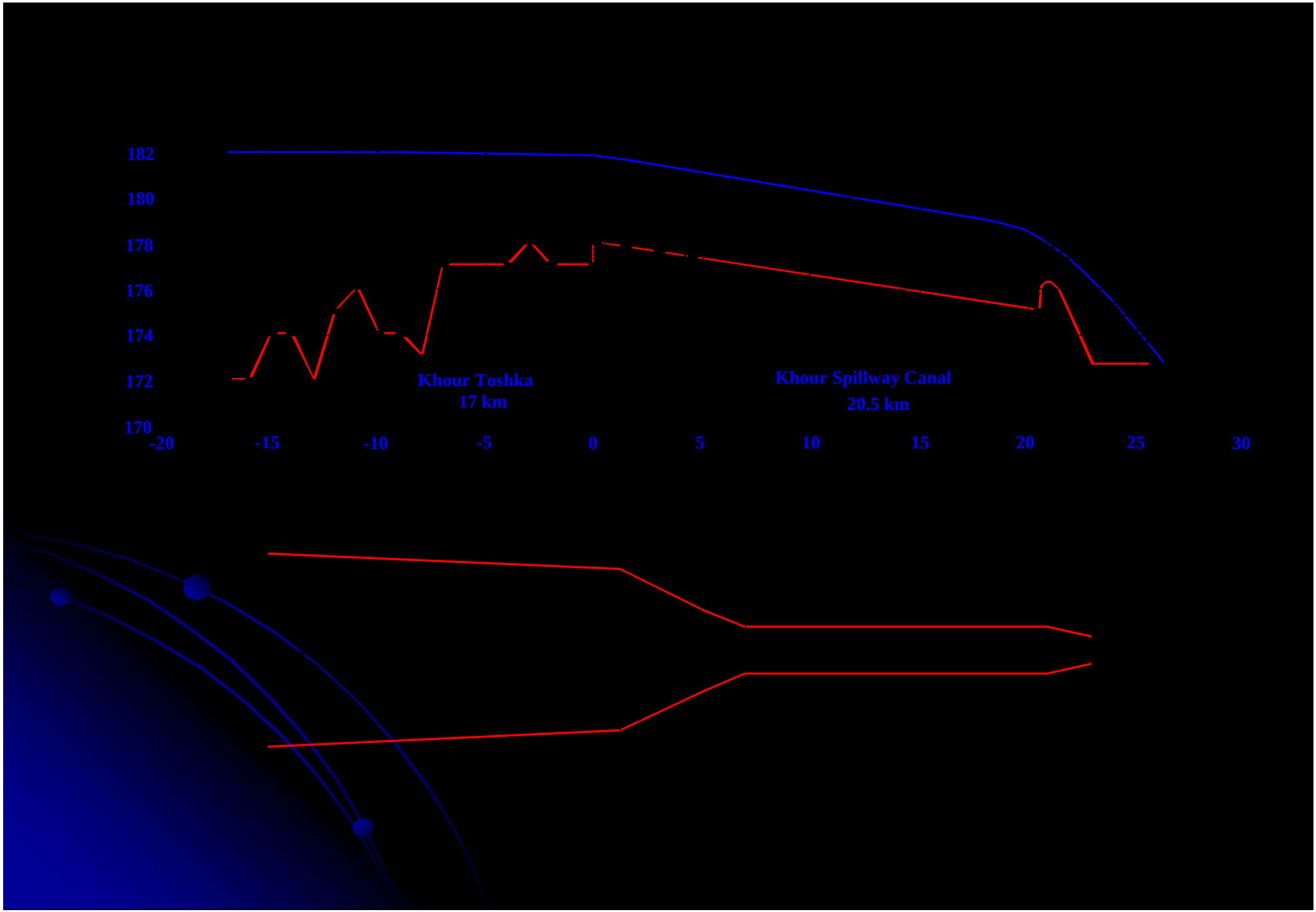
3.3 Toshka Channel

Toshka channel starts just DS of the sill with a bed level 178m.amsl which is the same as the sill crest level. The **length** of the channel to the depression is approximately **22 km.** The channel **width** is **750** m at the beginning and then decreases to be **440** m at the bridge located at distance of km 3 across the channel. Downstream of the bridge the **channel width is 350 m and it continues till km 20.5.** The longitudinal bed slope of the channel is 15 cm /km.

The channel section has been designed to make possible the maximum released discharge is 250 million m^3 /day (2894 m^3/s) at water level of 182.73 m amsl in the lake

3.4 The Ogee Weir

An Ogee weir with crest level 176m was constructed near the end of Toshka channel (at km 20.5), to *measure the excess passed discharge and to maintain the stability of the upstream channel cross sections*. Also, this weir is functioning *as a drop structure as the bed level at its upstream is 175 m amsl and at its downstream is 172.5 m. amsl*. Downstream of the weir, the channel is much *more steep and the bed material is weak sand stone which is also erodiable*.


