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ARAB REPUBLIC
OF
EGYPT

WATER MASTER PLAN

USAID / CAIRO
DEVELOPMENT
INFORMATION
CENTER

THE IRRIGATION AND DRAINAGE SYSTEM

March, 1981

MINISTRY OF IRRIGATION

UNDP IBRD

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Acknowledgements

This report was prepared by Eng. Gamil Mahmoud of the Master Water Plan staff with the assistance of Jack Farmer. Other project staff provided some input and comments on the computation of the cost of water. Eng. Bayoumi Attia prepared the section describing the distribution model.

The report was typed and assembled by Mrs. Violet Rizkallah.

FOREWORD

This report is one of a series of technical reports prepared to document the work done by or for the first phase of the Master Plan for Water Resources Development and Use EGY 73/024. A complete list of the reports prepared in this series is given below.

Number	Title
1.	Water Planning : Methods and Three Alternative Plans.
2.	Water Demands.
3.	Water Supply.
4.	Groundwater.
5.	Regulation Studies.
6.	Project Information System.
7.	Water Quality.
8.	The Organization, Administration and Legal Framework for Water Planning.
9.	Water and Wastewater Studies Municipal and Industrial Sectors.
10.	Industrial Water Use and Wastewater Production.
11.	Water Management Capabilities of the Alluvial Aquifer System of the Nile Valley, Egypt.

Number	Title
12.	Sediment Processes in the Nile River.
13.	Fisheries, Ecology, Health and Fish Farming.
14.	Hydrological Simulation of Lake Nasser.
15.	Mathematical Model for the Upper Nile.
16.	Agro Economic Model.
17.	Consumptive Use of Water by Major Field Crops in Egypt.
18.	Hydrogeological Evaluation of Environs of Lake Nasser.
19.	Economic Evaluation of Land Reclamation.
20.	The Irrigation System.

The first phase of the project was executed by the International Bank for Reconstruction and Development, financed by the United Nations Development Program, and the Ministry of Irrigation was the Co-operating Agency. Work began in October 1977 and the first phase concluded in March 1981. A bridging project document was signed in March 1980 to extend the work to December 1981 and to prepare for a second phase commencing January 1982.

CHAPTER 1

DESCRIPTION OF THE PRESENT SYSTEM

1.01 The Nile is the second longest river in the world being about 6700 Km long. It flows north wards from its sources in the south, near Lake Tanganika, up to its mouth at the Mediterranean Sea in the north.

1.02 The Nile River System and its irrigation and drainage system are unique as it has been developed over a period of more than five thousand years. The basin irrigation continued to be the only mean of irrigation in Egypt till the year 1820. In the year 1821, it was decided to introduce the cultivation of cotton & Sugar cane, and it was necessary to start conversion of the basin areas to perrenial to allow cultivation of those two crops. The original system has had to be modified to meet new requirements after shifting completely to perrenial system.

1.03 The irrigated lands in Upper and Middle Egypt lie on the sides of the river bank, except for Fayoum. The Delta area which starts just below or north of Cairo is generally divided into three areas:- East, Middle and West.

1.04 Releases of water are made at the High Aswan Dam (completed in 1971) and Aswan Dam (1902). Water control & distribution are managed by Seven barrages on the main Nile

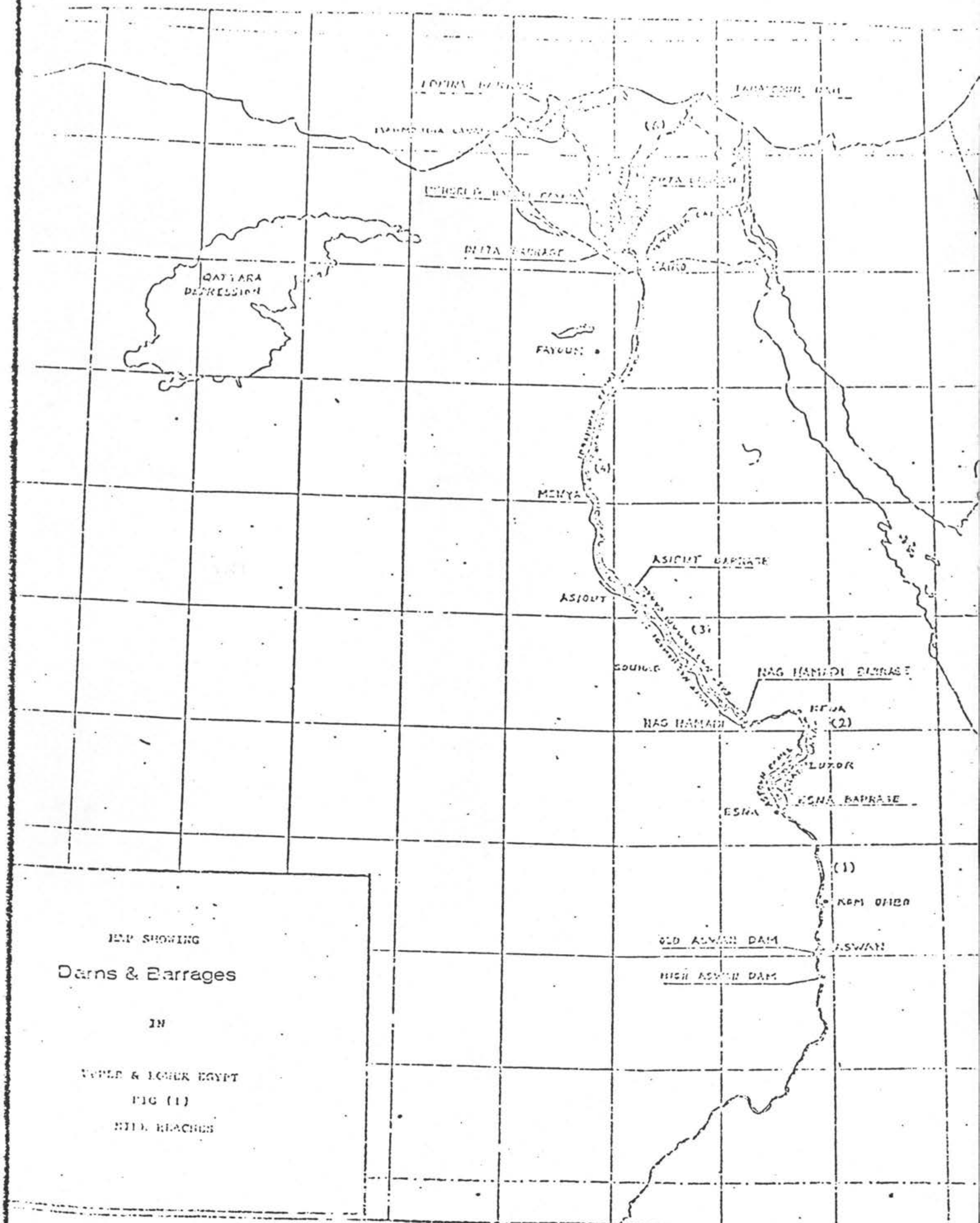
& its two branches. These barrages were constructed to fullfil two main objectives .... The first was to guarantee basin irrigation in low floods ... and the second was to allow the conversion of basin irrigation to perennial. The location & date of construction of the existing control structures over the Nile downstream the High Aswan Dam are as follows :-

Control Work	Location D.S. Aswan Dam	Year of completion	Date of Strengthening or re-modelling
Old Aswan Dam	-	1902	1912 & 1933
Esna Barrage	170 Kms	1908	1948
Nag Hammadi Barrage	354 "	1930	-
Assiout Barrage	547 "	1902	1938
Old Delta Barrage	965 "	1861	1901
New " "	965 "	1939	-
Zifta Barrage	1052 " on Damietta Branch	1902	1954
Edfina Barrage [illegible]	11/6 Kms on Rosetta Branch	1950	-

This gives Seven Nile reaches (1) Aswan - Esna.

(2) Esna - Nag Hammadi (3) Nag Hammadi - Assiout
(4) Assiout - Delta (5) Delta - Zifta
(6) Zifta - Farascour (7) Delta - Edfina

(See Figure (1)



MAP SHOWING

Dams & Barrages

IN

UPPER & LOWER EGYPT

FIG (1)

NILE REACHES

1.05 For MWP work, we have divided the irrigated lands into 50 command areas. From the stand point of the project, a canal command is defined as an area of approximately 100,000 gross feddans served from one or more sources by regulators or pump stations for which the in flows are known. For the project Agro-economic model runs, these command areas were aggregated into 15 units

1.06 The Drainage Authority also divides the agricultural land into 152 drain command areas. Similarly, a drain command can be defined as an area from which all drainage water leaves through one, or more main drain gravity outflow points or pump stations for which discharges can be known.

1.07 Basic information on the historic cropping pattern have been compiled by the project from the records of the Ministry of Agriculture on the bases of Administrative Districts. To relate the distribution system data to the areal distribution of crops, we have developed coefficient factors having the capability to establish a relationship between canal commands, drainage commands and administrative districts with an acceptable degree of accuracy.

A detailed description of how these factors were derived and their use to transfer data from one level to the other was given in the Second Interim Report.

1.08 One of the main applications of correlation between distribution system and areal distribution of crops is to compare the release patterns at Aswan or any other major diversion site that correspond to changes in cropping patterns throughout the system's command areas. The MWP project has prepared a group of Schematic diagrams for both irrigation & drainage system on the reach level for Upper Egypt and on the region level for the Delta. These Schematics will give a useful knowledge of the main irrigation & drainage network to be represented in the distribution system model (see figures 2 to 15).

