THE ARAB REPUBLIC OF EGYPT

MINISTRY OF IRRIGATION

FINAL REPORT

ON

FEASIBILITY STUDY

FOR

THE SOUTH HOSAINIA VALLEY AGRICULTURAL DEVELOPMENT PROJECT

(ANNEXES)

VOLUME 4

MARCH [illegible]

JAPAN INTERNATIONAL COOPERATION AGENCY

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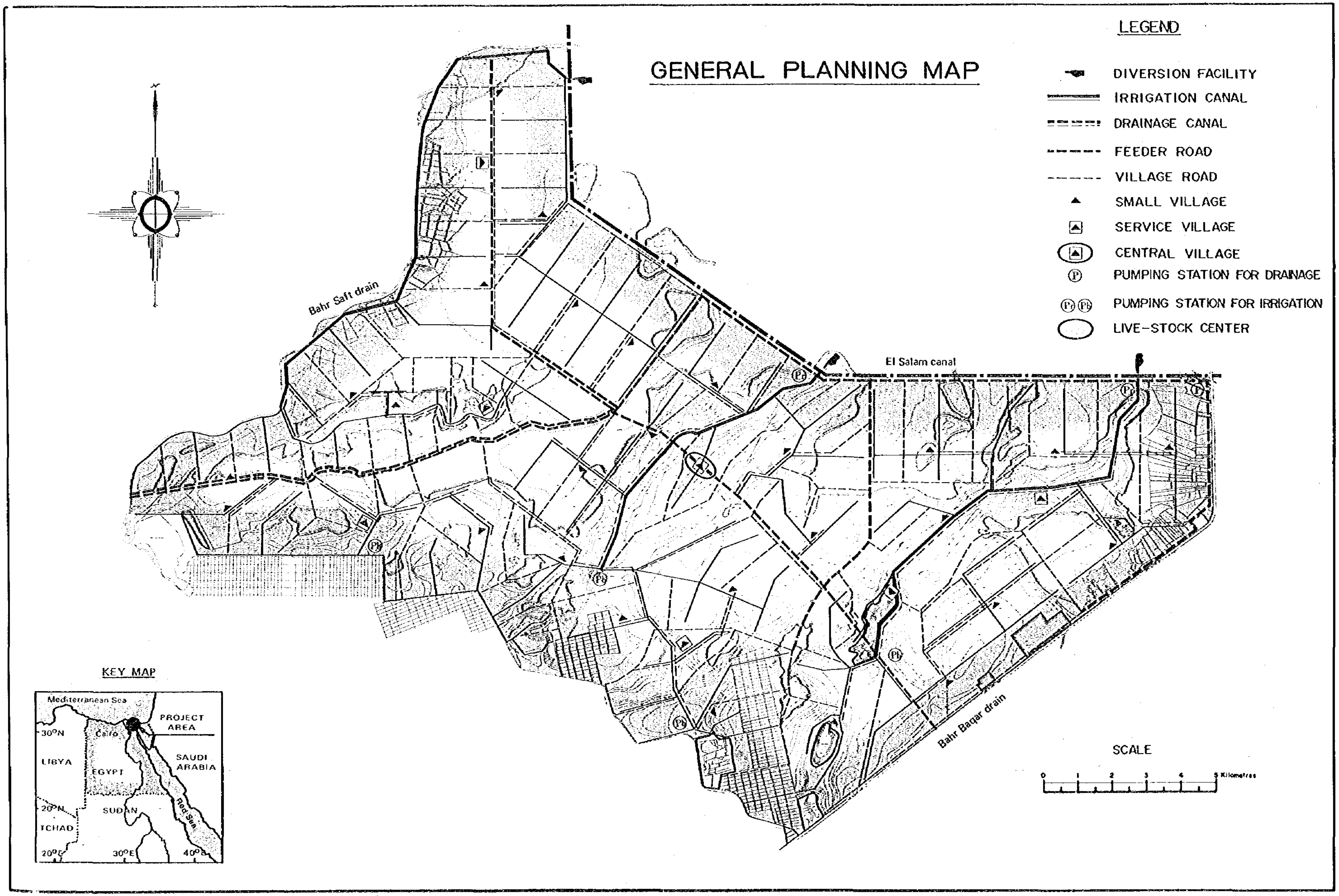
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ABBREVIATIONS AND GLOSSARY

ARE	:	Arab Republic of Egypt
B/C	:	Benefit Cost Ratio
CIF	:	Cost, Insurance and Freight
EIRR	:	Economic Internal Rate of Return
ET	:	Evapotranspiration
FAO	:	Food and Agriculture Organization
FC	:	Foreign Currency
FOB	:	Free on Board
FY	:	Fiscal Year (July 1st to June 30th)
IBRD	:	International Bank of Reconstruction and Development
JICA	:	Japan International Cooperation Agency
K	:	Potassium
LC	:	Local Currency
LE	:	Egyptian Pound = 1.4 US$ = 300 Japanese Yen
MOA	:	Ministry of Agriculture
MOI	:	Ministry of Irrigation
MOLR	:	Ministry of Land Reclamation
N	:	Nitrogen
O & M	:	Operation and Maintenance
P	:	Phosphorous
$, US$	:	Dollar, US$ = 0.74 LE

Units of Measurement

Length

mm	:	millimeter
cm	:	centimeter
m	:	meter
km	:	kilometer

Area

sq.cm, cm^2	:	square centimeter
sq.m, m^2	:	square meter
sq.km, km^2	:	square kilometer
MSM, 10^6m^2	:	million square meter

Volume

ℓ, lit	:	liter
cu.m, m^3	:	cubic meter
MCM, 10^6m^3	:	million cubic meter

Weight

g	:	gram
kg	:	kilogram
ton, m.t.	:	metric ton

Others

EL	:	elevation above mean sea level
MSL	:	mean sea level
FWL	:	full water level
HWL	:	high water level
LWL	:	low water level
sec	:	second
minu	:	minute
hr, hrs	:	hour or hours
min	:	minimum
max	:	maximum
%	:	percent
PPM	:	part per million
No.	:	Number
°C	:	degree centigrade
°F	:	degree fahrenheit
Cl	:	Chlorine
HP, PS	:	Horse Power
lit/sec	:	liter per second
m/s	:	meter per second

Conversion Factors

Unit	Comparison
Units of Length	
Millimeter (mm)	0.001 meter
Centimeter (cm)	0.01 meter
Meter (m)	100 cm
Kilometer (km)	1,000 meters
Units of Area	
Square centimeter (sq.cm)	0.0001 sq.m
Square meter (sq.m)	
Hectare (ha)	10,000 sq.m
Square kilometer (sq.km)	1,000,000 sq.m
Feddan	4,200 sq.m
Units of Volume	
Cubic centimer (cu.m)	0.001 cu.m
Liter (1,000 cu.m)	0.001 cu.m
Cubic meter (cu.m)	1,000 liters
Units of Weight	
Gram (g)	
Kilogram (kg)	1,000 g
Metric Ton (mt)	1,000 kg

Miscellaneous

1 cu.m per sec	=	1,000 liters per second (ℓ/s)
	=	35.3145 cu.ft per second (cfs)
	=	15,850 gallons per minute (gpm)
1 liter per second for 1 day	=	8.64 mm depth over one hectare
10 mm depth over 1 hectare	=	1.157 liters per second for 1 day
	=	3,532 cu.ft
1 horsepower (metric)	=	75 kg-m per second
	=	550 ft-lb per second
1 cu.m per day per feddan	=	0.238 mm/day = 2.38 ℓ/day/ha

E-1. PRESENT CONDITIONS

E-1-1. Irrigation

1) Irrigated Land

There are existing farm lands of 2,500 ha (about 6,000 feddans) in the Project Area. All of these farm lands have been irrigated because in general sufficient rainfall can not be expected in this country belonging to the arid zone countries. These farm lands distribute along the drains for relatively easy intake of irrigation water therefrom; that is, they are roughly divided into two groups, one, consisting of 1,700 ha (about 4,000 feddans) of the farm lands, is located along the Bahr Saft drain on the western border of the Project Area and the other, consisting of two farming complexes covering 800 ha (about 2,000 feddans) along the existing canal on the southern border of the Project Area. The low-lying lands extending along the Ramses drain have not been reclaimed into farm lands due to being sub-mergible areas.

The farm lands along the Bahr Saft drain, reclaimed by individual farmers more than 15 years ago, have been developed on the right bank of the drain with areal width ranging from 0.5 to 1.0 km, and some of these lands have come to provide the farming conditions at the similar level to those existing farm lands around the Project Area. These farm lands are cropped with paddy, cotton and maize in the summer season, while wheat, vegetables and Berseem (Egyptian clover) in the winter season.

2) Existing Irrigation Method

The irrigation water source for these lands is the Bahr Saft drain, from which the water is taken by gravity system into the irrigation canals provided in the fields and conveyed to the plots through the terminal facilities after lifted by small-size pumps called "Sakkia" which are operated by draft animals.

The irrigation water source for these lands, which has some problems in its quality due to originating in the drain, has been under the independent operation and maintenance of the related farmers. "Sakkia", iron-plate-made water lifting device with a lift of about 1.0 - 1.5 m and lifting capacity from 10 ℓ/sec to 25 ℓ/sec, is operated by draft animal-power, the horizontal rounding motion of which is converted into vertical motion by bevel gear so as to lift the water. The average acreage irrigated by one unit of Sakkia is about 10 ha (about 25 feddans). The Sakkia is usually operated by one or two head of cattle and its operating hours are 5 - 6 hours from early in the morning to noon when the atomospheric temperature is comparatively low. Since the detailed information on the Sakkia is not available, only estimate is made on total number of Sakkia operated in the Project Area by about 250 units on the basis of per unit irrigation capacity.

The draft animals as mover have decreased in number due to lack of fodder and being slughtered to cover shortage in beef supply. Under the situation, the animals have been recently being replaced with the small-size engines (five to nine Hp). Such engines are superior to animals in being operable at any time and any place, but the expensiveness has curbed rapid diffusion of the engines.

On the other hand, the small-size pumps (bore diameter 15 cm, five to six Hp) have been gradually increased in number, although the high cost has prevented them from becoming popular. Use of such pumping devices sometimes tends to cause inorderly water management, water disputes by individual farmers, imbalance in water use and large irrigation loss.

3) Existing Water Management

The Ministry of Irrigation has conducted an intermittent irrigation to practise the stringent water management for those farm lands reclaimed on the force account basis. The way that the Ministry of Irrigation has taken is to supply the water for four days and then to interrupt the operation for the following four days. Therefore, the farmers have to take water for their own farm lands during these four days when the irrigation water is available in the canal. For the winter season when the irrigation water requirements are comparatively small, the six-day interval method (six-day supply and six-day interruption) is applied.

Furthermore, operation and maintenance services for irrigation facilities such as canals and structures in every winter induce the water supply to completely stopped for three weeks in January or February. Every year, the Ministry of Irrigation decides the non-service period, during which repair and maintenance works are carried out for various equipment and facilities of the pumping stations, gates, canals, etc. This year, 1981, the Ministry has decided to impose about three-week non-service period from January 19 to February 9 with transitional periods of five days each before and after the said period for gradual decrease or increase in water of the canals.

The operation and maintenance of the terminal facilities have depended upon individual farmers' works. Those farmers who ill-maintain their terminal facilities will be penalized, sometimes by complete stop in water supply.

4) Irrigation Method to Existing Reclaimed Lands

The existing reclaimed lands extending along the southern border of the Project Area is dependent in its water supply upon the return flow from the upstream area outside the Project Area. These lands, having no exclusively dependable water sources, urgently require to secure a stable water source in both quality and quantity.

For the newly reclaimed farm lands, the Ministry of Land Reclamation has been making a re-arrangement of the pumping sites so as to cover a possibly larger acreage of lands by a unit of the device. Such efforts by the Ministry have been made to prevent the irrigation loss that had been caused largely from poor operation and maintenance by individual farmers.

One pump station of this kind will be located to cover the service area ranging from about 170 ha to 210 ha (about 400 to 500 feddans), and the respective irrigable areas will be determined by elevation of the lands in the range from EL 1.0 to 1.5 m. In other words, the irrigable areas commanded by a unit of pump is arranged along the contour lines so that fair distribution of the water can be easily secured for the farm lands in the upstream and those in the down stream.

In such a manner, a great care and effort have been made for possible water saving by the Ministry of Irrigation, the direct administration agency of the irrigation, and the Ministry of Land Reclamation, the representing agency of the beneficiary.

It is noteworthy that the water level in the canals is kept 0.5 - 1.0 m below the field surface; this is because, in higher water level than the field surface, (1) the seepage losses in the canal increase, thereby (2) the farmers can easily steal water resulting from difficulty in systematic water management, whereas (3) in low water level in the canal, the return flow can be used easily in recycling as well as the groundwater table is expected to be lowered. These are the major reasons why the water level in the main and lateral canals is kept lower than the elevation of the field surface.

E-1-2. Drainage

1) Present Condition

The drainage conditions in the Project Area are extremely unfavourable, and 12,200 ha (about 29,000 feddans) of the total Project Area of 31,400 ha (about 74,700 feddans), which occupies about 40 percent of the total, are submerged areas. Such a large-scaled submergence has been caused from absence of dykes to shut out the water of the Manzala Lake which fluctuates in the water level in a range from WL.0.0 to 0.5 m against the elevation of submerged areas below EL.0.25 to 0.5 m. Besides, the submerged areas, extending very flat, vary in acreage from fluctuation of the water level in the Lake.

Judging from the water traces observed around the submerged areas, the water level appears to rise up to WL 0.5 m while the minimum water level is estimated at WL 0.0 m. The water intrusion from the Manzala Lake will be completely intercepted by the embankment of the El Salam canal that is now under construction by the Ministry of Irrigation. Therefore, the present submerged areas will naturally be dried up when the said embankment is completed.

The hillock lands (cultivable waste lands) developing from south to west in the Project Area provide several hollow areas below EL 0.25 m, into which highly concentrated salty groundwater (about 30% of salinity concentration) has been flowing from the peripheral areas. However, no outlets with them but a large annual evaporation in the area have turned them into salty lakes with accumulation of chrysterized salt. The farmers living around the Project Area gather chrysterized salt for sale, and domestic use.

Considerable salt accumulation resulting from high groundwater table is observed in the ground surface in these arable waste lands. Such a phenomenon of salt accumulation is generally observed in the arid zone where evaporation takes place in a large amount. The evaporation causes the salt to be accumulated and chrysterized in the ground surface, and the degree of concentration is estimated at 15 percent on an average by soil analysis, althrough widely ranging from about five to 30 percent. The estimated amount of accumulated salt can be converted into about 150 tons salt/ha in the surface layer and hence the leaching treatment is essentially required for successful farming.

No systematic drainage networks are found in the existing farm land along the Bahr Saft drain, and the operation and maintenance of drainage facilities has been made by individual farmers as well as the terminal irrigation facilities.

The newly reclaimed lands around this area are drained by pumps, which can well control the groundwater table so as to prevent the soils from salt accumulation caused by high groundwater. The water level of these drainage canals is keeping about one meter below ground surface at the terminal field drains.

2) Drainage Modulus

According to FAO's "Research on Crop Water Use, Salt Affected Soils and Drainage in ARE", the drainage modulus by 2 mm/day (8 cu.m/feddan/day) is applicable to the general farm lands in Egypt, while the double of this value is recommended for the paddy fields. On the other hand, the drainage discharge can be estimated at 3.4 mm/day on an average (14.3 cu.m/feddan/day) based on the discharge records of the Bahr Hadous and information on its annual discharge of 28.4 billion m^3, catchment area of 2,290 m^2 (546,000 feddans). Therefore, the unit drainage discharge to be required for pumping in this area is estimated at 3 - 4 mm/day (12.6 mm/feddan/day - 16.8 cu.m/feddan/day).

No crop damages resulting from ill-drainage in the area have been observed due to absence of farm lands in the low-lying flat lands of the area, as mentioned in the previous paragraph.

E-1-3. Roads

There are no community roads nor farm roads in the Project Area. Only paths traced by tractors transporting the salts gathered from the lakes are found therearound. These paths, having about two to three meter width to alow a tractor to pass, have been affected by wind and rain to change in their courses from year to year. However, the paths are only available by two or three route running from south to north but not from east to west. Under the circumstances, it is almost impossible to access to the area by vehicles. In particular, there have been no human foot traces found in the submerged area due to total absence of roads, even tractor paths.

Around the Project Area, there is an operation and maintenance road running along the Bahr Baqar, the eastern border of the Area, but this is an earth paved road with four to five meters width and appears to be inadequately maintained.

Along the Bahr Saft drain, the western border of the Area, a two to three meters wide earth paved road is partly running but the maintenance services seem to be poorly rendered. Furthermore, no bridges nor any crossing structures over this drain are found except for ferry services available at several points for man, animals and light carts.

The roads running in the peripheral area of the Project Area, although all paved with asphalt, have rough surfaces resulting from poor maintenance works. The total width is about eight to ten meters, including passable width of six to eight meters. (Refer to Fig. E-1-1)

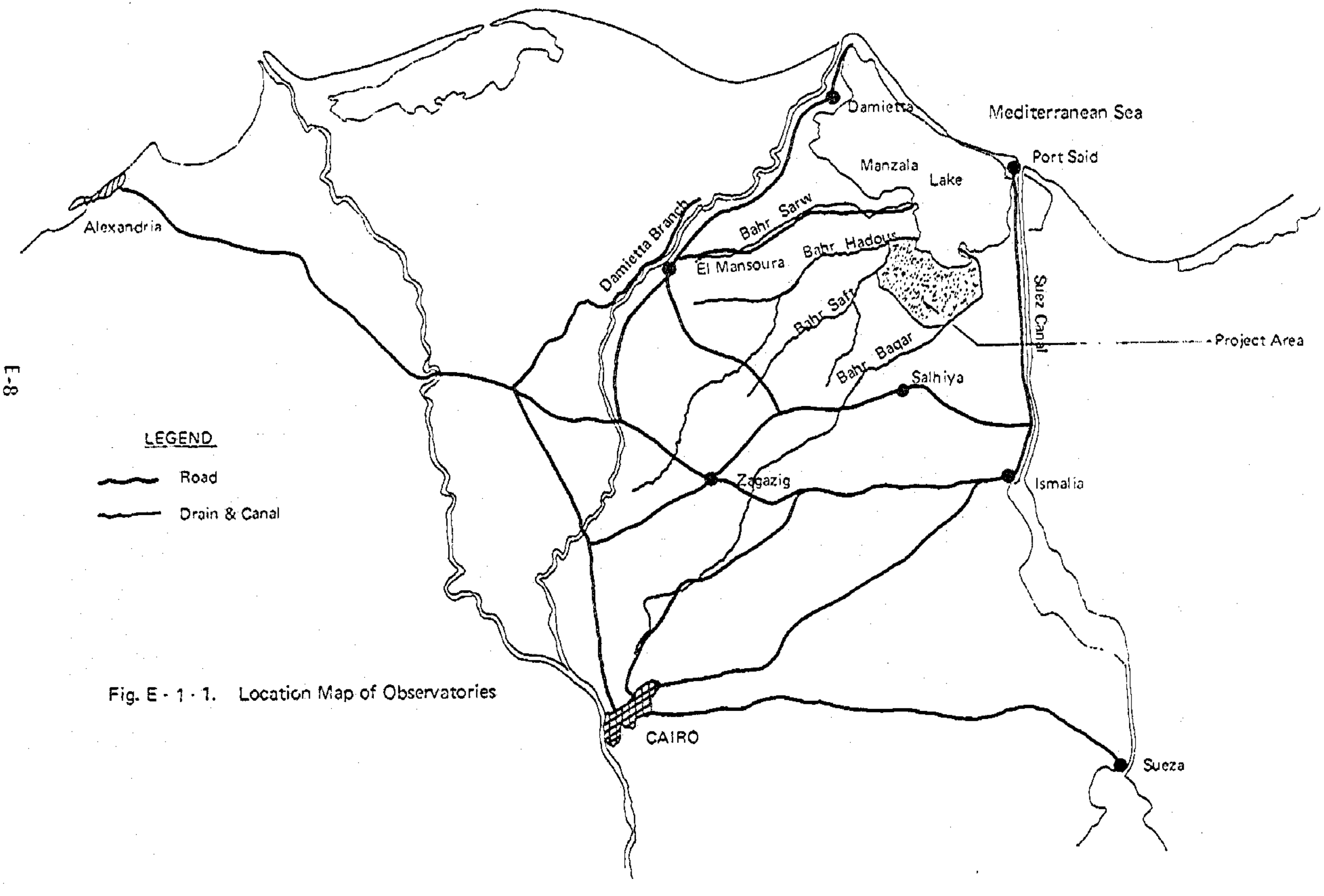


Fig. E - 1 - 1. Location Map of Observatories

E-2. IRRIGATION PLAN

E-2-1. Irrigation Method

1) General

Irrigation is herein defined as practice that the water is adequately diverted from sources, properly conveyed and rationally distributed to fields for meeting the requirements of agricultural crop production. Among many, the major purposes of irrigation are (i) to supply moisture essential for plant growth, (ii) to supply natural nutrients to plants through water, (iii) to control atmospheric temperature and plant environment, (iv) to eliminate harmful substances such as salts, etc., and (v) to protect plants by flooding in the fields from wind damages, and so forth.

