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MULTI-STAGE LIFT IRRIGATION - SOME ADVERSE ECONOMIC & ENVIRONMENTAL ASPECTS - A CASE STUDY

BY

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B.A. Malik [1]

ABSTRACT

Egypt had embarked upon a large-scale programme of development of high lands through multi-stage lift irrigation to meet her growing requirements. Several canals including the largest Nasr Canal covering an area of 113,000 hectare (280,000 acres), where commissioned in desert tracts along the western periphery of Nile Delta in late sixties. Some of the earlier canals, not long after coming into operation, started to suffer from water-logging and salinity seriously affecting land productivity and the environment. Two of these canals had to be abandoned. Detailed field investigations, presented here as a case study, identified, besides lack of effective drainage, some serious design deficiencies and inappropriate management and operational practices resulting in high salt content of canal water delivered for irrigation.

Pakistan has been rather fortunate that almost all of her 16 million ha (40 million acres) irrigated cropped area is served by gravity-flow irrigation networks. But not too far in the future, hither to higher lands, uncommandable by weir-controlled canals, would have to be developed through multi-stage irrigation to meet rising needs of her burgeoning population. However, the country lacks experience in engineering and management of multi-stage lift irrigation. Findings of the case study, based on Egypt's unhappy experience of multi-lift irrigation, should serve as a useful guide for the engineers to be charged with the responsibility of design and operation of such schemes envisioned in the high lands in particular west of the Indus River.

INTRODUCTORY

Irrigation would remain main stay of world food supply. Some 250 million hectare (618 million acres) of land are under irrigation all over the world. It represents 17% of the cropped area - providing one-third of the food supply. Irrigation so far has been practiced largely by gravity flow canals off-taking from diversion storage/dams.

Sequel to rising demand and diminishing land resources, future irrigation developments will increasingly encompass higher to uncommandable lands, particularly in arid regions, through lifting water by pumping. Advancement in prime mover and pump technology and availability of electric power, have rendered feasible development of higher lands lying generally on the periphery of alluvial plains of the rivers, waters of which are used for lift irrigation including many involve multi-stage pumping. In Egypt, for instance, many pump stations, are for multi-lift irrigation. Overall lifts may exceed 70m or 230ft (Table 1).

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Pakistan has been fortunate in as much as her 16 million ha (40 million acres) cropped area in the Indus Plains, is served by almost entirely by gravity canal network - the largest any where. However gravity flow irrigation may no longer be feasible in some regions. Depending upon regional priority and terrain, some areas may involve lift irrigation. For instance, Frontier Province would receive 14 per cent of water stored at Kalabagh Dam (Water Apportionment Accord 1991). The most obvious target for irrigation would be lands situationed at elevations higher than the areas commanded by gravity flow of Chashma Right Bank Canal. A high level canal from Kalabagh Dam besides being objectionable to a certain province, would appear to be infeasible, because of unfavourable terrain. Lift irrigation even by multi-stage pumping should prove to be more viable-technically as well as economically. More such areas would need to be developed through multi stage lift irrigation else where in the country too.

However, in the absence of field experience, high lifts might appear unweilding and daunting in Pakistan as illustrated by the author's personal experience. The writer, as Executive Engineer, Kalabagh Division in 1953, had prepared Samandwala 3-stage Lift Irrigation Scheme. He did this out of line of his duty, purely on humanitarian consideration to alleviate the poor plight of small holders of barren hilly lands along the left flank of Thal main canal. Remarks such as "impracticable, too high lift" raised many an eye brow among the peers. He was to realise back lash of this antagonism when he was one day summoned to the Irrigation Secretariat. Instead of his noble initiative being commended, much to his dismay, he was directed to see the Minister who had inquired about the scheme. The Minister, (father of our ex-President Farooq Leghari) was kind and courteous. After brief presentation, he raised a couple of questions about water rates and willingness of the beneficiaries to pay. He appeared to be satisfied and in favour of the scheme.

The writer was however, surprised to find a local politician of Mianwali, being called in. He had met the author at Kalabagh several times previously urging him to drop the idea. He had admitted ultimately that given facility of irrigation, these people would go out of his yoke and become his rivals. Having failed to bring me around, he exploited his political clout. Nonetheless the author left Lahore feeling hopeful of his scheme's acceptance and eventual socio-economic uplift of the poor villagers-little aware of strong under currents. He was in the process of submitting the scheme for approval, when his transfer orders arrived. He was disappointed to learn that the "high lift" phobia came handy in burying an otherwise so useful a scheme. Today Pakistan faced with vexing food deficits, could not permit such phobias or prejudices against high-lift irrigation developments any more.

Multi-stage lift irrigation schemes, however, if not designed properly and operated appropriately, could lead to adverse socio-economic and environmental consequence. It could create serious water logging ("sem") and salinity problems, as happened in Noubaria areas in Northern Egypt. Some multi-lift irrigation canals there had been beset with such problems; some so seriously that, as noted in the sequel,

they had to be abandoned. Government of Egypt felt deeply concerned and obtained technical assistance of FAO (Food and Agriculture Organization of the United Nations). The writer was assigned there by FAO as senior irrigation and drainage advisor. He studied the situation in general and that of Mechanized-Farm Canal system in particular. His investigations and findings, presented as a case study in this paper, may be of special interest to my professional colleagues in Pakistan.