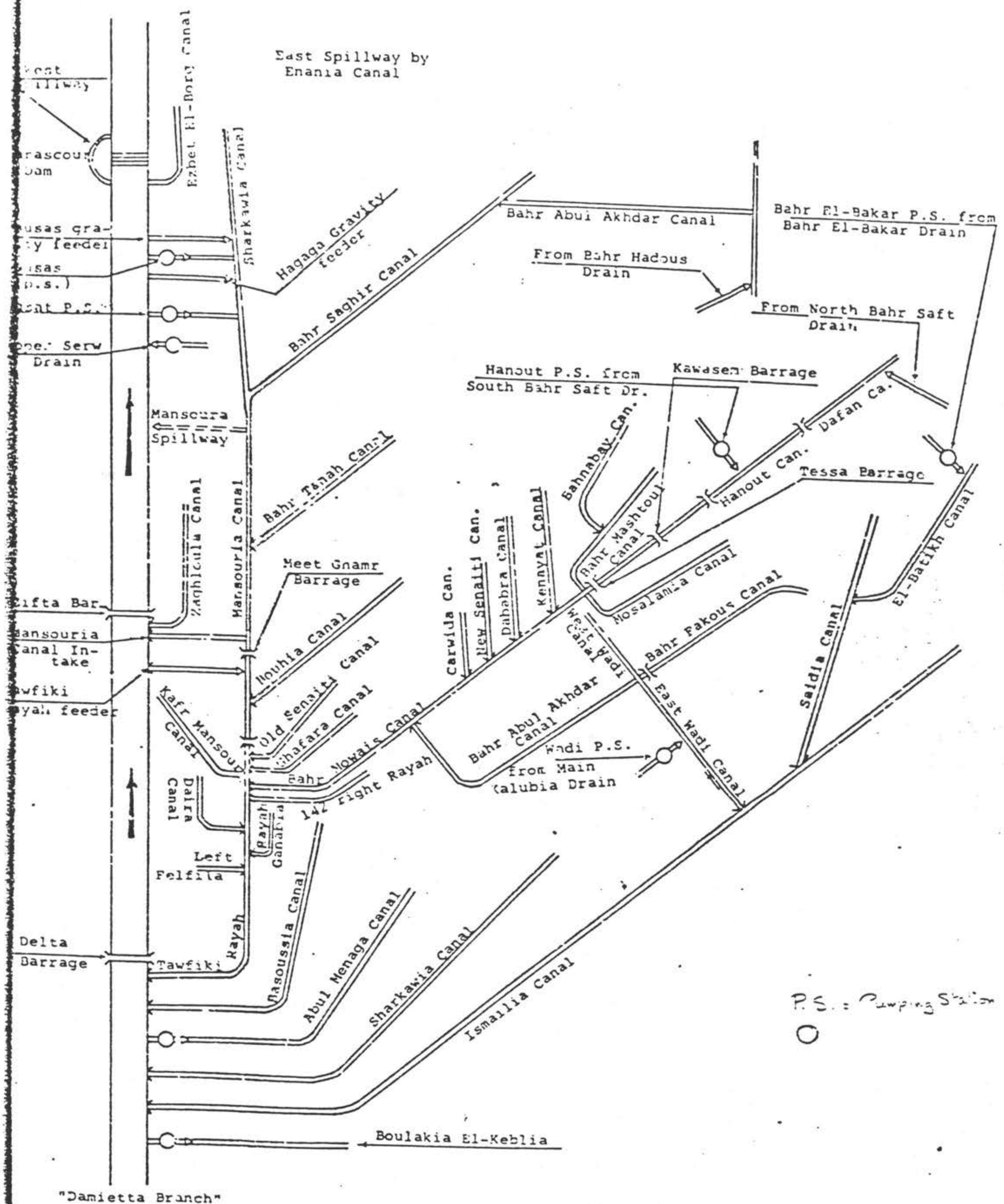


FIG (2)
A SCHEMATIC DIAGRAM FOR IRRIGATION SYSTEM
IN THE EASTERN DELTA

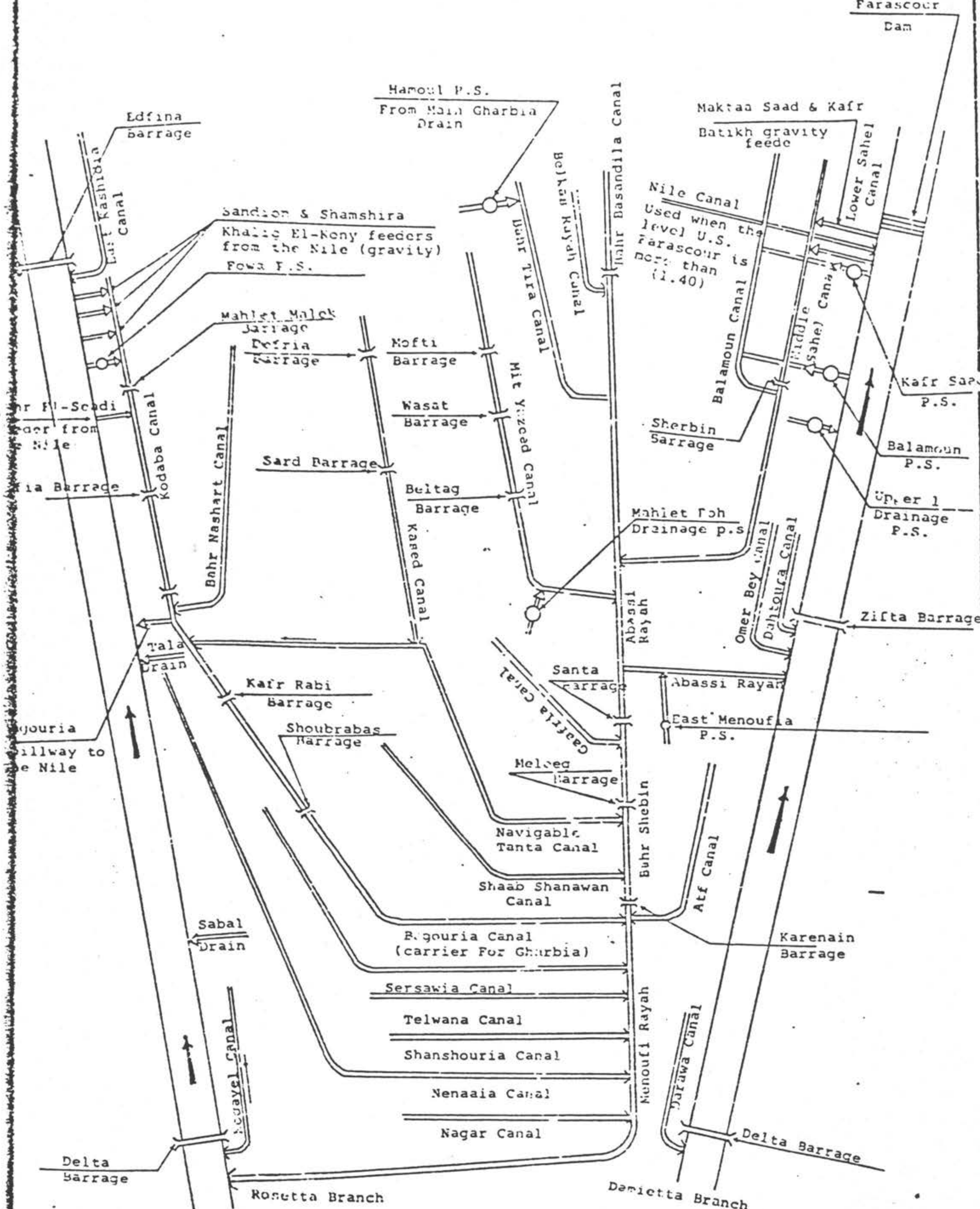


FIG (3)
A SCHEMATIC DIAGRAM SHOWING THE IRRIGATION SYSTEM
IN THE MIDDLE DELTA

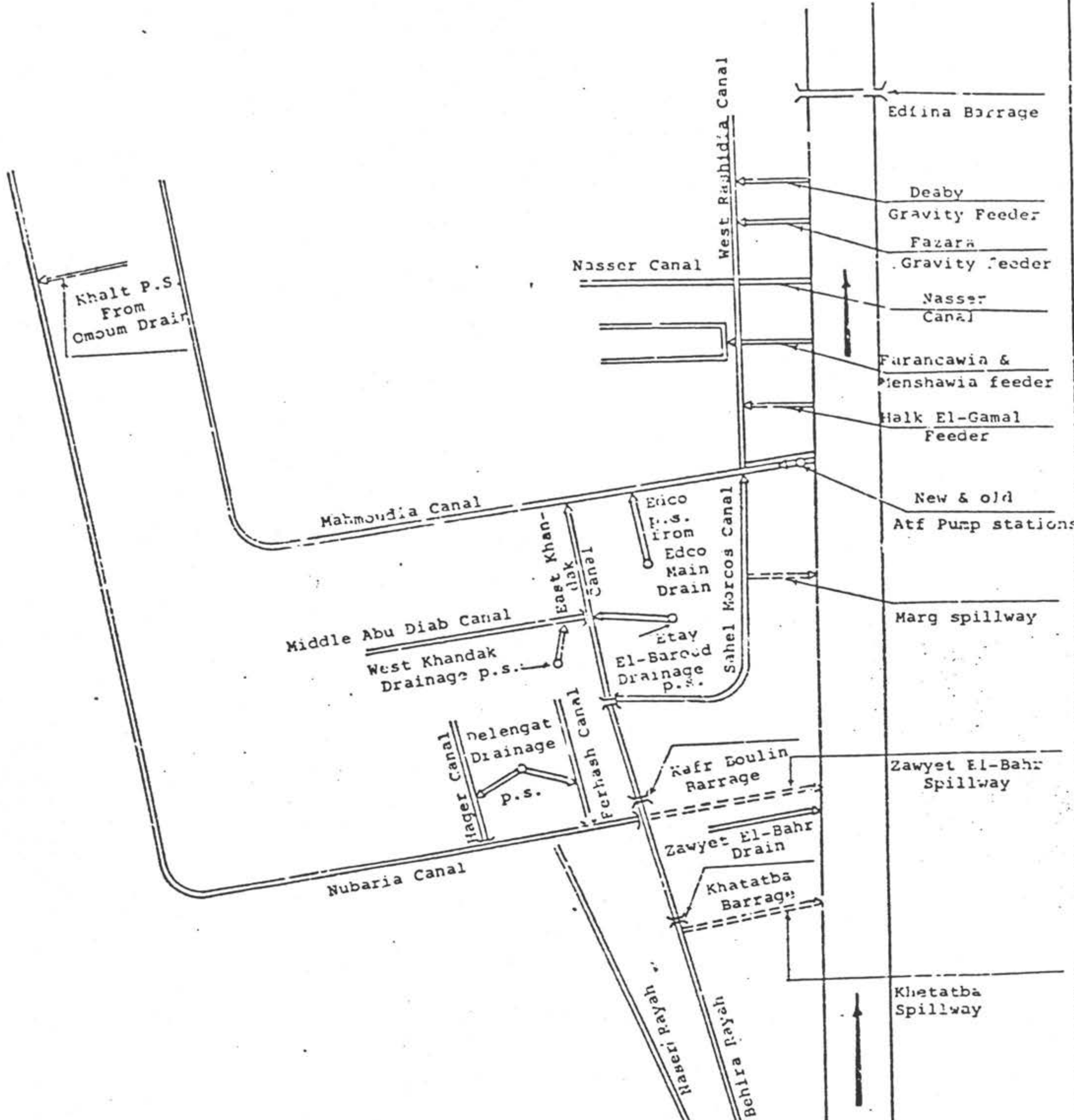
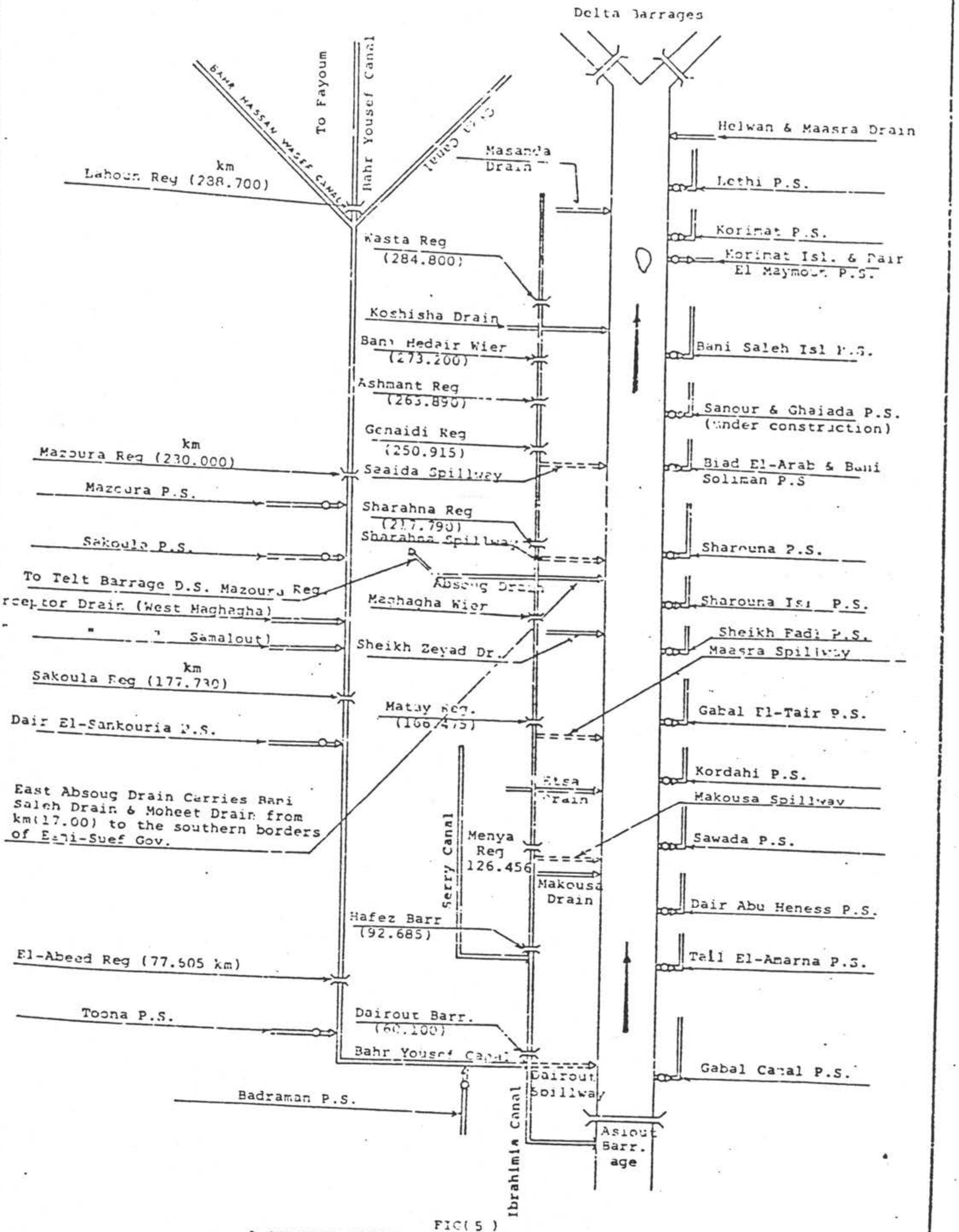


FIG (4)

A SCHEMATIC DIAGRAM SHOWING THE IRRIGATION SYSTEM

IN WESTERN DELTA



FIG(5)
A SCHEMATIC DIAGRAM FOR THE IRRIGATION SYSTEM
IN THE REACH ASSIOUT - DELTA

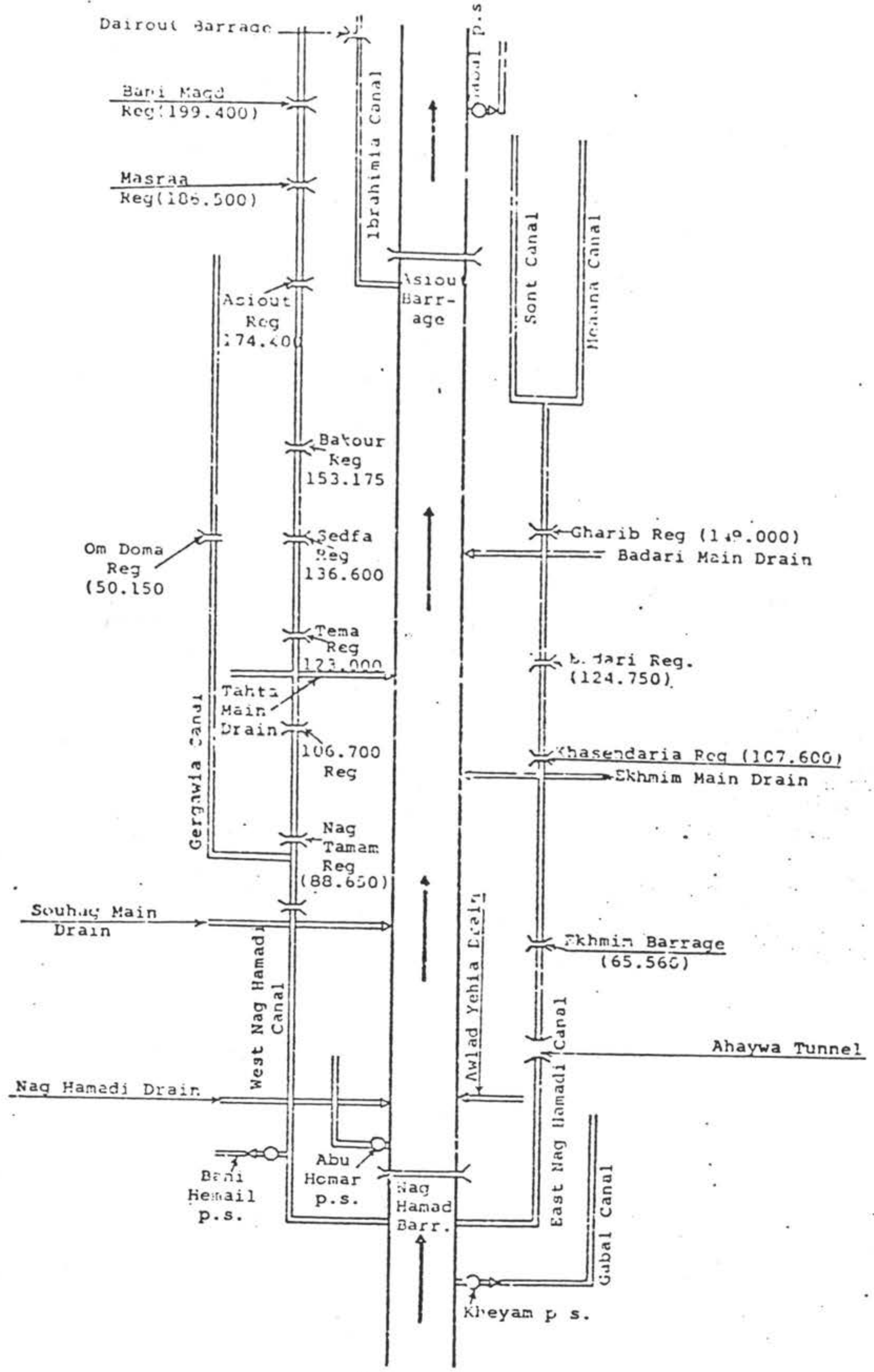


FIG (6)