Characteristic features of irrigation are summarized as follows;

(i) Water utilization in agriculture, relating closely to land and rural community in many cases, is an essential factor of the production and living mechanism in the rural areas.

(ii) The rural communities have their own habitual water utilization practices formed through long historical traces. These practices have been a bottleneck for smooth and effective operation of modernized irrigation organization, although being reasonable in some aspects.

(iii) The demands for irrigation water have a considerably large seasonal fluctuation throughout the year; in other words, the demands come up to the peak in summer.

(iv) In particular, the paddy irrigation water is in recycling use (return flow) through rivers, drains and the canals in the paddy field areas for the most effective utilization of water resources.

2) Irrigation Method

Irrigation methods, whatever kinds and types they may have, should be those to meet the conditions of soils and topography where the facilities are provided. Hence, it is essentially required to select the suitable method to these conditions and also to conduct an adequate water management to meet the specific features of soils and crops to be grown.

Irrigation is roughly specified into five types as follows;

(i) Flood irrigation

(ii) Basin irrigation - to soak an objective area surface as a whole

(iii) Furrow irrigation - to soak a part of objective area surface

(iv) Sprinkler irrigation

(i) Flood irrigation

Of the above five the item (i), the flood irrigation is commonly applied to paddy field, while the other four mainly to upland fields.

The flood irrigation, which is applied in the way that a certain area is enclosed with 30 - 50 cm high ridges to be flooded for irrigation, is suited to those lands with comparatively small percolation, consisting of clayey loam soils. In an area with sandy soil, large percolation should be protected.

(ii) Basin irrigation

a) Border method: This is often used for the lands densely grown with plants such as pasture, being applicable to any types of soils excepting for the soils composed of fine particles with relatively low intake rate. This method is suited to growing miscellaneous grain crops and pastures in the comparatively flat lands (slope: 3 - 5%). The basin irrigation requires less labour but much discharge, and the objective farm lands should be evenly leveled. When the land slope ranges within two percent, this method can be applied without causing soil erosion.

b) Basin irrigation (level border irrigation)

This method is applicable to almost flat lands and the soils and crops in any types; for instance, pastures, fruit-trees, miscellaneous grain crops and other upland crops grown in the ridged fields. The basin irrigation is often applied for fruit-tree cultivation, having a characteristic feature to make water infiltrate into soils quickly, or sometimes for leaching the newly reclaimed lands so as to eliminate the salts in the soils by deep infiltration.

(iii) Furrow irrigation

This method is commonly applied to almost all upland crops grown in the ridged fields and fruit-trees. This method is further specified into four by the furrow distances; large furrow method, small furrow method, corrugation method and rill method. By this method, irrigation water flows down through furrows to infiltrate into soils and spread horizontally to irrigate crop roots zones. This is a kind of partial flooding irrigation to soak a part of ground surface (1/2 - 1/5). As compared with the other type of basin irrigation, this method has a characteristic feature to save evaporation losses in operation and to facilitate the farming works in the said fields after irrigation.

(iv) Sprinkler irrigation

The irrigation method is generally applied to deliver irrigation water for upland crops. This method has many advantegeous points such as saving irrigation water in order to convey the water through pipeline systems and reducing the required farm labor-force in order to introduce the automatic water management systems in on-farm level. On the other hand, the method has many weak and dis-advantegeous points like the resistance to strong wind and the requirement of irrigation water with good quality. (Further details is shown in Annex F On-farm Development)

E-2-2. Irrigation Water Requirements

1) Meteorological

There are no observation stations located in the Project Area and San El Hogar. Hence, the 10-year meteorological records were collected at seven stations in the vicinity of the Project Area. On top of the above, the records covering a period from the start of observation to 1960 were collected at three stations by the average values.

The locations of these observatories are illustrated in Fig. E-1-1. (Refer to Appendix B-4).

(i) Port Said

Of the seven stations, three stations at Port Said, El Mansura and El Salhiya are located closely to the Project Area. However, the records observed at Port Said, facing the Mediterranea Sea, about 40 km north of the Project Area were not used in this study because Port Said is prevailed by the oceanic climate and those records of atomospheric temperature and wind velocity are different in nature from those observed around the Project Area, the inland area.

(ii) El Salhiya

Besides the above, the records observed at El Salhiya which is situated in the middle of the desert are rejected in this study because atmospheric temperature and humidity are different in nature from those observed at the reclaimed areas around the Project Area.

(iii) El Mansura

On the other hand, the records obtained at El Mansura, which is situated in almost the same latitude as the Project Area, are adopted to determine the dimensions of the El Salam Canal, and furthermore, the land conditions prevailing around the El Mansura station are the reclaimed lands and similar in topography and environmental conditions to those of the Project Area.

The records available for more than 30 years are monthly averages on seven items such as atmospheric temperature, humidity, wind direction, wind velocity, etc.

The general climate in the Project Area changes in cycle for both long and short-terms. And the climate charges from year to year. Since the above-mentioned records were observed more than 20 years ago, although considered valuable, estimations of evapotranspiration, etc. have been made on the records covering the last 10 years between 1969 and 1978.

2) Estimation of evapotranspiration

(i) Factors affecting evapotranspiration

There are many factors that affect consumptive use or evapotranspiration. The evapotranspiration rate depends on the specific crop, climate, soil moisture supply, salinity, and vegetative cover. Factors included in climate that particularly affect evapotranspiration are solar radiation, precipitation, temperature, daytime hours, humidity, wind velocity, and length of growing season. The quantity of water transpired by plants also depends upon the availability of moisture within the root zone, the stage of development of the plant, the amount of foliage, and the maturity of the leaf surfaces. In general, the factors which affect consumptive use may be divided into three groups as follows:

a) Climate factors
b) Water supply to plants
c) Plant characteristics

a) Climate factors

The amount of water required to raise a crop depends on the kind of crop and the climate. Evaporation and transpiration require energy which is obtained principally from the sun. The most important factor, therefore, that affects the consumptive use rate is the solar radiation. However, several other climatic factors such as humidity, wind or air movement, temperature, length of the day, precipitation, etc., influence consumptive use. Low relative humidity, long periods of sunlight, and high wind velocity will increase evapotranspiration. Among the other climatic factors, the solar radiation will be described as follows;

The solar radiation which arrives on the surface of the earth is the main source of the energy supply. Part of this energy is used in evapotranspiration, part is reflected or radiated back into space, and part is used in heating the soil, the air, and the vegetation. The amount of energy received by the plants depends on the crop cover and stage of growth.

The heat available for evapotranspiration is called net radiation, which is the difference between the incoming and the reflected, plus the long-wave radiation. During the day, part of the net radiation goes into heating the air, a small part goes into heating the soil and the vegetation, and the remainder is available for evapotranspiration. The evaporation which occurs at night is dependent on the heat supplied during the daytime to the water, the soil, and the air. Variations in the evapotranspiration rate occur from day to day because of changes in the available energy. A hot, dry windy day will increase the rate of evapotranspiration, whereas a cool, damp, still day will decrease it.

b) Water supply to plants

The soil moisture within the root zone is the primary factor affecting the water supply available to the plants. This depends on rainfall and irrigation as well as on stored moisture in the soil. The salinity of the soil solution in contract with the roots also affects the availability of the moisture to the plants as it increases the soil moisture potential. Soil conditions that affect or limit the root growth and development, indirectly affect the moisture supply.

c) Plant characteristics

It should be noted that not only different crops require different amounts of water, but that even the same crop needs different amount of water at different growth stages. The evapotranspiration rate increases to a peak and then diminishes as the crop matures. The physiology of the growing plant can be characterized by flowering, fruiting, and other distinctive status of the plant. Peak consumptive use comes at the beginning of flowering and at the end of the vegetative stage of growth. Water shortage during this period will reduce the size and the yield of the crop.

3) Methods of Determining Evapotranspiration

Various methods have been used by scientists and engineers to determine the consumptive use (evapotranspiration) of a crop and natural vegetation under field conditions during the past years. The methods of determining evapotranspiration can be conveniently divided into two main groups: direct methods and indirect methods. The methods most widely used will be described as follows:

i) Direct methods

The direct methods most widely used in engineering investigations are:

a) Soil moisture depletion studies
b) Tank and lysimeter experiments
c) Inflow-outflow method

a) Soil moisture depletion studies

This method is still an important supplement to evapotranspiration studies. The soil moisture depletion method is usually suitable for areas where soil is fairly uniform and the depth to ground water is such that the ground water will not influence soil moisture within the root zone. Precipitation must be measured and considered in computing the evapotranspiration.

Soil moisture in the major root zone is determined before and after each irrigation, usually with some measurements between irrigations. They are generally adequate for long-time evapotranspiration averages but technical difficulties prevent the use of soil moisture depletion methods for short-time evapotranspiration measurements. Recent advances in neutron moderation equipment provide a technique which will improve this method.

b) Tank and lysimeter experiments

One of the more common methods of determining use of water by individual agricultural crops and natural vegetation is to grow the plants in tanks or lysimeters and measure the quantity of water necessary to maintain satisfactory growth. Tanks as large as ten feet in diameter and ten feet deep have been used. However, in most consumptive-use studies, the tanks are about two to three feet in diameter and six feet deep.

The practicability of determining consumptive use by means of tanks or lysimeters is dependent upon the accuracy of reproduction of natural conditions. In addition to environment, artificial conditions are the result of limitations of soil, size of tank, or regulation of water supply. Weighing is the precise means of determining the consumptive use from tanks and this method was used as early as 1907. However, conditions and facilities will not always permit the weighing of tanks. It has been found that all tank vegetation must be protected from the elements by a surrounding growth of the same species.

c) Inflow-outflow method

Applying the inflow-outflow method, consumptive use (U) is equal to the water that flows into an irrigable area during a given period (I) plus the precipitation on the area (P) plus water in ground storage at the beginning of the period (Gs) minus water in ground storage at the end of the period (Ge), minus the outflow (R) for the same period. This method is most often used to determine annual values of consumptive use. When all volumes are measured in the same units,

$$U = (I + P) + (G_s - G_e) - R$$

The quantity, $(G_s - G_e)$ is considered as a unit so that absolute evaluation of G_s or G_e is unnecessary, the difference only being needed. This difference is the product of the difference in the average depth of water table during the period, and multiplied by the specific yield of the soil and by the area. The quantity (P) is obtained by multiplying the average precipitation by the area. The average consumptive use for the area is obtained by dividing the total volume of consumptive use by the area.

(ii) Indirect methods

Because of the difficulty in measuring directly, many scientists have developed formulas for estimating evapotranspiration from meteorological data. Generally speaking, these methods may be grouped into two main categories as follows:

Theoretical methods based on the physical of the vapor transfer and energy balance. No observation values of the evapotranspiration are available for the Project Area. Therefore, the estimation of the said values has been made by applying the theoretical equation based on the meteorological records mentioned previously. In general, the evapotranspiration is desirable to be prepared as the observation values by soil types in or around the Project Area covering at least several years. Since it is difficult, however, to obtain such records, many scientists have developed a variety of theoretical equations for the purpose. Among many, three methods of the Blaney-Criddle, Radiation and Modified Penman, which are highly evaluated for their suitability and internationally used by the World Bank, FAO and many other countries have been applied to determining the evapotranspiration for the Project through comparison of these three estimates.

a) Blaney-Criddle method

The Blaney-Criddle method utilizes mean monthly percent of daytime hours, temperature and a predetermined consumptive use coefficient for individual crops. This method has been used by Federal and State agencies in the United States of America and by various countries in arid and semi-arid areas throughout the world.

$$ETo = c\,[\,p\,(0.46\,T + 8)]$$

where;

ETo = reference crop evapotranspiration for month considered (mm/day)

T = mean daily temperature the month considered (°C)

p = mean daily percentage of total annual daytime hours obtained for a given month and latitude

c = adjustment factor which depends on minimum relative humidity, sunshine hours and daytime wind estimates

This equation was used for estimating the water requirement of the irrigable areas and determining the discharge in the El Salam canal in its planning stage.

The estimation by this method revealed that peak evapotranspiration takes place in June by 8.7 mm/day, the annual value by 2,008.6 mm and the daily mean value by 5.5 mm/day. (Refer to Table E-2-1, Fig. E-2-1 and Appendix E-1).

b) Radiation method

The radiation method is applicable only when those records on atmospheric temperature, sunshine hours, cloudiness and radiation are available. The basic equation is as follows:

$$ETo = C\ (W.Rs)$$

where;

ETo = reference crop evapotranspiration for the periods considered (mm/day)

Rs = solar radiation in equivalent evaporation (mm/day)

W = weighting factor which depends on temperature and altitude

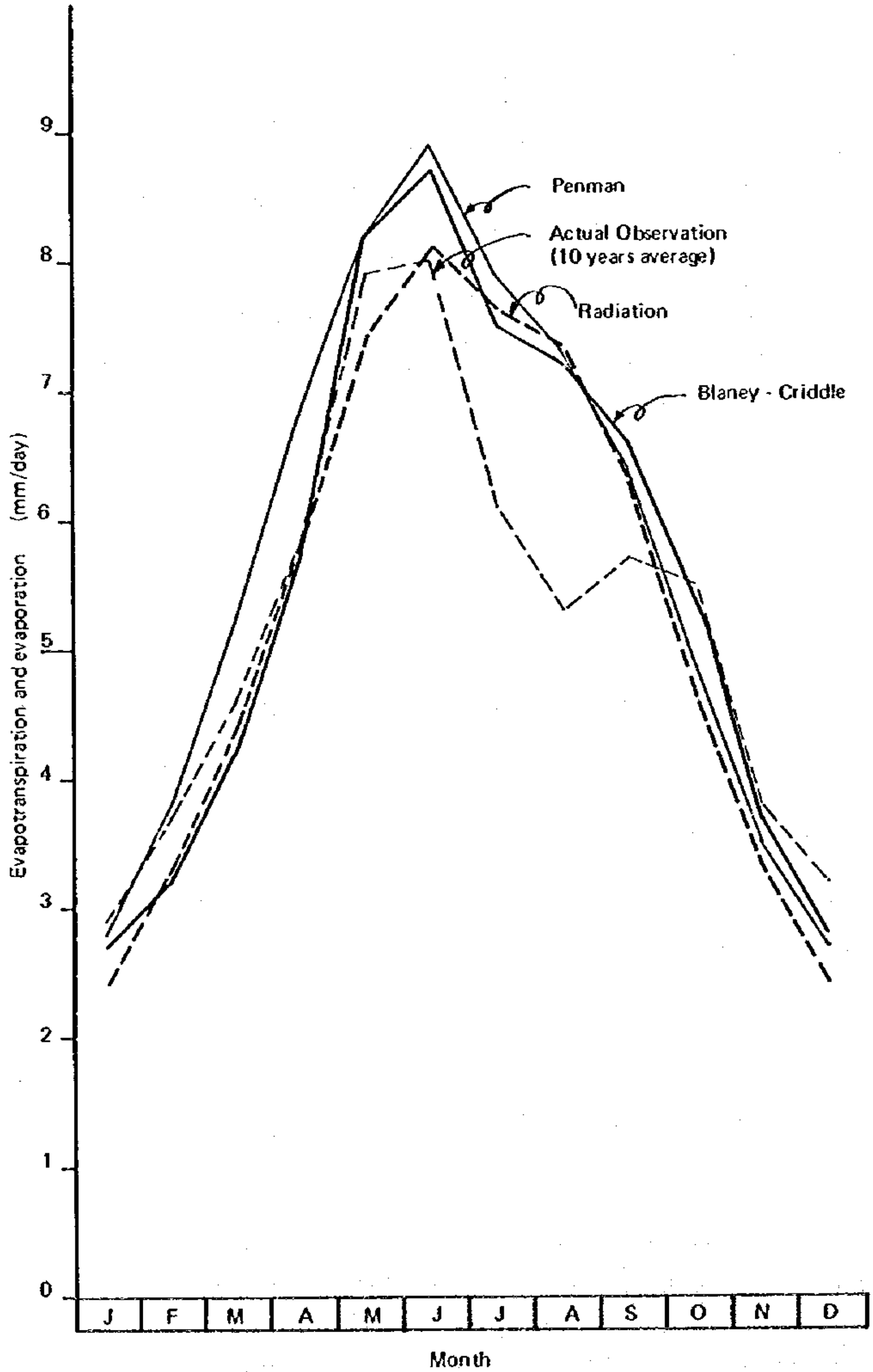
C = adjustment factor which depends on mean humidity and daytime wind conditions

The estimation by this equation has resulted in that peak evapotranspiration occurs in June by 8.1 mm/day, and the annual total and daily mean evapotranspiration are 1,916.5 mm/year and 5.3 mm/day, respectively. (Refer to Table E-2-2, Fig. E-2-1 and Appendix E-2)

c) Modified Penman method

The Modified Penman method has recently gained more popularity among scientists and engineers in the world. This method requires to provide such meteorological records as atmospheric temperature, humidity, wind velocity, sun-

Fig. E-2-1 Comparison of ETo



Station: El Mansura

Table E-2-1 ETo BY YEAR (BLANEY - CRIDDLE)

(Unit: mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1969	2.4	3.1	3.9	5.0	9.0	9.3	7.2	7.1	6.5	5.4	4.2	3.2
1970	2.8	3.6	5.1	6.5	8.0	8.9	7.2	7.1	6.4	6.2	3.3	2.6
1971	2.8	2.8	5.2	5.4	8.1	9.0	7.2	7.2	6.3	5.0	3.4	2.6
1972	3.1	3.3	3.6	5.9	7.8	9.0	7.7	7.7	8.0	5.3	3.6	2.8
1973	3.1	3.5	4.4	6.2	9.0	7.7	7.7	7.1	7.8	-	-	-
1974	-	2.8	3.8	5.7	7.8	9.0	7.7	7.7	6.4	6.7	4.1	2.4
1975	2.6	2.8	5.2	5.8	3.0	9.0	7.7	7.1	6.3	5.3	-	2.6
1976	2.6	2.6	3.6	4.6	8.0	7.2	7.2	7.0	6.1	5.4	4.2	3.2
1977	2.6	3.6	3.3	5.7	8.3	9.2	7.8	7.2	6.3	5.0	3.3	3.1
1978	2.4	3.5	3.6	6.5	8.3	9.0	7.7	7.0	6.1	4.7	3.4	2.8
Mean	2.7	3.2	4.2	5.7	8.2	8.7	7.5	7.2	6.6	5.4	3.7	2.8

Table E-2-2 MONTHLY ETo BY RADIATION METHOD

(Unit: mm/day)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1969	2.1	3.3	4.3	5.4	6.7	8.9	7.7	7.3	6.5	4.8	3.5	2.8
1970	2.6	3.4	4.4	6.5	7.5	8.4	7.7	7.3	6.5	4.8	3.4	2.4
1971	2.6	3.2	4.3	5.2	7.8	8.4	7.5	7.2	6.1	4.3	3.2	2.0
1972	2.6	3.4	4.3	5.2	6.6	7.6	7.5	7.3	6.5	4.8	3.3	2.3
1973	2.6	3.4	4.3	6.4	7.3	7.6	7.6	7.3	6.5	-	-	-
1974	-	3.2	4.2	5.2	7.7	8.6	7.5	7.3	6.1	5.0	3.4	2.2
1975	2.5	3.0	5.4	6.0	7.5	8.4	7.6	7.2	6.3	4.9	-	2.1
1976	2.3	2.8	4.4	5.3	7.3	8.3	7.6	7.2	5.9	4.4	3.3	2.5
1977	2.2	3.5	4.4	6.0	7.7	8.4	7.6	7.4	6.4	4.4	3.4	2.9
1978	2.3	3.5	4.2	6.3	8.0	8.4	7.6	7.2	6.0	4.4	3.1	2.3
Mean	2.4	3.3	4.4	5.8	7.4	8.1	7.6	7.3	6.3	4.6	3.3	2.4

shine hours. The basic equation for computation is as follows:

$$ETo = C\,[W.Rn + (1 - W)\cdot f(u)\cdot(ea - ed)]$$

where;

ETo = reference crop evapotranspiration (mm/day)

W = temperature - related weighting factor

Rn = net radiation in equivalent evaporation (mm/day)

f(u) = wind - related function

ea - ed = difference between the saturation vapour pressure at mean air temperature and the mean actual vapour pressure of the air (mbar)

C = adjustment factor to compensate for the effect of day and night weather conditions

The computation found that the month when peak evapotranspiration takes place is June by 8.9 mm/day, and the annual total and daily mean evapotranspiration are 2,083.4 mm/year and 5.7 mm/day, respectively. (Refer to Table E-2-3, Fig. E-2-1)

e) Result

As a result, the estimated values by above three methods have not made large differences from each other, although the Radiation method resulting in lower values than the others and the Penman method resulting in comparatively high values in peak by 8.9 mm/day and in annual total. Under the situation, either method is applicable to this study without causing any large difference. Hence, the ETo values estimated by Blaney-Criddle method have been adopted for the Project Area as the moderate values.

