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Egyptian policies for using low quality water for irrigation

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In many countries of the world, the problem of providing adequate water supplies has become a very critical issue as the demand for water increases in direct proportion to the explosive increase of population and the rapid development of industry. The gradual raise in the standard of living over the last decades has resulted in ever higher demands for water. To meet these tremendous and intensive needs worldwide, elaborate policies for maximizing the benefit to be obtained from every drop of water should be established.

The Egyptian economy depends to a great extent on agriculture, a condition which will continue for many years to come. About half of Egypt's population is involved in one way or another in agriculture, most of which is private business.

The River Nile water, being controlled by the High Dam at Aswan, is limited by the 1959 agreement between Egypt and Sudan. Egypt's share is 55.5 billion m^3 annually. The long-term storage in the Dam reservoir ensures this quota.

Looking to the future of water demands, whether for drinking purposes, industrial development or agricultural expansion, it is quite obvious that a very careful use of the available water resources (both surface and groundwater) is a must. Meanwhile, a strategy for the proper management and development of these resources should be urgently considered by the responsible authorities.

Because the irrigation efficiency in Egypt resulting from today's conventional irrigation methods is rather low, the Egyptian government has initiated two development programs to be implemented in parallel with each other. The first aims at improving irrigation efficiencies and introducing modern irrigation techniques, and the second concerns the use of agricultural drainage water directly or after mixing with fresh water.

This paper presents an overview of the water resources in Egypt and their current and future multi-use applications. It also deals with agricultural drainage water, both quantitatively and qualitatively, and with the plans of the Ministry of Public Works and Water Resources for using it and the constraints to be considered. Additionally, the major projects underway or proposed by the Ministry for the use of such low-quality water and its impact on plants and soil will be discussed.

I - Egypt's water resources and the importance of using drainage water

A close look at the High Aswan Dam since its operation in 1970 demonstrates that it has protected the country from the hazards of drought by providing adequate water supplies from the stored reserves of high-flow years. Perhaps the most threatening of these crises was the series of catastrophes that occured in Africa starting in 1979 and that is still continuing.

With such increasing need for water requirements for purposes of vertical and horizontal agricultural expansion, and with the scarcity of new water resources, the Ministry of Public Works and Water Resources has, in the past few years, thoroughly considered the issue of using drainage water which has now become an important item in water policy.

Reviewing the present and future water resources and their applications in different aspects, it is evident that the solution is not only restricted to overcoming the problem of low-flow years, but is is necessary to make best use of all possible water resources.

Since drainage water is part of the water balance, a clear correlation should be established between water management practices, irrigation development techniques and the quantity and quality of such drainage water.

Until now, a considerable amount of unused irrigation water flows to the drains running through canal tail-escapes. The reason for this is that the irrigation network was originally designed to operate 24 hours daily, yet most of the farmers have abandoned night irrigation. This is a social phenomenon that has necessitated intensive recent studies. Naturally, this phenomenon has led to the increase of drainage water and decrease of salt concentration.

There is a direct relation between irrigation methods and efficiency and excess water discharged to the drains or stored in the soil profile. Studies conducted by the Ministry of Public Works and Water Resources have shown that the proportion of drainage and irrigation water ranges generally between 46% and 54%. The average total drainage water escaping annually to the sea or lakes amounts to nearly 14 billion m^3.

Table 1 shows contributions from different parts of the Delta and Fayoum. Drainage water in the Upper Egypt is discharged back to the Nile.

The Ministry of Public Works and Water Resources has defined the present and future available water resources in its 1984 policy. However, this policy has been modified in the light of the consequences resulting from the low-flow years since 1979. The water resources by the end of the five-year plan of 1991/1992 and until the year 2000 have thus become as given in **Table 2**.

Water uses, excluding horizontal agricultural expansion, are as given in **Table 3**.

The balance between resources and uses can be allocated for land reclamation and horizontal expansion which is decided to be at a rate of 150,000 acres annually during the present five-year plan, increasing to a total new area of 2.3 million acres by the year 2000.

Field practices supported by experimental work have indicated that utilization of drainage water in irrigation of newly reclaimed saline soils improved soil permeability. It penetrates the soil easier than fresh water does and consequently has a greater leaching effect.

In the Nile Delta, an area of about one million acres now depends completely on drainage water for irrigation. Examples are areas served by water from Bahr El-Bakar, El-Gharbiya, El-Raisi, Hadous, Edku and El-Omoum main drains. Some pumping stations have been constructed on main drains in Lower Egypt where drainage water is lifted to be mixed with canal water.

The total drainage water utilized in irrigation purposes in Lower Egypt is now about 3.5 billion m^3 annually. As for Upper Egypt, the amount of drainage water returning to the Nile is estimated to be about 2.3 billion m^3 annually. However, these discharges did not lead to any noticeable increase in the concentration of total soluble salts (TSS) in the River Nile due to the dilution effect. Studies on the chemical composition of the Nile water have indicated that the concentration of TSS in Lower Egypt amounts to 250 ppm with only a slight difference from that of Upper Egypt, which ranges from 180 to 200 ppm.

II - Quantity and quality of drainage water

A measurement program for the quantity and quality of drainage water was established in 1979 by the Drainage Research Institute (DRI) of the Water Research Center. The objective of this program is to assess the potential of using drainage water for agriculture. Moreover, the recorded measurements may also be used for a simulation model to predict drainage water quantity under different irrigation management schemes.

The measurement program covers the Delta region and El-Fayoum. Measurements are usually carried out every two weeks at 117 locations as shown **Figure 1**.

1. Discharge measurements

Discharge measurements are carried out by the velocity-area method. In the 1979-1982 period, the flow velocity was usually measured with floats as well as pendulum, being easier than using currentmeters. At present, however, extensive efforts in establishing stage-discharge relationships via the currentmeter (rating curve) for each measurement location are being made. Automatic water level recorders have been installed for continuous recording. From the rating curves and readings of the recorders, accurate estimates of the drainage water discharge are provided.

For improving the accuracy of the past measurements, a data checking program was established to check the reliability of the previous discharge measurements, distinguishing and correcting the measurements of low accuracy.