A SCHEMATIC DIAGRAM FOR THE IRRIGATION SYSTEM IN THE REACH NAG HAMMADI - ASSIOUT

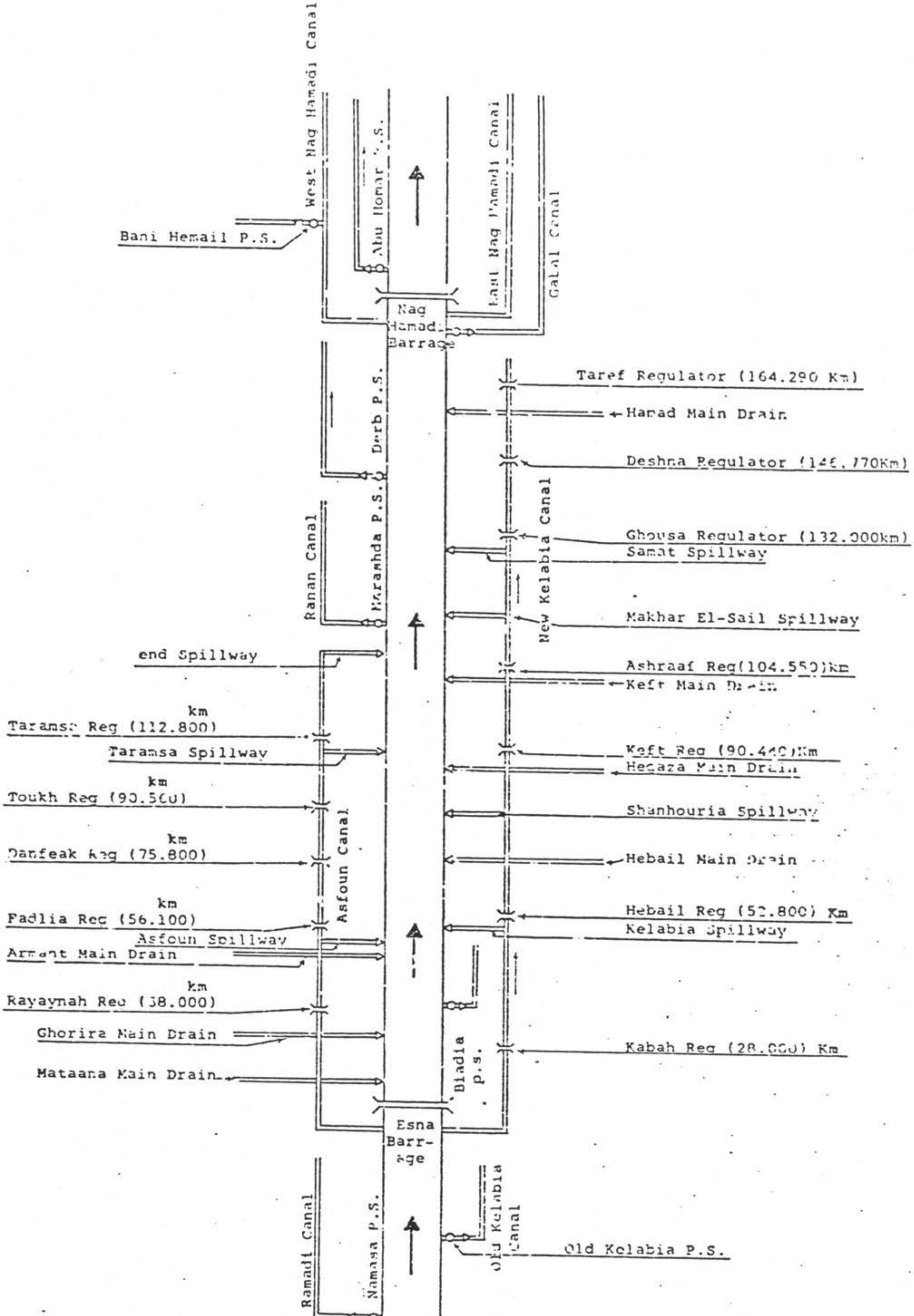


FIG (7)

A SCHEMATIC DIAGRAM SHOWING THE IRRIGATION SYSTEM IN THE REACH ESNA - NAG HAMMADI

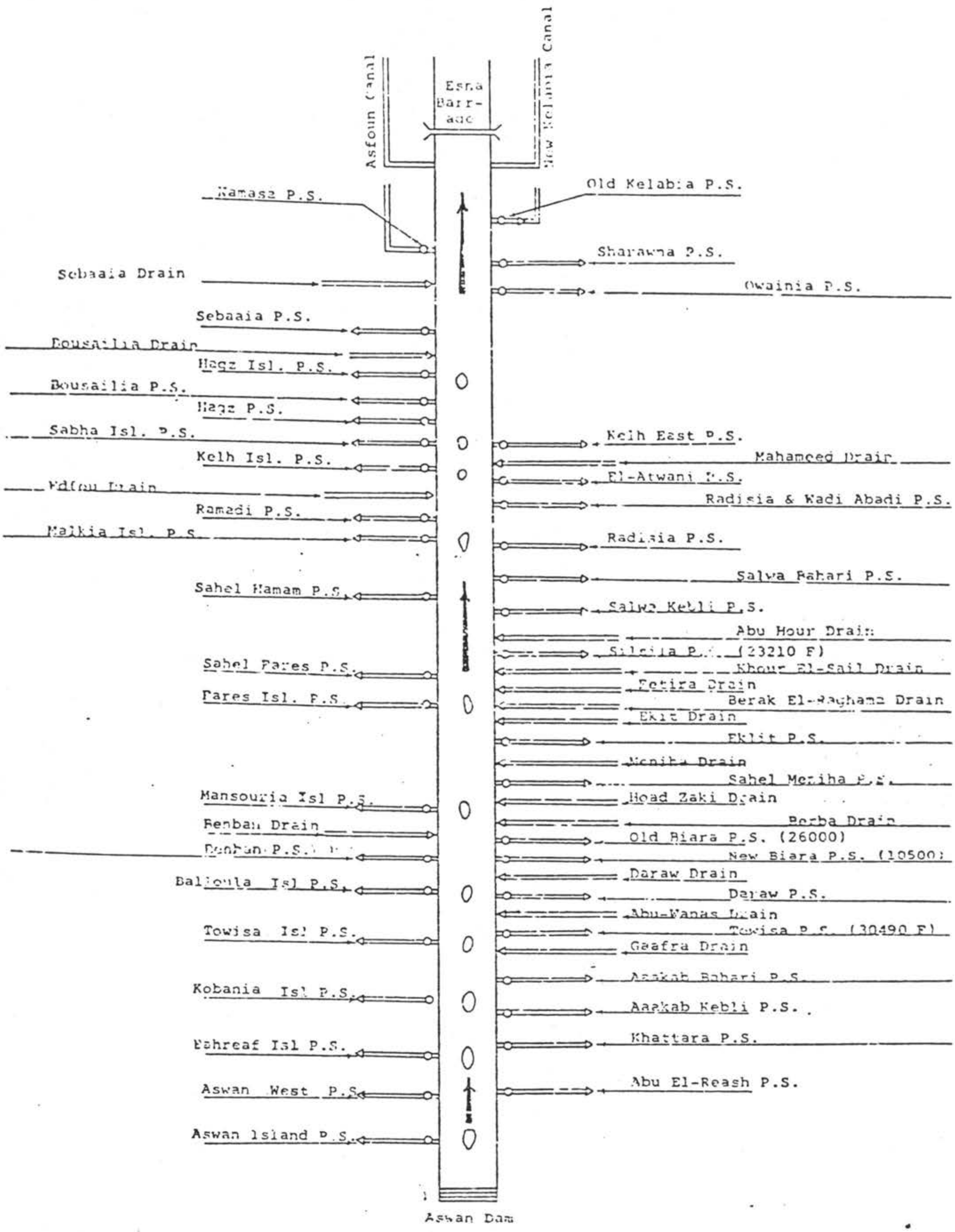


FIG (8)
A SCHEMATIC DIAGRAM FOR IRRIGATION SYSTEM
IN THE REACH ASWAN - ESNA

Note: Some of the Pump Stations in this reach were not shown on the schematic because of limited space

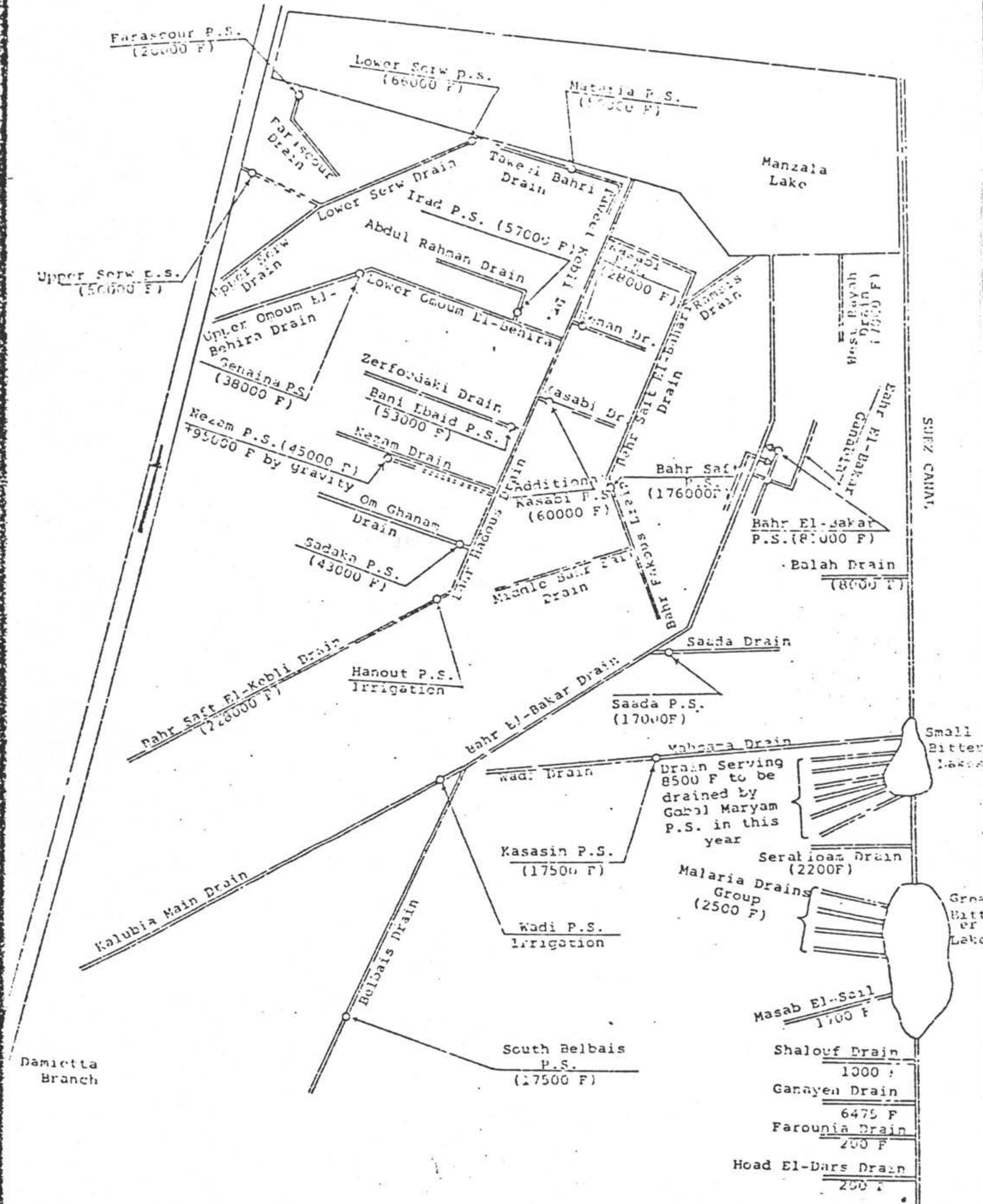


FIG (9)