182
180
178
176
174
172
170
-20
-15
-10
-5
0
5
10
15
20
25
30
Khour Toshka
17 km
Khour Spillway Canal
20.5 km

3.5 Toshka Depression

The Toshka Depression is a huge, wide depression in the western desert at the left side of the Nile. Its entrance at the end of Khor Toshka at a distance of 72 km from the Nile, some 250 km south of the HAD. *It covers an area of 6000 km^2, at level 180 amsl.* The topographic studies related to this project indicated that the depression is bounded by mountainous escarpments.

4. Benefits of Toshka Spillway

Toshka spillway is considered to be a project **complementary to HAD**. Its objective is mainly **to achieve full control of discharges released to the Nile course downstream of HAD**, Consequently, *it will fulfill the following benefits:*

-Preventing the ***increase of the degradation rates in the River course***, to protect the constructions erected on the river from overall degradation.

-***Increasing the capacity*** of protection against the dangers of high floods.

-***Increase the live storage capacity*** ***up to the level of 178 m amsl instead of 175 m amsl***.

-***Feeding of the groundwater reservoir south of the New Valley, to raise its safe yield .***

5. Role of Toshka Project in the Management of Floods of the years (1998/1999) and (1999/2000)

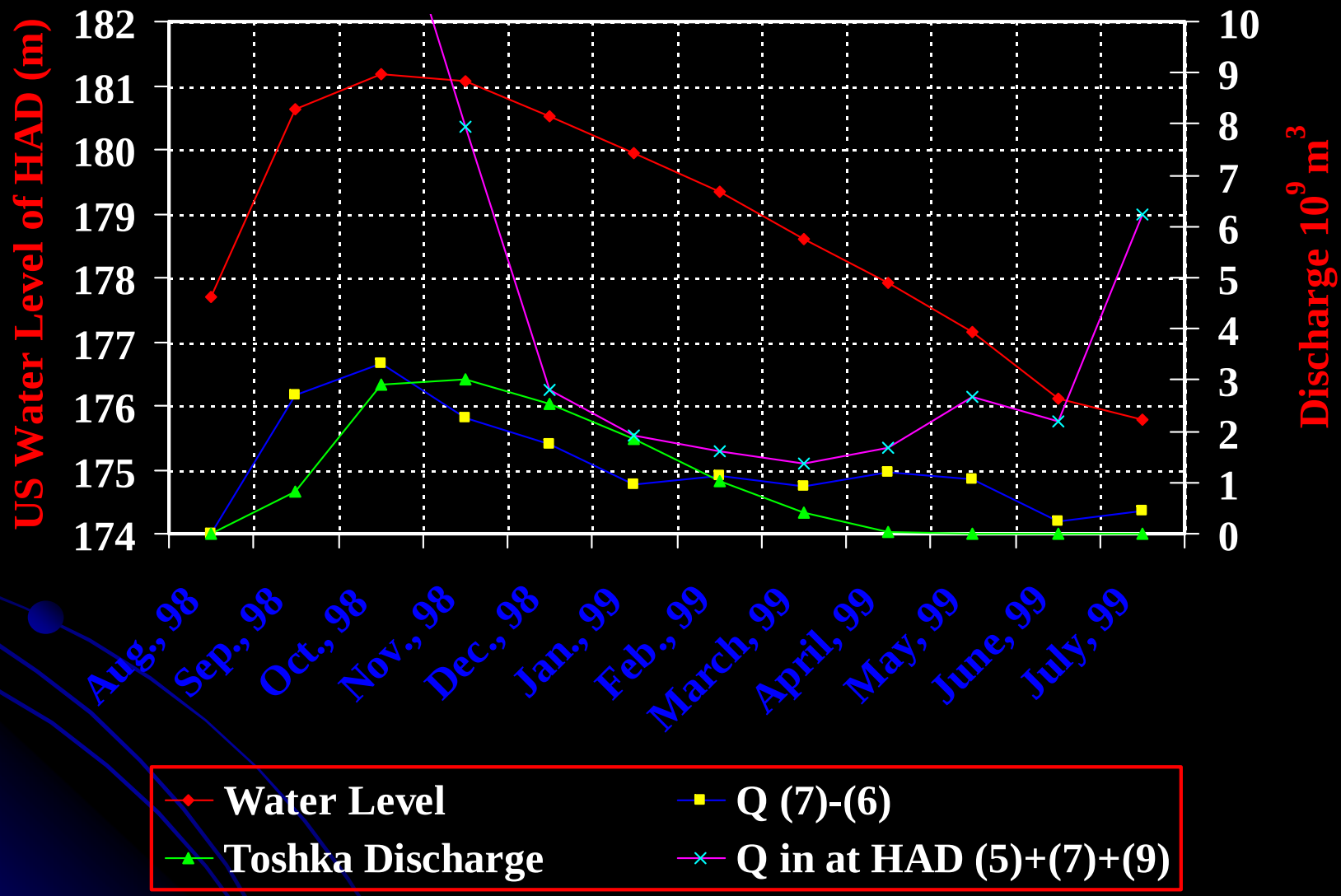
Flood water reached Toshka Spillway for the first time in the year 1996, and the amount of water spilled to the depression was 0.5 km^3. In the year 1998/99 the depression received 14.1 km^3 for the year (1999/2000).