Discharges at pumping stations in prevoius stages of the program were determined by multiplying the operating hours of each unit by its capacity as indicated on the unit. The accuracy of these calculations is not adequate.

To improve the accuracy of discharge measurements at pumping stations, time counters were installed for recording the operating hours of each pumping unit. Calibrations of pumping stations were carried out to determine the actual capacity of each unit for various lifting heads. Automatic water level recorders were installed for continuous reading of the water levels at both suction and delivery sides.

Drainage water discharges at the outfalls of drains are affected by backwater curves. In such a case, the discharge-stage relationship is not accurate, therefore a velocity-discharge relationship is adopted. All drainage measurements are being stored on the computer at DRI forming a data base for drainage water.

2. Water quality measurements

Data on water quality is being collected every two weeks from the different measurement locations. The electrical conductivity of drainage water is measured in the field by means of the EC meter mainly as a check. Collected water samples from measurement locations are analyzed at the DRI laboratory according to established and well known procedures.

The principal characteristics used to determine the quality of water for irrigation are:

- concentration of total soluble salts;

- sodium concentration and its proportion to calcium plus magnesium and bicarbonate content;

- concentration of boron or other toxic substances, other ions such as chloride or nitrate that may have an effect on particular crops or soils.

The quality of drainage water determines whether the water can be used directly or only after being mixed with fresh irrigation water, or not at all.

Recently, biological analysis of drainage water has been added to the program.

Analysis of collected data since 1977 indicates the following:

- about 80% of the drainage water discharged into the sea had a salinity below 2,000 ppm;

- actual concentrations vary between 400 and 00 ppm;

- highest salt concentrations were found in the western part of the Delta and locally in the eastern part, mainly due to soil salinity. The lowest figures were encountered in the central part;

- salinity of the drainage water rises from the southern to the northern part of the Delta, which is due to variation in soil texture as well as sea water intrusion. It is noticeable that the salinity of most drains south of contour 8 does not exceed 1,000 ppm, while that between contours 3 and 8 (mid Delta) reaches 1,500 ppm. In northern Delta areas, it may exceed 3,000 ppm (Bahr El-Bakar in eastern Delta 5,000 ppm; El-Max in eastern Delta 8,000 ppm);

- the quality of drainage water varies from one month to the other throughout the year at every location. Concentrations reach maximum value in

January and February due to the closure period when irrigation releases are at least a minimum, and during the months of June, July and August (peak water requirement period) when evaporation and evapotranspiration are at the maximum. Such concentrations are at a minimum during March, April and May due to weather conditions and flooding of rice areas. **Figure 2** shows a typical salinity curve for a drain;

– the quality of the drain water in Fayoum is relatively good.

Average water quantity and quality data for the 1980-1986 period is given in **Table 4**. **Figure 3** (A, B, C) shows the 1986 drainage water salinity of the Nile Delta.

The general criteria used by the Ministry of Public Works and Water Resources for the use of drainage water are as follows:

– less than 700 ppm: used directly for irrigation;

– 700–1,500 ppm: mixed with canal water at a ratio of 1:1;

– 1,500–3,000 ppm: mixed with canal water at ratios of 1:2 or 1:3;

– more than 3,000 ppm: not used for irrigation for the time being.

Heavily polluted drains are not considered for irrigation. International standards indicate that irrigation with water salinity around 2,000 ppm under normal conditions is not likely to produce harmful effects when used for sandy or light soils under proper management.

From **Table 4** it can be observed that 75% of drainage water released to the sea amounts to about 10 billion m^3 and has concentrations below 3,000 ppm.

III - Main projects for the use of drainage water

At present, approximately 3.5 billion m^3 of drainage water are being used for irrigation purposes yearly. Land development projects that will require an additional 3.5 billion m^3 of drainage water are under way (El-Salam Canal Project, Omoum Drain Project, Gharbiya Drain Project, Tagen and Bats drain projects). The ultimate goal with respect to the use of the drainage water resource is 10 billion m^3 yearly, to be reached by the year 2000. Some details about two of these main drainage water projects are given below.

1. El-Salam canal project

El-Salam Project is planned to collect excess Nile water from the Damietta Branch at the Farasqour Barrage, the drainage water from the Lower Serw pumping station and the drainage water from Bahr Hadous Drain.

The water thus collected will be used to irrigate newly reclaimed areas. One part is located on the western side of the Suez Canal with a surface of about 200,000 acres (84,000 ha) and the second of about 400,000 acres (168,000 ha) is located east of the Suez Canal in the north western part of the Sinai.

Starting at the Farasqour Barrage at km 20.4, the canal moves in a southeastern direction, passing the Harna Drain, until the delivery side of the Lower Serw pumping station. Nile and drainage water will be mixed by gravity. At km 17.5 of the canal, a pumping station will lift the water from 0.5 m to 2.25 m. After this pumping station, the canal moves to the eastern direction, then to the southern direction until it crosses Bahr Hadous Drain at km 48. A pumping station at that location will lift the water from 0.5 to 3 m. The canal moves southward and then eastward until it faces the Suez Canal at km 27.8 as shown in **Figure 4**.

The total length of the canal at this location is 82 km; **Table 5** gives a summary of six alternatives and the contribution of each source. The average yearly salinity is also mentioned for different salinities at the Farasqour Barrage. From this table it can be seen that the planned amount for El-Salam Canal (4.45 billion m^3) is only available when the discharge at Farasqour Barrage is between 2.5 and 2.8 billion m^3.

2. El-Omoum project

In the Western Desert adjacent to the Western Nile Delta, huge land reclamation projects are presently being implemented. In order to provide these areas with irrigation water, the Ministry of Public Works and Water Resources has conducted a study to evaluate the prospects of using drainage water from the El-Omoum drainage catchment area to increase the available water in the Nubariya and Nasr Canal for irrigation of new lands.

The El-Omoum catchment area is located in the Western Delta between the Mahmoudiya Canal and the Nubariya Canal. A number of alternatives for the use of drainage water and its consequences for the salinity of irrigation water were studied by the Drainage Research Institute. **Figure 5** shows the El-Omoum catchment area with the DRI measurement network.