A SCHEMATIC DIAGRAM SHOWING THE DRAINAGE SYSTEM IN THE EASTERN DELTA

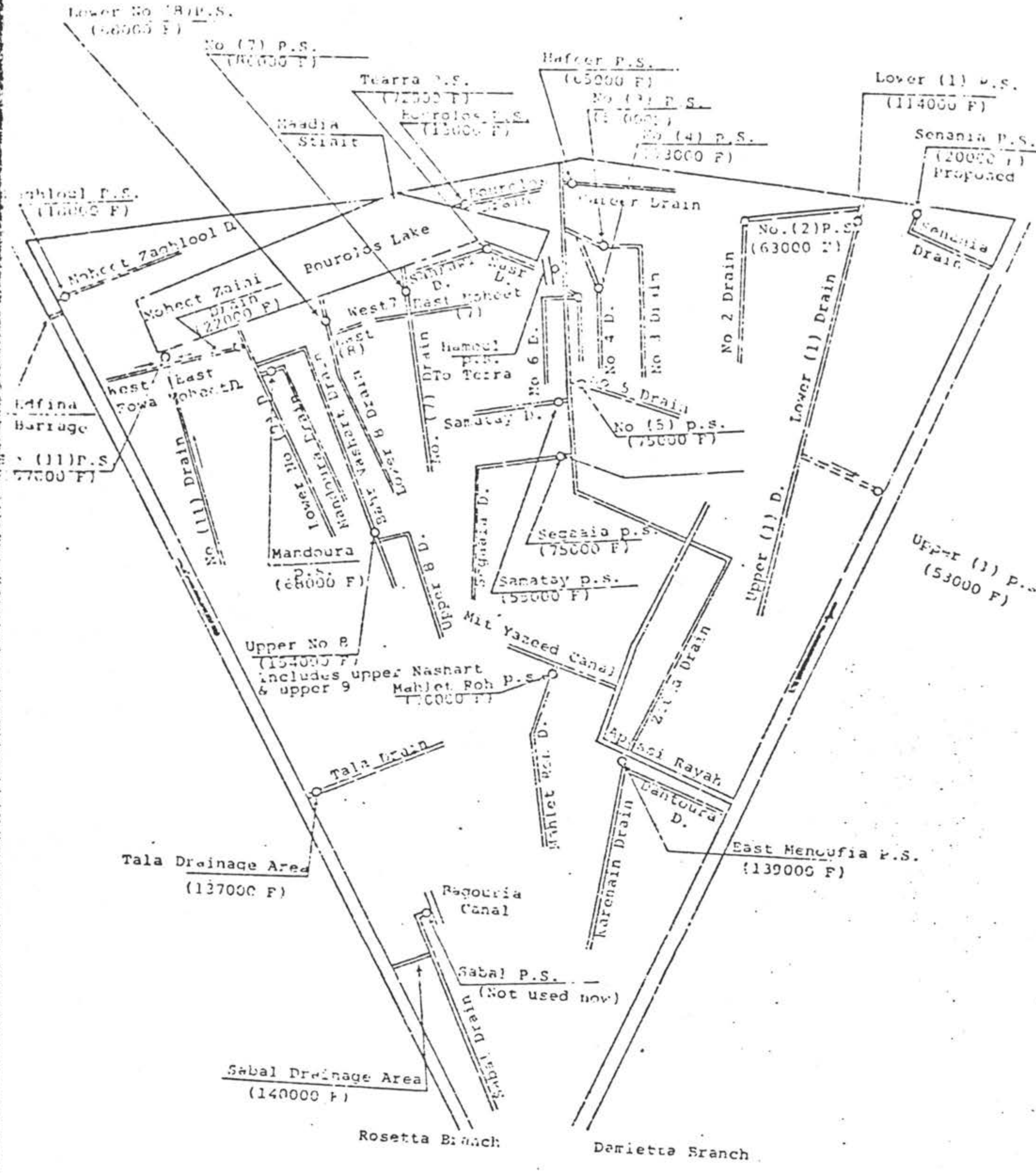


FIG (10)
A SCHEMATIC DIAGRAM SHOWING THE DRAINAGE SYSTEM
IN THE MIDDLE DELTA

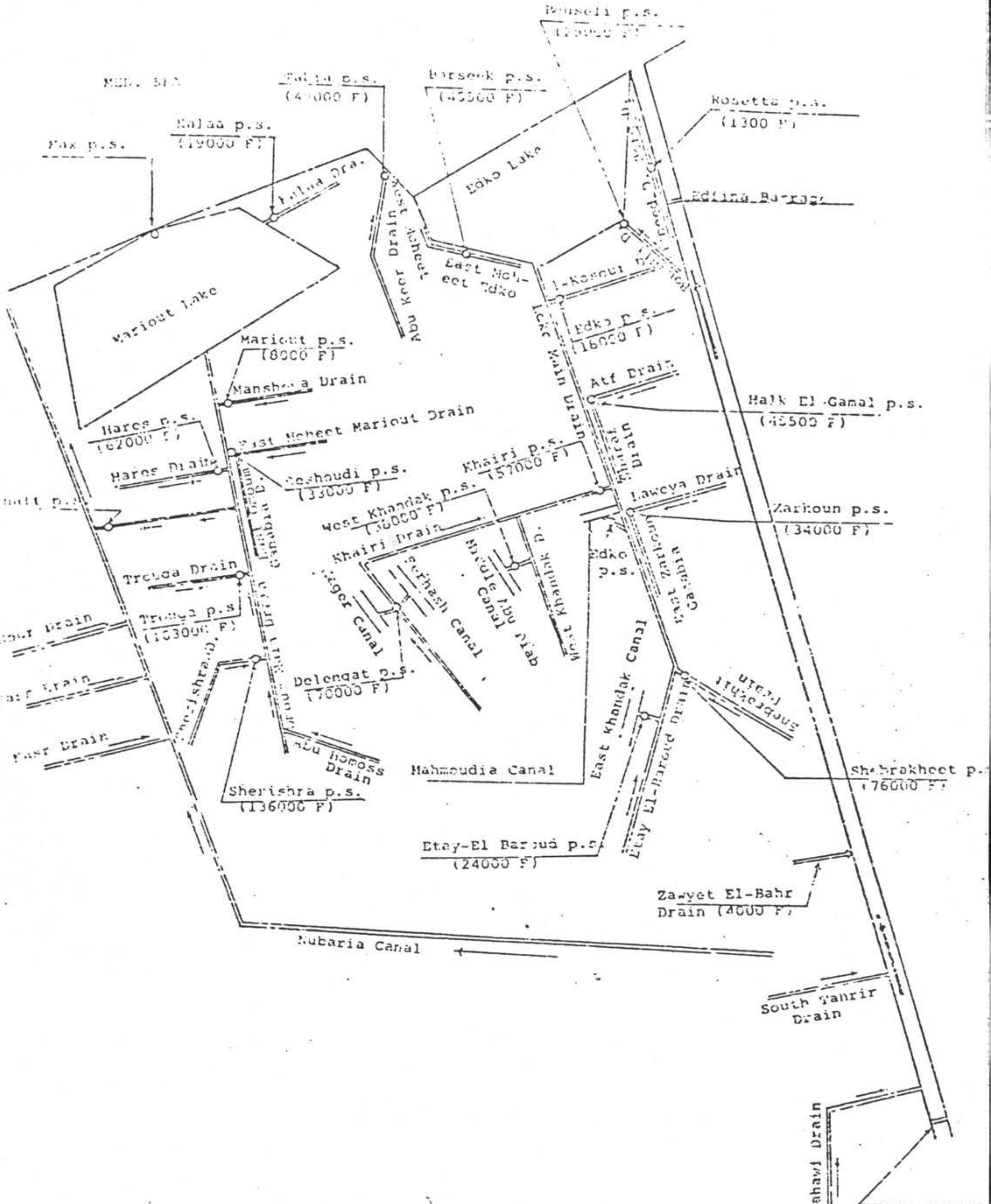


FIG (11)

A SHEMATIC DIAGRAM FOR THE DRAINAGE SYSTEM IN WESTERN DELTA

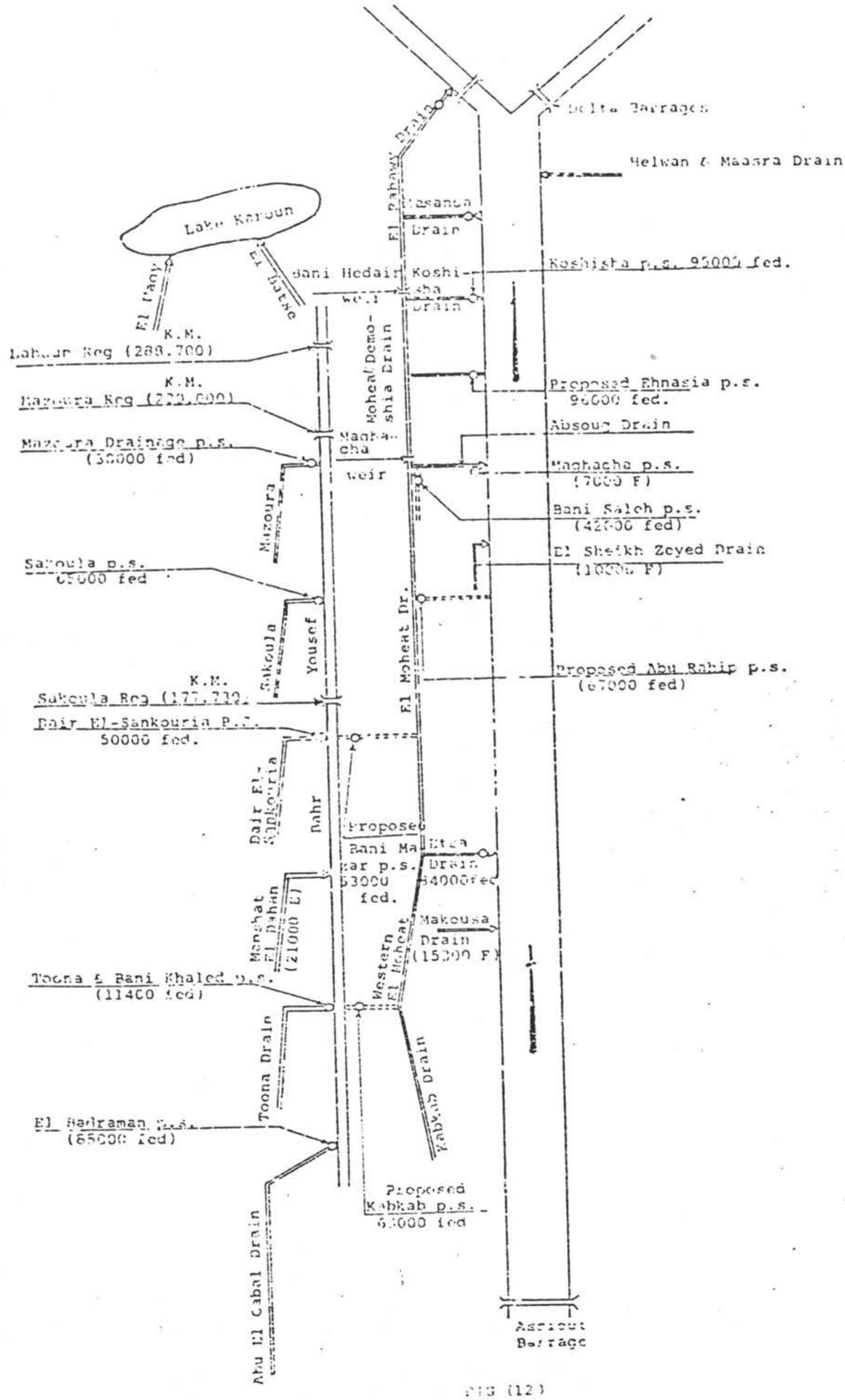


FIG (12)

A SCHEMATIC DIA[illegible] FOR THE DRAINAGE SYSTEM

[illegible] ASSIOUT-[illegible]

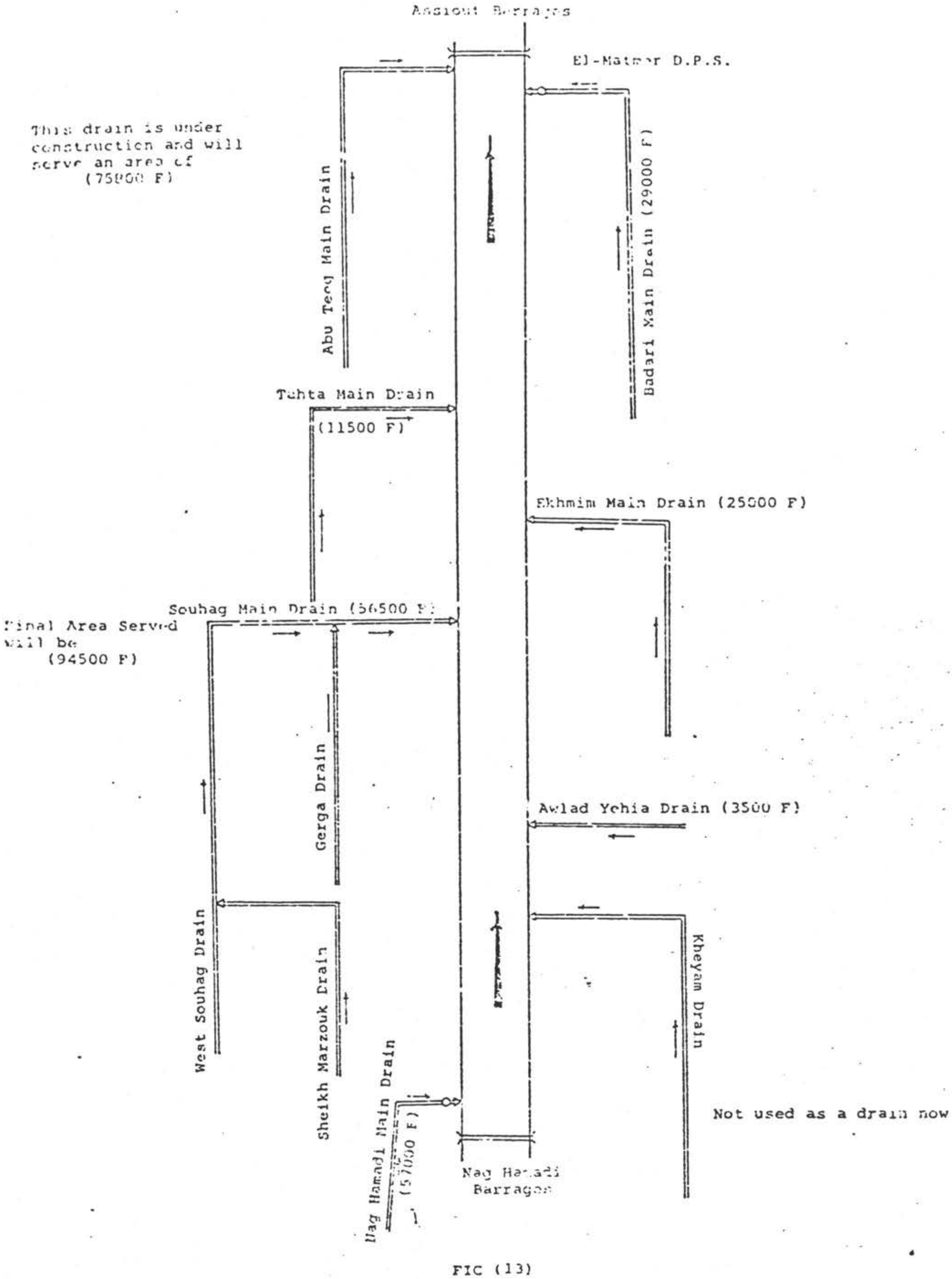
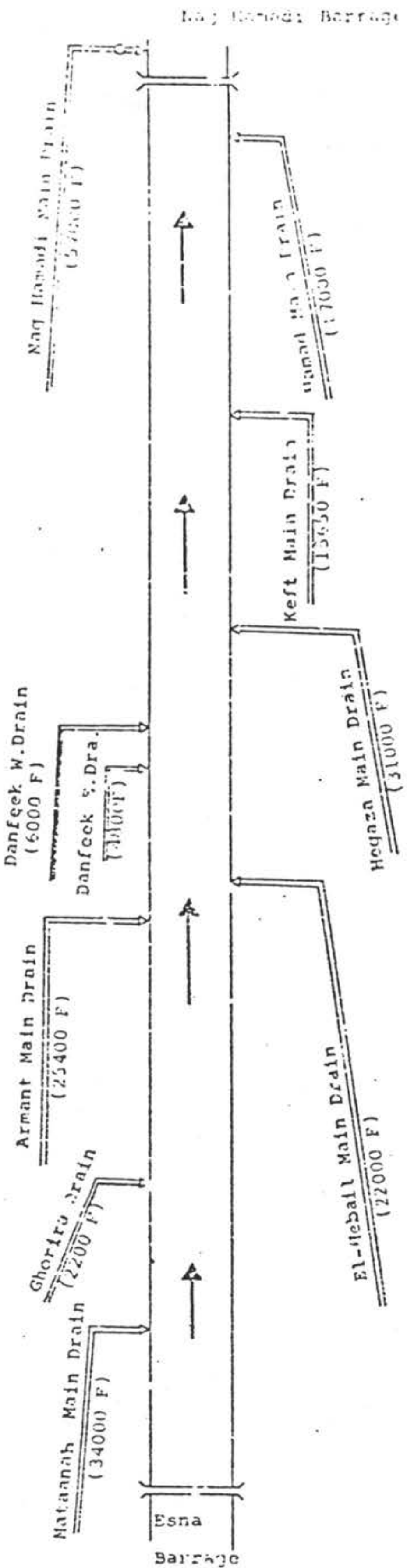