THE SETTING

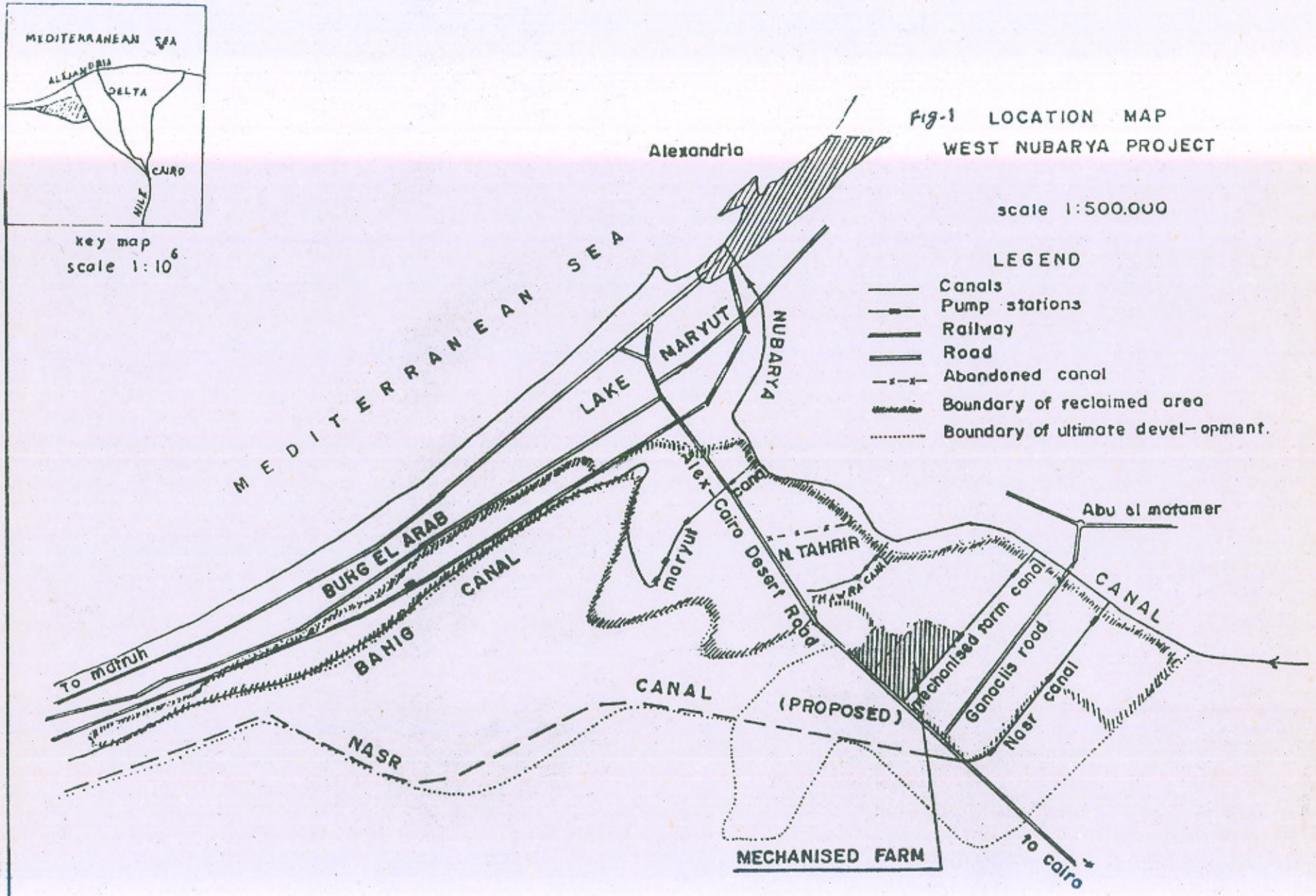
Egypt had land areas of 100 million ha (247 million acres). Only about 4% is arable. The rest comprises desert waste and barren lands. Egypt has dry climate with long rainless summers and short winters. Only a part of the Northern Delta and the Coastal belt has Mediterranean climate receiving some rainfall in winter. Agriculture cannot be practised there without irrigation.

Egypt's arable area ("old lands") of 2.4 million ha (6 million acres) lies in the Nile Valley and the Northern Delta. All this area is irrigated. Annual cropped area in 1980, was 4.6 million ha (11.5 million acres) and national annual cropping intensity 195% (Malik -1981).

The Nile Valley and the Delta have hosted irrigated agriculture since the dawn of civilisation. According to author's research study, Egypt is the only country in the world where large scale irrigation remained healthy throughout the ages, without any deleterious effects arising from silting, sem or salinity, as happened in Mesopotamia, Pakistan, India and elsewhere. This was due to non-perennial basin irrigation practices which, at the turn of the twentieth century, started to give place to perennial irrigation. In order to meet growing demand for food and cheap power from High Aswan Dam. Over 121000 ha (300,00 acres) of desert lands were to be "reclaimed" (developed) as a cutting edge of the 1952 - Revolution.