In the Western Delta, about 1.1 million acres are under irrigation and this area will be increased by 425,000 acres. In the northern part of the Western Delta approximately 100,000 acres can still be reclaimed.

Each year, 2.5 billion m^3 of drainage water is pumped by the Max pumping station to the Mediterranean Sea. Part of this quantity could be used to increase the required acreage of agricultural land by supplying it to the Nubariya Canal. Based on the water quality measurement program of the DRI, it was concluded that the drainage water from Truga PS, Shereshera PS and the water drained by gravity from Abu Hommes area can be used. The available quantities of drainage water of the mentioned sources total 1.1 billion m^3 per year.

It has been proposed in the study to dam the Omoum Drain directly downstream of Truga PS and to reverse the existing direction of flow towards the Nubariya Canal. For this purpose, the Shereshera Drain needs to be enlarged and three pumping stations are suggested. The proposed project is presented in **Figure 5**.

At km 46 in the Nubariya Canal, the input of El-Omoum Drain water has been proposed. The estimated discharges and salinity of El-Omoum drainage water, the irrigation water and the mixture of both are presented in **Table 6**.

3. Use of drainage water model

For the planning and implementation of the use of drainage water projects, it is of prime importance to be informed on the location, quantity, suitability and future changes of the drainage water resources in the Nile Delta.

Future changes in both quantity and quality of drainage water not foreseen under the present conditions of irrigation practice, cropping pattern, etc., affect the net output of drainage water. Both the quantity and quality of the drainage water depend on the efficiency of the irrigation system, the agricultural water use, the hydrological and chemical conditions of the soil. Complete use of all drainage water is impossible, since a substantial portion must be conveyed outside the agricultural area.

For the prediction of future effects of different water management strategies, a comprehensive measurement programme has been initiated and a mathematical model is being formulated. The model has to give answers to the effects of the different parameters on quantity and quality of drainage water including:

– predicting the time of the parameters that will be influenced by subsurface drainage, increases in cropping intensity and improved water management;

– calculating the overall water and salt balances for the Delta;

– indicating where and how drainage water can be used; and

– evaluating the effect of the use of drainage water on crop production and soil salinity.

In general, the main object is to assist in the planning of water management strategies for incorporating the use of drainage water.

A separate model has been formulated to calculate the irrigation water distribution between the sub-areas distinguished in the Nile Delta.

On a sub-area level, a model has been formulated simulating the farmer's behavior with respect to the unofficial use of drainage water if ever the irrigation water supply is insufficient.

For each identified subregion and for each crop present in this subregion, the calculation of crop water use, drainage rate, and soil salinity forms the core of the Reuse of Drainage Water Model. This part of the model is divided into four related submodels which are:

i) Sub-model for the calculation of irrigation efficiency;

ii) Sub-model for the calculation of actual evapotranspiration;

iii) Sub-model for the calculation of drainage rates;

iv) Sub-model for the calculation of soil and drainage water salinity.

All sub-models, except the soil and drainage water salinity sub-model, have been formulated and programmed.

The model has been tested for the eastern Delta area. Application of the model on the western and middle Delta area will take place during 1988.

After completion and testing of the model, a reliable tool will be available to plan and implement the use of drainage water projects which takes into consideration most of the changes that may occur in the future without considerable side effects with respect to drainage water, crop and soil. A simplified model flow chart is presented in **Figure 6**.

IV - Conclusions

The large-scale use of surface irrigation methods in the Nile Valley and Delta of Egypt – with low efficiencies – have led to the discharge of large quantities of drainage water with medium to low salt concentrations. The programs of the Ministry of Public Works and Water Resources to improve irrigation efficiencies and to modernize the irrigation systems will take many years and will require huge funds. Water that could be saved either for rehabilitation programs or for the use of agricultural drainage water could help the country satisfy a considerable part of its future medium-range water needs.

Caution should be taken when establishing programs for the use of drainage water. The impact (short or long) of such programs on soil properties and crop production should be carefully assessed. It always has to be kept in mind that improving irrigation efficiencies will reduce drainage water which will also be of much lower quality. Soil, water and plant monitoring programs are required to follow the changes which will take place and adjust policies accordingly. Such policies should be accompanied by a water-crop-soil management program to avoid any adverse effects. They will require the participation of many disciplines and have to consider the continuously increasing knowledge and experience in this field.

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Table 1: Volume of drainage water escaping yearly to the sea or lakes

Region	Volume in billion m^3		
	Average 1972-80	Average 1980-83	1986
Eastern Delta	5.213	4.439	4.016
Middle of Delta	5.583	4.754	4.985
Western Delta	2.676	4.092	4.240
El-Fayum	0.425	0.615	0.696
	13.897	13.900	13.937

Table 2: Available water resources by the year 2000

Source	Available water resources (billion m^3)		
	1987	by 1991	by 2000
- Nile water quota	55.5	55.5	57.5
- Underground water (in Nile delta and valley)	2.3	3.0	4.9
- Underground water (in desert and the Sinai)	0.5	0.7	3.0
- Reuse of drainage water	3.5	7.0	6.0
- Water management	--	--	--
- Saving of releases to sea through storage	--	--	2.0
Total	61.8	66.2	73.4

Table 3: Water uses excluding horizontal agricultural expansion (billion m^3)

	1987	by 1991	by 2000
Agriculture (in delta and valley deserts)	49.7	49.2	44.7
Agriculture (deserts)	0.5	0.7	1.3
Drinking & commercial	3.3	4.9	5.9
Industry	2.5	3.5	5.0
Navigation and power generation	2.8	2.0	2.0
Total	58.8	60.3	58.9

Table 4: Amount of yearly drainage water and its quality (average 1980-1986)

Salinity (PPM)	Discharge (billion m)	Percentage discharge/ Total discharge	Cumulative discharge percentage
1,000 or less	1.859	14	14
1,000 - 1,500	4.862	36	50
1,500 - 2,000	2.584	19	69
2,000 - 3,000	0.801	6	75
3,000 or more	3.528	25	100