Table E-2-3 CALCULATION OF ETo BY PENMAN

Station: El Mansura

Location: Lat. 31°00'N Long. 31°27'E Alt. 3.8 m

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Tmean	°C	1	12.6	13.7	15.9	19.2	23.0	26.0	26.9	26.8	25.6	22.7	18.6	13.9
ea	mbar	2	14.6	15.8	18.1	22.3	28.1	33.6	35.5	35.3	32.8	27.6	21.4	16.0
RH/100		3	0.65	0.63	0.59	0.56	0.53	0.55	0.61	0.62	0.61	0.59	0.63	0.67
ed		4	9.49	9.95	10.68	12.49	14.89	18.48	21.66	21.89	20.01	16.28	13.48	10.72
ea - ed 2 - 4		5	5.11	5.85	7.42	9.81	13.21	15.12	13.84	13.41	12.79	11.32	7.92	5.28
U2	km/day	6	259	264	314	290	276	259	211	187	182	194	225	256
f(u)		7	0.97	0.98	1.12	1.05	1.02	0.97	0.84	0.77	0.76	0.79	0.88	0.96
1 - W		8	0.41	0.39	0.36	0.33	0.28	0.25	0.24	0.24	0.25	0.28	0.33	0.39
(1 - W).f(u).(ea - ed)	mm/day	9	2.03	2.24	2.99	3.40	3.77	3.67	2.79	2.48	2.43	2.50	2.30	1.98
n		10	6.9	7.8	8.3	9.2	10.7	11.7	11.4	11.2	10.4	9.2	7.8	6.8
N		11	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
n/N		12	0.67	0.70	0.69	0.71	0.78	0.83	0.81	0.84	0.84	0.80	0.74	0.67
0.25 + 0.50 n/N		13	0.59	0.60	0.60	0.61	0.64	0.67	0.66	0.67	0.67	0.65	0.62	0.59
Ra		14	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
Rs		15	5.07	6.30	7.80	9.21	10.56	11.39	11.09	10.52	9.25	7.41	5.77	4.78
Rns		16	3.80	4.73	5.85	6.91	7.92	8.54	8.32	7.89	6.94	5.56	4.33	3.59
f(ed)		17	0.20	0.20	0.20	0.18	0.17	0.15	0.14	0.13	0.14	0.16	0.18	0.20
f(n/N)		18	0.70	0.73	0.72	0.74	0.80	0.85	0.83	0.86	0.86	0.82	0.77	0.70
f(T)		19	13.2	13.4	13.8	14.4	15.2	15.9	16.1	16.1	15.8	15.1	14.3	13.5
Rnl		20	1.85	1.96	1.99	1.92	2.07	2.03	1.87	1.80	1.90	1.98	1.98	1.89
Rn		21	1.95	2.77	3.86	4.99	5.85	6.51	6.45	6.09	5.04	3.58	2.35	1.70
W.Rn		22	1.15	1.69	2.47	3.34	4.21	4.88	4.90	4.63	3.78	2.58	1.57	1.04
ET		23	3.2	3.9	5.4	6.7	8.0	8.6	7.7	7.1	6.2	5.1	3.9	3.0
ET corr.		24	2.8	3.8	5.2	6.8	8.2	8.9	7.9	7.3	6.4	4.9	3.5	2.7

4) Crop Factor

A proposed cropping pattern is determined through the study on farming techniques, climate, labour balance, etc. The proposed cropping pattern plans to introduce cotton, paddy, maize (seed and soiling corn) as summer crops, while Berseem (Egyptian clover) and wheat as winter crops. Based on this plan, the crop factors (Kc) for the respective crops[1/] are shown in following table. The crop factors (Kc) of each crop fluctuate in ranges in the table.

Crop	Kc Value
Cotton	0.39 - 1.12
Paddy	0.95 - 1.21
Maize	0.30 - 1.11
Berseem	0.55 - 1.03
Wheat	0.37 - 1.12

These crop factors vary from one growing stage of plants to another. The proposed cropping pattern defines the seeding or planting period of the respective crops by one month in due consideration of a variety of conditions such as labour requirement, etc. Thereby, the growing stages stagger among those crops planted early and late. This means that the irrigation water requirements, when estimated by one crop factor for the whole, turns into a considerably large amount. Furthermore, the facilities to be constructed in design to meet such large water requirements will result in excessive investment.
(Refer to Appendix E-3)

5) Water Requirements

(i) Crop water requirements

The crop water requirements (ET crop) can be computed by multiplying the value of evapotranspiration (ETo) obtained through the process explained in the previous paragraphs by the crop factor (Kc). That is;

1/ Note: Referred to Irrigation and Drainage Paper No.24, FAO.

ET crop = ETo x Kc

The crop water requirements for those crops other than paddy can be computed by the above equation.

Since the paddy cropping, however, requires preparatory works such as nursery works, puddlings, etc., it is necessary to add the water requirements for these works to the above crop water requirements. The nursery period, according to the proposed cropping pattern, lasts one month in May, for which the crop factors for paddy were determined in consideration of the one month time-lag between early planting and late planting as in other plant croppings. (Refer to proposed cropping pattern in Annex D, Agriculture)

The necessary acreage for nursery bedding was determined by 1/8 of the total paddy cropping acreage. This acreage is too large compared with Japanese farming that need the nursery acreage is 1/20. In near future, this value 1/8, should be improved and reduced.

The puddling water, which is not required for growing any other crops than paddy, is applied to soaking the soils to saturation for facilitating transplanting works. The water requirements for puddling depend upon the length of transplanting period. In the case that transplanting is carried out for an irrigable area of (A) for a certain period (D days), the water requirements per day (Q), in taking puddling water requirement by (W), can be expressed by the following equation:

$$Q = W. A/D$$

In this equation, since W and A are constant, Q will decrease as D increases. The proposed cropping pattern defines the value of D by 30 days in taking into account various conditions such as climate. And the development of early and late maturing strains of paddy in Egypt as in Japan will permit the paddy water requirements to be reduced in peak time in future.

As mentioned already, the puddling water requirements are needed as the water to soak the paddy fields and computed by the following equation:

$$W = Ws + Wt + We + Wp$$

Where;

W = puddling water requirements

Ws = standing water on the field (50 mm)

Wt = pore space of top-soil layer (15 cm), 150 mm x 0.2 = 30 mm

We = Evaporation from water surface (mm), 8 mm/day x 4 days = 32 mm

Wp = percolation rate, 2 mm/day x 5 days = 10 mm

Therefore; $W = 50 + 30 + 32 + 10 = 122 \fallingdotseq 125$ mm

In the fields where the soils are moistened, one application of such puddling water can soak the soils to saturation, whereas, for dry season paddy cropping even in the moistened fields or cropping in the arid area, the field surface is too hard to be soaked adequately only by one application of the water. Therefore, for the hardened fields, it is recommended to apply to puddling water two times by half amount of necessary water in each application for turning top soils soft enough to paddy transplanting by effective soaking as well as saving water losses. In this case, the first irrigation should be carried out aiming at softening and moistening the top soils for ploughing and harrowing while the second aims at preparing planting bed for paddy transplanting.

In this way, the Project will adopt a plan to practise the first irrigation by 75 mm/day in depth five days before transplanting.

(ii) Leaching water

Salt accumulation in the top soils commonly occurs in the fields with low moisture content and high groundwater table in the areas where little rainfall is available for leaching the salts. Recently, even in Japan which is a comparatively pluvious country, cropping in the greenhouses has come to suffer from salt accumulation in the soils.

The following two leaching methods are proposed for eliminating the accumulated salts in the top soils; one is to take away the direct causes of the salt accumulation and the other is to remove the salts accumulated in the soils. The former includes those treatments to provide drainage facilities for decreasing the groundwater table and to supply the sufficient leaching water instead of rainfalls, while the latter is to replace the salt-polluted top soils with non-polluted soils but recommendable only for small areas such as in the greenhouse cultivation due to high cost requirement. Hence, the latter method will not be applicable to this Project.

In due consideration of a variety of Project conditions, leaching water supply, in place of rain water leaching, has been planned to decrease the groundwater table to prevent salt accumulation by capillary phenomenon through evaporation. It should be noted, however, that this treatment, requiring considerably time-consuming practices, sometimes causes leaching of nutrients in the soils by places. On the other hand, it is recommendable in view of economy and effective utilization of the facilities that leaching is practised for the wide areas involved in the Project through proposed irrigation facilities.

The leaching water can be roughly classified into two; the one is the water used for leaching in the early stage of the reclamation and the other for leaching for maintenance. Taking example, construction works require the construction cost as initial investment and then the O & M cost as follow-up, and the same idea can be applied to the leaching works in the Project in considering the first leaching as initial investment while the second as follow-up.

As for the leaching water applied immediately after reclamation is completed, the more leaching water is applied the more effective leaching is anticipated. Irrigation and Drainage Paper No.9 (FAO) describes that application of leaching water by 800 mm can reduce the EC value (electric conductivity value) to below ten percent of that before leaching is applied.

Furthermore, Prof. Kovda (India) has an opinion explained by the following:

$$Y = N \cdot 400 \cdot X \pm 100$$

where;

Y = quantity of water required for leaching in mm of depth of water

X = average salinity of soil expressed in percent of the depth one to two meters

N = coefficient depending on permeability of soil, depth of occurrence, and degree of salinity of groundwater of reclaimed field. Its value varies from 0.5 to 2.0

	Soil	Value of N
i)	Sandy silt	0.5
ii)	Loam and deep located groundwater	1.0
iii)	Clayey soil and high located saline groundwater	2.0

When applying the equation to this study in taking the average salinity of soil in the Project Area by about four percent and the coefficient by 1.0 as the value for deep groundwater after Project is completed, the necessary leaching water is estimated at Y = 1,600 ± 100 mm.

The leaching water to be required for the Project, therefore, is proposed by about 1,100 mm per year for two years taking into account the estimations as above and the results from interviews.

The leaching method of "60-day + subsoiling", which is recommended in Irrigation and Drainage Paper, is found most effective in leaching by 72.1 percent in percentage of salt removed (Initial Salinity > 40 tons/ha), while the method by 20-day interval shows high efficiency to leach about 62.7 percent in removed salinity for the case of the initial salinity < 40 tons/ha.

In this Project, however, since the 60-day interval method will exceed the capacity of the El Salam canal (30 cu.m/feddan/day), the 20-day interval method should be applied to, in other words, decrease in amount but increase in frequency. In summer, however, the water demand exceeds the canal capacity, even in reduced leaching water due to the irrigation water being added. Under the situation, the leaching shall be practised during eight months in the winter season from October to May in the following year. The necessary water for leaching during this season will total 1,093 mm, which is equivalent to the 20-percent increased amount of estimated evapotranspiration discussed later.

The ordinary leaching water requirements (so-called O & M purpose leaching water requirements) are estimated by the equation recommended in FAO's Irrigation and Drainage Paper No.29. The said equation is,

$$LR = ECw / (5\ ECe - ECw) \cdot K$$

where, LR = minimum leaching water requirement needed to control salts with ordinary surface irrigation methods (fraction)

ECw = electrical conductivity from water analysis (mmhos/cm)

ECe = value from the following table for a given crop appropriate to the tolerable degree of yield reduction (usually 10% or less), mmhos/cm

Le = leaching efficiency (fraction)

The net water requirements are determined by the following equation:

$$NWR = ET\ crop / (1 - LR)$$

where, NWR = net water requirement

ET crop = crop evapotranspiration demand

LR = leaching water requirement mentioned above

The leaching coefficient (Le) varies from soil to soil in the type. For the silty clay soils, distributing in the Project Area, the Le value shall be Le = 0.7 in taking into consideration of 30 percent reduction in efficiency due to small coefficient of percolation. Therefore, the leaching water requirements for almost of all upland crops ranges from 0.1 to 0.15 as illustrated in Table E-2-4. The value of Le for the Project is determined by 0.2 with some allowances over the minimum value quoted above.

6) Water Balance

(i) Available water amount for the Project

The irrigation water source for this Project is the El Salam canal, the construction works of which are now in progress so that the first stage construction can be completed by 1984 as discussed already. The capacity of this canal is designed by 30 cu.m/feddan/day. Besides the above, an irrigation program is established for the South Hosainia District of about 73,000 feddan, for which 2.19 million cu.m/day of water are to be secured under water right.

Table E-2-4 Leaching Water Requirement (LR)

Crop	ECe		LR	
	P.P.M	mmhos/cm	Fraction 1/	70% Efficiency
Cotton	6,000	10.8	0.03	0.04
Wheat	4,500	8.2	0.04	0.06
Rice	3,000	5.5	0.06	0.09
Beans (Egyptian)	3,000	5.5	0.06	0.09
Soybean	3,000	5.5	0.06	0.09
Spinach	3,000	5.5	0.06	0.09
Tomato	2,000	3.8	0.09	0.13
Cabbage	1,900	3.6	0.10	0.14
Potato	1,900	3.6	0.10	0.14
Sweet Potato	1,900	3.6	0.10	0.14
Pepper	1,900	3.6	0.10	0.14
Onion	1,300	2.5	0.15	0.21
Carrot	650	1.2	0.36	0.51
Alfalfa	1,900	3.6	0.10	0.14
Sugerbeat	6,000	10.8	0.03	0.04
Greenpea	1,000	1.9	0.20	0.29

$$LR = ECw / (5\ ECe - ECw)$$

Where: LR; the minimum leaching water requirement

ECw; electrical conductivity of water (1.6 mmhos/cm)

ECe; electrical conductivity of saturation extract of soil without any reducting production based on the Report of the Peace Canal prepared by the Ministry of Irrigation. (mmhos/cm).

Note: The value of ECe is based on the table in the report of the summary of the El Salam Canal presented by MOI. As the value of ECw the expected electrical conductivity of the mixed water from the El Salam Canal is 1.6 mmhos/cm (800 P.P.M.) should be applied to estimate the leaching water requirement.

1/ 100% Efficiency.

(ii) Some considerations on the proposed cropping pattern

The irrigation water requirements fluctuate in increasing or decreasing from kinds and strains of crops to be introduced, their seeding or transplanting periods, etc. In particular, in those projects like this Project that the main canal capacity is decided prior to determination of the cropping pattern, the crops to be introduced should be selected and arranged to control the crop water requirements for meeting the discharge available as mentioned above.

The proposed crops have been selected by the Agronomist in consideration of a variety of conditions such as meteorology, farm mechanization plan, labour requirement, expected benefits, etc.; paddy, cotton, maize, soiling maize as summer crops, while both varieties of berseem of four-time harvesting and two-time harvesting and wheat as winter crops. These crops will be grown in three-year rotation cropping pattern. According to the Agronomist, however, among the said summer crops the change in seeding or transplanting period is available only for maize and soiling maize but not for paddy and cotton. Hence, seeding period of maize and soiling maize will be varied to draw down the peak water demand in the summer season.

Maize is commonly sown for one month from May 15 to June 15 and harvested for one month from August 15 to September 15. For this ordinary seeding program, an alternative plan is prepared with some days advancement and same days delay in seeding time for water balance computation. Especially, the following four patterns of soiling maize growing have been considered;

Case	Seeding		Harvesting	
1.	5/15 - 7/15	2 months	8/1 - 9/30	2 months
2.	6/1 - 7/15	1.5 months	8/1 - 9/30	1.5 months
3.	6/1 - 6/30	1.0 month	9/1 - 9/30	1.0 month
4.	6/15 - 7/15	1.0 month	9/1 - 9/30	1.0 month

Table E-2-5

Inventory of Alternative Plan for Water Balance

(No.3 - 1)

No. of Winter Crops	No. of Summer Crops	Seeding Time of Maize	Crop Intensity of Summer Crops	Return Flow	Shortage at Peak Period	Case
3	3	Ordinary	100 %	not used	Short	A-1
			68		Sufficient	A-2
			100	used	Sho./Suf.*	A-3
			86		Sufficient	A-4
		10 days stagger before ordinary	100	not used	Short	B-1
			65		Sufficient	B-2
			100	used	Sho./Suf.*	B-3
			82		Sufficient	B-4
		10 days stagger after ordinary	100	not used	Short	C-1
			73		Sufficient	C-2
			100	used	Sho./Suf.*	C-3
			93		Sufficient	C-4
	4 (Cropping period of green cut maize: Seeding 5/15 - 7/15, Harvesting 8/1 - 9/30)	Ordinary	100	not used	Short	D-1
			69		Sufficient	D-2
			100	used	Sho./Suf.*	D-3
			86		Sufficient	D-4
		10 days stagger before ordinary	100	not used	Short	E-1
			67		Sufficient	E-2
			100	used	Sho./Suf.*	E-3
			84		Sufficient	E-4
		10 days stagger after ordinary	100	not used	Short	F-1
			71		Sufficient	F-2
			100	used	Sho./Suf.*	F-3
			91		Sufficient	F-4

Note: Sho./Suf.* = Sufficient when supplemental water resources such as farm pond will be provided.

(cont'd)

Inventory of Alternative Plan for Water Balance

(No.3 - 2)

No. of Winter Crops	No. of Summer Crops		Seeding Time of Maize	Crop Intensity of Summer Crops	Return Flow	Shortage at Peak Period	Case
3	4	Cropping period of green cut maize Seeding 6/1 - 7/15 Harvesting 8/15 - 9/30	Ordinary	100 %	not used	Short	G-1
				72		Sufficient	G-2
				100	used	Sho./Suf.*	G-3
				91		Sufficient	G-4
			10 days stagger before ordinary	100	not used	Short	H-1
				70		Sufficient	H-2
				100	used	Sho./Suf.*	H-3
				89		Sufficient	H-4
			10 days stagger after ordinary	100	not used	Short	I-1
				74		Sufficient	I-2
				100	used	Sho./Suf.*	I-3
				94		Sufficient	I-4
		Cropping period of green cut maize Seeding 6/1 - 6/30 Harvesting 9/1 - 9/30	Ordinary	100	not used	Short	J-1
				70		Sufficient	J-2
				100	used	Sho./Suf.*	J-3
				89		Sufficient	J-4
			10 days stagger before ordinary	100	not used	Short	K-1
				69		Sufficient	K-2
				100	used	Sho./Suf.*	K-3
				86		Sufficient	K-4
			10 days stagger after ordinary	100	not used	Shot	L-1
				73		Sufficient	L-2
				100	used	Sho./Suf.*	L-3
				93		Sufficient	L-4

Note: Sho./Suf.* = Sufficient when supplemental water resources such as farm pond will be provided.

(cont'd)

Inventory of Alternative Plan for Water Balance

(No.3 -3)

No. of Winter Crops	No. of Summer Crops		Seeding Time of Maize	Crop Intensity of Summer Crops	Return Flow	Shortage at Peak Period	Case
3	4	Cropping period of green cut maize Seeding 6/15 - 7/15 Harvesting 9/1 - 9/30	Ordinary	100 %	not used	Short	M-1
				74		Sufficient	M-2
				100	used	Sho./Suf.*	M-3
				92		Sufficient	M-4
			10 days stagger before ordinary	100	not used	Short	N-1
				70		Sufficient	N-2
				100	used	Sho./Suf.*	N-3
				89		Sufficient	N-4
			10 days stagger after ordinary	100	not used	Short	0-1
				76		Sufficient	0-2
				100	used	Sho./Suf.*	0-3
				94		Sufficient	0-4

Note: Sho./Suf.* = Sufficient when supplemental water resources such as farm pond will be provided.

The combinations of the above-mentioned cropping patterns have resulted in the alternative plan as shown in Table E-2-5, which has been adopted for the water balance computation.

(iii) Water balance calculation (Estimation on water requirements)

The following four cases developed from the respective cropping patterns have been taken into consideration for estimating water requirements.

- 1) The water source depends upon the El Salam Canal only.
- 2) Cropping acreage is reduced to meet the amount of water available by water source of 30 cu.m/feddan.
- 3) Return flow available is used in addition to the water used in Case - 1.
- 4) Cropping acreage is reduced to solve the water shortage completely when return flow is used.

The amount of return flow available is computed by the following equation. The return flow available for (n)th decade is assumed to be obtained by subtracting evapotranspiration (ET) and Deep percolation (2 mm/day x 10 days = 20 mm or 2 mm/day x 11 days = 22 mm) from irrigation water (Q) at (n - 1)th decade most of the return flow is considered to be water resulting from as operation losses. The flow of water will take about five days from the uppermost fields in the Area down to the pumping station for catching the return flow on conditions of flow velocity by 0.2 m/sec and flowing distance by about 40 km, the longest distance of the drainage canal.

On the other hand, the discharges in the Bahr Hadous drain and so forth have decreased in their amount and water level in February. These decreases in discharge are assumed to be caused by complete stop of canal flow for operation and maintenance services of the related facilities. It is expected that the drainage water by irrigation water flows into the drainage canals within 10 to 20 days after irrigation is practised.