Besides land, water is also a serious constraint there. The River Nile is the only primary source of water in Egypt. According to agreement with Sudan, Egypt's annual share of Nile water is limited to 55.5 milliards m^3 (45 maf - million acre feet). With substantial drainage, as of 1980, was of the order of 68 milliards m^3 (65 maf). About 16 milliards m^3 (13 maf) wasted to the Mediterranean Sea unused every year. It may be of interest to mention here how deeply concerned Egypt felt about this wasteful outflow to the sea.

The writer was assigned again to Egypt. This time by the World Bank, as Chief Technical Advisor and Project Manager, "Master Plan for Water Resources Development and Use" The Minister incharge or Irrigation Ministry (invariably and Irrigation Engineer) had indicated some government priorities. Two of the important ones were; (a) "zero" Nile discharge to the sea and (b) to enhance annual cropping intensity from 195% to 210% .
What a contrast with our situation wherein construction of Kalabagh Dam -socio-economically so vital, is being held hostage to a political quagmire by a lobby against


MEDITERRANEAN SEA
ALEXANDRIA
DELTA
CAIRO
NILE
key map
scale 1:10^6
Alexandria
MEDITERRANEAN SEA
LAKE MARYUT
NUBARYA
BURG EL ARAB
BAHIG CANAL
To matruh
Alex-Cairo Desert Road
maryut canal
N TAHRIR
THAWRA CANAL
Abu al matamer
CANAL
Mechanised farm canal
Ganaclis road
Nasr canal
NASR CANAL (PROPOSED)
MECHANISED FARM
to cairo
Fig-1 LOCATION MAP
WEST NUBARYA PROJECT
scale 1:500.000
LEGEND
Canals
Pump stations
Railway
Road
Abandoned canal
Boundary of reclaimed area
Boundary of ultimate development.
B.A. MALIK



storage of even part of 43 milliards m^3 (35 maf) of surplus flow going waste to the Arabian Sea every year while the people and the nation's economy continue to suffer from increasing water, food and power shortage.

With the foregoing general background of site situation, what follows is an overview of multi-lift irrigation schemes and in depth study of the conditions obtaining on Mechanized-Farm Canal system as investigated by the author.

MULTI-STAGE LIFT IRRIGATION CANALS

Five lift-irrigation schemes were implemented in West Noubaria (Table 1). The source of water supply for all the schemes was Noubaria Canal running along the eastern border of the reclaimed tract. Particulars of all these canals are given in Table 1.

North Tahrir Canal

This was the first development commissioned in 1959. It served an area of 21,000 acres extending a little west of the Alexandria Cairo Desert Road (Fig.1). Canal capacity was 106 cusecs (cubic feet/second). Aggregate lift 40 ft accomplished through five stage pumping. Due to severe water quality degradation by highly saline inseepage, as explained later, the canal was abandoned in February, 1973.

Thawra Canal

The Thawra Canal started operation in 1969 to irrigate 20,000 acres, situated south of North Tahrir Canal command (Fig.1). Its discharge capacity was 572 cusecs and overall lift 59 ft. involving 3 stage pumping. Canal water quality deteriorated badly by saline inseepage into its deep reaches, and by inflow of Nour drain.

Maryut Canal

Maryut Canal was opened in 1971 to irrigate an area of 71,000 acres on the north-west of North Tahrir command. It extended beyond Desert Road (Fig.1). Canal discharging was 688 cusecs. There were 4 pump stations to lift water by 98 ft. Inseepage and its salinity remained low compared with other canals, primarily because of a relatively large discharge and existence of less permeable strata.

Nasr Canal

The Nasr Canal - the largest network, started irrigation in 1971 with discharge capacity of 4100 cusecs at head. It was to irrigate ultimately 280,000 acres west of the Desert Road and extending beyond El Alumni, (of World War II fame) along the Mediterranean Coast (Fig.1). There were to be 6 pump stations for an overall lift of 230 ft. At the time of study (1977) the canal, with lined section, had been built upto

the Desert Road. Three pump stations raised water through a lift of 102 ft. to irrigate 62,000 acres.

TABLE 1. Multi Stage Lift Irrigation Canals

Canal	Opened	Area Irrigated		Discharge		Pumping Stages	Overall lift	
	(year)	(ha)	(acre)	m^3/s	(cusec)	(number)	(m)	(ft).
North Tharir Canal	1959	8500	(21000)	3	(106)	5	12	(40)
Mechanized Farm Canal	1967	4200	(10400)	6.2	(219)	3	25.8	(85)
Thawra Canal	1968	10500	(26000)	16.2	(2572)	3	18.4	(60)
Maryut Canal	1969	28700	(71000)	19.5	(688)	4	28	(92)
Nasr Canal	1979	121000*	(280000)	116	(4100)	6	70	(230)

*Till the time of writer's study only 60,000 fedans were under reclamation. (B.A.Malik - 1977)

Table 2: Average 3 hourly water salinity of Mechanized Farm canal Pump Station 3 (ppm)*