FIG (13)

A SHEMATIC DIAGRAM FOR THE DRAINAGE SYSTEM

IN THE REACH NAG HAMMADI - ASSIOUT

ALI SHOUSHA



(FIG (14)
A SCHEMATIC DIAGRAM FOR THE DRAINAGE SYSTEM
IN THE REACH ESNA - NAG HAMMADI

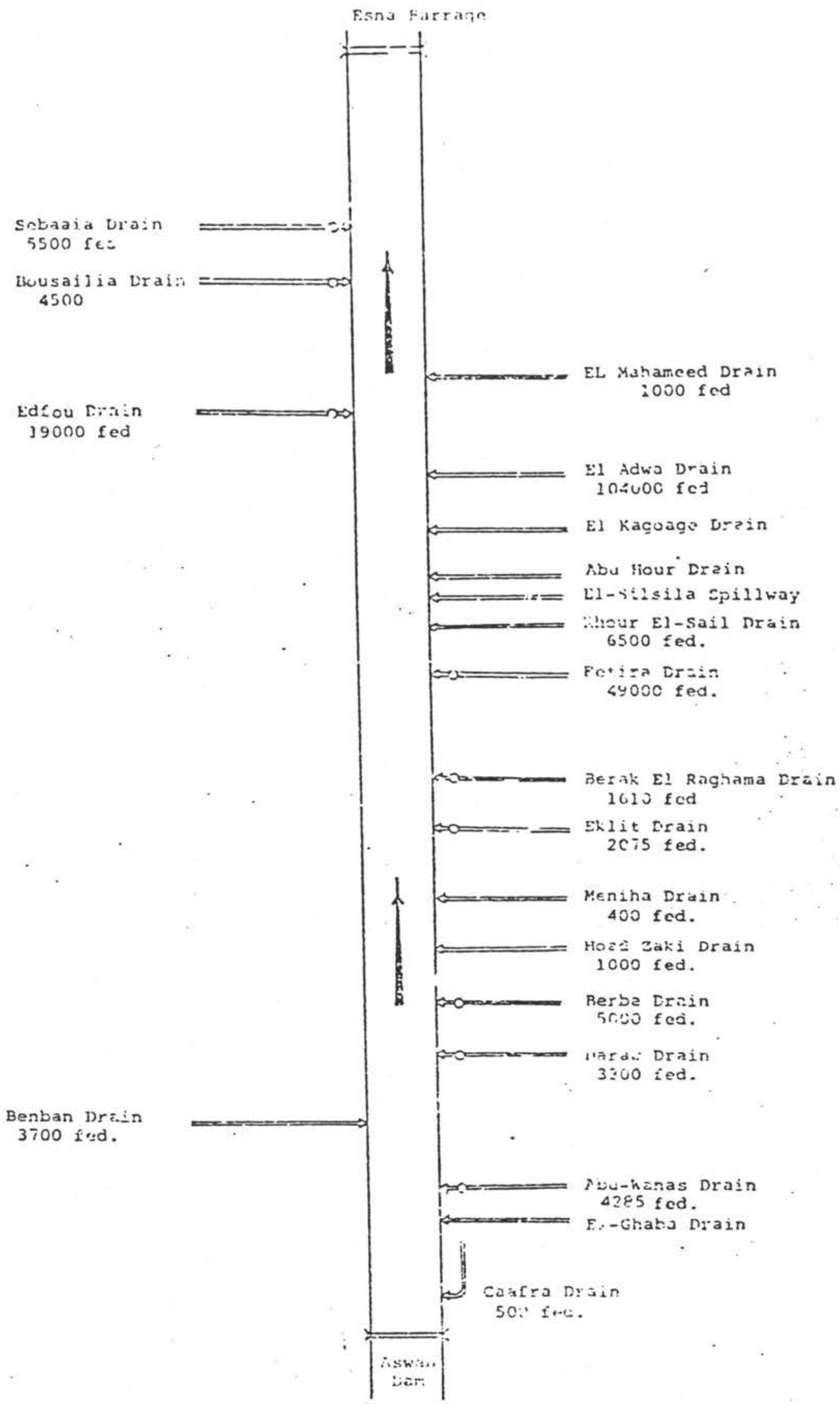


FIG (15)
A SCHEMATIC DIAGRAM FOR THE DRAINAGE SYSTEM
IN THE REACH ASWAN - ESNA

CHAPTER 2

SYSTEM INVENTORY

2.01 The inventory of the Irrigation and Drainage System is part of a larger data package to be described in Technical Report 6 " Project Information System ". That larger system was established to store and process data to serve three purposes :- the calibration and application of the Agro-Economic model, the calibration of the distribution model (and computation of command area balances), and the preparation of an inventory of the physical components of the irrigation and drainage system. Each of these files is referenced to a different set of geographical areas. The data in the socio-economic file were drawn from administrative districts which are the building blocks of the Governorates. The Canal data are filed according to 50 canal commands, 15 group canal commands, and 7 Nile reaches. The Drain file data are filed according to 152 drain command areas, 115 group commands, and 6 terminal components.

2.02 The geographic boundaries for these three files do not co-incide. All boundaries were mapped and planimetered, and coefficients were developed to record the extent to which areas overlapped each other. With such coefficients it is possible to compute what portion of which drain command and administrative district is in each canal command, what portions of specific canal commands and administrative districts are in each drain command, and what portion of specific canal commands and drain commands are in each Administrative District. In summary, regardless of for which of the three sets of geographic boundaries the information was obtained, it can be retrieved according to the other geographic boundaries.

2.03 The kinds of data stored for the Canal and Drain files are listed below.

Irrigation Canal file

- Canal command characteristics : including name, gross command area and description of the canal network.

- Canal group characteristics : including name, location downstream from Aswan and description of canals serving constituent command areas.

- Nile Reach characteristics : including name; length, average width, and historic 10-day discharges and water levels.

- Irrigation structures : function, hydraulic area, and construction type.

- Gravity discharge sites : location, source of supply, function, hydraulic characteristics, and historic 10-day discharges.

- Irrigation pump stations : location, source of supply function, physical and hydraulic characteristics, historic 10-day discharges and energy consumption.

- Crossing works : number and area of openings, length and type of construction.

- Net contribution identifiers : linkages required to identify works that move water into, or out of, canal commands or group commands.

Drainage Canal file

- Drain Command Characteristics : name, gross commanded area, and description of network of drains it contains.

- Drain Group Command Characteristics : name, location downstream from Aswan for return flow point. description of canals that serve its constituent drainage commands.

- Drainage structures : function, hydraulic area, construction type.

- Gravity Discharge sites : location, source of supply, function, hydraulic characteristics and historic data on 10-day discharge volumes.

- Drainage and Irrigation pump stations : location, source of supply, function, physical and hydraulic characteristics, historic date on 10-day discharge volumes and energy consumption.

- Return flow identifiers : linkages with canal file to identify discharge sites and pump stations that recycle water to the irrigation system.

2.04 At the time this Technical Report was prepared the data files were complete but the retrieval programs were not all developed. It was necessary to assemble manually the inventory data presented on the following pages (by reference to the data sheets used as input to the Project Information System). Recently, an IBM software package (GIS) has been installed in Cairo. It can be used to activate processing and retrievals from the system (including pre programmed formats for the output).

TABLE (1)

IRRIGATION CHANNELS

Order	Kms	Total Kms	Bed Widths (meters)				
			< 2	2-5	5-10	> 10	Nav. > 10
1	186.1 200.9 458.9 672.6 668.8	= 2187.2	186.1	200.9	458.9	678.9	668.8
2	1691.0 2856.0 1201.6 328.2 808.0		1691.0	2856.0	1201.6	328.2	808.0
3	3241.8 3961.7 779.7 279.8 148.7	= 8411.7	3241.8	3961.7	779.7	279.8	148.7
4	3200.5 3227.7 710.8 144.4 78.4	= 7361.8	3200.5	3227.7	710.8	710.8	78.4
5	1741.5 1465.5 344.6 46.8 38.1	= 3636.5	1741.5	1465.5	344.6	46.8	38.1
6	868.0 472.1 38.8 11.3 -	= 1390.2	868.0	472.1	38.8	11.3	-
7	217.3 202.3 17.3 - -	= 436.9	217.3	202.3	17.3	-	-
		30309.2	11146.2	12386.2	3551.7	1483.1	1742.0

TABLE (2)

DRAINAGE CHANNELS

Order	Kms.	Total Kms	Bed Widths (meters)				
			<2	2-5	5-10	>10	Nav >10
1	381.9		381.9				
	789.4			789.4			
	625.3				625.3		
	89.6					89.6	
	237.2	=2123.4					237.2
2	1376.8		1376.8				
	1706.7			1706.7			
	718.7				718.7		
	154.7					154.7	
	105.6	=4062.5					105.6
3	1880.3		1880.3				
	1990.1			1990.1			
	589.6				589.6		
						141.9	
	-	=4601.9					-
4	1587.6		1587.6				
	1353.0			1353.0			
	292.9				292.9		
	142.3					142.3	
	-	=3375.8					-
5	1258.6		1258.6				
	651.5			651.5			
	152.9				152.9		
	47.7					47.7	
	-	=2110.7					-
6	653.3		653.3				
	206.1			206.1			
	28.6				28.6		
	2.8					2.8	
	-	= 890.8					-
7	281.4		281.4				
	50.4			50.4			
	-				-		
	-					-	
	-	= 331.[illegible]					-
		17497.0	7419.9	6747.3	2408.0	579.0	342.8

TABLE 3

Characteristics of
Irrigation Structures

Number of Structures by Function, Hydraulic Area and Type of Construction

Type	Hydraulic Area less than 3 sq.m					Hydraulic Area 3 to 6 sq.m					Hydraulic Area 6 to 12 sq.m					Hydraulic Area 12 to 24 sq.m					Hydraulic Area greater than 24 sq.m				
	Construction					Construction					Construction					Construction					Construction				
	RC	M	P	S	T	RC	M	P	S	T	RC	M	P	S	T	RC	M	P	S	T	RC	M	P	S	T
INTAKE REG.	747	1759	1481	—	—	536	420	47	—	—	225	172	18	—	—	79	45	6	—	—	57	31	1	—	—
HEAD REG.	257	582	516	—	—	139	240	32	—	—	116	96	19	—	—	72	57	2	—	—	77	33	—	—	—
WEIRS	9	46	10	—	—	15	17	—	—	—	6	19	—	—	—	2	16	—	—	—	15	7	—	—	—
TAIL ESCAPE	73	48	1616	—	—	3	9	4	—	—	2	2	—	—	—	2	—	—	—	—	2	—	—	—	—
SPILLWAY	3	2	126	—	—	2	2	—	—	—	2	2	—	—	—	2	1	—	—	—	6	5	—	—	—
BRIDGES	580	673	1569	8	212	1848	266	21	5	306	1775	129	8	5	352	1017	71	15	1	108	847	23	4	25	79
CROSSING WORKS	22	—	478	—	—	8	—	44	1	—	2	—	3	—	—	7	—	1	—	—	1	—	—	—	—

Notes : RC = Reinforced concrete M = Masonry P = Pipe S = Steel T = Timber

TABLE 4

Characteristics Of

Drainage Structures

Number of Structures by Function, Hydraulic Area and Type of Construction

TYPE	Hydraulic Area less than 3 sq.m					Hydraulic Area 3 to 6 sq.m					Hydraulic Area 6 to 12 sq.m					Hydraulic Area 12 to 24 sq.m					Hydraulic Area greater than 24 sq.m				
	Construction					Construction					Contruction					Contruction					Contruction				
	RC	M	P	S	T	RC	M	P	S	T	RC	M	P	S	T	RC	M	P	S	T	RC	M	P	S	T
OUTLETS	103	577	897	—	—	133	127	12	—	—	175	44	2	—	—	81	14	3	—	—	21	10	—	—	—
WEIRS	—	40	—	—	—	—	2	—	—	—	—	1	—	—	—	—	3	—	—	—	2	—	—	—	—
BRIDGES	1061	1019	1231	6	262	1044	357	4	5	200	1167	139	—	2	134	714	44	6	3	71	244	2	—	6	55
CROSSING WORKS	3	—	132	—	—	4	—	95	—	—	7	—	—	99	—	13	—	248	—	—	5	—	202	—	—

CHAPTER 3

COST OF WATER IN THE SYSTEM

3.01 A reliable estimate of the average economic cost of water in the nation's distribution system is truly important because it would help decision makers to determine where to allocate water and where not to. Uses which would yield an economic return to water superior to its cost would generally command priority over proposed allocations where the cost of water would be superior to anticipated returns.