Table 5: Yearly available water and salinities for El-Salam canal and the contribution of different sources, when the salinity at Farasqour barrage is 250 and 370 ppm respectively

Alternative	Total amount available ($10^6 m^3$)		From Farasqour ($10^6 m^3$)		From Bahr Hadous ($10^6 m^3$)		From Lower serw ($10^6 m^3$)	Salinity of mixture (PPM)	
	250	370	250	370	250	370		250	370
A	4070	4070	2110	2110	1291	1391	569	753	810
B	3729	3500	2110	2110	1050	821	569	767	782
B	3940	3859	2110	2110	1261	1180	569	802	856
C	4450	4450	2715	2820	1166	1061	569	800	800
C	4450	4450	2620	2676	1261	1205	569	900	900
D	4450	4450	2556	2556	1391	1391	569	761	830

Table 6: Estimated discharges and salinity of El-Omoum drainage water including irrigation water and mixtures

Month	Total Omoum mixed water		Total intake Nubareya canal + Nasser Rayah			Mix of Omoum water + Nubareya canal						
	Q	TDS	1977/1980	1983	TDS bridge km 52	availability of 100% 1977-1980		100% 1983		80 % 1977-1980	80 % 1983	
	10^6 m^3	$g.m^{-3}$	10^6 m^3	10^6 m^3	$g.m^{-3}$	10^6 m^3	$g.m^{-3}$	10^6 m^{-3}	g.m	10^6 m^{-3}	10^6 m^{-3}	
January	85.96	2392	174.58	177.90	350(1)	261	1024	264	1015	208	211	
February	53.09	2633	199.76	129.00	350	253	829	182	1016	202	146	
March	79.68	2255	320.73	309.10	245	400	645	389	657	320	311	
April	85.28	2075	320.90	384.50	290(2)	406	665	470	614	325	376	
May	88.12	2106	347.50	404.50	300	436	665	493	623	348	394	
June	89.07	2164	371.88	409.80	260	461	628	499	600	369	399	
July	87.15	2287	418.90	436.30	265	506	613	523	610	405	419	
August	100.10	2090	357.23	443.60	290	457	684	544	621	366	435	
September	115.77	1990	363.03	387.10	330	479	731	503	713	383	402	
October	116.12	2026	356.28	385.65	330	472	747	502	722	378	401	
November	99.20	2160	320.05	343.50	340	419	770	443	748	335	354	
December	98.45	2292	275.18	326.00	360	374	869	424	808	299	340	
Total	1,098	2196	3826	4137	305/290	4924	715	5235	699	3938	4188	