TABLE 2. Average 3 hourly water salinity of mechanized farm canal pump station III. (ppm)*
Recorded during September 4-7, 1976

Dates	Hours								
	06	09	12	15	18	21	00	03	06
Sep 4-5	2944	3168	3168	3072	2688	2688	2688	2528	2528
Sep 5-6	2528	2528	2944	2944	2944	2880	2816	2624	2624
Sep 6-7	2624	2624	2944	2944	2944	2688	2432	2368	2368
Average	2699	2773	3019	2987	2891	2752	2645	2507	2507

* parts per million

MECHANIZED FARM CANAL - THE CASE STUDY

The Project

Mechanized Farm, situated adjacent to and east of Alexandria-Cairo Desert Road, lay between Thawra and Nasr canals. The M-F canal formed the southern boundary of the project area (Fig.1). It is a block of 10,400 acres. The terrain drops towards the Noubaria Canal. Similarly to other canal commands it was a sandy tract before reclamation. Its soils are generally coarse in texture with low moisture holding capacity.

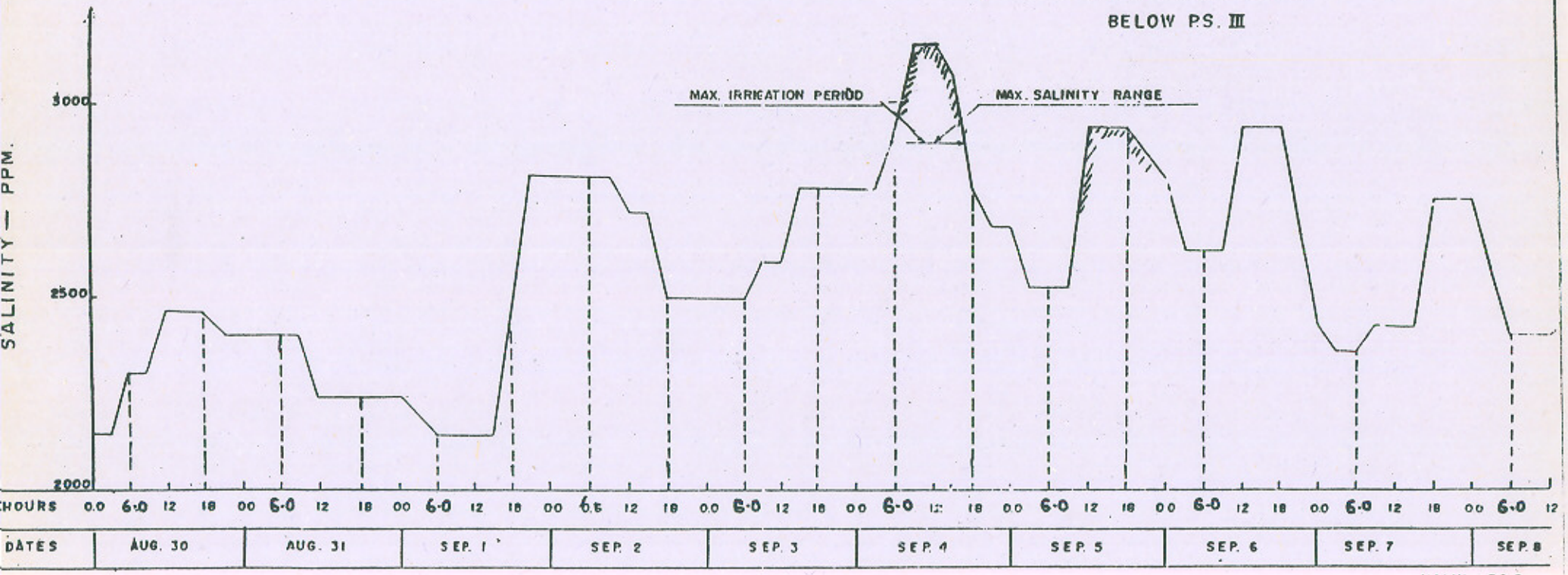
The area was reclaimed and developed by M-F Canal commissioned in 1967 with discharge at head of 219 cusecs. The 17.5 km along canal took off from west bank of Nuobaria Canal. It had cement concrete lined section in filling reaches. Water was lifted through 85 ft. b 3-stage pumping (Fig.2). Lift at each stage was 26 ft. Each pump station had 6 units of 44 cusecs capacity each, driven by electric prime movers. Irrigation started after delivery pool of last pump station. Water was distributed by lined channels. No field drainage had been provided initially.

M-F Canal was a bilateral foreign-aided project. It was designed, constructed and initially operated by expatriates. It was managed as a state farm. Subsequently maintenance and operation of main canal an the 3 pump stations became the responsibility of Ministry of Irrigation Field irrigation, agricultural operations and overall farm management was with the Ministry of Agriculture through a semi-autonomous state agricultural company.

Apparently expatriate designers of the project had failed to take cognizance of the serious problems of highly saline seepage inflow into the deep reaches of the main canal inherent to multi-lift irrigation practice already 50 manifest here. Practically the same design of canal and field distribution network was followed as on other canals in trouble here. Groundwater table initially lay 50 ft - far below the land surface in 1967. Construction of F-M Canal and the pump stations was done in the dry. However, soon after introduction of irrigation without effective drainage, water table rose within 6 ft. of surface by 1975 (Malik-1976).