3.02 The annual cost of water is the sum of the annual cost of operating the entire irrigation /drainage system, the annual cost of maintaining it, and the annual equivalent of all necessary capital investment replacements over a given period of time. Detailed numbers on actual budget expenditure are available, hence estimating operation and maintenance costs poses no serious problems. Difficulty arises in that these values are, of course, financial ones and not economic Electric energy is an important element in operating the system and one where the market rate is markedly different from the true economic value (about LE 0.007 vs LE 0.042). Therefore, in the following paragraphs, whenever possible the economic price of electrical energy is used; the other cost items cannot as yet be adjusted.

3.03 Estimating the annual equivalent cost of all capital investments in the system is more complicated. It amounts to estimating the cost of future replacements in the system, discounting these to a 1980, or present, value and then amortizing this value over the expected useful life of that replacement. In order to do this in a systematic manner, all major structures and pieces of equipment in the system were grouped in 2-way tables, that is according to the length of useful life and the estimated year of replacement.

3.04 The replacement and annual equivalent costs of different categories of structures are estimated in the following paragraphs.1/ These are grouped under the following headings; Nile barrages, large regulators, major structures, irrigation structures, drainage structures and irrigation/drainage pump-stations. In the final paragraphs, operation and maintenance costs will be added in order to arrive at the overall costs.2/

3.05 Nile barrages. Of the 7 main barrages, 3 are scheduled to be replaced in this century and the others 60-75 years from now as shown in Table (5). For the purpose of estimating the average cost of water in the system, only Esna, Nag Hammadi and Assiout barrages need to be considered.

1/ The Aswan Dam complex has not been included here.

2/ All data and assumptions used here are provided by the Ministry of Irrigation.

TABLE (5)

Annual equivalent cost for replacing Nile Barrages

Barrage	Date Completed	Date Previous Remodelling	Date Now Remodelling	Replacement date	1978 Cost replacement 1/	1980 Cost replacement 2/	Annual equiv.Co 4/
					mill L.E.	mill L.E.	mill L.E
Esna	1908	1948	Gates 1958	1980 - 1985	90	121.5	10.1
Nag Hammadi	1930	---	—	2000	90	121.5	1.8
Assiout	1902	1938	—	1995	90	121.5	2.9
Rosetta	1939	—	—	2039	80	To be replaced in the next century	
Damietta	1939	—	—	2039	75		
Edfina	1950	—	—	2050	70		
Zifta	1902	1954	—	2055	75		
						Sub- total of annual equiv. Cost	14.8
						Steel parts 3/	0.5
						Total	15.3

1) Original estimates in 1978 prices.
2) adjusted for 1980, adding 35% for price increases from 1978.
3) at 10% of total replacement cost, useful life of 25 years.
4) discount rate 10% P.a.

TABLE (6)

Replacement Dates & Cost of Large Regulators

Regulator	Date Completed.	Date Provious Remodelling	Date New Remodeing	Replacement Date	1973 Cost Replace-ment L.E.
sphoun Head Work	1947			2074	4 million
olabia " "	1947			2074	4 "
ast Nag Hammadi Head Work	1930			2030	4 "
est " " " "	1930			2030	4 "
l Ebrahimia Head Work	1870	1902	1955	2050	14 "
ayah El Behiry Head Work	1939			2039	14 "
l Massery Head Work	1939			2039	4 "
l Menoufi " "	1890	1909		2010	14 "
l Tawfiki " "	1889	1938	1956	2050	14 "
l Sharkawiya Head Work	1888	1960		2050	14 "
irout Group	1868			2040	14 "
l Abbasy " "	1890	1970		2070	14 "
ahr Yoursef " "	1868	1962		2070	14 "
l Mahmoudia " "	1834	1965		2070	14 "

3.06 Large regulators. None of the 14 large regulators shown in Table (6) is scheduled to be replaced in this century; all replacement is scheduled to take place during a period ranging between 30 to 95 years from now. Hence for purpose of estimating the average cost of water in the system, the large regulators need not be considered.

Irrigation structures

3.07 Based on the system inventory, and the estimated unit replacements costs (1980 prices) per meter square of hydraulic area, an estimate of the aggregate 1980 replacement cost of the entire group of structures can be prepared.

3.08 Useful lives of these irrigation structures were estimated as indicated in table (7) is also assumed that the structures are now-in the average - at one half of their useful life and that, in view of the large number of structures involved, the average annual cost of replacement will be identical in every year.
Table (7) gives annual replacement cost for irrigation structures

Drainage structures

3.09 Based on the system inventory, and the estimated unit replacement costs (1980 prices) per meter square of hydraulic area, an estimate of the aggregate 1980 replacement cost of

TABLE (7)

Annual Replacement Cost For Irrigation Structures

Type of Structure	Hydraulic Area M^2					Unit cost of Replacement	Total Cost		
	R.C.	M.	P.	S.	T.		RC.+M+P	S.	T.
						L.E./M^2	L.E. mill	L.E. mill	L.E. mill
ntake Regulators	9405	8880	3479	—	—	3000	65.29	—	—
ead Regulators	6472	5322	1383	—	—	2500	32.94	—	—
eirs	1039	879	20	—	—	1500	2.91	—	—
ail Escapes	285	154	3250	—	—	1500	5.54	—	—
pillways	285	229	252	—	—	1500	1.15	—	—
ridges	47265	5810	3718	1001	9757	2500	209.48	2.50	24.39
rossing Works	250	—	482	3	—	5000	3.67	0.02	—
Total							320.93	2.52	24.39
seful life	50	50	50	30	15				
nnual Replacement cost L.E. Million							12.84	0.17	3.25
Total							16.26		

TABLE (8)

Annual Replacement Cost For Drainage Structures

Type of Structure	Hydraulic Area M^2					Unit cost of Replacement	Total Cost		
	R.C.	M.	P.	S.	T.		RC.+M+P	S.	T.
						L.E./M^2	L.E.mill	L.E.mill	L.E.mill
…lets	4593	2733	1920	—	—	2500	23.12	—	—
…ins	72	152	—	—	—	1500	0.34	—	—
…idges	42559	5729	2538	322	5888	2500	127.27	0.81	14.72
…ossing Works	197	—	701	—	—	5000	4.48	—	—
Total							155.21	0.81	14.72
…seful life	50	50	50	20	15				
…nnual Replacement cost L.E. Million							6.21	0.05	1.96
Total							8.22		

the entire group of structures can be prepared.

3.10 Useful lives of these drainage structures were estimated as indicated in table (8). It is also assumed, as in the foregoing paragraphs that the structures are now-in the average at one half of their useful life and that the average annual cost of replacements will be identical in every year.

Irrigation and drainage pumpstations

3.11 The MOI estimates the total replacement cost of all irrigation and drainage pump stations for the period 1952-2000 at about LE 120 million (1978 prices), corresponding to about LE 162 million at 1980 prices. Accounting for the fact that about 40% of this represents replacement works which ought to have taken place before 1980 but which have been deferred to the period beyond 1980, the annual replacement costs may be estimated as follows;

- ordinary annual replacement costs	4.86
- additional deferred annual replacement costs	LE 3.24
	LE 8.10

Operation and Maintenance Costs

3.12 Administratively these expenditures fall broadly into three categories, those of the Irrigation Department and those of the Electrical and Mechanical, in addition to the actual expenditure of operating and maintaning the High Aswan Dam and

Old Aswan Dam. The first includes the actual expenditure in both chapters I & II of the annual budget. The second includes all expenditures necessary for the operation and maintenance of the nation's irrigation and drainage pump stations.

Operation & Maintenance
Costs L.E. Million

Irrigation Department:	1979 Expenditure	Adjusted for 1980 1/
Chapter I (Salaries & Wages)	12.03	13.83
Chapter II (Current expenditure)	22.07	25.38
sub-total L.E. million	34.10	39.21
Electrical & Mech. Dept.	**1978 Expenditure**	**Adjusted for 1980 2/**
Materials & Indispensables	5.51	7.44
Wages, Operation.	5.56	7.51
Wages, maintenance	1.06	1.43
Spares	0.32	0.43
Maintenance Materials	0.18	0.24
Sub-total L.E Million	12.63	17.05
Aswan Dam Authority:-	**1979 Expenditure**	**Adjusted for 1980 1/**
Chapter I	1.31	1.51
Chapter II	0.62	0.71
Sub-total L.E. million	1.95	2.22
All Operation & Maint Costs		58.48

1/ 15% inflation

2/ 35% inflation

The price differential in 1980 between the financial and economic prices of electric energy is about LE 0.035/kWh. Estimated energy consumption for 1980 is 635 x 10^6 kWh. This means that the "materials indispensables" line in the above table would have to be increased by LE 22.22 if energy were costed at its economic price.

Estimated Total Annual Costs of System
(LE million, 1980 values)

	LE million
1. Capital goods	
Nile Barrages	15.30
Large regulators	—
Irrigation structures	16.26
Drainage "	8.22
Irrigation & drainage pumps	8.10
Sub-total	47.88
2. Operation & Maintenance	58.48
GRAND TOTAL	106.36
3. Energy cost adjustment	22.22
GRAND TOTAL	128.58

Conclusion:

The Egyptian share of the Nile waters being 55.5 X $10^9 m^3$, it follows from the above calculations that the average cost of water in the system can be estimated as follows:

- energy costed at financial price; LE 1.92/1000 m^3
- " " " economic cost[1/]: LE 2.32/1000 m^3

1/ adjusting energy cost only; all other cost items still equal to the financial ones.

CHAPTER 4

RECOMMENDED MEASUREMENT PROGRAMS

4.01 The most important and critically needed program is the one for measurement. Flows released from the High and Old Aswan Dams are distributed to the agricultural lands and other users in a complex system of canals and drains. Growing requirements for water have been served up till now by the system, but further increases will require a very high standard of operation and management. It is accepted that an important step in achieving that goal is to introduce a better standard of accuracy in measuring water deliveries in the canal system and return flows from the drains.
For the purposes of water management, water distribution system is divided into Irrigation Directorates and further sub-divided into command areas. The inflow to a command area can be computed using water level data above and below regulating structures and rating curves previously developed.

4.02 Most of the rating curves and other calibrating diagrams were developed many years ago. Now they may be inaccurate due to silt deposition or erosion in the channels above and below the structures, wear and tear on the structures themselves or even structural modifications. So, it is very important to improve on the accuracy of future flow computations by checking the previously developed curves in addition to calibration of new sites. Introducing new procedures and modern equipments that are best suited to each site will be the ideal solution.

4.03 An assessment of " Critical Measurement Needs " has been made by the Master Water Plan staff to allow for a better estimation of :-

1- the loss and gain in the seven Nile reaches to allow for a better control of the amounts of water to be released from Aswan Dam all the year round to match with the actual requirements. Table (9) gives the number of recommended measurement points for such study.

2- an improved water distribution between Irrigation Directorates enabling the Ministry of Irrigation to compute the inflow to each directorate accurately. Table (10) summarizes the number of needed measurement points for such case.

3- the national water balance by having more accurate figures for outflows to the sea and lakes. Table (11) indicates the number of recommended measurement locations for national water balance studies. The total balance of the recommended program gives 286 locations needing immediate implementation. Recently, current meters have been provided by MWP to the Ministry of Irrigation field staff and arrangements have been made for the Hydraulic Research Institute to train staff in the calibration of flow regulating structures, and the installation and operation of water level recorders. This training will facilitate implementation of this urgent and critically needed program for calibrating or checking main irrigation and drainage structures.

TABLE (9)

NUMBER OF RECOMMENDED MEASUREMENT POINTS TO ALLOW FOR ESTIMATION OF LOSS & GAIN IN THE NILE

Nile Reach	Pump Stations			Intake Regulators	Gravity Feeders	Spillways	Gravity Drainage outfalls	Nile Barrage	Total
	Irrigation	Drainage	Total						
Main Nile									
Aswan - Esna.	59	2	61	2	—	1	14	1	79
Esna- Nag Hamadi.	4	-	4	2	—	7	9	1	23
Nag Hamadi - Assiout	1	-	1	1	—	4	9	1	15
Assiout - Delta.									
. Middle Egypt	16	2	18	-		9	6	-	33
. U.S. Delta Barr.	2	-	2	9	—	-	-	2	13
Damietta Branch									
Delta - Zifta									
. East Delta	-	-	-	2	1	-	-	1	4
. Middle Delta	-	-	-	3	-	-	-		3
Zifta - Farascour.									
. East Delta	2	1	3	1	2	1	-	-	7
Middle Delta	2	1	3	1	2	-	-	-	6
Rosetta Branch									
Delta - Edfina									
. Middle Delta	2	-	2	2	4	1	2	-	11
. West Delta	3	-	3	2	4	3	3	-	15
Total	91	6	97	25	13	26	42	6	209

TABLE (10)

Number of Recommended Measurement Points For Water

DISTRIBUTION BETWEEN DIRECTORATES

Region	Pump Stations	Intake Regulators	Head Regulators	Total
Upper Egypt	1	–	3	4
Middle Egypt	–	3	5	8
Eastern Delta	–	3	2	5
Middle Delta	–	8	6	14
Western Delta	–	1	2	3
Total	1	15	18	34

TABLE (11)

Number of Recommended Measurement Points for National Water Balance Studies

Region	Pump. Stations	Spill Ways	Gravity Drainage outfalls	Nile Barrage	Total
Eastern Delta:					
• To Med. Sea & Northern Lakes	3	1	4	–	8
• To Red Sea & Eastern Lakes	1	–	11	—	12
Middle Delta	9	1	2	1	13
Western Delta	6	2	2		10
Total	19	4	19	1	43

CHAPTER 5

A MATHEMATICAL SIMULATION MODEL OF THE IRRIGATION DISTRIBUTION SYSTEM

IN EGYPT

Introduction

5.01 Systems engineering analysis offers a great variety of techniques for water resources planning. These include simulation, linear, nonlinear and dynamic programming and have all been used with varying degrees of success in deriving optimum development strategies for water resources development or utilization. The major complexities of even relatively small water resources systems have restricted the utility of the analytical approach techniques. While not necessarily the most suitable in all cases. the simulation approach does have the advantage that it is a single logical step forward from traditional methods. It requires no great mathematical skills, and it is versatile in the sense that it may be adapted to a wide range of problems at various levels of complexity depending on both the aims of the study and the quality of the available data.

5.02 As part of the activities of the UNDP/UNTOC project EGY/73/023 - Assistance to the Hydraulic and Sediment Research Institute, a mathematical model of the irrigation distribution system has been developed by Mr. James Nemec, consulted to the above mentioned project.

