A.4. Land Reclaimability Classification

A.4.1. Classification System and Specifications

In the Phase I Report, the land classification for land reclamation was made based on the soil potentiality evaluation. In the present study, however, the reclaimability of lands in the entire Project Area was classified in accordance with the USBR system.

This system classifies the irrigation suitability of lands into six classes according to the physical aspects of land, that is, soil, topography and drainage conditions.

The definitions of respective classes are as below;

Class 1. Arable: Lands that are highly suitable for irrigation farming, being capable of producing sustained and relatively high yields of a wide range of climatically adapted crops at reasonable cost.

Class 2. Arable: This class comprises lands of moderate suitability for irrigation farming, being measurably lower than Class 1 in productive capacity, adapted to somewhat narrower range of crops, more expensive to prepare for irrigation or more costly to farm.

Class 3. Arable: Lands that are suitable for irrigation development but are approaching marginality for irrigation and are of distinctly restricted suitability because of more extreme deficiencies in the soil, topographic, or drainage characteristics than described for Class 2 lands.

Class 4. Limited Arable or Special Use: Lands are included in this class only after special economic and engineering studies have shown them to be arable. They may have an excessive, specific deficiency or deficiencies susceptible of correction at high cost, but are capable of supporting a farm family if operated in units of adequate size or in association with better lands.

Class 5. Nonarable: Lands in this class are nonarable under existing conditions, but have potential value sufficient to warrant tentative segregation for special study prior to completion of the classification, or they are lands in existing projects whose arability is dependent upon additional scheduled project construction or land improvements. The designation of Class 5 is tentative and must be changed to the proper arable class or Class 6 prior to completion of the land classification.

Class 6. Nonarable: Lands in this class include those considered nonarable under the existing project or the project plan because of failure to meet the minimum requirements for the other classes of land, arable areas definitely not susceptible to delivery of irrigation water or to provision of project drainage, and Classes 4 and 5 lands when the extent of such lands or the detail of the particular investigation does not warrant their segregation.

The specifications of land reclaimability classification was prepared, following the principle of the USBR system. Table A-3 shows the specifications for the Project Area.

Table A-3 Specifications of Land Reclaimability Classification

Land Characteristics	Class 1 - Arable	Class 2 - Arable	Class 3 - Arable	Class 4 Limited Arable
Soil				
Texture	SiL, SCL, SiCL	SiL, SCL, SiCL	SCL, C	C
Depth to hard pan or to barrier layer	> 2.00 m	> 2.00 m	> 1.50 m	> 1.00 m
Salinity (ECe)	< 4 mS/cm	< 8 mS/cm	< 16 mS/cm	< 32 mS/cm
Alkalinity (ESP)	< 15%	< 15%	< 15%	< 15%
" (pH)	< 8.0	< 8.0	< 8.5	< 8.5
Topography				
Slope, Relief }	No restriction	No restriction	No restriction	Slightly rough surface
Drainage				
Hydraulic conductivity	Moderately well	Moderate	Moderately poor	Poor
Groundwater table	> 200 cm	> 150 cm	> 100 cm	> 50 cm

Note: Class 5: Include lands which are continuously submerged by water.

Class 6: Include lands which do not meet the minimum requirements for the other land classes.

The land classes except for Class 1 are further sub-divided into subclasses by the limiting factors, namely soil(s), topography(t), and drainage (d) conditions.

For the Project Area, eight subclasses were found as 2s, 3sd, 4Rsd, 4Pt, 5sd (4Rsd), 5sd (6sd), 6t and 6sd.

A.4.2. Land Reclaimability

As the results of field investigation and laboratory analysis, a land reclaimability classification map of the Project Area was prepared as shown in Figure A-16. And the acreages by land reclaimability classes are as bellow;

Land Class	Sub Class		Area (feddan)	(%)
Class 2	2s		6,850	9.2
Class 3	3sd		16,590	22.2
Class 4	4Rsd		18,340	24.6
	4Pt		1,620	2.2
		Sub-total	19,960	26.8
Class 5	5sd(4Rsd)		25,360	33.9
	5sd (6sd)		750	1.0
		Sub-total	26,110	34.9
Class 6	6sd		4,210	5.6
	6t		980	1.3
		Sub-total	5,190	6.9
		Total	74,700	100.0

As shown in the classification map, there are no Class 1 lands to be found within the Project Area. General descriptions for each subclass are as follows;

Class 2s: The lands are best suited to the irrigated agriculture within the Project Area. Large portion of these lands are presently cultivated or have been levelled for cultivation. These lands have no limitations for reclamation except for salinity. the salinity is correctable. Because the drainability is moderately well or moderate, leaching can be readily carried out. Various field crops can be grown on these lands. These lands are distributed along the western and southern boundaries of the Project Area.