This study has applied an assumption that the return flow resulting from irrigation at (n - 1)th decade will be available at (n)th decade.

(iv) Conveyance loss and application loss

a) Field application efficiency

It is most important to increase the irrigation efficiency in the country because of the limitation of the water resources. The water management system on farm level should be introduced through farmers' organization. As for the irrigation methods, the basin and level border or furrow irrigation will be applicable for the Project Area. In consideration of above water management system and irrigation methods, the fraction 0.75 will be used for the Project Area.

Field Application Efficiency by Irrigation Methods

Irrigation Method	Field Application Efficiency	
	US (SCS)	ICID*
Graded borders	0.60 to 0.75	0.85
Basin and level borders	0.60 to 0.80	0.53
Contour ditch	0.55 to 0.70	
Furrows	0.55 to 0.70	0.57
Corrugation	0.50 to 0.70	

Source: * M.G Bos and J. Nugetetren Irrigation Efficiency in small farm area. ICID 1974 or publication No.19, International Institute for Land Reclamation and Improvement, Wageningen 1974.

b) Distribution efficiency

Distribution efficiency is defined as a ratio between water released at the headworks and that received at the field inlet. The main factors which decide the distribution efficiency are water supply system, size of the

Project Area and effectiveness of water management system.

Distribution efficiency is obtained from a recent ICID's study on irrigation efficiency in some 90 projects in progress. Conveyance losses from main canal up to field ditch are estimated at 15%.

(v) Gross water requirement

Gross water requirement is defined as total amount of water including leaching water, irrigation application losses, conveyance losses and water for other purposes. Following equation has been adopted to calculate gross water requirement.

$$GWR = (NWR/(1-LR) / (1-IAL-CL) + DW / (1-CL)$$

where; GWR = gross water requirement
NWR = net water requirement
OR = leaching water requirement in fraction
IAL = irrigation application loss in fraction
CL = conveyance loss in fraction
DW = other purpose water such as drinking water

The water balance computation illustrated in Table E-2-6 on the above four cases have found that the Case 0-3 is most advantageous of the four because of securing the cropping intensity of 200 percent in maximum but reducing water shortage to minimum. The water shortage by three mm/10 days is much smaller than in any other cases. The Case 0-3 provides the cropping pattern consisting of 33 percent of paddy, 33 percent of cotton, 17 percent of maize and 17 percent of soiling maize for the summer season, and 33 percent of 4-time harvesting berseem, 34 percent of 2-time harvesting berseem, 33 percent of wheat for the winter season.

In this case, the annual mean of the daily water requirements is estimated at 6.7 mm/day (= 67 cu.m/day/ha = 28 cu.m/day/feddan), and the return flow is estimated at 192 mm/90 days

Table E-2-6 Results of Water Balance

CASE	CROPPING PROPORTION (%)								GWR	SHORT-AGE	RETURN FLOW
	COT.	PAD.	MAI-1	MAI-2	BER-4	BER-2	WHEA.	TOTAL	(mm)	(mm)	(mm)
A-1	33	33	34	-	33	34	33	100	2,482	221	-
A-2	23	23	22	-	33	34	33	68	1,958	-	-
A-3	33	33	34	-	33	34	33	100	2,482	34	187
A-4	29	29	28	-	33	34	33	86	2,265	-	87
B-1	33	30	34	-	33	34	33	100	2,493	235	-
B-2	21	22	22	-	33	34	33	65	1,901	-	-
B-3	33	33	34	-	33	34	33	100	2,493	113	122
B-4	27	27	28	-	33	34	33	82	2,191	-	68
C-1	33	33	34	-	33	34	33	100	2,481	227	-
C-2	24	25	24	-	33	34	33	69	2,031	-	-
C-3	33	33	34	-	33	34	33	100	2,481	15	212
C-4	31	31	31	-	33	34	33	93	2,371	-	148
D-1	33	33	17	17	33	34	33	100	2,463	206	-
D-2	23	24	11	11	33	34	33	69	1,968	-	-
D-3	33	33	17	17	33	34	33	100	2,463	14	192
D-4	28	29	15	14	33	34	33	87	2,236	-	70
E-1	33	33	17	17	33	34	33	100	2,467	197	-
E-2	22	23	11	11	33	34	33	67	1,922	-	-
E-3	33	33	17	17	33	34	33	100	2,467	41	161
E-4	28	29	14	13	33	34	33	84	2,229	-	71
F-1	33	33	17	17	33	34	33	100	2,460	204	-
F-2	23	24	12	12	33	34	33	71	1,982	-	-
F-3	33	33	17	17	33	34	33	100	2,460	11	193
F-4	30	30	16	15	33	34	33	91	2,315	-	108
G-1	33	33	17	17	33	34	33	100	2,461	198	-
G-2	24	24	12	12	33	34	33	72	2,010	-	-
G-3	33	33	17	17	33	34	33	100	2,461	8	190
G-4	31	31	14	15	33	34	33	91	2,339	-	116
H-1	33	33	17	17	33	34	33	100	2,468	190	-
H-2	23	24	11	12	33	34	33	70	1,979	-	-

(cont'd)

CASE	CROPPING PROPORTION (%)								GUR	SHORT-AGE	RETURN FLOW
	COT.	PAD.	MAI-1	MAI-2	BER-4	BER-2	WHEA.	TOTAL	(mm)	(mm)	(mm)
H-3	33	33	17	17	33	34	33	100	2,468	17	173
H-4	30	30	14	15	33	34	33	89	2,300	-	88
I-1	33	33	17	17	33	34	33	100	2,460	192	-
I-2	25	25	12	12	33	34	33	74	2,048	-	-
I-3	33	33	17	17	33	34	33	100	2,460	4	188
I-4	32	31	15	16	33	34	33	94	2,374	-	129
J-1	33	33	17	17	33	34	33	100	2,486	233	-
J-2	23	24	12	11	33	34	33	70	1,996	-	-
J-3	33	33	17	17	33	34	33	100	2,486	14	219
J-4	30	30	15	14	33	34	33	89	2,318	-	113
K-1	33	33	17	17	33	34	33	100	2,494	222	-
K-2	23	23	11	12	33	34	33	69	1,971	-	-
K-3	33	33	17	17	33	34	33	100	2,494	24	198
K-4	29	29	14	14	33	34	33	86	2,272	-	79
L-1	33	33	17	17	33	34	33	100	2,483	220	-
L-2	25	24	12	12	33	34	33	73	2,045	-	-
L-3	33	33	17	17	33	34	33	100	2,483	9	211
L-4	31	31	16	15	33	34	33	93	2,374	-	142
M-1	33	33	17	17	33	34	33	100	2,458	191	-
M-2	25	24	13	12	33	34	33	74	2,036	-	-
M-3	33	33	17	17	33	34	33	100	2,458	7	184
M-4	31	31	15	15	33	34	33	92	2,342	-	122
N-1	33	33	17	17	33	34	33	100	2,465	195	-
N-2	23	24	12	11	33	34	33	70	1,981	-	-
N-3	33	33	17	17	33	34	33	100	2,465	19	176
N-4	30	30	14	15	33	34	33	89	2,296	86	-
O-1	33	33	17	17	33	34	33	100	2,454	195	-
O-2	25	26	13	12	33	34	33	76	2,070	-	-
O-3	33	33	17	17	33	34	33	100	2,454	3	192
O-4	31	32	16	15	33	34	33	94	2,373	-	139

which is equivalent to 7.8 percent of the total water requirement of 2,454 mm/yeaer. The water in shortage will be 3.0 mm/10 days (0.3 mm/day), which is equal to 2.2 percent of the water requirements of 13.7 mm/day.

7) Same Analysis of Water Quality

The gross water requirement is calculated as 13.7 mm/day in the last decade of June which is the peak period of water requirement through the year.

The water resources of the Project Area are the El Salam canal water and a return flow from the Area. According to the MOI the maximum amount of water requirement is tentatively decided as 30 cu.m/feddan/day (= 10.5 mm/day). Therefore, 3.2 mm/day will be a shortage during the last decade of June. If the distribution plan of the El Salam canal water will be changed according to the detailed survey of the whole irrigable area and the amount of the water allocated to the Area will be increased, the shortage will disappear because of increase in the water from the El Salam canal.

If there is no surplus of water in the El Salam canal after the detailed survey of the whole irrigable area, the amount of return flow should be used or the irrigable area should be reduced. The later is available because the Project Area should be fully developed in considering the construction cost. In the Project, the former has a problem of water qualities because the salt concentration of return flow is higher. During the field survey the salt concentration of about 2,000 PPM of the drain water was observed. The amount of 2.9 mm/day of the return flow is available for the Area.

On the other hand, irrigation water with 800 PPM of salt concentration is supplied to the Area. Therefore, the weight average of salt concentration is estimated as follows;

$$\frac{800 \times 10.5 + 2,000 \times 2.9}{13.4} = 1,059 \text{ PPM}$$

Salt tolerant crops such as cotton, paddy, etc. are proposed for the Area. The crops will permit the above salt concentration without any reduction of the yield.

8) Unit Water Requirement

As a result of the study made in the previous paragraph, the peak water requirements on the decade basis, appearing in the last decade of June, is computed at 13.7 mm/day. Therefore, the unit water requirement is;

$$q = \frac{13.7 \times 10}{86,400} = 0.001585 \text{ cu.m/sec/ha}$$
$$= 1.585 \text{ ℓ/sec/ha}$$

This value of the unit water requirement is the base for determining the section of the irrigation canals.

E-2-3. Irrigation Facilities

1) Canal Alignment

The irrigation canals in the Project Area have been aligned based on the topographic map at the scale of 1:10,000 with 25 cm contours. Prior to alignment works on the basis of the above topographic map, due considerations were given to various items as follows;

- Designed water level in the El Salam canal now under construction,
- Comparison of construction costs of main and lateral canals in depending upon the irrigation method taken at on-farm level,
- Alignment of the main and lateral canals in view of the land consolidation, and
- Selection of station sites for booster pumps.

(i) Determination of irrigation method

In Egypt, irrigation has been carried out in keeping designed water level of the main and lateral canals some 0.5 m below the field surface for the purpose of saving conveyance losses and protecting stealing water. Hence, water supply at on-farm level has been made by Sakkia or portable-pumps.

This method will increase the Operation and Maintenance Cost (O & M cost) due to using the pumps for terminal level water supply, although deemed advantageous in keeping the balance in cut and bank of the canals from the viewpoint of earth works.

On the other hand, the designed water level of the El Salam canal is to be maintained at EL.two to three meters in the Project Area, which, the water head available, should be utilized as effectively as possible. As a result of the above considerations, the irrigation plan in this Project will adopt the gravity system as adequate method.

(ii) Relations with land consolidation plan

An intensive on-farm development program will be employed in the Project in consideration of the fact that the farm lands in the Project Area are newly-reclaimed lands to realize the rational farm management in future. As a consequence, each farm plot will be of rectangle with 210 m in length of run and 100 m in width, and the short side (width) shall face the farm road and the tertiary irrigation canal. The canal alignment has been made in taking into account the layout mentioned above so as to reduce the land levelling cost in earth works. (Refer to Annex F, On-farm)

(iii) Establishment of irrigation block

The Project Area is unevenly divided by the Ramses Drain running through the Area into two; one covers 5,930 ha, namely M_1 block, and the other 14,970 ha. Conveniently, however, the topo-map indicates that two hillocks cross in direct angle to the El Salam canal, and in making better use of these hillocks, the Area can be divided into three irrigation blocks namely M_1, M_2 and M_3, which cover 5,930 ha, 8,640 ha and 6,330 ha, respectively, in approximately even acreages.

(iv) Main canal alignment

On main canal will be provided in each irrigation block and these main canals will extend about 16.0 km, 9.0 km and 13.0 km, respectively, and their alignment shall run along the possibly high-elevated parts of the Area to sufficiently secure the water head given by the El Salam canal.

a) Block M_1 (Irrigable area (A) = 5,930 ha)

The water to be supplied to this block shall be diverted at the Sation No.49.6 on the El Salam canal and the main canal is laid out along the relatively higher-elevated portion along the Saft drain. Originally, a consideration was given to provision of gravity irrigation system to cover the whole Project Area according to the designed water level of the El Salam canal. However, since this system, when employed in the Project, is deemed uneconomical due to much more requirement for construction works in canal embankment, booster pumps shall be installed at the end point on the main irrigation canal. (Refer to Fig. E-2-2)

b) Block M_2 (A = 8,640 ha)

Diverting the water to this block shall be made at Station No.61.0 on the El Salam canal, and the main irrigation canal is to be laid out along the high elevated strip land extending southwest.

In this case also, it has become necessary to install booster pumps at the end point of the main canal, the Station No.9.3 km on the secondary canal S-M and at the end point of the secondary canal S-N-2, although the designed water level of the El Salam canal is planned to be fully utilized. This is unavoidable due to the fact that the elevation of the irrigable area in the southwest is comparatively high. (Refer to Fig. E-2-3)

c) Block M_3 (A = 6,330 ha)

The Water diversion point for this block is the Station No.70.3 on the El Salam canal. In the topographic conditions quite similar to those of the Block M_2, booster pumps shall be installed at the end point on the main irrigation canal even with the designed water level of the El Salam canal to be fully utilized. (Refer to Fig. E-2-4)

v) Secondary canal alignment

Alignment for the secondary canals should be made in considering the topographic conditions prevailing in the related areas as well as for the main canals. The proposed secondary canal alignment has been so arranged as to run along the hillocks for the intricated topography, while 2.0 km intervals for the flat lands to cope with the requirement of land consolidation works. When the water is diverted directly from the main canal to the tertiary canal, double channels shall be provided along the main canal for smooth water diversion.

vi) Booster pumps and pumps for utilizing return flows

Booster pumps, as previously discussed, will be installed at the terminals of the main canals in the Project Area, and at the terminals of the secondary canals as well for securing the necessary water head for gravity irrigation to the fields. In the Project Area, the booster pumps, installed at five stations, will command the area of 9,125 ha, equivalent to about 43 percent of the total irrigable area. Provision of such boosters is inevitably required in the Project due to the fact that the El Salam canal has been designed to run through the comparatively low-lying part of the Area, and furthermore, a due consideration