(1) Estimation

(2) Check May 1985: 280 $g.m^{-3}$

Figure 1: General view of the measurement network

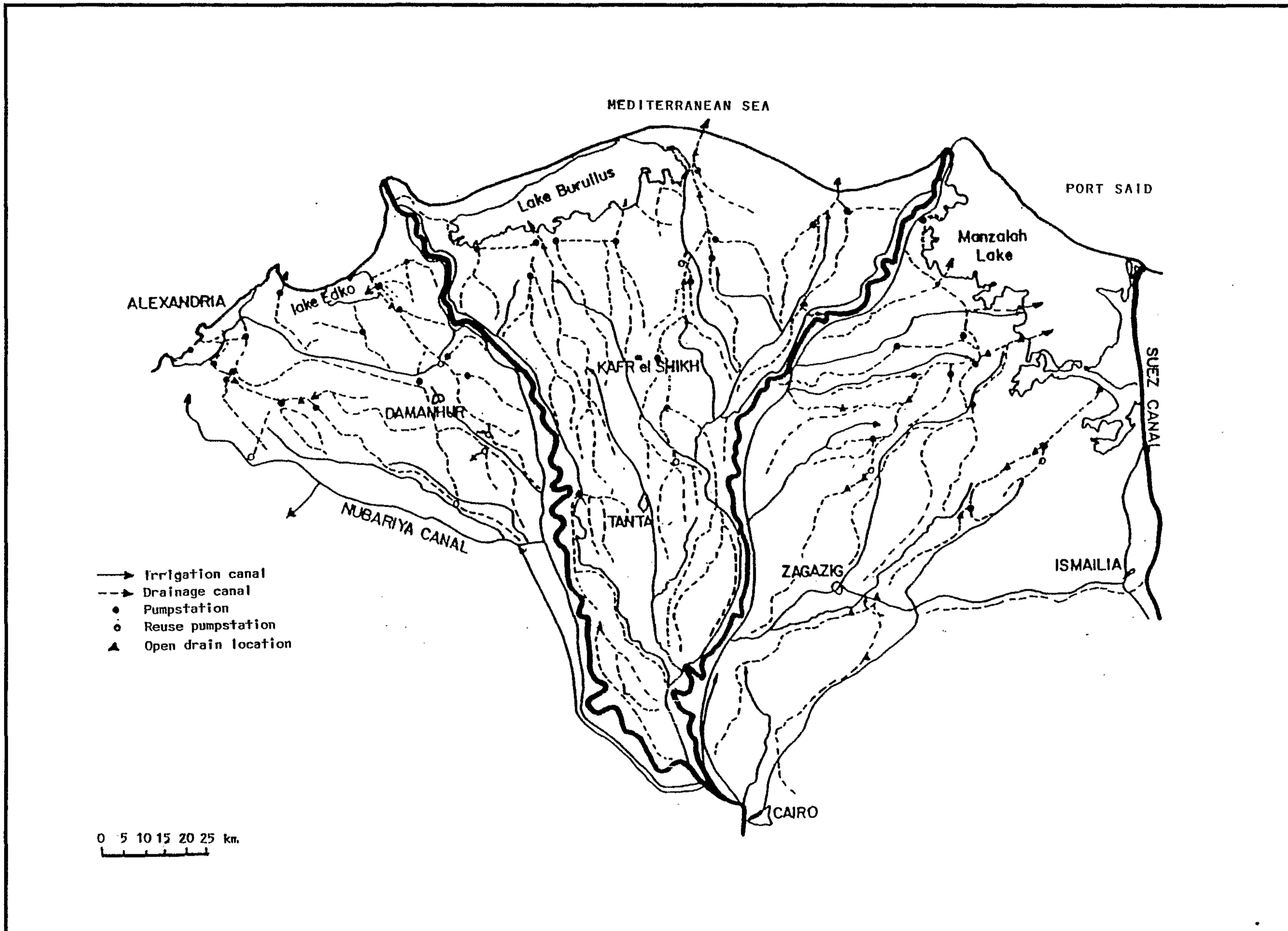

Figure 2: Water salinity variation of four locations along the Bahr Hadus drain

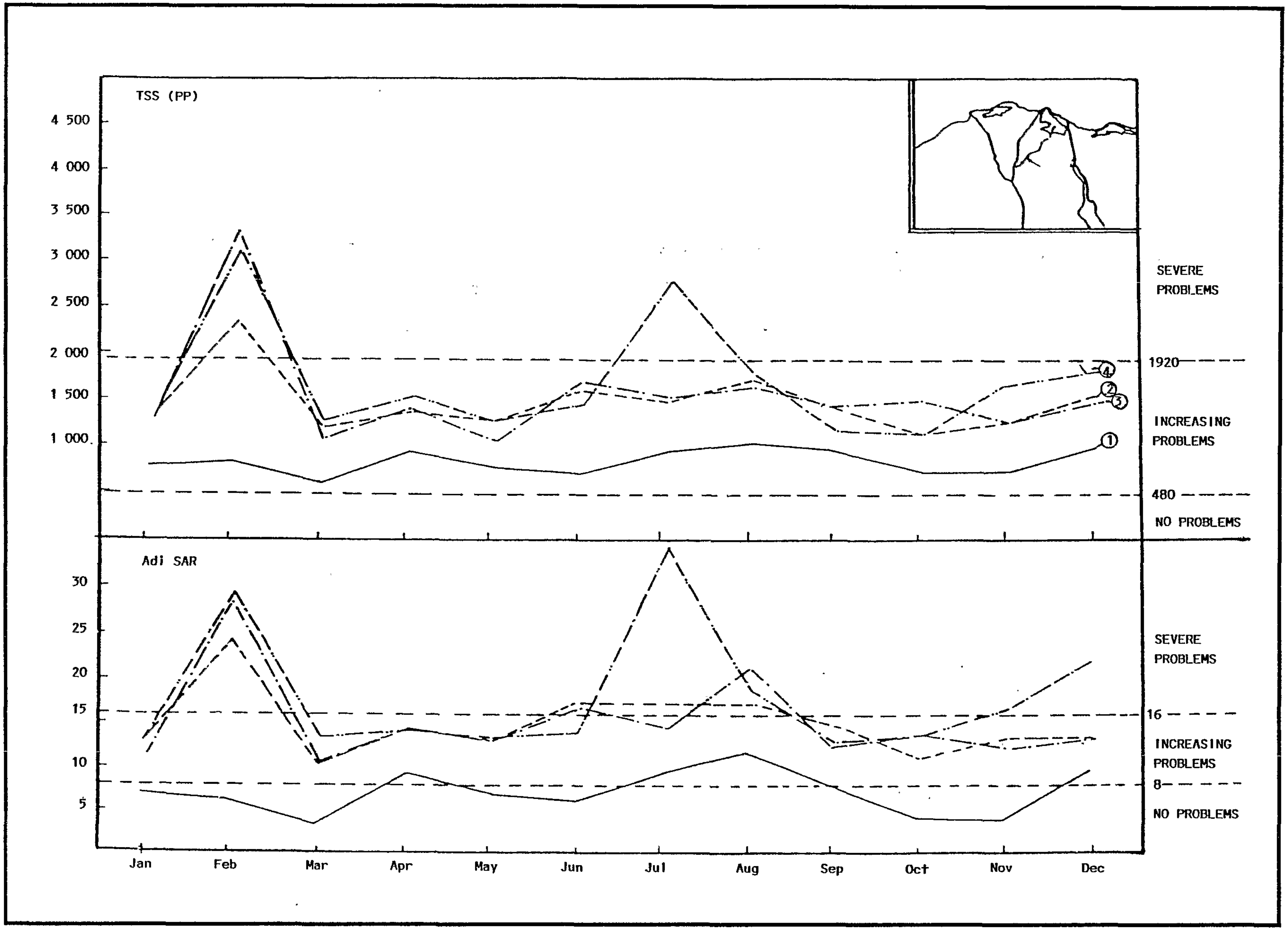

Figure 3a: Average salinity, 1986, of drainage water in the Western Delta in g salts/m³