Class 3sd: The lands are suitable for irrigated agriculture, but greater risk may be involved in farming them than the better classes of lands. Under proper management they are expected to have adequate payment capacity. Most lands of this class have inferior drainability to the Class 2 lands, therefore, leaching may be more intensive, that is, dense spacing of drains, and soil improvement may take a longer time. Some salt tolerant plants such as Salicornia and Tamarix are being grown. Some parts of these lands are now used as rice paddy. Field crops as well as paddy rice can be grown on these lands after leaching.

Class 4Rsd: These lands have drainage and salinity limitations for reclamation. In particular, drainability of these lands is inferior to the better classes. Most lands of this class are barren or are used as fish pond at present. Sufficient leaching through providing a dense drain network is required. After leaching, these lands can be used as rice paddy. Furthermore, some field crops may be cultivated under proper management.

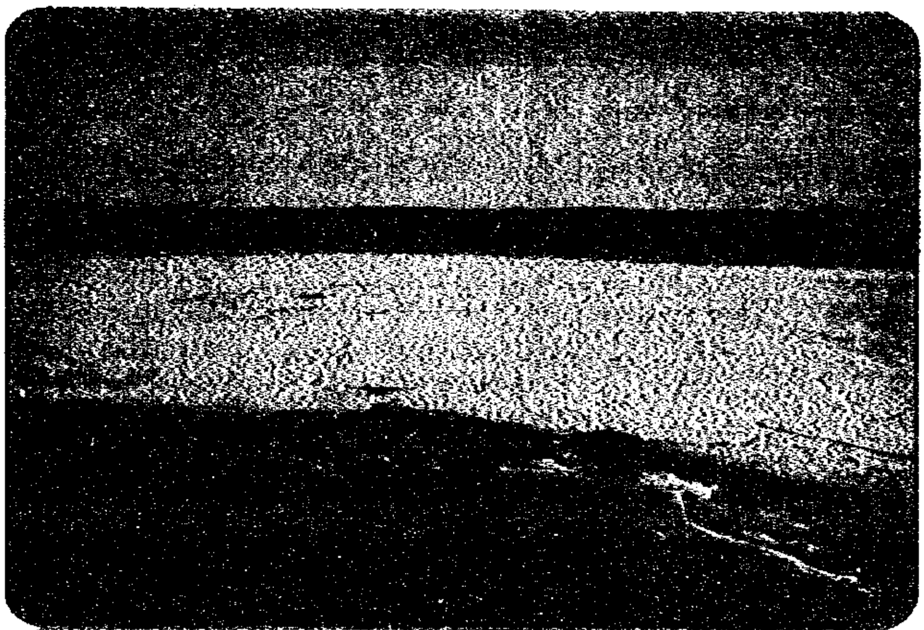
Class 4Pt: These lands have unfavorable relief, such as clay dunes. The topography limitation can be ameliorated so these lands should be included in the reclaimable area. The drainability is fair, therefore, salinity may be corrected with ease. The surface of the land is covered with wind-blown puffy silty clay. Small shrubs, mainly Tamarix grow sparsely on these lands. These lands can be used as pasture, however, some field crops may be cultivated under proper management. These lands are distributed in the foothfill areas.

Class 5sd: Swamp and inundated lands which are continuously submerged by water fall into this class. First of all desiccation of lands is necessary for reclamation. Most lands in this class may be arable, however, drainability is very poor so that further detailed investigation is required after desiccation before final evaluation can be made. Tentatively, these lands are anticipated to be Class 4Rsd after desiccation, 5sd (4Rsd). In small portions, the land surface may form depressions after desiccation, therefore, those parts may be excluded from the reclaimable area, 5sd (6sd).