5.03 His report outlined the methodology used in the model and described the data required and the assumptions to be made in its development.

5.04 This chapter of the report does not intend to give a detailed description of the simulation model, but rather to give a general outline of it, with the necessary warnings and limitations of its use in real applications.

Major Objectives of the Model

5.05 The major objectives of the model, as has been stated by Nemec, is : to provide the ability to determine rapidly, before the start of the irrigation season, the irrigation requirements for all the Nile basin below Aswan, within the constraints imposed by land characteristics, water control structures, water delivery and irrigation system and other operating procedures; to allow multi-purpose planning of this system on a 5-day incremental basis; and to assists in the day-to-day operation of the system.

5.06 Unfortunately, the present version of the model does not fulfil the predescribed objectives, however a significant programming effort (and cost) had been invested in the development of this real-time operational model.

General Outline

5.07 The mathematical model of the irrigation distribution system as designed by Nemec is structured to constitute the basic elements of :

1- A demand sub-model that estimates the irrigation water requirements of an area given its cropping pattern, crop calendar, and climatological characteristics, and,

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1/ Nemec's main report was published as Working Document of the EGY/73/023 project entitled "A Mathematical Model of the Irrigation Distribution System in Egypt"

2- A distribution sub-model that sums these requirements through a node-and-branch network representation of the water distribution system to yield the accumulated demand at various upstream locations.

5.08 The model is modular in design, as illustrated in Figures 16 and 17. Any part of it can be modified without interfering with the overall design of the model. The major programming effort in developing the package was in the development of the basic file handling routines in the demand sub-model which is far more sophisticated than the distribution sub-model.

5.09 Major parameters of the model such as efficiencies, leaching requirements of canal seepage losses can be defined individually for each unit areas or each canal section. In order to simplify the input to the model, a standard value is defined for each of these parameters - generally named by default value - and specific values need be given only when they differ from this standard value.

5.10 No optimization process is built into the model. However, given a series of different sets of conditions, the results will indicate the best solution of those considered, will lead the user in the right direction and assist him to find an optimum one by additional runs of the model.

Major Concepts of the Model

5.11 The major concepts used and developed in the model are defined as follows :

- Climatic region

  An area whose climatic conditions are defined by a unique set of climatic variables. In general it represents the area for which the data collected at a given meteorological station can be considered valid, in particular the model requires the input or the computation of potential evapotranspiration in each of the defined climatic regions. Since crop characteristics may vary with different climatic conditions, in particular their cropping calendar, they can be defined individually for any of the climatic regions or generally for all regions where no specific characteristics are defined.

- Command Area

  A cultivated area for which a specific crop pattern can be defined and fed by a unique irrigation canal at a given point of its course. This can be the total area served by a canal from a given regulator, or a portion thereof according to some administrative boundary, the area served by a major drain, or other considerations. It can also be the total area served by a group of pumps that can be considered lumped together in one single point of the system.

  The command area is the unit for which the irrigation demand is computed as a whole and whose influence on the system is then computed upstream of its application node.

- Node Numbering System

  A node is any point of the system at which the flow of water is defined (Figure 18). A regulator serving a command area is conceptualized as a node, the point of water withdrawal for municipal and industrial use is also a node, as well as any barrage at which the resultant demand is to be computed. Agricultural, municipal or industrial flows, can be considered as separate nodes. Return flows are treated as negative demands.

  Every node is assigned a unique five-digit identification.

The numbering system is devised on the basis of dividing the River Valley into seven reaches. Each reach is bounded by two major barrages. The first digit to the left specifies the reach. The second digit to the left specifies the type of node, whether water is withdrawn or returned by the gravity or pumping. The third and fourth digits specify the group command area, and the last digit specifies the individual command areas. All the nodes to the right bank of the river will take an even number, while all nodes to the left bank will take an odd number. The attached Tables 12 and 13 represent the node numbers of the canal group command, which is defined as the the area served by a first order off-take from the Nile and made up of one or more command areas.

- Return Flow Node

  A node at which the return flows of a command area or the return flows associated with municipal and industrial demands are returning into the system. Return flows are treated as negative demand.

- Crop Pattern

  A list of the net cropped area for each crop grown in a command area. A crop pattern is input to the demand sub-model, and is defined with two parallel arrays containing the crop numbers and the corresponding area respectively.

- Period

  The time increment of the model (Period) is defined as one sixth of a month or 5 days. Thus a calendar year contains 72 periods.

- Model Duration

  The model is set up to simulate one year of operations for the agricultural demand as well as the distribution models.

Distribution Model Elements

5.12 The elements on which the distribution model are based can be defined as follows (see Figure 19).

- Geometry
  a- Upstream node number
  b- Downstream node number
  c- Canal section between two nodes defined with its time lag and loss factor
  d- Up to 15 previously simulated canal sections taking their water from the elements upstream node.
- Demands defined at the elements upstream node :
  a- Agricultural demand
  b- Municipal demand
  c- Industrial demand.
- Return Flows defined at the elements upstream node :
  a- Agricultural return flows
  b- Municipal return flows
  c- Industrial return flows.

Data Required for the Model

5.13 The agricultural demand model requires basically three types of data.

a- Climatic data to evaluate the potential evapotranspiration in every climatic region.
b- Crop characteristics and cropping calendar for every crop planted in the areas under consideration.
c- Crop pattern (net areas under cultivation) and other parameters for each of the command areas condidered.

5.14 The distribution model requires at least the following five types of data.

a- The results of the agricultural demand model of the agricultural demand at every command area.

b- Municipal water demands, and their point of application.

c- Industrial water demands, and their point of application.

d- Canal characteristics for every canal section including time-lags and losses factor.

e- A description of ih geometry of the system with canal sections representing the link between two nodes logically and sequentially defined from downstream to upstream.

Files Description

5.15 The files used by the model can be divided into two categories. There are ten primary input files and two files containing intermediate and final results. Table 14 lists these 12 files with their names as used by the model. The model is set up so that the files used as input by a program can actually be loaded by any other program.

5.16 Another list of programs used for handling these files and carrying on the different computations are shown in Table 15.

Present Status of the Model

5.17 The Master Water Plan project inherited the partially documented set of computer programs that had been developed under the former UNDP/UNTOC project(EGY/73/023) .

5.18 At that time there was no fully tested and documented program package, there were no follow-up plans for obtaining the required data inputs, and work had hardly started on preparation for model calibration. Moreover there was not even a general acceptance within the Ministry of Irrigation of some major concepts used in its formulation, (e.g. consumptive use based estimates of diversion requirements). A significant part of the total programming effort had been spent in developing a module to compute these estimates, yet the results obtained show great discrepancies when comparing with those obtained on experimental basis. These discrepancies probably resulted from the methods used in computing the potential evapotranspiration (ET_o) using one of the known theoretical methods (such as Penman) without the necessary calibration of its constants and parameters. However, accepted values of consumptive use can be loaded directly into one of the model files and can be used, thereafter, by the other programs of the model.

5.19 It should be noted also that the available programs do not constitute a true flow routing model. It takes no account of level or discharge capacity constraints, and effects within channels or in the pools above barrages are not included.

5.20 Given the complexity of the Egyptian irrigation and drainage system, and the major data gathering effort required to support any serious attempt to calibrate the model, it was decided by the MWP to defer calibration until the project information system was operational.

5.21 Now that the data are available in the project information system, the calibration of the model can begin. From the work already done by the MWP, it is known that calibration will not be a small task. Before beginning, it would be advisable to make an estimate of the time, manpower, and computer costs that would be needed for calibration. Nevertheless, it is recommended that the [illegible] gave this task high priority during the bridging project.

TABLE 12

Node Numbering System

(Five - digit identification)

- To identify the reach downstream a dam or main barrage on the River Nile :-
  1. D.S. Aswan
  2. D.S. Esna B.
  3. D.S. Nag Hammadi B.
  4. D.S. Assuit B.
  5. D.S. Delta B. (Rosetta)
  6. D.S. Delta B. (Damietta)
  7. D.S. Zifta B.

- Type of Node

  Extractions

  0. By gravity to Agric.
  1. By pumping to Agric.
  2. By gravity to M + I
  3. By pumping to M + I
  4. ------------------

  Return flows

  5. By gravity from Agric.
  6. By gravity from M + I
  8. By pumping from M + I
  9. ---------------- ---

- [illegible] 1st order

- Command [illegible] order [illegible]

TABLE 13

LIST OF NODE NUMBERS

REACH 1

D.S. ASWAN DAM	10000
PUMP STATIONS D.S. ASWAN (27)	11020
OLD KALLABIA P.S.	11040
KALLABIA C.	10060
KAMASA P.S.	11010
ASFON C.	10030
D.S. ESNA B.	20000

REACH 2

BAYADIYA P.S.	21020
KHEYAM P.S.	21040
EAST NAG HAMMADI C.	20060
MARASHDA P.S.	21010
DERB P.S.	21030
WEST NAG HAMMADI V.	20050
D.S. NAG HAMMADI B.	30000

REACH 3

ABU HIMMAR P.S.	31010
EBRAHIMIA C.	30020

REACH 4

GABAL P.S.	41020
TEL EL AMARNA P.S.	41060
DAIR ABU HINESS P.S.	41040
SAWAD P.S.	41080
KHARFAHI P.S.	41100
GEBEL EL TAIR P.S.	41120
SHEIKH FADEL P.S.	41140
SHAROUNA ISLAND P.S.	41160
SHARAHNA P.S.	41180
BYAD EL ARAB P.S.	41200
BANI SOLIMAN P.S.	41220

REACH 4 (cont.)

BENI SALEH P.S.	41240
KORIMAT ISL.	41260
DAIR EL MAYMOUN P.S.	41280
EL KORIMAT P.S.	41300
ELLEITHY P.S.	41320
BOLIAKIA P.S.	41340
ISMAILIA C.	40040
SHARKAWIA C.	40060
ABU EL MENAGA P.S.	41360
BASOUSSIA C.	40100
TAWFIKI R.	40120
DAHAWA C.	40050
MENOUFI R.	40220
NAGAYEL C.	40440
NASSIRI R.	40010

REACH 7

BAHR EL SASDI	50020
FOWA P.S.	51040
KHALIG EL KEN F.	50060
SHAMSHIRA F.	50080
EAST RASHIDIA C.	50120
NEW ATF P.S. (MAHMOUDIA)	51010
OLD ATF P.S.	50030
HALK EL-GAMMAL F.	50050
MENSHAWEIA & FARANSAWEYA C.	50070
NASSER CANAL	50090
EL ESSLAH C.	50110
FAZAR G.F.	50130
DEBI G.F.	50150

TABLE 14

FILES DESCRIPTION

Number	File Name	Contents
11	IDN - MONTHLY	Monthly data by month
12	IDN - CROPS	Crop characteristics by crop & by climatic region
13	IDN - AREAS	Cropping pattern by command areas
14	IDN - CANALS	Canals properties by section
15	IDN - PERIOD	72 period values for ETO-Rainfall and G. Water
21	IDN - AGRO	Agricultural demands by command areas
22	IDN - MUN	Municipal demands
23	IDN - IND	Industrial demands
26	IDN - AGRF	Agricultural return flow
27	IDN - MUNRF	Municipal return flow
28	IDN - INDRF	Industrial return flow
31	IDN - NODS	Complete results of current run, demands at every node of the system.

TABLE 15

PROGRAM DESCRIPTION

1- Agricultural Demand Sub-Model

Program	Function
CF 11	Creates File 11
IF 11	Loads monthly data in File 11
CF 15	Creates File 15
IF 15	Computes and loads period values in File 15
IF 12	Loads crop characteristics in File 12
CF 13	Creates File 13
IF 13	Computes and loads crop pattern in File 13
OT 11	Lists contents of File 11
OT 13	Print-out a summary of selected crop patterns from File 13
CF 21	Creates File 21
PENC	Computes potential Evapotranspiration by Penman combination method.
CAID	Computes agricultural demands for all command areas

2- Distribution Sub-Model

Program	Function
CF 14	Creates File 14
IF	Load canal characteristics in File 14
CF 22	Create Files 22, 23, 26. 27, 28
CF 23	
CF 26	
CF 27	
CF 28	
IF 20	Loads monthly data of industrial and municipal demands and also agricultural, municipal and industrial return flows
CF 31	Creates File 31
CDD	Computes diversion requirements
OT 31	Prints selected results of diversion requirements from File 31