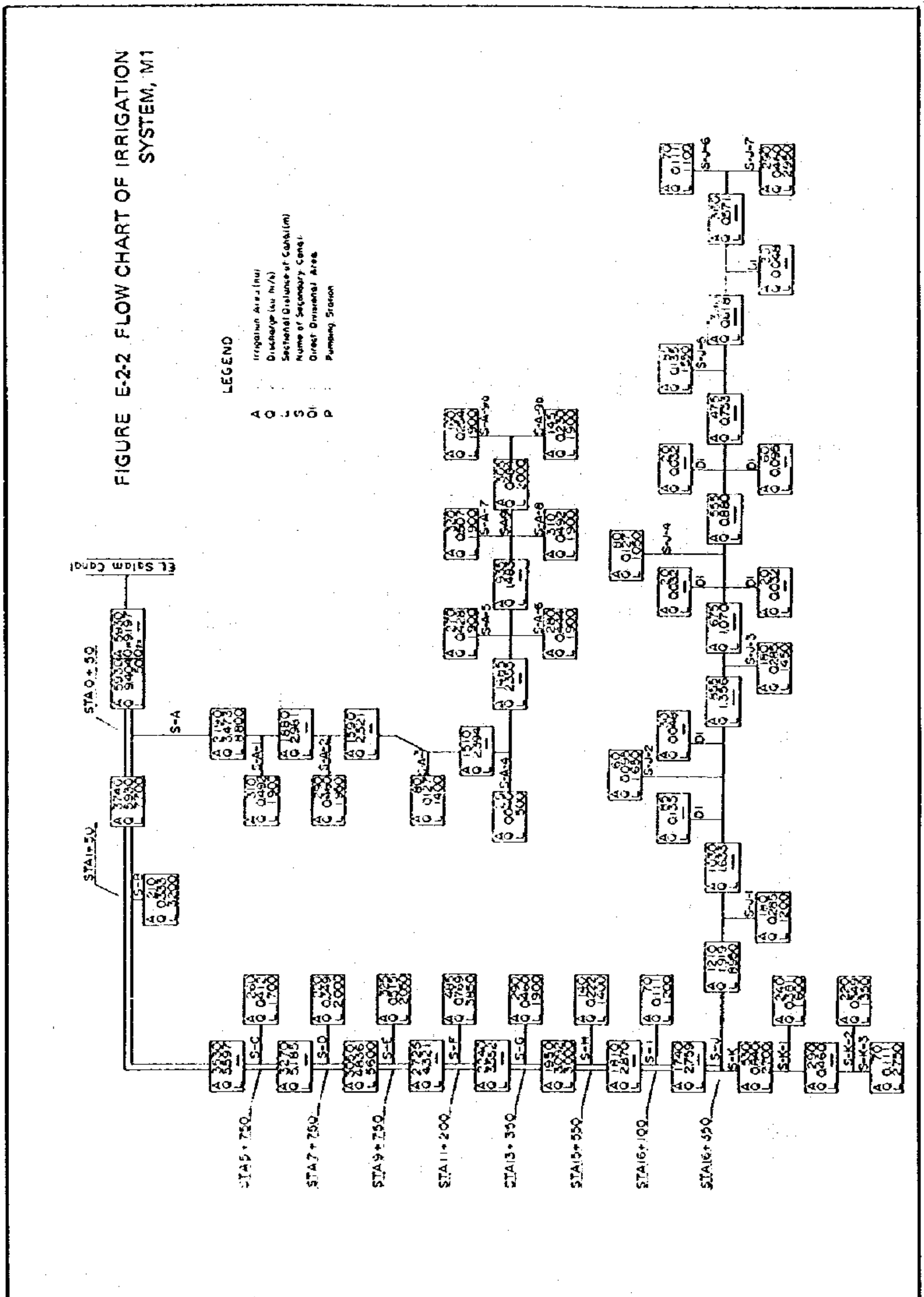


FIGURE E-2-2 FLOW CHART OF IRRIGATION SYSTEM, M1

FIGURE E-2-3 FLOW CHART OF IRRIGATION SYSTEM, M2

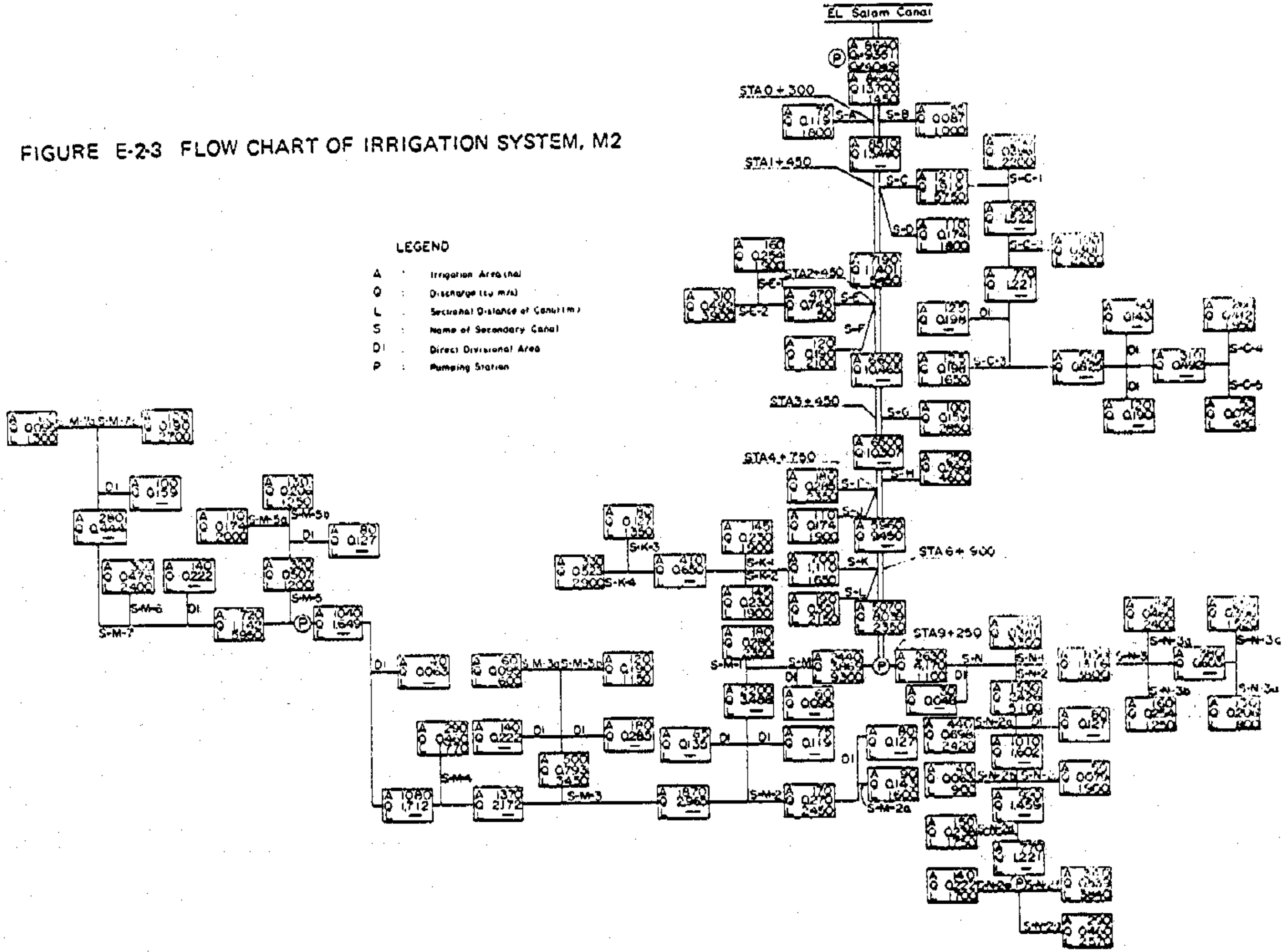
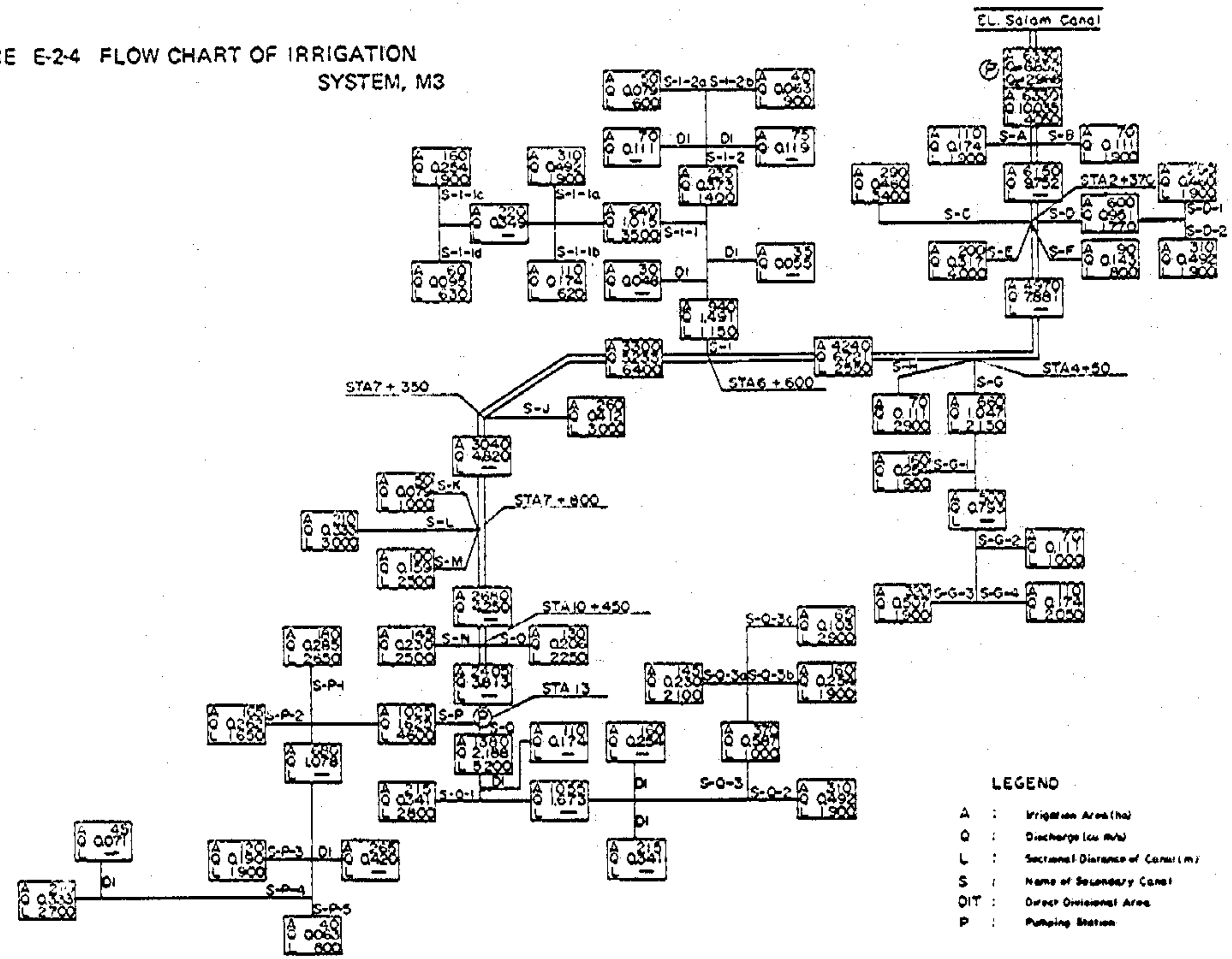


FIGURE E-2-4 FLOW CHART OF IRRIGATION SYSTEM, M3



was given to establishment of two pumping stations so that the proposed cropping pattern could be successfully implemented with return flows to be utilized effectively in the Project Area poor in water source. The following table shows the dimensions of the pumps to be used in the Project. (Refer to Table E-2-7)

2) Study on the Canal Profile

The canal profile has been prepared based on the proposed canal route drawn in the topo-maps developed from the field surveyings. And then, the canal section has been determined as well as water head has been properly allocated based on the design discharge and canal type. The Manning's formula was applied to the hydraulic computation for the purpose. (Refer to attached drawing)

(i) Capacity

The determination of canal capacity will be based upon the area to be irrigated and water duty for crop maintenance including farm wastes and conveyance losses in canals.

(ii) Cross-section

Unlined canals (earth canals) will be constructed trapezoidal in shape with side slopes determined from stability studies of bank materials and empirical considerations. Usually, a side slope of 1-1/2 : 1 is used.

(iii) Ratio of base width to depth

The equation commonly used in Egypt is adopted for computing the ratio of base width to depth.

When water depth is more than 1.62 m,

$$d = 0.1\ (S/2 + 4) \cdot \sqrt{b}$$

When water depth is less than 1.62 m,

$$d = \{0.0025 \cdot (S + 8)^2 \cdot b\}\ /\ 1.62$$

Table E-2-7 List of Proposed Pump Equipment
(Irrigation)

Description	Unit	Pumping Station								
		M_1	M_2 - No.1		M_2 - No.2	M_2 - No.3	M_3		M_4	M_5
Total head	m	2.0	1.5		1.5	3.4	3.0	2.0	6.7	6.8
Delivery discharge	cu.m/min	55	77	83	33	24	32	44	30	60
Pump										
Type		Vertical Mixed Flow Pump								
Diameter	mm	700	800	600	600	ø500	ø600	ø600	800	700
No. of pump	sets	3	3	3	3	3	3	3	3	3
Motor										
Output	KW	30	30	30	15	22	30	22	120	95
Synchronous speed	rpm	230	170	155	250	490	420	270	490	585
No. of poles		4	4	4	4	12	14	4	12	10
Voltage	V	400	400	400	400	400	400	400	3,000	3,000
No. of motor	sets	3	3	3	3	3	3	3	3	3

Where, d : depth of canal

s : slope per kilometer in centimeter

b : bed width

According to the above estimations, the relevant ratio is found to be in a range from 2.5 to 3.0.

(iv) Freeboard

An adequate freeboard should be provided to furnish a factor of safety against a rise of water surface above the computed normal flow due to error in operation, and variation in the canal friction coefficient. The freeboard so provided will also allow a degree of operational flexibility such as occasionally applying a larger than the designed amount of water over a short period of time. Usually, the freeboard will be determined by 50 cm.

(v) Berm width

The berm width for canals are determined by either requirement for operating equipment or requirement for minimizing seepage and protecting the integrity of the canal against by damage from mechanized farm equipments, the width shall be 6.0 m for secondary canal and 8.0 m for main canals. The general criteria for O & M roads is discussed in section pertaining to access and O & M roads. When not used as O & M roads such as an opposite site of the above roads, the berm should be with minimum 1.5 meter width.

(vi) Water surface

The water surface profile during crop maintenance should be set at least 50 centimeters above the ground surface from the point where the canal can already irrigate. If water section is partially or entirely on fill, compaction of embankment to the water surface (minimum) is necessary to prevent excess seepage and percolation through fill.

(vii) Longitudinal slope

The velocity in the canal as determined from computation by the Manning's Formula has been looked into on whether falling in a range of critical velocities for silting and scouring.

The water surface grade line is tentatively drawn on the profile of the natural round with the most appropriate slope, the slope being 1/20,000 (= 5 cm/km or 0.00005) for main canals, 1/20,000 or 1/10,000 (= 5 cm/km or 10 cm/km, 0.00005 or 0.0001) for secondary canals depending upon topographic conditions. (Refer to attached drawings)

(viii) Length of irrigation canal

The measurement of the canal length on the 1/10,000 topographic map has resulted in as follows;

Name	Length (km)	Intensity (m/ha)
Main canal	38.6	1.8
Secondary canal	284.5	13.6
Total	323.1	15.4

(Refer to Table E-2-8)

Note: See the paragraph on "On-farm" regarding the canal length of the tertiary canals and minors.

3) Canal Structures

Many different types of canal structures such as regulating structures and water measurement structures should be provided in the irrigation system to effectively convey, regulate, and measure the discharge. As canal structures, following facilities will be needed. (Refer to attached drawings)

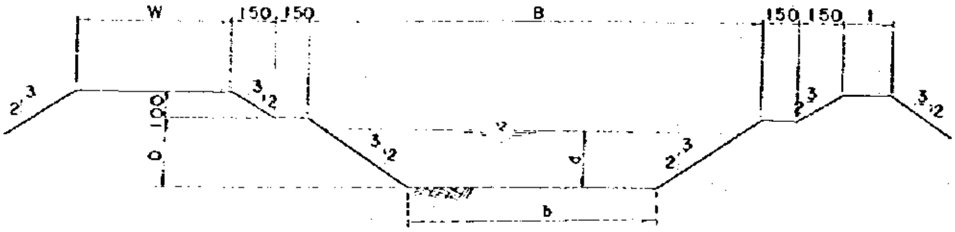
Regulating structures

Checks, Turn-outs, Division Boxes, etc.

Water measurement structures

Parshall flumes, double orifice gates

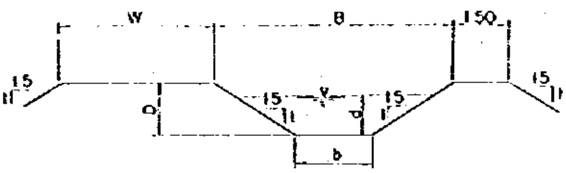
Table E-2-8 ELEMENTS OF MAIN AND SECONDARY IRRIGATION CANAL SECTION



Project Area		Canal Length (m)	Service Area (ha)	Discharge (cu.m/s)	Slope of Canal	Velocity (m/s)	b (m)	d (m)	D (m)	t (m)	B (m)	W (m)
M1		50	5,930	9.404	1/20,000	0.553	7.20	1.74	2.20	2.00	13.30	8.00
		7,700	3,740	5.930	"	0.498	5.90	1.51	2.00	"	11.80	"
		5,600	3,050	4.836	"	0.474	5.40	1.41	1.90	"	11.10	"
		3,000	1,950	3.092	"	0.420	4.50	1.17	1.70	"	9.60	"
Sub-Total		16,350										
M2		1,450	8,640	13.700	1/20,000	0.405	11.90	2.24	2.70	2.00	20.00	8.00
		5,450	7,190	11.401	"	0.388	10.70	2.13	2.60	"	18.50	"
		2,350	5,070	8.039	"	0.359	8.80	1.93	2.40	"	16.00	"
Sub-Total		9,250										
M3		700	6,300	10.035	1/20,000	0.562	7.50	1.78	2.30	2.00	14.40	8.00
		3,350	6,330	10.035	"	0.378	10.00	2.06	2.60	"	17.80	"
		2,550	4,240	6.721	"	0.346	8.00	1.84	2.30	"	14.90	"
		6,400	3,300	5.233	"	0.326	6.90	1.71	2.20	"	13.50	"
Sub-Total		13,000										
Total		38,600										
M1	S-A	8,800	2,190	3.473	1/20,000	0.295	5.70	1.49	2.00	2.00	11.70	6.00
	S-J	8,950	1,210	1.919	"	0.256	4.60	1.20	1.70	"	9.70	"
Sub-Total		17,750										
M2	S-C	5,750	1,210	1.919	1/20,000	0.256	4.60	1.20	1.70	2.00	9.70	6.00
	S-M	9,300	2,440	3.869	"	0.305	6.00	1.57	2.10	"	12.30	"
	S-N	1,100	2,630	4.170	"	0.309	6.10	1.59	2.10	"	12.40	"
	S-N-2	5,100	1,530	2.426	"	0.270	5.00	1.30	1.80	"	10.40	"
Sub-Total		21,250										
M3	S-P	4,600	1,025	1.625	1/20,000	0.245	4.30	1.12	1.60	2.00	9.10	6.00
	S-Q	5,200	1,380	2.188	"	0.263	4.80	1.25	1.75	"	10.05	"
Sub-Total		9,800										
Total		48,800										

(cont'd)

ELEMENTS OF SECONDARY IRRIGATION CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
M1	S-A	(8,800)								
	S-A-1	1,900	310	0.492	1/10,000	1.60	0.80	1.30	5.50	6.00
	S-A-2	1,950	290	0.460	"	1.50	0.75	1.25	5.25	"
	S-A-3	1,400	80	0.127	"	1.00	0.50	1.00	4.00	"
	S-A-4	500	25	0.040	"	0.60	0.30	0.80	3.00	"
	S-A-5	1,900	270	0.428	"	1.50	0.75	1.25	5.25	"
	S-A-6	1,900	280	0.444	"	1.50	0.75	1.25	"	"
	S-A-7	1,900	320	0.507	"	1.60	0.80	1.30	5.50	"
	S-A-8	1,900	310	0.492	"	1.60	0.80	1.30	"	"
	S-A-9	2,000	305	0.484	"	1.60	0.80	1.30	"	"
	S-A-9a	1,900	160	0.254	"	1.20	0.60	1.10	4.50	"
	S-A-9b	1,900	145	0.230	"	1.20	0.60	1.10	"	"
	S-B	3,200	210	0.333	"	1.40	0.70	1.20	5.00	"
	S-C	1,700	260	0.412	"	1.50	0.75	1.25	5.25	"
	S-D	2,000	220	0.349	"	1.40	0.70	1.20	5.00	"
	S-E	2,050	325	0.515	"	1.60	0.80	1.30	5.50	"
	S-F	3,850	485	0.769	"	1.80	0.90	1.40	6.00	"
	S-G	1,900	290	0.460	"	1.50	0.75	1.25	5.25	"
	S-H	1,400	140	0.222	"	1.20	0.60	1.10	4.50	"
	S-I	1,200	70	0.111	"	0.90	0.45	0.95	3.75	"
	S-J	(8,950)								
	S-J-1	1,200	180	0.285	1/10,000	1.30	0.65	1.15	4.75	6.00
	S-J-2	1,650	60	0.095	"	0.90	0.45	0.95	3.75	"
	S-J-3	1,450	180	0.285	"	1.30	0.65	1.15	4.75	"
	S-J-4	1,050	80	0.127	"	1.00	0.50	1.00	4.00	"
	S-J-5	1,550	85	0.135	"	1.00	0.50	1.00	"	"
	S-J-6	1,100	70	0.111	"	0.90	0.45	0.95	3.75	"
	S-J-7	2,950	290	0.460	"	1.50	0.75	1.25	5.25	"
	S-K	2,700	530	0.840	"	1.90	0.95	1.45	6.25	"
	S-K-1	1,600	240	0.381	"	1.40	0.70	1.20	5.00	"
	S-K-2	1,350	220	0.349	"	1.40	0.70	1.20	"	"
	S-K-3	2,750	70	0.111	"	0.90	0.45	0.95	3.75	"
Sub-Total		55,800								
M2	S-A	1,800	75	0.119	1/10,000	0.90	0.45	0.95	3.75	6.00
	S-B	1,000	55	0.087	"	0.80	0.40	0.90	3.50	"
	S-C	(5,750)								
	S-C-1	2,200	250	0.396	1/10,000	1.50	0.75	1.25	5.25	6.00
	S-C-2	2,200	190	0.301	"	1.30	0.65	1.15	4.75	"
	S-C-3	1,650	125	0.198	"	1.10	0.55	1.05	4.25	"

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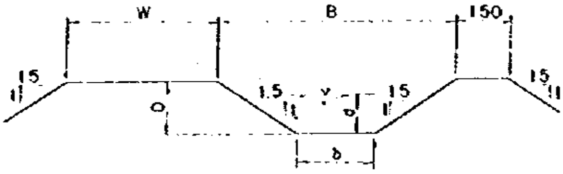
ELEMENTS OF SECONDARY IRRIGATION CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
M2	S-C-4	1,950	260	0.412	1/10,000	1.50	0.75	1.25	5.25	6.00
	S-C-5	450	50	0.079	"	0.80	0.40	0.90	3.50	"
	S-D	1,800	110	0.174	"	1.10	0.55	1.05	4.25	"
	S-E	50	470	0.745	"	1.80	0.90	1.40	6.00	"
	S-E-1	1,900	160	0.254	"	1.20	0.60	1.10	4.50	"
	S-E-2	3,900	310	0.492	"	1.60	0.80	1.30	5.50	"
	S-F	2,100	120	0.190	"	1.10	0.55	1.05	4.25	"
	S-G	2,850	100	0.159	"	1.00	0.50	1.00	4.00	"
	S-H	4,600	250	0.396	"	1.50	0.75	1.25	5.25	"
	S-I	2,350	180	0.285	"	1.30	0.65	1.15	4.75	"
	S-J	1,900	110	0.174	"	1.10	0.55	1.05	4.25	"
	S-K	1,650	700	1.110	"	2.10	1.05	1.55	6.75	"
	S-K-1	1,900	145	0.230	"	1.20	0.60	1.10	4.50	"
	S-K-2	1,900	145	0.230	"	1.20	0.60	1.10	"	"
	S-K-3	1,350	80	0.127	"	1.00	0.50	1.00	4.00	"
	S-K-4	2,900	330	0.523	"	1.60	0.80	1.30	5.50	"
	S-L	2,150	190	0.301	"	1.30	0.65	1.15	4.75	"
	S-M	(9,300)								
	S-M-1	2,350	180	0.285	1/10,000	1.30	0.65	1.15	4.75	6.00
	S-M-2	2,450	170	0.270	"	1.30	0.65	1.15	"	"
	S-M-3	3,450	500	0.793	"	1.90	0.95	1.45	6.25	"
	S-M-3a	600	60	0.095	"	0.90	0.45	0.95	3.75	"
	S-M-3b	1,150	120	0.190	"	1.10	0.55	1.05	4.25	"
	S-M-4	1,770	290	0.460	"	1.50	0.75	1.25	5.25	
	S-M-5	1,200	320	0.507	"	1.60	0.80	1.30	5.50	"
	S-M-5a	2,000	110	0.174	"	1.10	0.55	1.05	4.25	"
	S-M-5b	1,250	130	0.206	"	1.10	0.55	1.05	"	"
	S-M-6	2,400	300	0.476	"	1.60	0.80	1.30	5.50	"
	S-M-7	5,950	720	1.142	"	2.10	1.05	1.55	6.75	"
	S-M-7a	1,300	60	0.095	"	0.90	0.45	0.95	3.75	"
	S-M-7b	2,700	120	0.190	"	1.10	0.55	1.05	4.25	"
	S-N	(1,100)								
	S-N-1	3,300	240	0.381	1/10,000	1.40	0.70	1.20	5.00	6.00
	S-N-2	(5,100)								
	S-N-2a	2,420	440	0.698	1/10,000	1.80	0.90	1.40	6.00	6.00
	S-N-2b	900	40	0.063	"	0.80	0.40	0.90	3.50	"
	S-N-2c	1,900	50	0.079	"	0.80	0.40	0.90	"	"
	S-N-2d	1,750	150	0.238	"	1.20	0.60	1.10	4.50	"
	S-N-2e	1,700	140	0.222	"	1.20	0.60	1.10	"	"
	S-N-2f	3,840	340	0.539	"	1.60	0.80	1.30	5.50	"