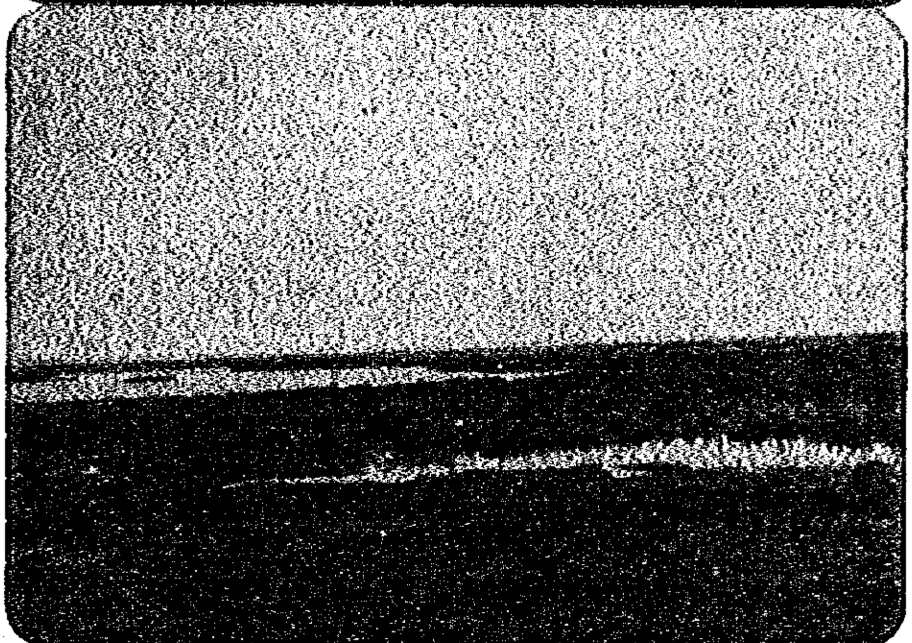
Class 6t: These lands are elevated and segregated from the surrounding area. These hills ar locally called "Tell" and most of them are ruins of ancient dwellings. The lands have fair drainage condition, however, irrigability is poor because of their higher elevation. These lands are barren at present. The higher lands are situated on the southern fringe of the Project Area, however, they have continuous elevation to the surrounding area. Therefore, their topography may not be a constraint for irrigated agriculture using the gravity system.

Class 6sd: The lands are mostly depressions or swamps. Some of them are permanently submerged by brackish water flowing into adjoining lands. The soils have very poor drainability in general. Even though the soils have fair permeability, discarding the drained water is difficult. Finally, these lands are excluded from the reclaimable area because of their strong salinity as well as very poor hydraulic conductivity. Leaching may be tedious due to the restricted drainage. At present, most lands are barren.

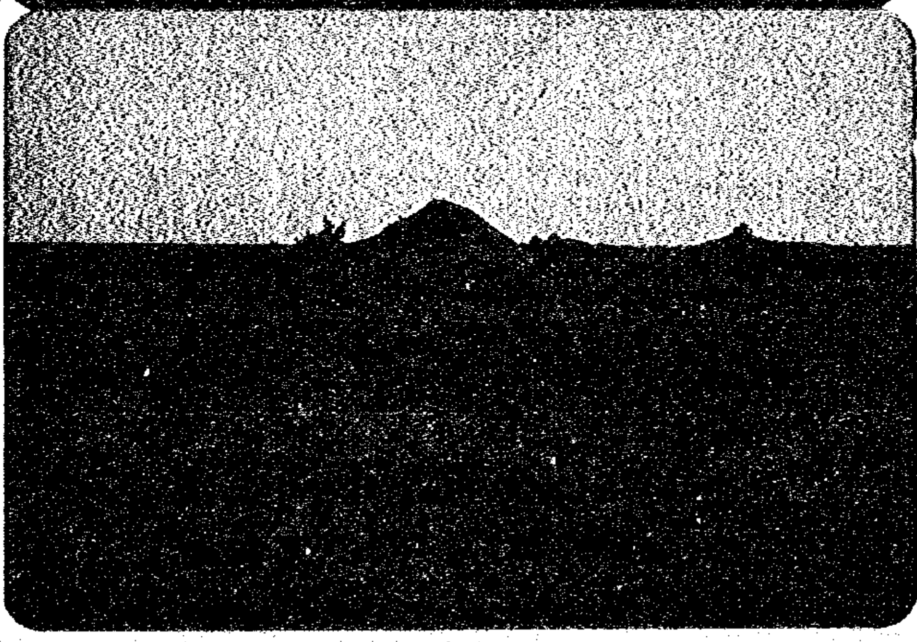
Major Constraints of Land Reclaimability