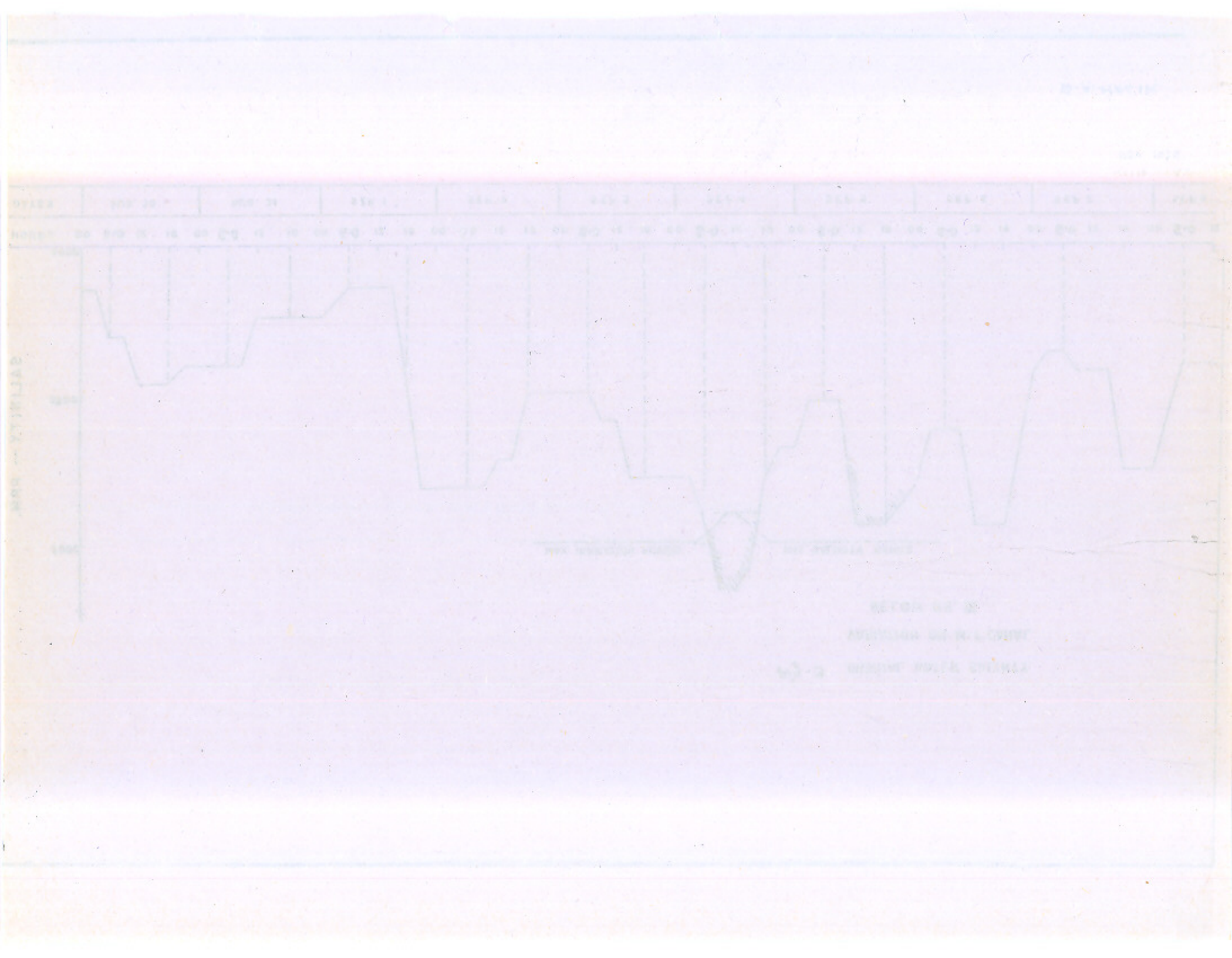
Groundwater rose far higher than canal water levels in the deep reaches upstream of P.S. II & III, inducing saline inseepage. Salinity level of water at the delivery of P.S. III became too hazardous for plant growth. Rise in groundwater also caused wide spread sem and soil salinization. Shallow field drains were later dug. But these proved of little avail. High water table conditions, use of highly saline water in irrigation, defective management, wrong irrigation practices and lack of drainage, led to serious drop in land productivity, unhygenic conditions and general environmental degradation in the area. Condition of the main canal and the pump stations was, at best poor adversely affecting water conveyance capacity. Situation of the field irrigation and drainage network was equally bad. This was the bleak scenario when

Fig. 3 DIURNAL WATER SALINTY VARIATION ON M-F CANAL BELOW P.S. III



MALIK / F.A.O
NOV. 1976

B. A. MALIK



the writer joined FAO team of experts as signed to the "Project for the Control of Water logging and Salinity in the Areas West of Noubaria Canal".