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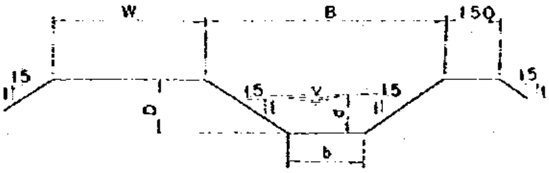
ELEMENTS OF SECONDARY IRRIGATION CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
N2	S-N-2g	2,570	290	0.460	1/10,000	1.50	0.75	1.25	5.25	6.00
	S-N-3	3,800	830	1.316	"	2.20	1.10	1.60	7.00	"
	S-N-3a	2,400	290	0.460	"	1.50	0.75	1.25	5.25	"
	S-N-3b	1,250	160	0.254	"	1.20	0.60	1.10	4.50	"
	S-N-3c	1,520	250	0.396	"	1.50	0.75	1.25	5.25	"
	S-N-3d	800	130	0.206	"	1.10	0.55	1.05	4.25	"
Sub-Total		101,270								
N3	S-A	1,900	110	0.174	1/10,000	1.10	0.55	1.05	4.25	6.00
	S-B	1,900	70	0.111	"	0.90	0.45	0.95	3.75	"
	S-C	3,400	290	0.460	"	1.50	0.75	1.25	5.25	"
	S-D	1,770	600	0.951	"	2.00	1.00	1.50	6.50	"
	S-D-1	1,900	290	0.460	"	1.50	0.75	1.25	5.25	"
	S-D-2	1,900	310	0.492	"	1.60	0.80	1.30	5.50	"
	S-E	4,000	200	0.317	"	1.30	0.65	1.15	4.75	"
	S-F	800	90	0.143	"	1.00	0.50	1.00	4.00	"
	S-G	2,150	660	1.047	"	2.10	1.05	1.55	6.75	"
	S-G-1	1,900	160	0.254	"	1.20	0.60	1.10	4.50	"
	S-G-2	1,000	70	0.111	"	0.90	0.45	0.95	3.75	"
	S-G-3	1,900	320	0.507	"	1.60	0.80	1.30	5.50	"
	S-G-4	2,050	110	0.174	"	1.10	0.55	1.05	4.25	"
	S-H	2,900	70	0.111	"	0.90	0.45	0.95	3.75	"
	S-I	1,150	940	1.491	"	2.40	1.20	1.70	7.50	"
	S-I-1	3,500	640	1.015	"	2.00	1.00	1.50	6.50	"
	S-I-1a	1,900	310	0.492	"	1.60	0.80	1.30	5.50	"
	S-I-1b	620	110	0.174	"	1.10	0.55	1.05	4.25	"
	S-I-1c	1,900	160	0.254	"	1.20	0.60	1.10	4.50	"
	S-I-1d	630	60	0.095	"	0.90	0.45	0.95	3.75	"
	S-I-2	1,400	235	0.373	"	1.40	0.70	1.20	5.00	"
	S-I-2a	600	50	0.079	"	0.80	0.40	0.90	3.50	"
	S-I-2b	900	40	0.063	"	0.80	0.40	0.90	"	"
	S-J	3,000	260	0.412	"	1.50	0.75	1.25	5.25	"
	S-K	1,000	50	0.079	"	0.80	0.40	0.90	3.50	"
	S-L	3,000	210	0.333	"	1.40	0.70	1.20	5.00	"
	S-M	2,500	100	0.159	"	1.00	0.50	1.00	4.00	"
	S-N	2,500	145	0.230	"	1.20	0.60	1.10	4.50	"
	S-O	2,250	130	0.206	"	1.10	0.55	1.05	4.25	"
	S-P	(4,600)								
	S-P-1	2,650	180	0.285	1/10,000	1.30	0.65	1.15	4.75	6.00
	S-P-2	1,650	165	0.262	"	1.20	0.60	1.10	4.50	"

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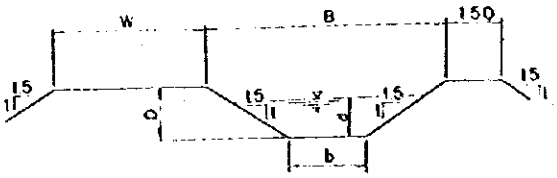
ELEMENTS OF SECONDARY IRRIGATION CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
P3	S-P-3	1,900	120	0.190	1/10,000	1.10	0.55	1.05	4.25	6.00
	S-P-4	2,700	210	0.333	"	1.40	0.70	1.20	5.00	"
	S-P-5	800	40	0.063	"	0.80	0.40	0.90	3.50	"
	S-Q	(5,200)								
	S-Q-1	2,800	215	0.341	1/10,000	1.40	0.70	1.20	5.00	6.00
	S-Q-2	1,900	310	0.492	"	1.60	0.80	1.30	5.50	"
	S-Q-3	1,000	370	0.587	"	1.70	0.85	1.35	5.75	"
	S-Q-3a	2,100	145	0.230	"	1.20	0.60	1.10	4.50	"
	S-Q-3b	1,900	160	0.254	"	1.20	0.60	1.10	4.50	"
	S-Q-3c	2,900	65	0.103	"	0.90	0.45	0.95	3.75	"
Sub-Total		78,620								
Total		235,690								

(i) Structures

(a) Check

Checks are used to regulate the canal water surface upstream on the structure and to control the downstream flow.

(b) Turn-out

Turn-outs are used to divert water from main canals or secondary to rotation areas. A double-gated turn-out (that is a combination of 0.60 m x 0.90 m orifice and ϕ600 mm R.C. Pipe installed with gates) should be used to measure or regulate the discharge.

(c) Parshall Flume

Parshall flume are specially designed in line with open channel measuring structures in which channel water flows over a broad, flat-converging section through a narrow downward sloping throat section and then diverges on an upward sloping floor.

Parshall flume shall be installed at the head of main and secondary canals, as closely as possible to canal discharge regulating gates for convenience of operation, but enough away from the gates so that the flow can be uniform and free from eddies, turbulence, and waves. (Refer to attached drawings)

2) Operation and Maintenance Roads

Operation and maintenance roads are to be provided along the embankment of main and secondary canals with an intensity of about 15 meters per ha. The O & M roads also should be provided along tertiary canals (Refer to Annex On-farm).

E-3. DRAINAGE PLAN

E-3-1. Drainage Plan

1) General

Drainage plans are commonly worked out for the purpose of eliminating surface runoff and removing excessive moisture in the soils. In this Project, however, the drainage plan aims mainly at removing excessive soil moisture that causes salt accumulation rather than at eliminating surface runoff which takes place very little because of rainfall as small as 50 mm per annum.

The drainage plan, when accomplished, will permit the Project to obtain the following effects;

1. Highly intensive and stabilized land use will be realized.
2. Land productivity will be increased.
3. Environment of farm works will be improved.

2) Basic Strategy of the Drainage Plan

As described in the Annex C on "Project Area", there are two major causes resulting in ill-drainage in the Project Area; one is excessive surface water in the submerged areas, which has resulted from high water level in the Manzala Lake and the other is the higher groundwater table which has caused salt accumulation in the top soils.

(i) Submerged area

In the former case, the water submerging the lands is estimated at 60 MCM (12,200 ha x 0.5 m). The adverse flow from the lake to stand in the Area will be intercepted by the dykes now under construction as embankment of the El Salam canal, and the standing water within the Area after shutting out by the said dykes will be eliminated through evaporation and pumping out by the proposed facilities in the Project. Drainage capacity of the proposed pumping facilities is estimated as follows:

$$(60 \times 10^6 \text{ cu.m})/(7.257 \text{ cu.m/sec}) / 86{,}400 \doteqdot 96 \text{ days}$$

Consequently, the proposed facilities can drain the area completely within about 100 days even in neglecting evaporation.

Removing the groundwater is one of the major factors to carry out farming works successfully.

A land is said to be waterlogged when the soil pores within the root zone of the crops, normally grown, are effectively saturated due to lack of aeration of the soil thus leading to reduction in the yield of crops. The depth of water table at which such conditions arise depends upon the height of capillary fringe and the type of crops grown. In agricultural soils, the height of capillary fringe varies from 0.9 to 1.5 m. It is more in fine grained soils and less in coarse grained soils. The yield is adversely affected when the capillary meniscus surface is within 0.6 m of natural ground surface.

The depths of water table at which the yield of different crops is adversely affected are as follows:

Crop	Depth of Water Table (cm)
Sugarcane	30
Paddy	60
Grain	90
Wheat	90 - 125
Barley	90
Fodder	120
Maize, Bajra and cotton	125
Lucerne	210 - 240

3) Optimum Depth of Water Table

The depth of water table is significant in overall water management. The importance of groundwater table in farm land is described by the following specifications set by leading institutions in United States for long term credit to develop agricultural lands.

Classification	Range in Water Table Depth
Good	Static water table at 2.1 m. Up to 1.8 m for period of 30 days in 3 year.
Fair	Water table at 1.8 m. Up to 1.25 m for a period of 30 days. No general rise.
Poor	Some alkali on the surface. Water table at 1.25 m to 1.8 m. Up to 0.9 m for a period of 30 days.
Bad	Water table less than 1.25 m and rising. Natural and artificial drains too far away to drain land.

4) Ill-effects of Waterlogging

Waterlogging affects the productivity of lands due to the following reasons.

a) Lack of aeration

Saturation of soil pores within the root zone of the plants cut off the normal circulation of air and as a result the plants cannot thrive as it affects the activity of soil bacteria and in turn retardation in formation of organic acids to dissolve plant food material.

b) Creation of salinization

Continuous flow of water from the sub-soil causes high salinization and deposits sodium salts in the soil at or near the surface which may prove toxic. Accumulation of salts in root zone of crops corrode the roots, reduce their yield and ultimately destroy the plant.

c) Growth of natural weeds and their competition with crops

In waterlogged soil, water-loving wild plants grow profusely which interfere and affect the growth of useful crops. Moreover, extra investment in terms of money and time has to be made by the cultivator to remove the wild growth.

d) Delayed cultivation operation

Excessive moisture content, in the soil affect and interfere with the normal cultivation operations of tilling and ploughing. As a consequence, ploughing and mulching are delayed. Use of heavy tractors for cultivation poses a problem as they tend to sink in the saturated soil.

e) Inhibiting activities of soil bacteria

Presence of excess water in the soil, reduces the supply of oxygen and in turn cessation of nitrification process.

f) Reduction in soil temperature

Rise of sub-soil water promotes low soil temperatures which restrict root growth of plant especially the fine root system and lowers the biotic activity in the soil, which in turn reduces production of available nitrogen.

g) Low yield

Waterlogged soil warm up slowly, absorb much less heat compared to dry one which hampers the seed germination and seedling growth. Maturity period of crops is also reduced and hence low yield.

h) Adverse effect on plant nutrients

The reactions involving the plant nutrients in the soil and those added as fertilizers are affected.

i) Adverse effect on community health

Damp climate of waterlogged area and breeding of mosquitoes in the standing water present hazards to community health.

j) Loss of cash crops

High subsoil water restricts the use of land to crops such as paddy, whereas cash crops may be desired to be grown in the area.

k) Diseased crops

Physiological disease in caused by waterlogging conditions. Decay of roots is common. External symptoms on the foliage, fruits etc. are indicative of want of proper aeration.

5) Drainage Method

There are two countermeasures to be taken for solving these problems; one is to provide open drainage canal system and the other tile or mole drainage system. The comparison of these two systems is tabulated in the following Table E-3-1.

Table E-3-1. Surface (Open) Drain Vs. Sub-surface (Tile Drain)

	Surface Drain	Tile Drain
1.	First cost comparatively low.	High initial cost.
2.	Land coming under the drain section is lost for ever for cultivation.	Being underground, no loss of land and no obstruction to agricultural operations.
3.	Large capacity of the drain.	Small capacity of the drain.
4.	Suitable for removal of surface runoff.	Suitable for removal of sub-soil-water.
5.	Limited lowering of water table possible.	Comparatively deep lowering of water table is the main object.
6.	Perpetual problem of weed growth removal. Harbours and distributes obnoxious weeds.	Immune from weed growth.
7.	Scouring of bed and sloughing of the sides have to be taken care of.	Permanent section.
8.	Open to inspection.	Being underground, causes of failure hard to detect.
9.	Repairs economical and convenient.	Repairs very costly and inconvenient.
10.	Can function with flatter slope.	Require steeper slope.
11.	Bridges and other means of communication have to be provided at high cost.	Net saving in cost on this account.

12.	High maintenance cost. Require frequent cleaning.	Low maintenance cost.
13.	Helps in marginal reduction of soil salinity.	Must for permanent reclamation of saline and alkali soils.

The characteristic features of the respective systems are detailed in Table E-3-1. The soils of the Project Area are of silty-clay which belongs to soil type vulnerable to development of cracks. Tile or mole drains to be provided immediately after reclamation in the areas with such soil characters will permit the leaching water to be lost through cracks and are not expected to gain the successful leaching effect. Thereby, tile or mole drainage systems, if adopted in the Project Area, should be constructed 10-15 years after the reclamation in taking into account the crack conditions in the soils.

6) Drainage Modulus (q)

In general, the amount of drainage is expressed as difference between inflow (Qin) of rainfall, etc. to the drainage area and outflow (Qout) of evaporation, transpiration, etc. from the area; in other words, the residual amount of water (Q) to be drained out of the Project Area within a given time (T). The following equation expresses the above relations.

$$Q = Q/T = (Qin - Qout) / T$$

In the Project Area, a greater part of the amount corresponding to (Qin) is irrigation water, since the rainfall is negligibly small by about 50 mm per annum and the no direct inflow of drain water from the upperstream is observed. On the other hand, the amount corresponding to (Qout) is evapotranspiration and deep percolation. The outer water level —— the water level in the canals surrounding the Project Area —— measures WL + 1.0 m, while the inner water level will measure WL - 1.0 to - 3.0 m due to decrease in groundwater table after completion of the Project.

Hence, the gravity drainage will become impossible. As mentioned previously, the maximum irrigation water requirement appears by 13.7 mm/day in the end of June, while evapotranspiration and deep percolation are estimated at 8.2 mm/day and 2.0 mm/day as a result of field survey. Therefore, the drainage modulus (q) is expressed by;

$$13.7 - (8.2 + 2.0) = 3.5 \text{ mm/day } (14.7 \text{ m}^3\text{/feddan/day})$$

For the Bahr Hadous drain, the annual discharge is 2.84 billion cu.m for the catchment area of 2,300 km^2 (546,000 feddans), and the unit discharge is estimated as follows;

$$(28.4 \times 10^9 \text{ cu.m}/2{,}300 \times 10^6) \times 1{,}000$$
$$= 3.4 \text{ mm/day } (14.3 \text{ cu.m/feddan/day})$$

On the other hand, the FAO's Research on Crop Water Use, Salt affected Soils and Drainage in the ARE quotes the design discharge by 2.0 mm/day for upland cropping and 4.0 mm/day for paddy cropping. Basing on these values, the drainage modulus is computed as follows;

$$2 \text{ mm/day} \times 2/3 + 4 \text{ mm/day} \times 1/3 = 2.7 \text{ mm/day}$$
$$(11.3 \text{ cu.m/feddan})$$

In due consideration of these values, 3.0 mm/day (12.6 cu.m/feddan/day) is adopted as the moderate value of the drainage modulus. Thereby, the total amount of the drainage in the Project Area is estimated at Q = 7,257 cu.m/sec. (Refer to Fig. E-3-1)

The drainage method should be determined in consideration of a variety of factors such as layout of drainage canals in the Project Area, topography, inner and outer water levels, etc. The drainage canals shall be laid down in the low-lying lands in the Area so as to allow the gravity drainage available from the farm drains to the main drainage canals. The drainage canals should be so provided at the upstream end as to have adequate section and sufficient depth to constantly keep the water surface 1.0 m below the field surface. (See Annex F, On-farm)

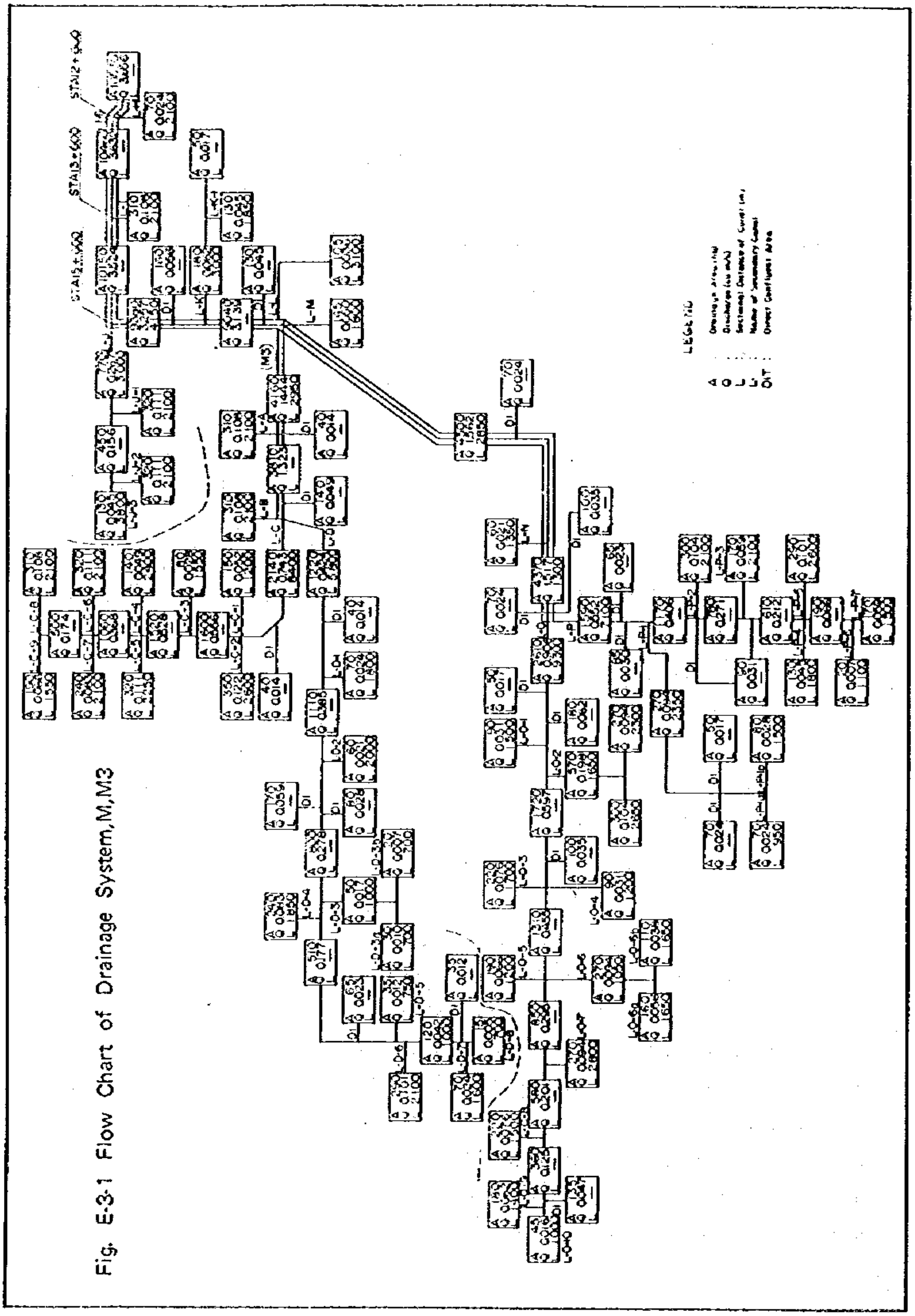


Fig. E-3-1 Flow Chart of Drainage System, M, M3

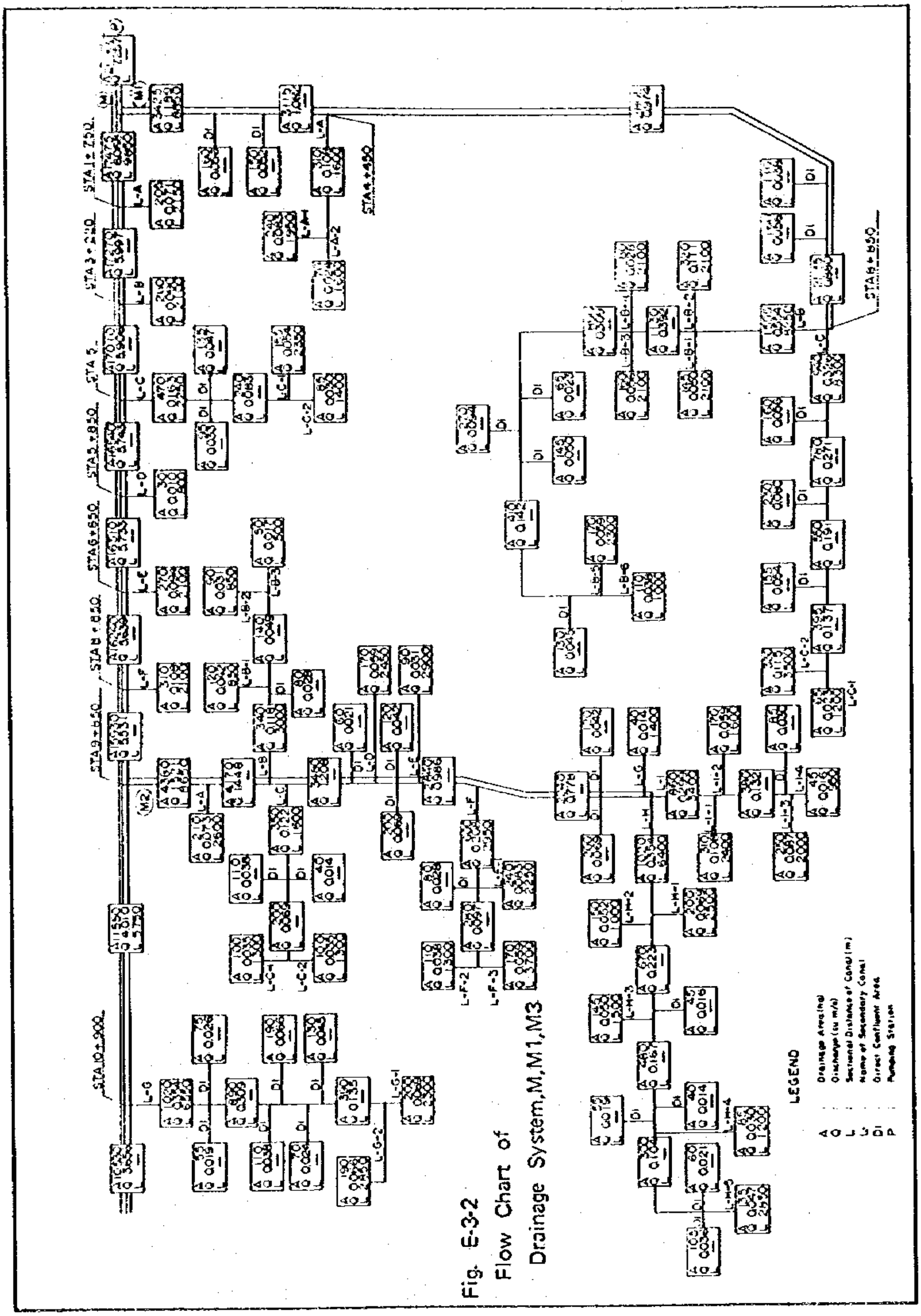


Fig. E-3-2 Flow Chart of Drainage System,M,M1,M3

For smooth flowing-down of the run-off from the fields to the downstream end of the drainage canals, the canal slope should be 1/20,000 (=0.00005 or 5 cm/km) and the water level at the end will be about WL - 3.5 m. On the other hand, the outer water level at the Bahr Baqar drain is WL + 1.0 m, which fluctuates little throughout the year. Consequently, the pumping facilities are required for draining the water to the outside of the Project Area.