High Saly
Accumulation



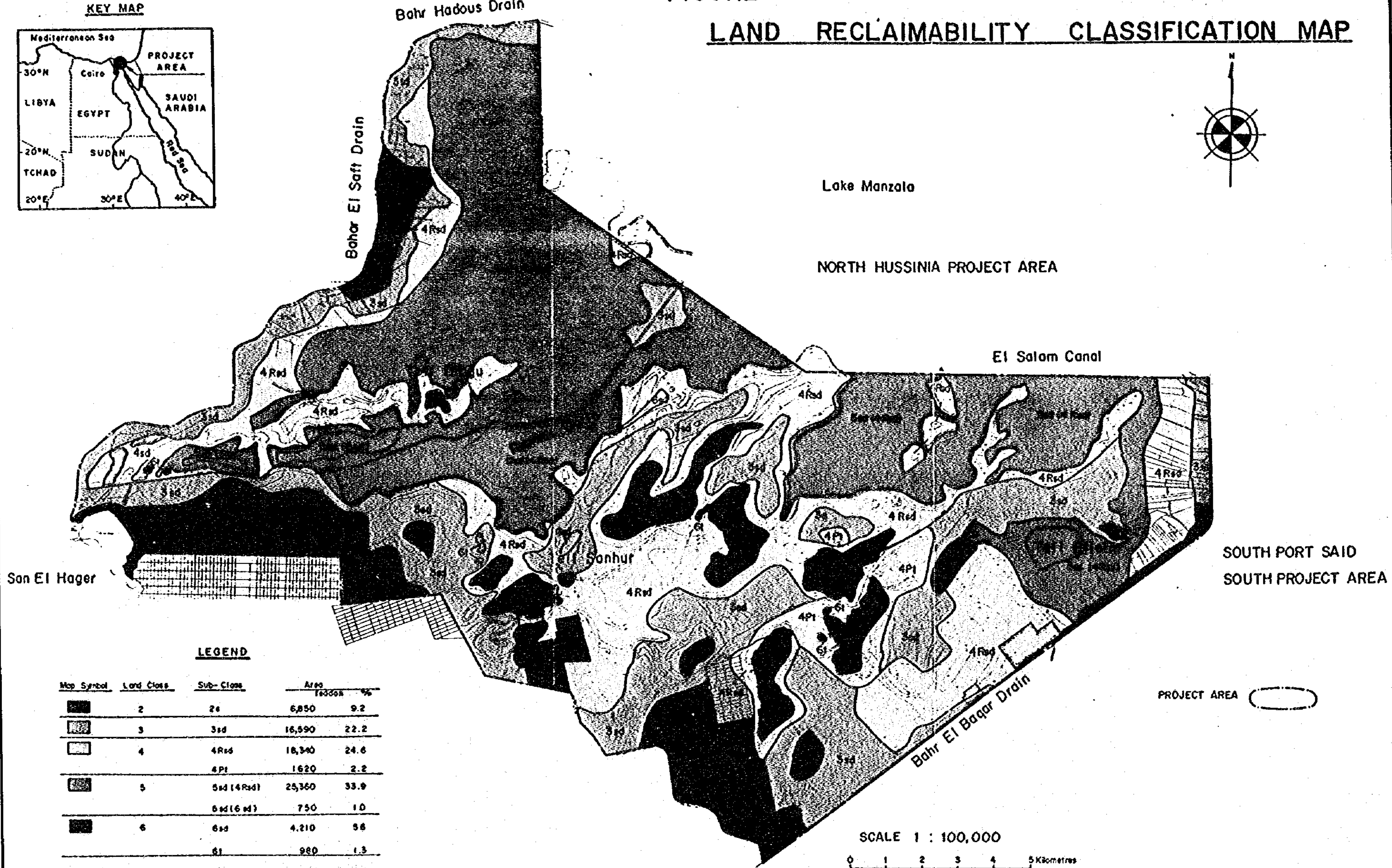
Poor Drainage



Clay Dune

FIGURE A-16

LAND RECLAIMABILITY CLASSIFICATION MAP



LEGEND

Map Symbol	Land Class	Sub-Class	Area feddan	%
	2	2s	6,850	9.2
	3	3sd	16,590	22.2
	4	4Rsd	18,340	24.6
		4Pt	1620	2.2
	5	5sd (4Rsd)	25,360	33.9
		6sd(6sd)	750	1.0
	6	6sd	4,210	5.6
		6t	980	1.3
		Total	74,700	100.0

A.5. Land Reclamation for Agricultural Use

It is obvious that drainage and leaching are two basic requirements for the successful reclamation of such saline and alkali soils as the Project Area soils. The practical way to remove excess soluble salts from the soils is by washing them out. In the area where saline and alkali soils occur, the underlying layers are poorly permeable; therefore, artificial drainage is required to remove the salty drainage water for preventing the soils from re-salinization.

Various methods for amelioration of saline and alkali soils have been developed in the course of land reclamation projects in many countries. Up to now, however, no sole nor absolute method has been established. The success of the reclamation of saline and alkali soils depends on the adequate combination of various amelioration methods.

In Egypt as well as other countries, it has been recognized that the leaching in combination with rice growing is very useful as means of reclaiming extremely saline soils with poor permeability.