Hydro-Salinity Studies

A work plan was prepared by the author. Accordingly a programme of field observations of canal discharges and water salinity was initiated. Automatic water level and salinity recorders were installed. Observations were carried out at various point along F-M Canal. Observations were carried out at various point along F-M Canal, Salinity of M-F Canal at its intake from the Noubaria Canal was low. It rose more than eight times at delivery end of P.S. III. Diurnal (3-hourly) water salinity observation there (Table II) revealed that low "salt content changed from morning to noon and the evening. Amount of annual slat deposit by irrigation was of the order of 287,000 tonnes; some 69% of which remained recalculating in the soil system". (Malik-1976).

Case of High Salt Content

Factor responsible for excessive rise in water salinity were identified. These included the following:-

1. High water table conditions
2. Saline Inseepage
3. Wrong system management and operation
4. Drainage inflow of Drain D-7
5. Inappropriate irrigation regime.

Factors 1 and 2 have already been noted. Field studies focussing on the other aspects were carried out as follows:-

System Management and Operation

Being a state farm under a socialist regime, the farm labour worked, not according to agricultural requirements, but by the hours fixed by Labour Ministry. Field operations stopped in the afternoons, on Fridays and other holidays not excluding week long breaks, when the workers returned to far off native villages to celebrate two Eid feasts every year.

Irrigation was limited to day time hours only - starting from about 8 o'clock in the morning till 3-4 o'clock in the afternoon. Generally 2 units operated at Pump Station P.S. I and 3 units at P.S. II and III. The third unit at the latter pump stations took care of Drain D-7 inflow and the inseepage through the canal prism. Pumping was intermittent at night; generally limited to on unit only at P.S. II and III, to provide relief against accumulation of inseepage and drain flow. Pumping started again early in the morning at 5-6 hours with one or two units, to fill up branch canals before irrigation began in the field at about 8 hours.

A major factor responsible for high canal water salinity besides, saline inseepage and Drain D7 inflow, was the operational pattern of pump station imposed by farm management practices. The three pump stations were located at intervals of 8 and 7km between. P.S. I and II respectively. Water took time to travel from Noubaria Canal to the point of delivery at P.S. III - a distance of 17km. When pumping started in the morning, it took 2-3 hours for fresh water to reach P.S. II and 4-6 hours to arrive at 2-3 P.S. III. In the meanwhile P.S. III remained supplying high salinity water for the irrigation that had accumulated during the previous night in the canal prism. Salinity rose further as more water arrived from P.S. II which had higher salt content from inseepage and inflow of Drain D7. Average water salinity at off take of M-F Canal was 400 ppm. It rose to 3600 ppm at P.S. III.

Diurnal Salinity Variation

Salinity phenomenon was studied in greater detail by monitoring water quality around the clock by means of an automatic salinity recorder installed at delivery side of PS 3. Fig3 represents 3 hourly - salinity graph for 3 days viz. Sep. 4,5 and 6, 1976. Rising limb of the graph showed that water salinity started to rise around 6 o'clock in the morning. It rose sharply around 8-9 a.m. (when irrigation commenced) on arrival of P.S. 2 discharge. Salinity reached its peak at mid-day. Thereafter it dropped on dilution by arrival of fresh water from Noubaria Canal. It continued to drop past mid-night reaching a plateau before pumping resumed around 6o'clock the following morning (Table 2). The interval between hours of 8 in the morning and 3-4 in the afternoon was the period of maximum irrigation for the day. Note shaded areas on Sep. 4-5 in fig3.

It will thus be noted that irrigation was being practiced with water containing the highest amount of salts for the day. For instance on 4th September irrigation started with water salinity of 2944 ppm reaching maximum level content of 3072 ppm when irrigation operations were coming to close for the day. The lowest salinity reached in the following night was 2528 ppm (Table 2). More or less similar pattern was reflected by salinity graphs of the other two days.