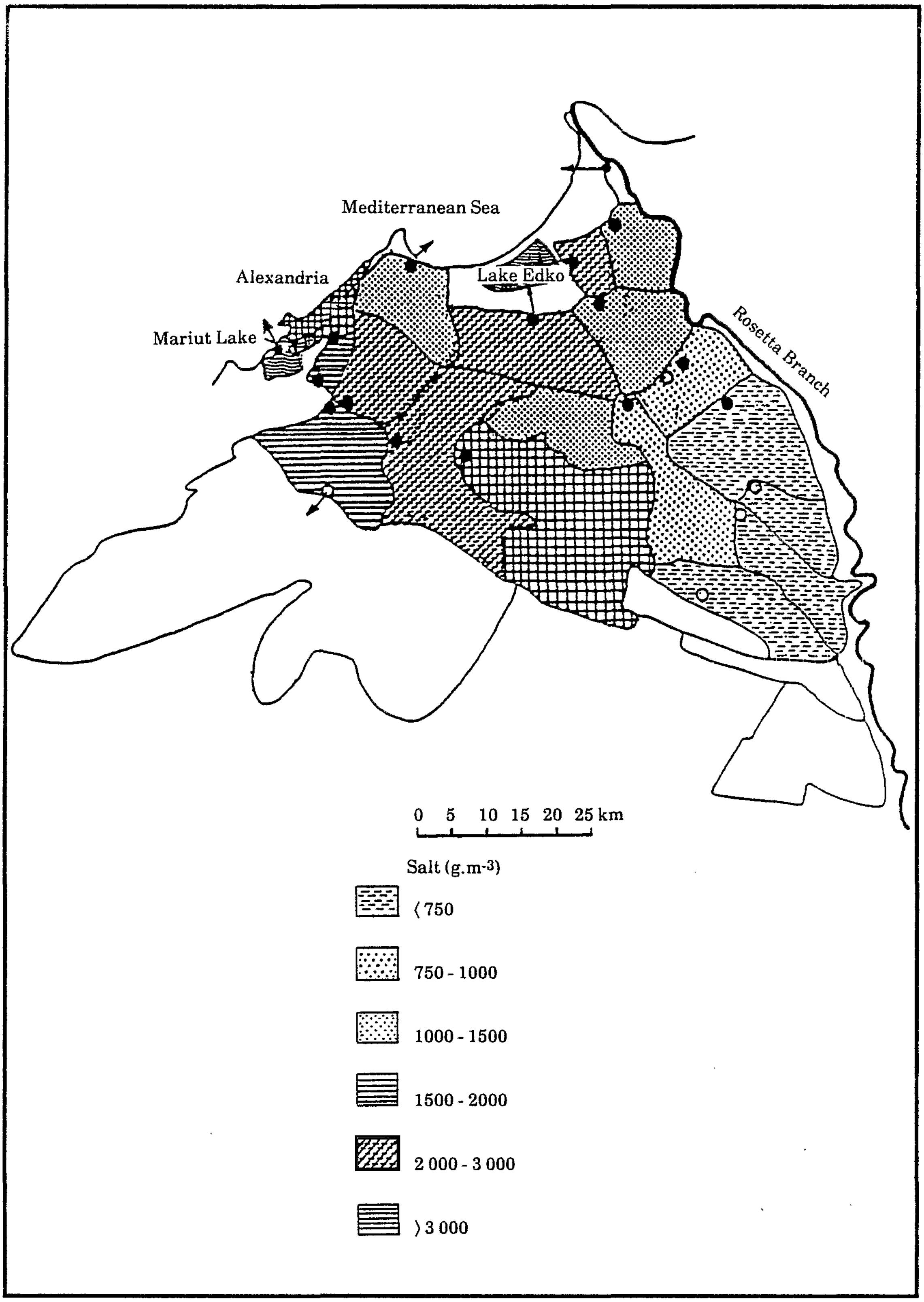

Figure 3b: Average salinity, 1986, of drainage water in the Middle Delta in g salts/m³

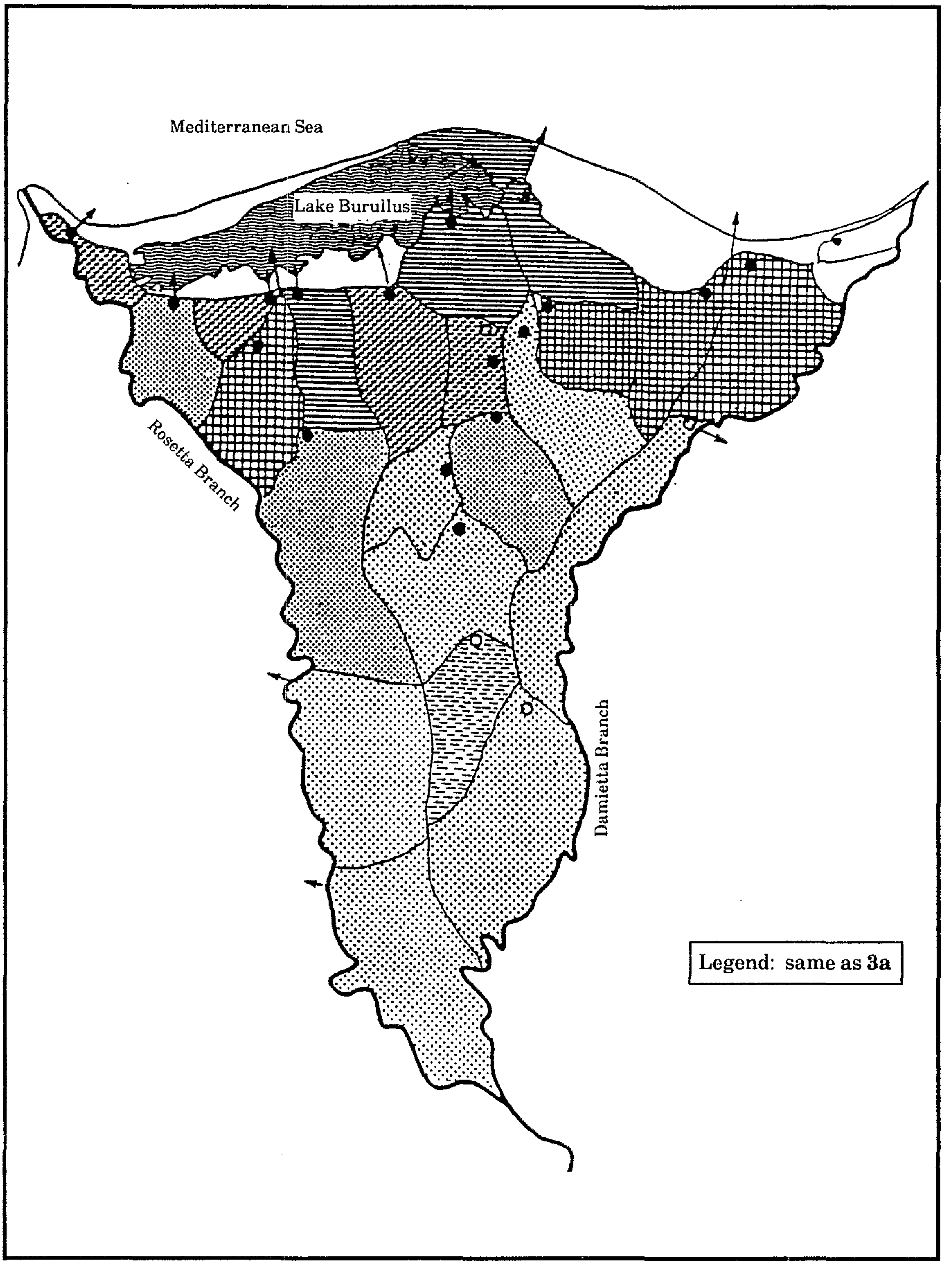

Figure 3c: Average salinity, 1986, of drainage water in the Middle Delta in g salts/m³