E-3-2. Drainage Canals

1) Drainage Method

Pumping drainage shall be employed in the Project Area in considering the relations with formation of farm drain networks at the level of on-farm development and with water level in the existing drainage canals surrounding the Project Area.

The farm ditches should be designed with ditch bottom 1.0 or more below the field surface for securing leaching effect with the groundwater table lowered. And careful studies on the profiles of the main and lateral drainage canals stringently based on the above criterion have resulted in inability in gravity drainage due to the designed drainage water level being 3.0 m or more below the field surface.

2) Drainage Canal Alignment

The drainage canal alignment as well as the irrigation canal alignment is determined in depending the topography prevailing in the related areas. The Project Area, in general, dips from southeast to northeast, although partially intricated in its topography. The drainage canal alignment, accordingly, has been made to meet the requirements of land consolidation in the flat lands, while to meet the topography in the intricated land conditions.

The main drainage canal, aligned along the El Salam canal as mentioned attached Map, shall be linked with drainage pumping station so as to drain the water to the Bahr Baqar drain.

The Ramses drain, only one navigation canal existing in the Project Area, shall be utilized as drainage canal with redigging.

2) Drainage Canal Profile

The studies on the main and lateral canal profiles based on the topo-map developed from the field surveyings, have resulted in a plan to construct a main drainage canal and three sub-main canals in the Area. The total length of the main canal is 23.9 km and the sub-main canals extend 20.5 km in total, while the lateral canals extend 247.7 km in total. (Refer to Table E-3-2) The canal density for the total drainage area was estimated at 14 m/ha.

The canal slopes were designed by 1/20,000 for the main canals and 1/10,000 for the lateral canals. When adopting these values in slopes, the average flow velocity ranges from 0.25 m/sec to 0.4 m/sec. (Refer to Table E-3-2)

4) Pumping Station

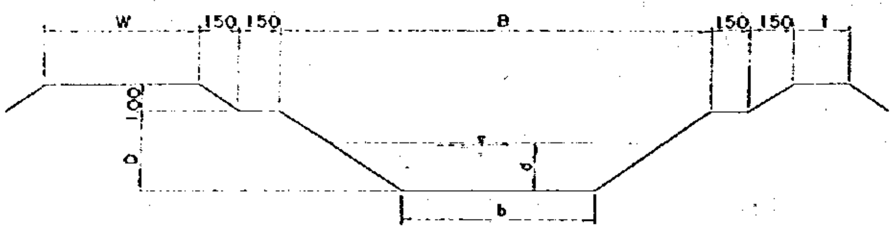
The pumping stations to be established at the terminal of the main drainage canal shall be located at the northeastern end of the Project Area, which is almost the same site that the Ministry of Irrigation has once planned to provide the pumping station for drainage improvement for part of the area. The following facilities are specifically designed for eliminating the designed drainage discharge of 7.26 cu.m/sec.

Type of Pump	Diameter (mm)	No. of Pump	Delivery Discharge (cu.m/min)	Power (kw)	Voltage (v)
Vertical Mixed Flow Pump	1,000	3	146 x 3	220 x 3	4,000

5) Cross-Section of Canal

The cross-section of drainage canals was determined in taking into account the designed drainage discharge, canal profile and canal type. And detailed studies on the most effective cross-section in hydraulics and safety to scouring have resulted in employing the

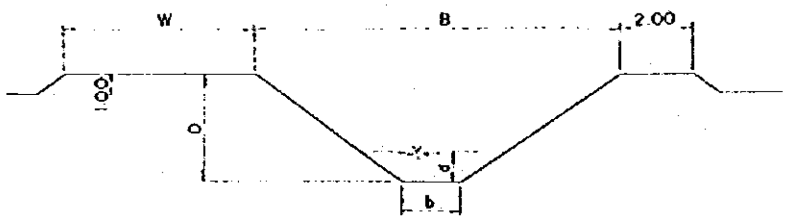
Table E-3-2 ELEMENTS OF MAIN AND SECONDARY DRAINAGE CANAL SECTION



Project Area		Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	Velocity (m/s)	b (m)	d (m)	D (m)	t (m)	B (m)	W (m)
M		9,850	17,475	6.068	1/20,000	0.337	7.50	1.78	5.00	2.00	22.50	6.00
		5,570	11,550	4.010	"	0.309	6.10	1.59	4.30	"	19.00	"
		4,150	9,380	3.257	"	0.292	5.60	1.46	4.00	"	17.60	"
		2,850	4,500	1.562	"	0.245	4.30	1.12	3.40	"	14.50	"
		1,300	4,370	1.517	"	0.241	4.20	1.10	3.30	"	14.10	"
Sub-Total		23,900										
M1		8,850	3,425	1.189	1/20,000	0.229	3.90	1.02	4.00	2.00	15.90	6.00
Sub-Total		8,850										
M2		8,650	4,380	1.521	1/20,000	0.241	4.20	1.10	3.60	2.00	15.00	6.00
Sub-Total		8,650										
M3		2,950	4,160	1.444	1/20,000	0.237	4.10	1.07	3.60	2.00	14.90	6.00
Sub-Total		2,950										
Total		44,350										
M	L-J	3,000	770	0.267	1/20,000	0.156	2.20	0.57	2.80	2.00	10.60	6.00
	L-O	9,300	2,610	0.906	"	0.213	3.50	0.91	3.10	"	12.80	"
	L-P	7,100	1,590	0.552	"	0.188	2.90	0.76	3.00	"	11.90	"
Sub-Total		19,400										
M1	L-B	8,250	1,595	0.554	1/20,000	0.188	2.90	0.76	3.00	2.00	11.90	6.00
	L-C	8,300	940	0.326	"	0.166	2.40	0.63	2.80	"	10.80	"
Sub-Total		16,550										
M3	L-C	8,400	2,140	0.743	1/20,000	0.201	3.20	0.84	3.00	2.00	12.20	6.00
	L-D	5,800	1,220	0.424	"	0.175	2.60	0.68	2.90	"	11.30	"
Sub-Total		14,200										
Total		50,150										

(cont'd)

ELEMENTS OF SECONDARY DRAINAGE CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
N	L-A	2,150	205	0.071	1/10,000	0.80	0.40	3.20	10.40	6.00
	L-B	2,100	260	0.090	"	0.90	0.45	3.25	10.65	"
	L-C	2,250	470	0.163	"	1.10	0.55	3.35	11.15	"
	L-C-1	2,350	155	0.054	"	0.70	0.35	3.15	10.15	"
	L-C-2	1,400	85	0.030	"	0.60	0.30	3.10	9.90	"
	L-D	800	30	0.010	"	0.40	0.20	3.00	9.40	"
	L-E	2,100	270	0.094	"	0.90	0.45	3.25	10.65	"
	L-F	2,100	310	0.108	"	0.90	0.45	"	"	"
	L-G	6,550	1,020	0.354	"	1.40	0.70	3.50	11.90	"
	L-G-1	2,300	200	0.069	"	0.80	0.40	3.20	10.40	"
	L-G-2	2,850	190	0.066	"	0.80	0.40	3.20	10.40	"
	L-H	2,100	70	0.024	"	0.50	0.25	3.05	9.65	"
	L-I	2,100	310	0.108	"	0.90	0.45	3.25	10.65	"
	L-J	(3,000)								
	L-J-1	2,100	320	0.111	1/10,000	0.90	0.45	3.25	10.65	6.00
	L-J-2	2,100	320	0.111	"	0.90	0.45	3.25	10.65	"
	L-J-3	3,800	130	0.045	"	0.70	0.35	3.15	10.15	"
	L-K	3,000	180	0.062	"	0.70	0.35	3.15	10.15	"
	L-K-1	1,850	130	0.045	"	0.70	0.35	3.15	10.15	"
	L-L	3,100	105	0.036	"	0.60	0.30	3.10	9.90	"
	L-M	1,800	145	0.050	"	0.70	0.35	3.15	10.15	"
	L-N	1,350	60	0.021	"	0.50	0.25	3.05	9.65	"
	L-O	(9,300)								
	L-O-1	1,500	90	0.031	1/10,000	0.60	0.30	3.10	9.90	6.00
	L-O-2	1,650	570	0.198	"	1.10	0.55	3.35	11.15	"
	L-O-2a	2,650	300	0.104	"	0.90	0.45	3.25	10.65	"
	L-O-2b	2,300	270	0.094	"	0.90	0.45	3.25	10.65	"
	L-O-3	1,700	220	0.076	"	0.80	0.40	3.20	10.40	"
	L-O-4	1,200	90	0.031	"	0.60	0.30	3.10	9.90	"
	L-O-5	1,200	190	0.066	"	0.80	0.40	3.20	10.40	"
	L-O-6	1,050	270	0.094	"	0.90	0.45	3.20	10.50	"
	L-O-6a	1,650	160	0.056	"	0.70	0.35	3.15	10.15	"
	L-O-6b	1,650	110	0.038	"	0.60	0.30	3.10	9.90	"
	L-O-7	2,800	270	0.094	"	0.90	0.45	3.25	10.65	"
	L-O-8	1,500	220	0.076	"	0.80	0.40	3.20	10.40	"
	L-O-9	1,400	180	0.062	"	0.70	0.35	3.15	10.15	"
	L-O-10	1,000	45	0.016	"	0.50	0.25	3.05	9.65	"
	L-P	(7,100)								
	L-P-1	2,350	270	0.094	1/10,000	0.90	0.45	3.25	10.65	6.00
	L-P-1a	950	70	0.024	"	0.50	0.25	3.05	9.65	"

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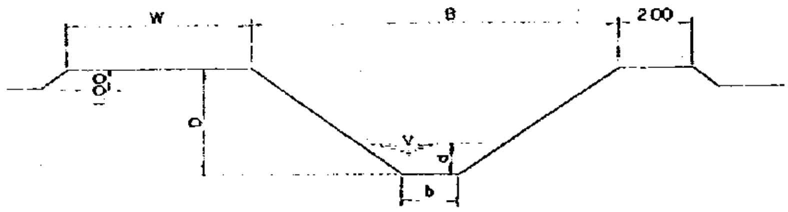
ELEMENTS OF SECONDARY DRAINAGE CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
M	L-P-1b	1,500	80	0.028	1/10,000	0.60	0.30	3.10	9.90	6.00
	L-P-2	2,100	300	0.104	"	0.90	0.45	3.25	10.65	"
	L-P-3	2,100	170	0.059	"	0.70	0.35	3.15	10.15	"
	L-P-4	1,800	130	0.045	"	0.70	0.35	3.15	10.15	"
	L-P-5	2,600	290	0.101	"	0.90	0.45	3.25	10.65	"
	L-P-6	1,100	20	0.007	"	0.40	0.20	3.00	9.40	"
	L-P-7	1,500	170	0.059	"	0.70	0.35	3.15	10.15	"
Sub-Total		89,500								
M1	L-A	1,600	310	0.108	1/10,000	0.90	0.45	3.25	10.65	6.00
	L-A-1	1,950	240	0.083	"	0.80	0.40	3.20	10.40	"
	L-A-2	1,600	70	0.024	"	0.50	0.25	3.05	9.65	"
	L-B	(8,250)								
	L-B-1	2,100	145	0.050	1/10,000	0.70	0.35	3.15	10.15	6.00
	L-B-2	2,100	320	0.111	"	0.90	0.45	3.25	10.65	"
	L-B-3	2,100	160	0.056	"	0.70	0.35	3.15	10.15	"
	L-B-4	2,100	80	0.028	"	0.60	0.30	3.10	9.90	"
	L-B-5	2,300	170	0.059	"	0.70	0.35	3.15	10.15	"
	L-B-6	1,000	110	0.038	"	0.60	0.30	3.10	9.90	"
	L-C	(8,300)								
	L-C-1	1,200	65	0.023	1/10,000	0.50	0.25	3.05	9.65	6.00
	L-C-2	3,500	330	0.115	"	0.90	0.45	3.25	10.65	"
Sub-Total		21,550								
M2	L-A	2,600	210	0.073	1/10,000	0.80	0.40	3.20	10.40	6.00
	L-B	3,900	340	0.118	"	0.90	0.45	3.25	10.65	"
	L-B-1	850	120	0.042	"	0.70	0.35	3.15	10.15	"
	L-B-2	850	90	0.031	"	0.60	0.30	3.10	9.90	"
	L-B-3	500	50	0.017	"	0.50	0.25	3.05	9.65	"
	L-C	1,600	350	0.122	"	0.90	0.45	3.25	10.65	"
	L-C-1	1,300	100	0.035	"	0.60	0.30	3.10	9.90	"
	L-C-2	1,300	100	0.035	"	0.60	0.30	3.10	9.90	"
	L-D	2,450	170	0.059	"	0.70	0.35	3.15	10.15	"
	L-E	2,900	90	0.031	"	0.60	0.30	3.10	9.90	"
	L-F	2,950	600	0.208	"	1.10	0.55	3.35	11.15	"
	L-F-1	2,250	240	0.083	"	0.80	0.40	3.20	10.40	"
	L-F-2	1,300	110	0.038	"	0.60	0.30	3.10	9.90	"
	L-F-3	3,700	170	0.059	"	0.70	0.35	3.15	10.15	"
	L-G	1,400	40	0.014	"	0.40	0.20	3.00	9.40	"
	L-H	6,400	1,020	0.354	"	1.40	0.70	3.50	11.90	"
	L-H-1	2,500	200	0.069	"	0.80	0.40	3.20	10.40	"
	L-H-2	1,000	150	0.052	"	0.70	0.35	3.15	10.15	"

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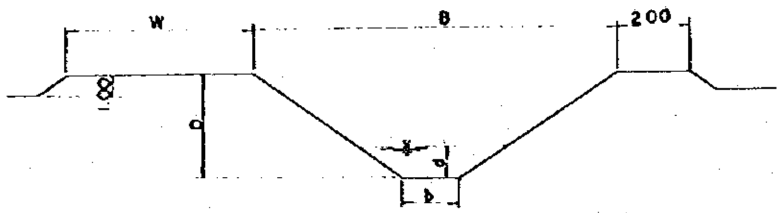
ELEMENTS OF SECONDARY DRAINAGE CANAL SECTION



Project Area	Name of Secondary	Canal Length (m)	Service Area (ha)	Discharge (cu m/s)	Slope of Canal	b (m)	d (m)	D (m)	B (m)	W (m)
M2	L-H-3	1,500	145	0.050	1/10,000	0.70	0.35	3.15	10.15	6.00
	L-H-4	1,200	85	0.030	"	0.60	0.30	3.10	9.90	"
	L-H-5	2,850	135	0.047	"	0.70	0.35	3.15	10.15	"
	L-I	3,400	860	0.299	"	1.30	0.65	3.45	11.65	"
	L-I-1	2,400	310	0.108	"	0.90	0.45	3.25	10.65	"
	L-I-2	1,600	170	0.059	"	0.70	0.35	3.15	10.15	"
	L-I-3	2,000	250	0.087	"	0.80	0.40	3.20	10.40	"
	L-I-4	950	45	0.016	"	0.50	0.25	3.05	9.65	"
Sub-Total		54,750								
M3	L-A	2,100	310	0.108	1/10,000	0.90	0.45	3.25	10.65	6.00
	L-B	2,100	310	0.108	"	0.90	0.45	"	"	"
	L-C	(8,400)								
	L-C-1	1,200	150	0.052	"	0.70	0.35	3.15	10.15	6.00
	L-C-2	2,600	350	0.122	"	0.90	0.45	3.25	10.65	"
	L-C-3	1,550	80	0.028	"	0.60	0.30	3.10	9.90	"
	L-C-4	2,400	140	0.049	"	0.70	0.35	3.15	10.15	"
	L-C-5	2,250	320	0.111	"	0.90	0.45	3.25	10.65	"
	L-C-6	2,100	320	0.111	"	0.90	0.45	"	"	"
	L-C-7	2,100	240	0.083	"	0.80	0.40	3.20	10.40	"
	L-C-8	2,100	310	0.108	"	0.90	0.45	3.25	10.65	"
	L-C-9	1,550	190	0.066	"	0.80	0.40	3.20	10.40	"
	L-D	(5,800)								
	L-D-1	1,800	70	0.024	"	0.50	0.25	3.05	9.65	6.00
	L-D-2	2,000	60	0.021	"	0.50	0.25	"	"	"
	L-D-3	1,000	50	0.017	"	0.50	0.25	"	"	"
	L-D-3a	700	30	0.010	"	0.40	0.20	3.00	9.40	"
	L-D-3b	700	20	0.007	"	0.40	0.20	"	"	"
	L-D-4	1,850	240	0.083	"	0.80	0.40	3.20	10.40	"
	L-D-5	750	35	0.012	"	0.40	0.20	3.00	9.40	"
	L-D-6	2,100	290	0.101	"	0.90	0.45	3.20	10.50	"
	L-D-7	1,600	70	0.024	"	0.50	0.25	3.05	9.65	"
	L-D-8	700	15	0.005	"	0.30	0.15	2.95	9.15	"
Sub-Total		35,250								
Total		201,050								

criteria provided by the Egyptian Government (MOI).

6) Appurtenant Structures

The major structures appurtenant to the proposed drainage networks are culverts and O & M roads. For culverts, there are two kinds, the culvert box and the pipe drain. The culvert box shall be used as crossing structures for the canals with large discharges, while the pipe drain for those with comparatively small discharge. (Refer to attached drawings)

The O & M roads, discussed in the paragraph on Roads, shall be provided along the main and lateral canals for their O & M purposes, having passable width of 5.0 m and the shoulder of 0.5 m on both sides - 0.5 m x 2 = 1.0 m. The O & M roads shall be earth-paved roads sufficiently compacted by heavy equipment.

E-4. ROAD PLAN

1) Type and Function of Roads

Five types of roads will be constructed in the Project, that is trunk roads, village roads, main farm roads, secondary farm roads and on-farm. All types of roads mentioned above will play a role of operation and maintenance roads because these roads are located along the irrigation and drainage canals.

(i) Trunk roads

Trunk roads will mainly function to connect major villages in the Project Area and the surrounding major cities and towns. The roads will be used for transporting daily goods, farm inputs and outputs from out side of the Area.

(ii) Village roads

Village roads will function to connect a small village with the other small villages, service villages and central villages.

(iii) Farm roads

Farm roads are classified into three types, namely the main farm roads, secondary farm roads and on-farm roads. The main farm roads in the Project fall in the category of the above-mentioned village roads. The secondary farm roads to be constructed along secondary irrigation and drainage canals will be used as O/M roads. Furthermore, on-farm roads of 4.0 m in total surface width will be utilized for O/M roads for tertiary canals.