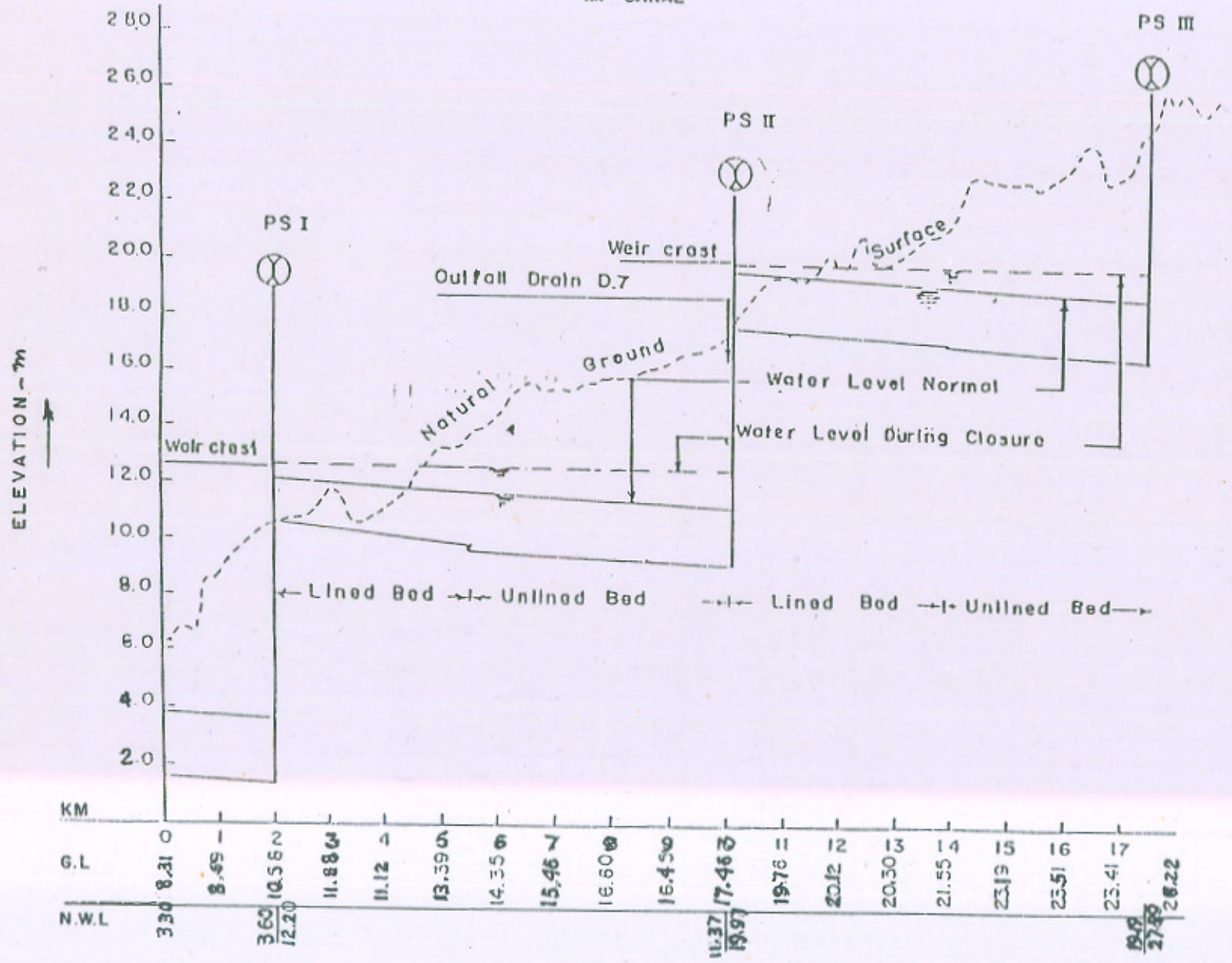
Day to Day Salinity Variation

Daily water salinity variation had also been studied. Six hourly salinity variation at P.S. 3 were observed for an 8 day period (August 30 through September 7, 1976). By and large, similar pattern of daily salinity variation emerged, as had been indicated by the diurnal 8 hourly graphs (Fig. 3).