FIG 16

SCHEMATIC DIAGRAM OF THE AGRICULTURAL DEMAND MODEL

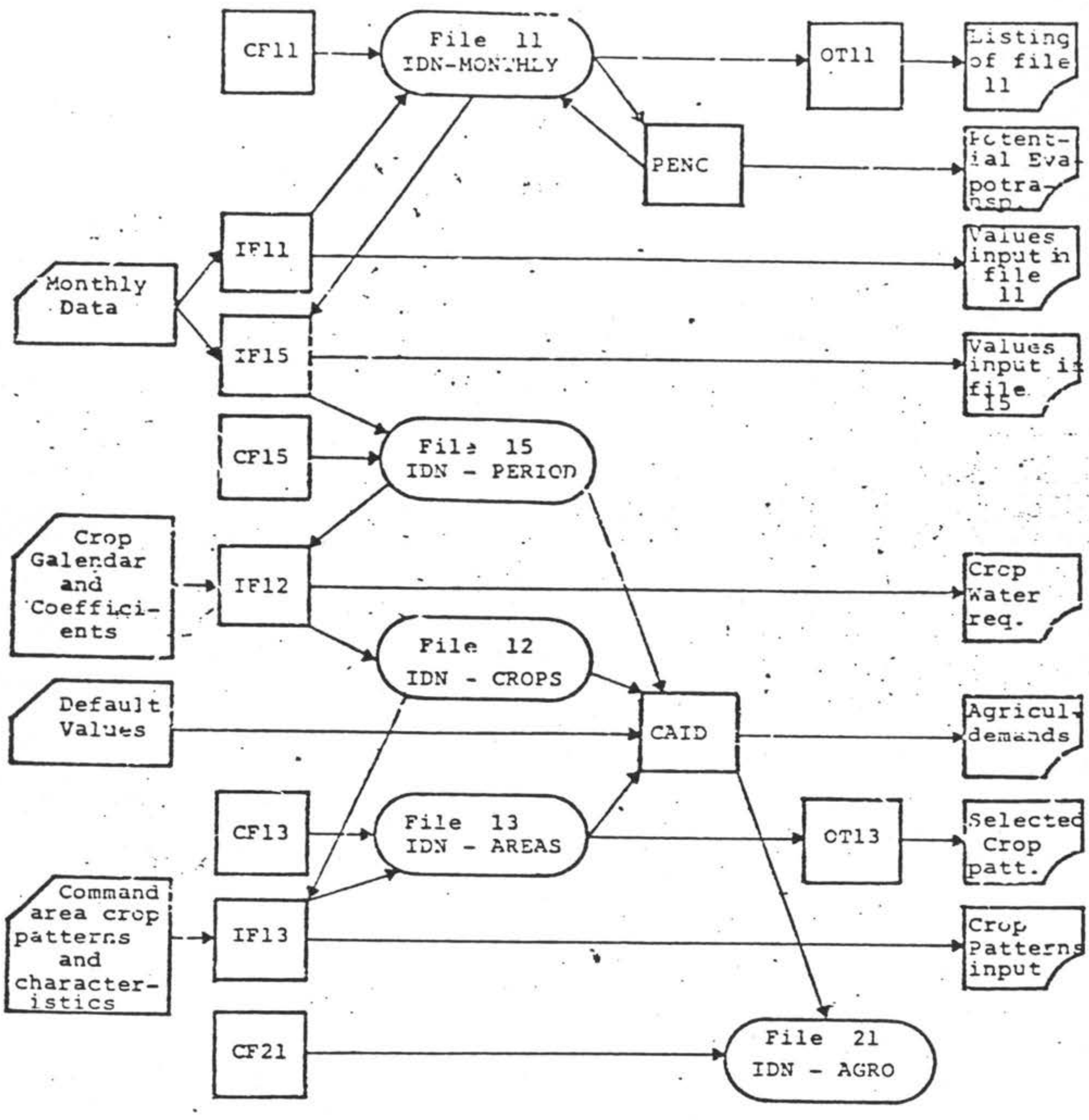


FIG 17

SCHEMATIC DIAGRAM OF THE DISTRIBUTION MODEL

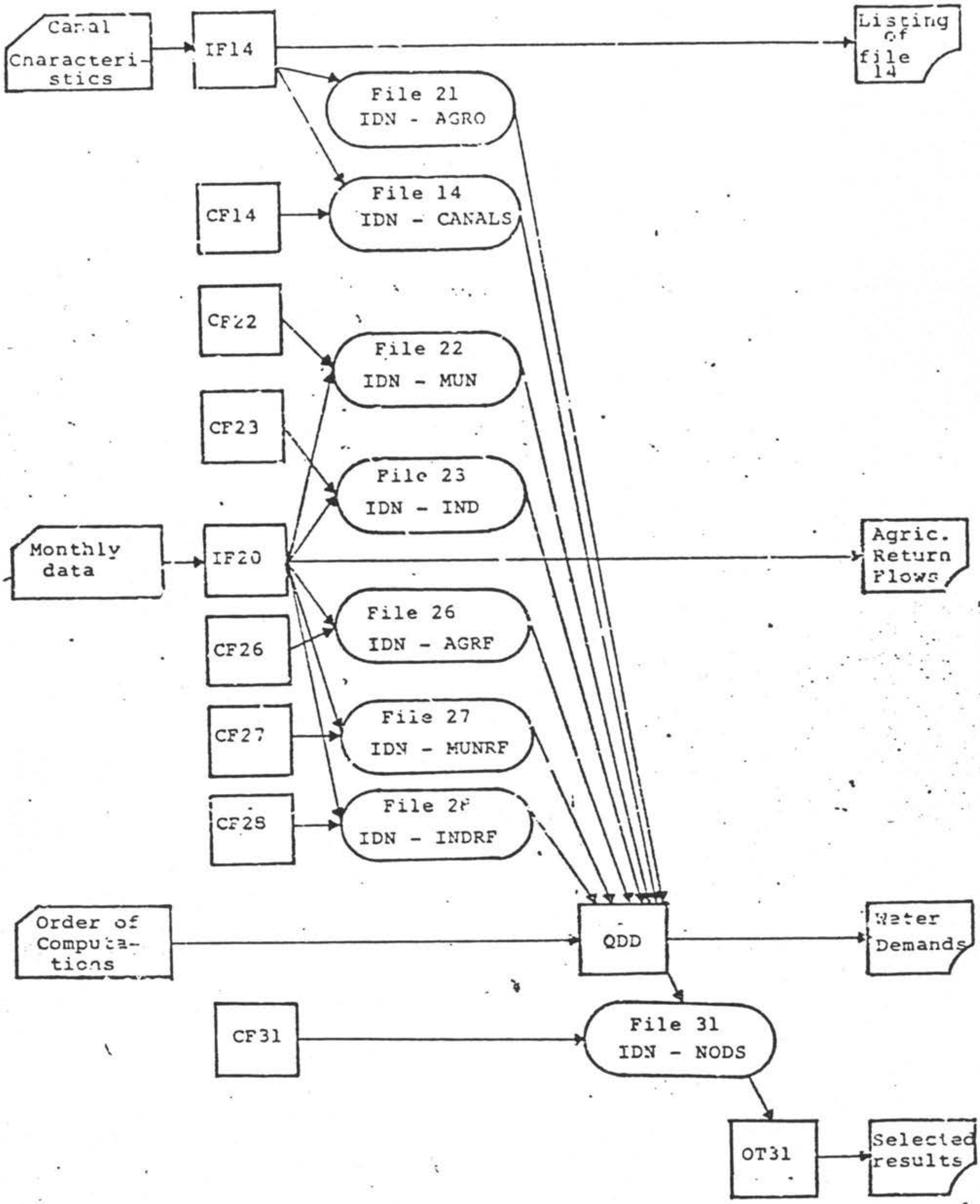


FIG 18

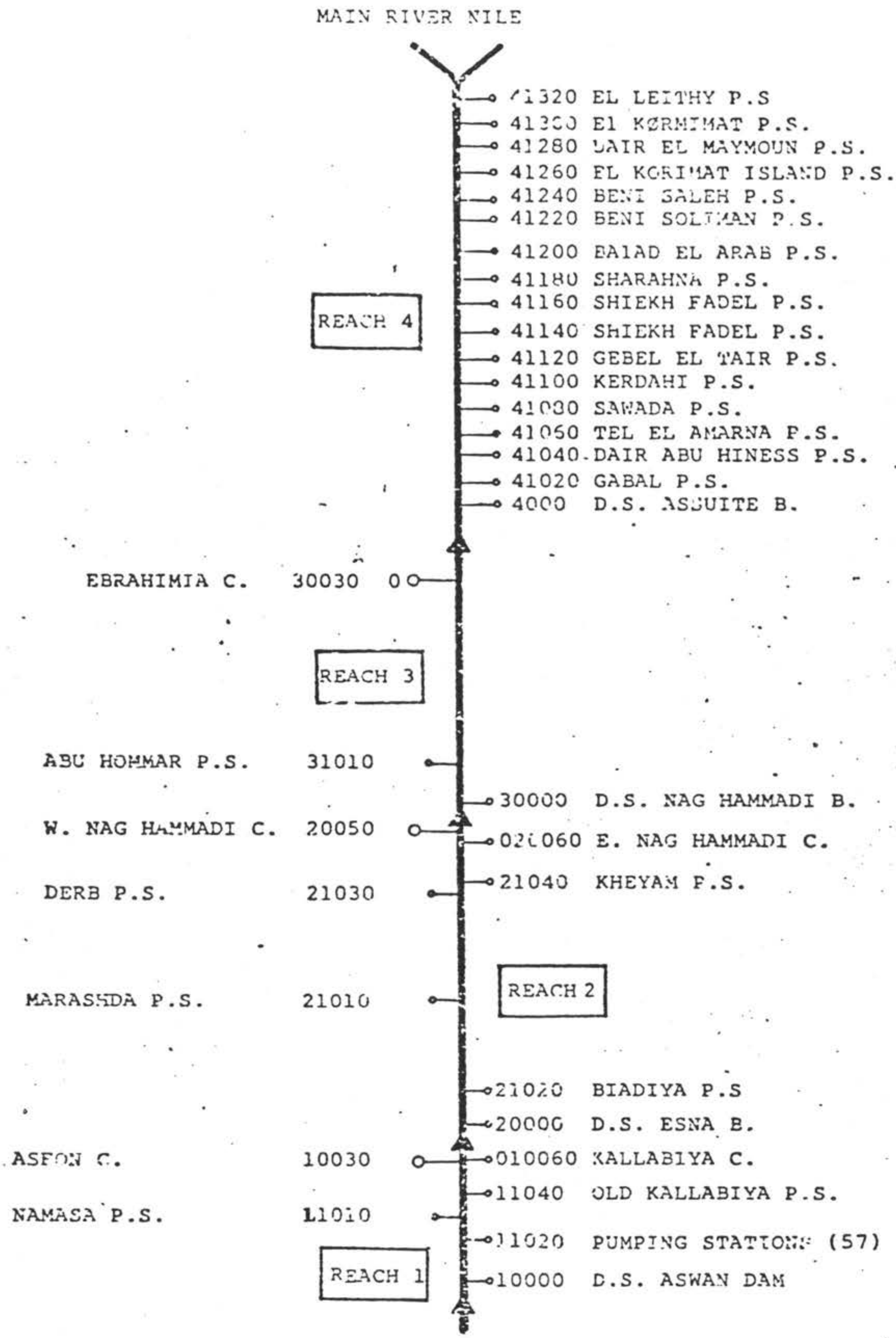
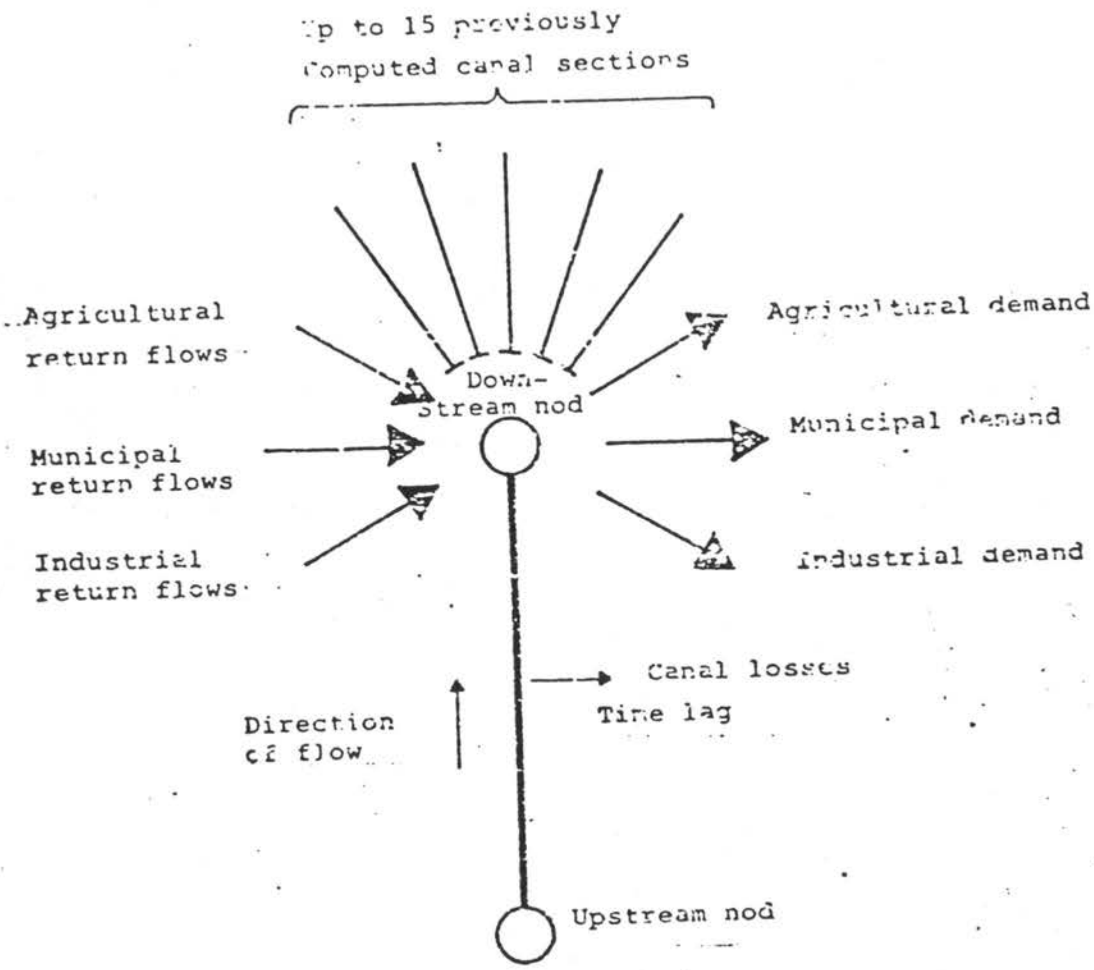

MAIN RIVER NILE
41320 EL LEITHY P.S
41300 El KØRMIMAT P.S.
41280 DAIR EL MAYMOUN P.S.
41260 EL KORIMAT ISLAND P.S.
41240 BENI SALEH P.S.
41220 BENI SOLIMAN P.S.
41200 BALAD EL ARAB P.S.
41180 SHARAHNA P.S.
41160 SHIEKH FADEL P.S.
41140 SHIEKH FADEL P.S.
41120 GEBEL EL TAIR P.S.
41100 KERDAHI P.S.
41080 SAWADA P.S.
41060 TEL EL AMARNA P.S.
41040 DAIR ABU HINESS P.S.
41020 GABAL P.S.
4000 D.S. ASSUITE B.
REACH 4
EBRAHIMIA C. 30030 0
REACH 3
ABU HOMMAR P.S. 31010
30000 D.S. NAG HAMMADI B.
W. NAG HAMMADI C. 20050
020060 E. NAG HAMMADI C.
DERB P.S. 21030
21040 KHEYAM P.S.
MARASHDA P.S. 21010
REACH 2
21020 BIADIYA P.S
20000 D.S. ESNA B.
ASFON C. 10030
010060 KALLABIYA C.
11040 OLD KALLABIYA P.S.
NAMASA P.S. 11010
11020 PUMPING STATIONS (57)
REACH 1
10000 D.S. ASWAN DAM

FIG 3?



Distribution Model

Diagram of an element