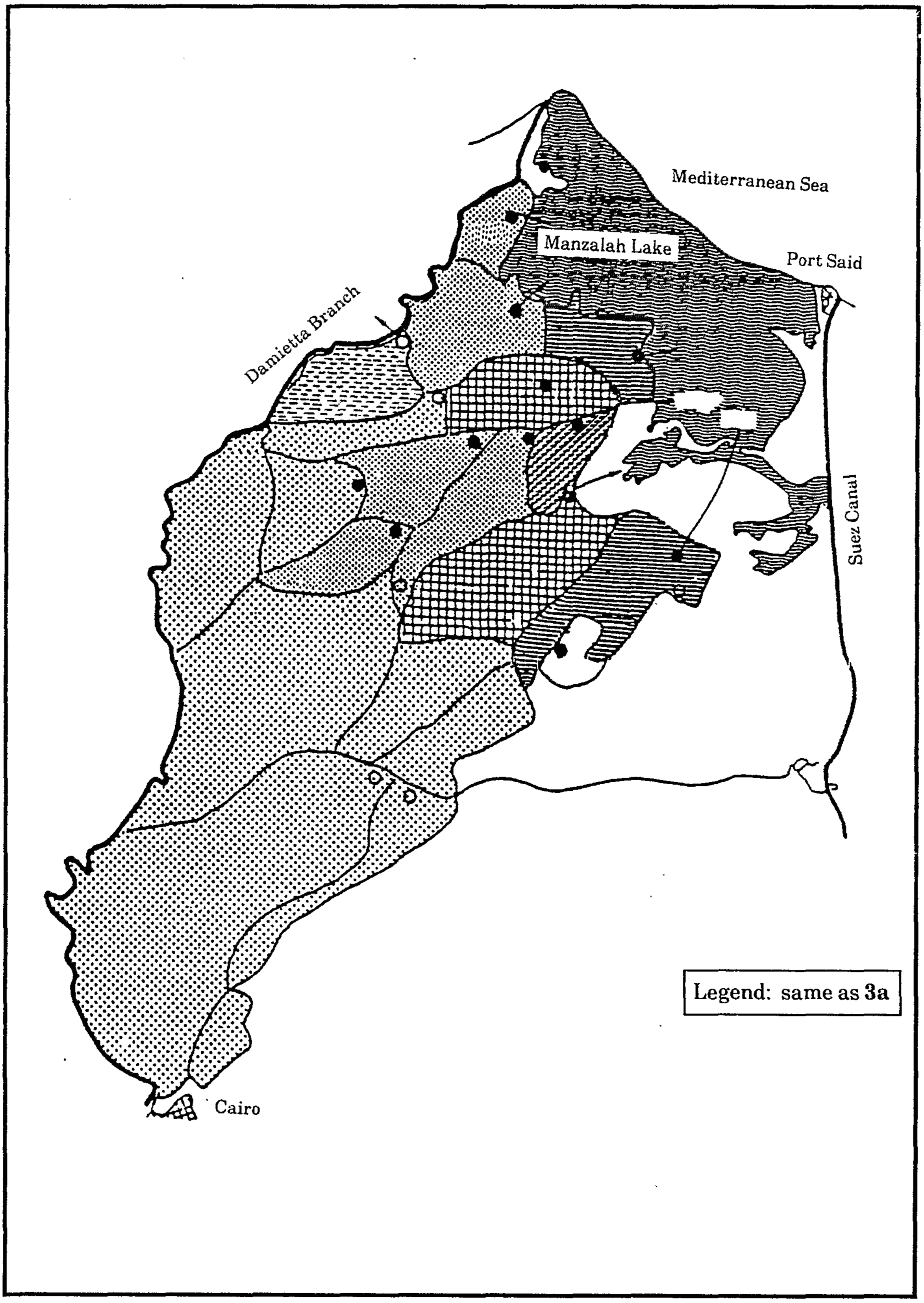

Figure 4: El Salam Canal Project

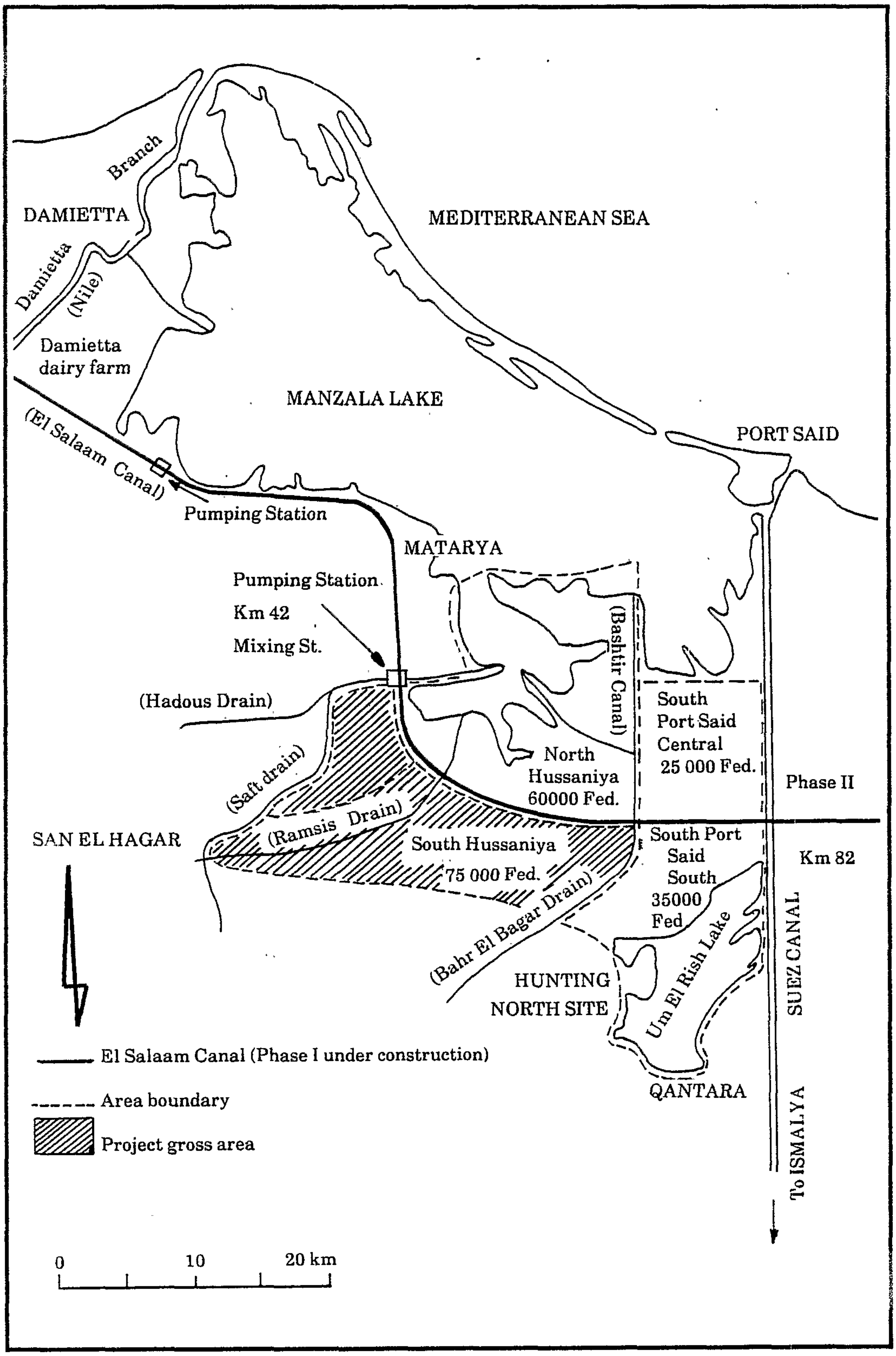