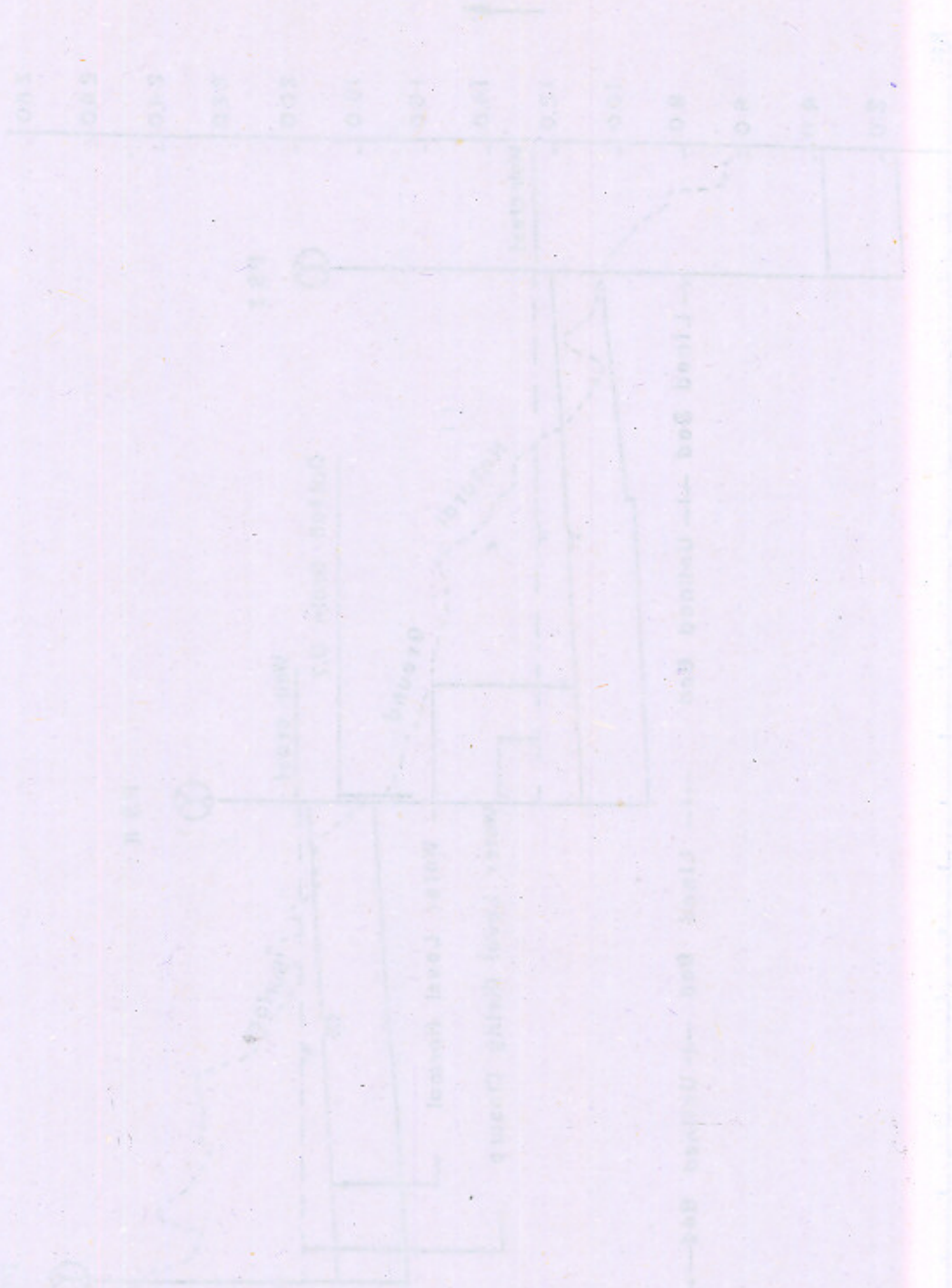
Ameliorative Measures

The foregoing study of diurnal and daily water salinity variation confirmed that irrigation during day time only, was the major cause of land salinisation and poor productivity. It was obvious that salinity hazard of M-F Canal could be minimized by

Fig. 2 LONGITUDINAL PROFILE OF MF CANAL



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avoiding use of highly saline water. The situation could be improved through ameliorative measures including the following:-

- Round-the-clock pumping.
- Diversion of Drain D-7
- Drainage outlets
- Supplemental supply from Nasr Canal.

Round-the-Clock Operation

By continuous canal operation water salinity could be lowered markedly. First by accumulation of saline water at night. Secondly continuing fresh water inflow from Noubaria Canal would lessen salinity of inseepage and Drain D7 discharge. Roughly it was estimated that F-M Canal salinity could drop by one-third from 2900 to 1900 ppm.

Diversion of Drain D7.

There could be nothing as preposterous as the saline discharge of Drain D7 into M-F Canal above P.S. 2. The author agitated against this expedient and got a scheme approved for diversion of Drain D7. Canal water salinity could reduce from 2900 to 1400 ppm or by one half.

Aquifer Flushing - Drainage Outlets

During annual canal closure for 3-4 weeks in January-February, the author observed a phenomenon unlike on gravity-flow irrigation canals. A day after stoppage of pumping, M-F Canal started flowing in reverse direction. Inseepage from the adjoining areas of high water table filled the canal prism to force flow back to the Noubaria Canal over waste weirs provided at P.S. 1 & 2. Observations showed that outflow at P.S. 1 continued at a decreasing rate through out the closure period from January 10th to February 5th. A flow depletion curve drawn by the author, showed that the outflow on 4th February - a day before the canal reopened, was 0.32 m^3/s - about one third of discharge observed on 11th January - one day after pumping stopped on 10th January. Total highly saline outflow over the waste weirs, during the closure period, was 1.5 million m^3. This helped in flushing out some of the aquefir saline. Properly designed drainage outlets, as proposed by the author, could be more effective.

Introduction of drainage outlets at P.S. 1 & 2 could also help, besides partial flushing out aquefir saline at end of canal closures. They could prevent irrigation with high salinity water on the resumption of operations at the end of long holidays such s on the occasions of two Eid festivals every year.

"There was however, a note of caution in the design and operation of drainage outlets. The size of discharge opening should not be too large to empty the canal too rapidly

to avoid damage to lining and banks. Care were to be taken, while opening the outlets that water level in the canal dropped gradually so as to release static pressure behind canal banks gradually" (Malik 1976).

Supplemental Supply from Nasr Canal.

Water was pumped from Branch 6 of Nasr Canal into the delivery pool of P.S. 3 for the purpose of augmenting M-F Canal supply and to dilute its salinity. Need for supplemental supply arose because M-F canal operated during day time only and failed to meet full crop requirements. The other reason for short supply was reduced draft of suction side of P.S. 2. This was caused by wrongly laying stone lining 13m higher than canal bed upstream of the suction area. Besides reducing draft, higher bed level did not permit canal prism to pass design discharge. Hence the need for supplemental supply from Nasr Canal.

The amount of additional supply however fell short of irrigation requirements besides net effect of commingly appeared to be marginal because of high salt content of M-F canal water and inadequate component of Branch 6 supply. But round-the-clock operation of M-F canal, as recommended, could dispense with the need for supplemental supply since more than full requirements could be met by M-F canal itself.

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