The following Table and Figure shows the monthly variation of water level upstream HAD with the following terms:

- *inflow upstream HAD*
- *amount of water spilled to Toshka depression*
- *amount of water spilled to the sea.*

End of the Month (1)	water level H upstream (2)	Δ H (3)	Vol. of Storage (V) (4)	Δ (V) (5)	Water Demand (6)	Actual Q from HAD (7)	Δ Q (7)-(6) (8)	Toshka Discharge (9)	Q in at HAD (5)+(7)+(9) (10)
	(m)	(m)	(Bil. m3)	(Bil. m3)	(Bil. m3)	(Bil. m3)	(Bil. m3)	(Bil. m3)	(Bil. m3)
Aug.,98	177.690	2.940	135.764	15.764	6.450	6.450	0.000	0.000	22.214
Sep.,98	180.640	2.950	153.532	17.768	4.235	6.930	2.695	0.827	25.525
Oct., 98	181.190	0.550	157.035	3.503	3.495	6.825	3.330	2.912	13.240
Nov., 98	181.080	-0.110	156.320	-0.715	3.400	5.660	2.260	3.005	7.950
Dec., 98	180.510	-0.570	152.713	-3.607	2.125	3.880	1.755	2.549	2.822
Jan., 99	179.940	-0.570	149.134	-3.579	2.705	3.655	0.950	1.846	1.922
Feb., 99	179.330	-0.610	145.413	-3.721	3.205	4.325	1.120	1.018	1.622
March, 99	178.610	-0.720	141.099	-4.314	4.375	5.290	0.915	0.401	1.377
April, 99	177.910	-0.700	136.996	-4.103	4.545	5.730	1.185	0.038	1.665
May, 99	177.140	-0.770	132.684	-4.312	5.935	6.990	1.055	0.000	2.678
June, 99	176.120	-1.020	127.148	-5.536	7.500	7.735	0.235	0.000	2.199
July, 99	175.790	-0.330	125.408	-1.740	7.535	7.965	0.430	0.000	6.225
Total 98/99				5.408	55.505	71.435	15.930	12.596	89.439
Aug. 99	178.16	2.37	138.414	13.006	6.450	7.115	0.665	0.000	20.121
Sep. 99	180.54	2.38	152.902	14.488	4.235	6.580	2.345	1.027	22.095
Oct. 99	181.39	0.85	158.385	5.483	3.495	4.455	0.960	2.540	12.478

Table (1): Hydrological characteristics of HAD through year 98/99


US Water Level of HAD (m)
182
181
180
179
178
177
176
175
174
10
9
8
7
6
5
4
3
2
1
0
Discharge 10^9 m^3
Aug., 98
Sep., 98
Oct., 98
Nov., 98
Dec., 98
Jan., 99
Feb., 99
March, 99
April, 99
May, 99
June, 99
July, 99
Water Level
Toshka Discharge
Q (7)-(6)
Q in at HAD (5)+(7)+(9)

6.Future Plan for Increasing the Spillway Capacity

The capacity of Toshka Spillway may need to *be increased to limit the outflow from Lake Nasser into the river downstream*.

Through the flood of year (1998/1999), the Ogee weir was calibrated and the discharge was related to the water head above the weir crest, or to the upstream water level of HAD. The results of the calibration are the following two equations:

$$Q = 2.012\ BH^{1.569}$$

$$Q = 519.84\ h - 93028$$

This calibration indicates that ***the maximum discharge of the channel will be about 137 million m^3/day (1586 m^3/s) at a water level of 182 m amsl***, ***instead of 250 million m^3/day (1894 m^3/s) which was the designed discharge***. That leads to the need to investigate ***the possible methods for increasing the discharge capacity***.

Many alternatives were proposed and tested by a mathematical model (WENDY 1-D) developed by Delft Hydraulics to determine the corresponding discharge that can be passed through the channel. The optimum solution was a combination between deepening and widening the bed width of the Toshka channel. Also, it involves *replacing the Ogee weir with control structure having a lower floor level*.

7. Summary and Conclusions

*For the safety of HAD against over topping and to protect the Nile River bed against degradation in case of surplus discharge is to be released DS the HAD, **Toshka spillway was constructed to pass this surplus water to maintain the river discharge at a level which is required for meeting the water demands of Egypt**.

Toshka spillway proves its function during the last two successive floods where more than 27 Milliard m^3 were passed through it.

*The Ogee weir was ***calibrated and the obtained results revealed that the maximum discharge of the spillway at a water level in the lake of 182 amsl is about 1546 m^3/s which is much less than the original design discharge (2894 m^3/s)***.

*A one-dimensional model was employed based on the tpographic and hydrographic data for the 17 km length of Khor Toshka in addition to 20.5 km length of the channel.

The model was formulated by using WENDY program which was developed by Delft Hydraulics.

Many alternatives for enlargement of Toshka canal capacity were tested using the mentioned numerical model to find out the most economic and efficient alternative.

*The most optimum solution appears to be a sort of combination between deepening and widening the channel bed, in addition to replacing the Ogee weir with a simple control structure having a lower floor level.

Thankyouforyourkindattention