Figure 5: El Omoum Reuse project

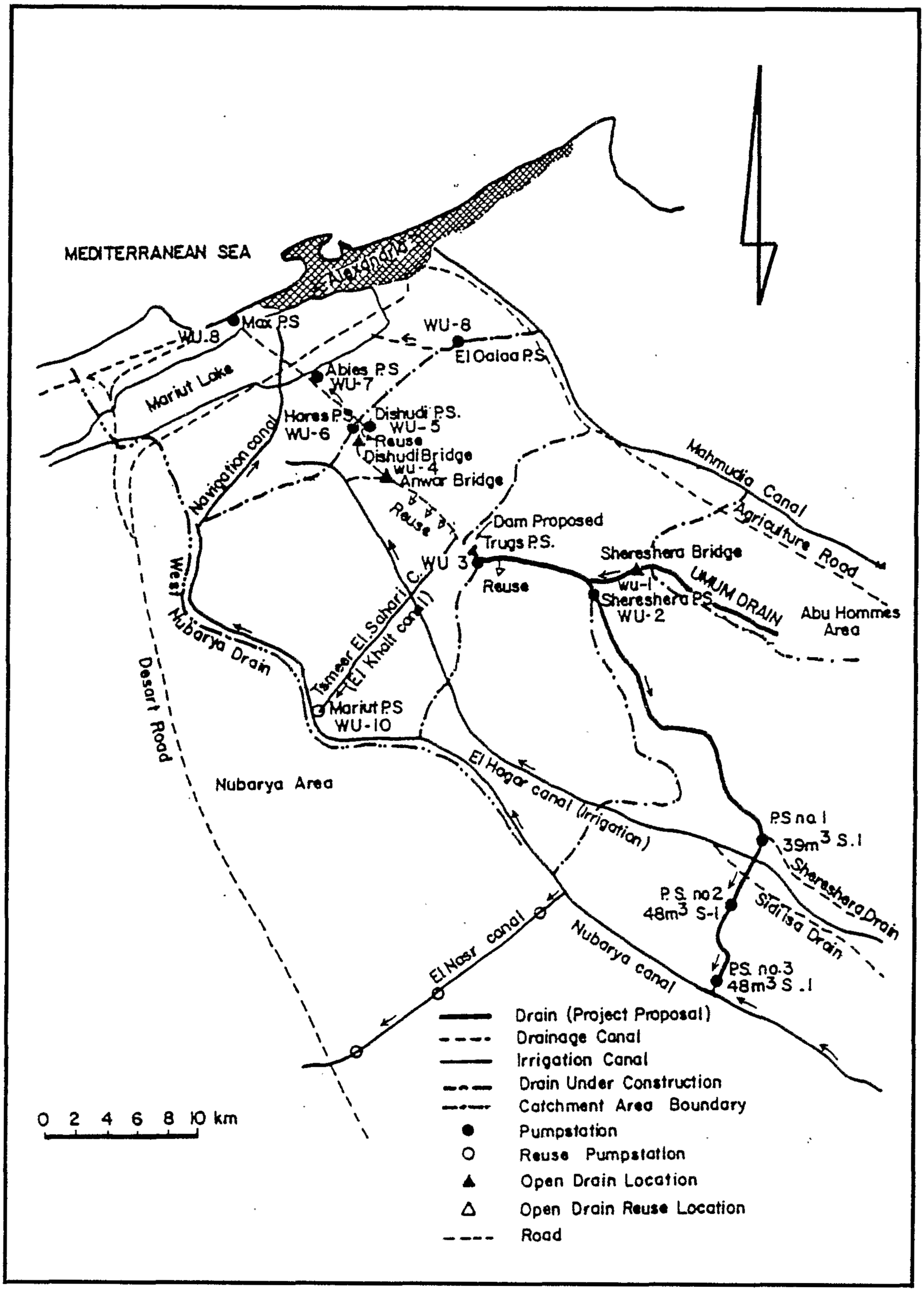

Figure 6: Reuse of drainage water model flow chart