2) Type and Structure of Roads

(i) Trunk roads

The construction of two routes of trunk roads has been planned to connect the existing road running through the heart of the Project Area from the north to southeast and the national road passing through the eastern most of the Project Area. A length of these two trunk roads will be about 42 km (2 m/ha) in total. Trunk roads will have an effective width of seven meters to allow the passing of a heavy farm machine and heavy truck each other. Furthermore, additional width of one meter will be secured for the shoulder of this type of roads. Tree will be planted on the shoulder. Therefore, the total width of this type of roads will be nine meters. Taking into consideration traffic volume after the implementation of the Project, trunk roads will be provided with asphalt pavement. (Refer to Table E-4-1)

(ii) Village roads

The construction of village roads of about 82 km long 3.9 m/ha in total has been planned mainly along irrigation and drainage canals. The effective width of this type of roads will be six meters so that farm machines such as tractors and trucks will be able to pass each other. As same as trunk roads, village roads will be provided with a shoulder of 1.0 m wide at their both sides for tree planting. Therefore, the total surface width will be eight meters. Taking into consideration the traffic volume after implementation of the Project, the road surface will be paved with asphalt.

(iii) Farm road

a) Main farm road

It is considered that trunk roads and village roads mentioned above will fully play a role of farm roads in the Project Area. Roads having the same scale as that of village roads will be constructed along the proposed main irrigation canals. Portions out of the name of village roads will be structurally provided with gravel pavement. The total length will be about 21 km (1.0 m/ha).

b) Secondary farm road

The secondary farm roads will be constructed along the main drainage canals and secondary irrigation and drainage

Table E-4-1. Passable Width and Combination of Traffic

Effective Width	Combination of Traffic	
9.0 (m)	Combine 50 ps class	
	Passenger car	Combine 90 ps class
	Truck	
	Tractor 50 ps class	
	Two combine 50 ps class	
7.0	Passenger car	
	Truck	Combine 50 ps class
	Tractor 50 ps class	
	Tractor 10 ps class	Combine 70 ps class
	Power tiller	Combine 90 ps class
6.0	To passenger cars	
	Truck	Passenger car
	Tractor 50 ps class	
	Combine 20 ps class	
	Two trucks	
	Truck	Tractor 50 ps class
		Combine 20 ps class
	Two tractors 20 - 30 ps class	
	Tractor 20 - 30 ps class	Tractor 50 ps class
5.0	Tractor 10 ps class	Passenger car
	Power tiller	or truck or tractor
	Animal carts	ps class
4.0	Tractor 10 ps class	
	Power tiller	Tractor 10 ps class
	Animal carts	or power tiller
3.0	Two animal carts or one passenger car	
	or one tractor 50 ps class	
2.0	One tractor 10 ps class or one power tiller	

canals as well as for operation and maintenance purpose of the canals. The width of this type of roads will be six meters, that is, the effective surface width of five meters plus the shoulder of one meter. This width will be necessary for large-scale tractors and operation and maintenance machines to pass each other.

c) On-farm road

On-farm roads will be constructed along the teritary canals. Taking into account the large-scale farm machines, the on-farm roads will be provided with the total width of four meters which consists of the effective surface width of three meters and shoulder of one meter. No pavement will be given to this type of roads.

The detail information about above mentioned roads are as follows;

Table E-4-2 Dimensions of Roads

Name or Road	Length (m)	Width Total (m)	Width Passing (m)	Pavement	Remarks
1. Trunk Road	42	9	7	Asphalt	
2. Village Road	82	8	6	Asphalt	
3. Farm Road					
Main farm road	21	8	6	Gravel	
Secondary f. road	483	6	5	Non	
On-farm road	701	4	3	Non	
Total	1,329				

Density of road: 64 m/ha (27 m/feddan)

Appendix E

Appendix E-1 Calculation of Eto by Blaney-Criddle

CALCULATION OF ETo BY BLANEY - CRIDDLE

Station: El Mansura Lat. 31°N Long. 31°27'E Alt. 3.8 m (Unit: mm/day)

(1969)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	11.8	15.1	17.6	18.1	23.1	27.2	25.9	26.5	26.7	23.2	19.5	14.7
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + 8)		3	3.2	3.7	4.3	4.7	5.8	6.6	6.2	6.1	5.7	4.9	4.1	3.4
RH		4	M	M	M	M	L	L	M	M	M	M	M	M
n/N		5	L/M	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	2.4	3.1	3.9	5.0	9.0	9.3	7.2	7.1	6.5	5.4	4.2	3.2

(1970)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	14.2	14.4	16.5	19.7	22.8	25.7	26.2	27.1	25.8	21.9	18.6	13.7
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + 8)		3	3.5	3.7	4.2	4.9	5.7	6.3	6.2	6.1	5.6	4.7	4.0	3.3
RH		4	M	M	L	L	L	L	M	M	M	L	M	M
n/N		5	L/M	M/H	M	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	L/M
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	2.8	3.6	5.1	6.5	8.0	8.9	7.2	7.1	5.4	6.2	3.3	2.6

CALCULATION OF ETo BY BLANEY - CRIDDLE

Station: El Mansura   Lat. 31°N   Long. 31°27'E   Alt. 3.8 m   (Unit: mm/day)

(1971)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	14.3	13.3	15.9	17.6	23.5	26.0	26.2	27.4	25.5	22.2	17.9	13.6
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + B)		3	3.5	3.5	4.1	4.7	5.8	6.4	6.2	6.2	5.5	4.7	3.9	3.3
RH		4	M	M	L	L	L	L	M	M	M	M	M	M
n/N		5	L/M	L/M	M/H	L/M	M/H	M/H	M/H	M/H	M/H	M/H	L/M	L/M
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	2.8	2.8	5.2	5.4	8.1	9.0	7.2	7.2	6.3	5.0	3.4	2.6

(1972)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	12.6	13.1	15.4	20.4	21.8	26.0	26.8	28.2	26.9	22.9	18.6	14.4
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + B)		3	3.3	3.5	4.1	5.0	5.6	6.4	6.3	6.3	5.7	4.8	4.0	3.4
RH		4	M	M	M	L	L	L	M	M	L	M	M	M
n/N		5	M/H	M/H	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H	L/M	L/M
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	3.1	3.3	3.6	5.9	7.8	9.0	7.7	7.7	8.0	5.3	3.6	2.8

CALCULATION OF ETo BY BLANEY - CRIDDLE

Station: El Mansura   Lat. 31°N   Long. 31°27'E   Alt. 3.8 m   (Unit: mm/day)

(1973)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	12.1	14.3	16.5	18.2	23.0	25.8	27.8	26.9	25.9	-	-	-
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	-	-	-
P(0.46T + 8)		3	3.3	3.6	4.2	4.7	5.8	6.4	6.4	6.1	5.6	-	-	-
RH		4	M	M	M	L	L	M	M	M	L	-	-	-
n/N		5	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	-	-	-
U_2		6	M	M	M	M	M	M	M	M	M	-	-	-
ETo		7	3.1	3.5	4.4	6.2	9.0	7.7	7.7	7.1	7.3	-	-	-

(1974)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	-	13.4	16.6	19.2	22.2	26.0	27.2	26.8	25.8	24.0	18.9	12.7
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + 8)		3	-	3.5	4.2	4.9	5.6	6.4	6.4	6.4	5.6	5.0	4.0	3.2
RH		4	M	M	M	L	L	L	M	M	M	L	M	M
n/N		5	-	L/M	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H	M/H	L/M
U_2		6	-	M	M	M	M	M	M	M	M	M	M	M
ETo		7	-	2.8	3.8	5.7	7.8	9.0	7.7	7.7	6.4	6.7	4.1	2.4

CALCULATION OF ETo BY BLANEY - CRIDDLE

Station: El Mansura   Lat. 31°N   Long. 31°27'E   Alt. 3.8 m   (Unit: mm/day)

(1975)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	12.1	12.9	15.9	21.6	22.4	26.0	27.1	26.0	25.0	23.1	-	14.2
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + B)		3	3.3	3.5	4.1	5.2	5.7	6.4	6.3	6.0	5.5	4.8	-	3.3
RH		4	M	M	L	M	L	L	M	M	M	M	-	M
n/N		5	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	-	L/M
U_2		6	M	M	M	M	M	M	M	M	M	M	-	M
ETo		7	2.6	2.8	5.2	5.8	8.0	9.0	7.7	7.1	6.3	5.3	-	2.6

(1976)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	12.3	11.7	14.8	18.8	22.7	25.5	26.7	25.6	24.4	23.2	19.7	14.8
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + B)		3	3.3	3.3	4.0	4.8	5.7	6.3	6.3	5.9	5.4	4.9	4.1	3.4
RH		4	M	M	M	M	L	M	M	M	M	M	M	M
n/N		5	L/M	L/M	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	2.6	2.6	3.6	4.6	8.0	7.2	7.2	7.0	6.1	5.4	4.2	3.2

CALCULATION OF ETo BY BLANEY - CRIDDLE

Station: El Mansura   Lat. 31°N   Long. 31°27'E   Alt. 3.8 m   (Unit: mm/day)

(1977)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	12.5	15.2	14.8	19.0	23.9	26.5	27.9	27.6	25.1	20.9	19.0	13.0
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + 8)		3	3.3	3.7	4.0	4.9	5.9	6.5	6.5	6.2	5.5	4.6	4.0	3.2
RH		4	M	M	M	L	L	L	M	M	M	M	M	M
n/N		5	L/M	M/H	M/H	L/M	M/H	M/H	M/H	M/H	M/H	M/H	M/H	H
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	2.6	3.6	3.3	5.7	8.3	9.2	7.8	7.2	6.3	5.0	3.3	3.1

(1978)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
T mean	°C	1	11.8	13.9	15.4	19.2	24.3	25.9	27.5	25.7	24.5	23.3	16.0	14.7
P		2	0.24	0.25	0.27	0.29	0.31	0.32	0.31	0.30	0.28	0.26	0.24	0.23
P(0.46T + 8)		3	3.2	3.6	4.1	4.9	5.9	6.4	6.4	5.9	5.4	4.9	3.8	3.4
RH		4	M	M	M	L	L	L	M	M	M	M	M	M
n/N		5	L/M	M/H	L/M	M/H	M/H	M/H	M/H	M/H	M/H	L/M	L/M	L/M
U_2		6	M	M	M	M	M	M	M	M	M	M	M	M
ETo		7	2.4	3.5	3.6	6.5	8.3	9.0	7.7	7.0	6.1	4.7	3.4	2.8

Appendix E-2 Calculation of ETo by Radiation Method

CALCULATION OF ETo BY RADIATION METHOD

(1969)

Station: EL MANSURA

(Unit: mm)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	5.7	7.4	6.7	9.4	10.2	12.1	11.8	11.3	10.6	9.1	8.7	7.6
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.53	0.58	0.53	0.61	0.62	0.68	0.67	0.67	0.68	0.65	0.66	0.63
Rs	1 x 4	5	4.6	6.1	6.9	9.2	10.2	11.6	11.3	10.5	9.4	7.4	6.1	5.1
T mean		6	11.8	15.1	17.6	18.1	23.1	27.2	25.9	26.5	26.7	23.2	19.5	14.7
W		7	0.56	0.62	0.66	0.66	0.72	0.76	0.75	0.76	0.76	0.72	0.68	0.63
W.Rs	5 x 7	8	2.6	3.8	4.6	6.1	7.3	8.8	8.5	8.0	7.1	5.3	4.1	3.2
RH mean		9	M/H	M/H	M/H	M/H	M/H	L/M	M/H	M/H	M/H	M/H	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.1	3.3	4.3	5.4	6.7	8.9	7.7	7.3	6.5	4.8	3.5	2.8

(1970)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	7.1	8.1	8.4	9.9	10.4	11.7	11.7	11.1	10.8	9.4	7.9	7.0
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	6.59	0.61	0.6	0.63	0.63	0.66	0.67	0.67	0.69	0.66	0.63	0.50
Rs	1 x 4	5	5.1	6.4	7.8	9.5	10.4	11.2	11.3	10.5	9.5	7.5	5.9	4.9
T mean		6	14.2	14.4	16.5	19.7	22.8	25.7	26.2	27.1	25.8	21.9	18.6	13.7
W		7	0.61	0.61	0.65	0.68	0.72	0.75	0.75	0.76	0.75	0.71	0.67	0.61
W.Rs	5 x 7	8	3.1	3.9	5.1	6.5	7.5	8.4	8.5	8.0	7.1	5.3	4.0	3.0
RH mean		9	M/H	M/H	M/H	L/M	L/M	L/M	M/H	M/H	M/H	L/M	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.6	3.4	4.4	6.5	7.5	8.4	7.7	7.3	6.5	4.8	3.4	2.4

CALCULATION OF ETo BY RADIATION METHOD

(1971)

Station: El Mansura

(Unit: mm)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	7.1	7.6	8.5	8.8	11.0	11.7	11.5	10.9	10.5	9.4	7.4	5.3
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.59	0.59	0.60	0.59	0.65	0.66	0.66	0.66	0.67	0.62	0.60	0.51
Rs	1 x 4	5	5.1	6.2	7.8	8.9	10.7	11.2	11.1	10.4	9.2	7.1	5.6	4.1
T mean		6	14.3	13.3	15.9	17.6	23.5	26.0	26.2	27.4	25.5	22.2	17.9	13.6
W		7	0.61	0.60	0.64	0.66	0.73	0.75	0.75	0.76	0.74	0.71	0.66	0.61
W.Rs	5 x 7	8	3.1	3.7	5.0	5.9	7.8	8.4	8.3	7.9	6.8	5.0	3.7	2.5
RH mean		9	M/H	M/H	M/H	M/H	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.6	3.2	4.3	5.2	7.8	8.4	7.5	7.2	6.1	4.3	3.2	2.0

(1972)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	7.3	8.6	7.5	8.0	9.9	11.7	11.3	10.9	10.6	9.2	7.3	6.7
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.60	0.64	0.56	0.56	0.61	0.66	0.65	0.66	0.68	0.65	0.60	0.58
Rs	1 x 4	5	5.2	6.7	7.3	8.5	10.1	11.2	10.9	10.4	9.4	7.4	5.6	4.7
T mean		6	12.6	13.1	15.4	20.4	21.8	26.0	26.8	23.2	26.9	22.9	18.6	14.4
W		7	0.59	0.59	0.63	0.69	0.71	0.75	0.76	0.77	0.76	0.72	0.67	0.62
W.Rs	5 x 7	8	3.1	4.0	4.6	5.9	7.2	8.4	8.3	8.0	7.1	5.3	3.8	2.9
RH mean		9	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.6	3.4	4.3	5.2	6.6	7.6	7.5	7.3	6.5	4.8	3.3	2.3

CALCULATION OF ETo BY RADIATION METHOD

(1973)

Station: EL MANSURA

(Unit: mm)

Item	No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n	2	7.8	8.0	8.9	10.1	11.4	11.6	11.2	11.3	10.6	-	-	-
N	3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)	4	0.63	0.61	0.54	0.64	0.67	0.66	0.65	0.67	0.68	-	-	-
Rs 1 x 4	5	5.4	6.4	7.0	9.7	11.1	11.2	10.9	10.5	9.4	-	-	-
T mean	6	12.1	14.3	16.5	18.2	23.0	25.8	27.8	26.9	25.9	-	-	-
W	7	0.58	0.61	0.65	0.66	0.72	0.75	0.77	0.76	0.75	-	-	-
W.Rs 5 x 7	8	3.1	3.9	4.6	6.4	8.0	8.4	8.4	8.0	7.1	-	-	-
RH mean	9	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	M/H	-	-	-
U daytime	10	2	2	2	2	2	2	2	2	2			
ETo	11	2.6	3.4	4.3	6.4	7.3	7.6	7.6	7.3	6.5	-	-	-

(1974)

Item	No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n	2	-	7.3	7.9	8.6	11.3	11.8	11.3	11.3	10.1	9.8	8.3	6.3
N	3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)	4	-	0.58	0.58	0.58	0.66	0.67	0.65	0.67	0.66	0.68	0.65	0.56
Rs 1 x 4	5	-	6.1	7.5	8.8	10.9	11.4	10.9	10.5	9.1	7.8	6.0	4.5
T mean	6	-	13.4	16.6	19.2	22.2	26.0	27.2	26.8	25.8	24.0	18.9	12.7
W	7	-	0.60	0.65	0.67	0.71	0.75	0.76	0.76	0.75	0.73	0.67	0.59
W.Rs 5 x 7	8	-	3.7	4.9	5.9	7.7	8.6	8.3	8.0	6.8	5.7	4.0	2.7
RH mean	9	-	M/H	M/H	M/H	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H
U daytime	10	-	2	2	2	2	2	2	2	2	2	2	2
ETo	11	-	3.2	4.2	5.2	7.7	8.6	7.5	7.3	6.1	5.0	3.4	2.2

CALCULATION OF ETo BY RADIATION METHOD

(1975)

Station: EL MANSURA

(Unit: mm)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	7.0	7.1	9.6	9.7	10.7	11.7	11.4	11.3	10.3	9.8	-	5.6
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.59	0.57	0.65	0.63	0.64	0.66	0.66	0.67	0.67	0.68	-	0.53
Rs	1 x 4	5	5.1	6.0	8.5	9.5	10.6	11.2	11.1	10.5	9.2	7.8	-	4.3
T mean		6	12.1	12.9	15.9	21.6	22.4	26.0	27.1	26.0	25.0	23.1	-	14.2
W		7	0.58	0.59	0.64	0.71	0.71	0.75	0.76	0.75	0.74	0.72	-	0.61
W.Rs	5 x 7	8	3.0	3.5	5.4	6.7	7.5	8.4	8.4	7.9	6.8	5.6	-	2.6
RH mean		9	M/H	M/H	L/M	M/H	L/M	L/M	M/H	M/H	M/H	M/H	-	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	-	2
ETo		11	2.5	3.0	5.4	6.0	7.5	8.4	7.6	7.2	6.3	4.9	-	2.1

(1976)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	6.9	6.5	8.0	8.7	10.0	11.5	11.4	11.3	10.0	8.6	7.7	7.3
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.58	0.54	0.58	0.59	0.61	0.66	0.66	0.67	0.65	0.62	0.62	0.61
Rs	1 x 4	5	5.0	5.7	7.5	8.9	10.1	11.2	11.1	10.5	9.0	7.1	5.8	4.9
T mean		6	12.3	11.7	14.8	18.8	22.7	25.5	26.7	25.6	24.4	23.2	19.7	14.8
W		7	0.58	0.58	0.62	0.67	0.72	0.74	0.76	0.75	0.73	0.72	0.68	0.62
W.Rs	5 x 7	8	2.9	3.3	4.7	6.0	7.3	8.3	8.4	7.9	6.6	5.1	3.9	3.0
RH mean		9	M/H	M/H	M/H	M/H	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.3	2.8	4.4	5.3	7.3	8.3	7.6	7.2	5.9	4.4	3.3	2.5

CALCULATION OF ETo BY RADIATION METHOD

(1977)

Station: EL MANSURA

(Unit: mm)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.3	11.4	9.3	8.1
n		2	6.4	8.3	8.8	8.8	10.6	11.3	11.2	11.1	10.6	9.1	8.2	9.2
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.56	0.62	0.62	0.59	0.64	0.65	0.65	0.67	0.68	0.65	0.64	0.71
Rs	1 x 4	5	4.8	6.5	8.1	8.9	10.6	11.1	10.9	10.5	9.4	7.4	6.0	5.8
T mean		6	12.5	15.2	14.8	19.0	23.9	26.5	27.9	27.6	25.1	20.9	19.0	13.0
W		7	0.59	0.63	0.63	0.67	0.73	0.76	0.77	0.77	0.74	0.69	0.67	0.59
W.Rs	5 x 7	8	2.8	4.1	5.1	6.0	7.7	8.4	8.4	8.1	7.0	5.1	4.0	3.4
RH mean		9	M/H	M/H	M/H	L/M	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.2	3.5	4.4	6.0	7.7	8.4	7.6	7.4	6.4	4.4	3.4	2.9

(1978)

Item		No.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ra	mm/day	1	8.6	10.5	13.0	15.1	16.5	17.0	16.8	15.7	13.8	11.4	9.3	8.1
n		2	6.9	8.6	8.2	9.6	11.2	11.7	11.6	11.2	10.0	8.5	7.1	6.3
N		3	10.3	11.1	12.0	12.9	13.7	14.1	14.0	13.3	12.4	11.5	10.5	10.1
(0.25 + 0.5 n/N)		4	0.58	0.64	0.59	0.62	0.66	0.66	0.66	0.67	0.65	0.62	0.59	0.56
Rs	1 x 4	5	5.0	6.7	7.7	9.4	10.9	11.2	11.1	10.5	9.0	7.1	5.5	4.5
T mean		6	11.8	13.9	15.4	19.2	24.3	25.9	27.5	25.7	24.5	23.3	16.8	14.7
W		7	0.56	0.61	0.63	0.67	0.73	0.75	0.76	0.75	0.74	0.72	0.65	0.63
W.Rs	5 x 7	8	2.8	4.1	4.9	6.3	8.0	8.4	8.4	7.9	6.7	5.1	3.6	2.8
RH mean		9	M/H	M/H	M/H	M/H	L/M	L/M	M/H	M/H	M/H	M/H	M/H	M/H
U daytime		10	2	2	2	2	2	2	2	2	2	2	2	2
ETo		11	2.3	3.5	4.2	6.3	8.0	8.4	7.6	7.2	6.0	4.4	3.1	2.3