A.5.1. Drainage Improvement

For the land reclamation in the Project Area soils, the corrections for poor drainability is of most importance. In order to improve the surface and internal drainage and to lower groundwater table, it is essential to establish the sufficient drainage system having an adequate depth, spacing, and capacity.

The drainage system in saline soils must be designed to desalinize not only the topsoil but also upper subsoil in order to control both the water and salt balances. For the Project

Area, it is considered to be one and a half meter from the surface.

As regards types of drainage, the shallow horizontal drainage, about one meter deep, has been widely used. But leaching with shallow drainage has not succeeded in a lasting improvement because it fails to eliminate secondary salinization. On the other hand, the deep horizontal drainage can lower the groundwater table to a critical depth that makes no longer secondary salinization. Reducing the risk of secondary salinization, the leaching with deep drainage results in a lasting desalinization.

As regards construction, the drainage system may be open or closed. Between these two types of drains, no essential difference in efficiency has been observed if the required depth is maintained. Open drains are easier to construct in sufficient capacity but are frequently more difficult to operate because the channel walls tend to crumble, whereas the closed drains, made of plastic pipes wrapped by gravels for example, work perfectly for long periods, requiring virtually no repairs.

Results of the "Pilot Project for Drainage of Irrigated land, UAR" conducted by FAO at six pilot areas in the Nile Delta suggest the prosperities of mechanically manufactured and laid plastic pipes.

For the Project Area, the field drains within a farm plots were designed to be 1.5 m deep and 25 m spacing as open drains at the early stage of reclamation period to secure the full capacity and to collect the surface drainage, and then those would be replaced by closed drains after leaching. Details of the design are shown in Appendix B in Volume II.

It should be noted that such field drains cannot facilitate prosperously without improving soil permeability above and at the depth of drain. Soil permeability can be improved by physical, biological, and chemical amelioration methods.

a. Physical Amelioration

Several mechanical methods have been used to increase soil permeability for saline and alkali soils, that is, deep plowing, subsoiling, and sanding.

Deep plowing can increase soil permeability directly by mixing fine and coarse textured layers and obtain a more uniform soil through plowing from about 40 to 150 cm deep. This is especially beneficial on stratified soils as the Project Area soils having impermeable layers lying between permeable layers.

Subsoiling is to pull chisels with a powerful tractor through the soil to open channels to improve soil permeability by breaking up impermeable layers. The beneficial effects of subsoiling usually persist for several years if an indurated horizon is broken.

Sanding is an effective means of making a fine textured, but not heavy clayey, surface soil more permeable by incorporating sands into it. But the effect is not reliable for the Project Area soils mainly consisting of heavy clay.

b. Biological Amelioration

Both alive and dead plants have beneficial effect of improvement of soil permeability as well as of soil fertility.

Incorporating large amounts of manure in the soil also improves the surface soil permeability by loosening the compacted soils in addition to improving the soil fertility.

Growing deep rooting plants such as legumes (alfalfa berseem etc.) promotes the reclamation of saline soils lacking internal drainage by penetrating their root systems and by lowering the groundwater table, and consequently allowing the salt leaching.

In additions, the shading effect of living plants or the mulching effect of plant residue or manure lead to reduce the evaporation from the soil surface, as a result, to slower the build-up of surface salt accumulation with the upward movement of soil water.

c. Chemical Amelioration

Chemical amendments are used for reclamation of alkali soils to improve the soil permeability through to replace exchangeable sodium, which disperse clay fraction, by calcium. Known amendments are soluble calcium salts such as gypsum and $CaCl_2$, slowly soluble calcium compounds as limestone, and acidifying materials as sulphuric acid and sulfur etc. Gypsum is the most common amendments for reclamation of alkali soils in this Region.

Gypsum Requirement

In the Project area, some portions, mainly in the cultivated areas where the lands had been irrigated once, fall into the category of saline-alkali soils according to the definition made by the U.S. Salinity Laboratory, that is, the ESP values exceed 15 percent.

The Project Area soils generally contain a considerable amount of gypsum. These gypsum existing in the soils at relatively high level can play an important role as a source of Ca ion in replacing Na at the exchange complex and contribute to the substantial decrease in exchangeable sodium during the leaching process as below;

$$2NaX + CaSO_4 \rightleftarrows Ca\ X + Na_2SO_4$$

X: Soil exchangeable complex

However, the gypsum is considerably affected by leaching owing to its relatively greater solubility than lime1/. As a result, the gypsum content, especially in the surface layer is markedly decreased after leaching.

Thus, the possiblity of the increasing soil alkalinity after leaching may be expected. Accordingly, the addition of gypsum amendment to the soils before leaching is recommended because it improves the soil drainability through maintaining the ESP values at low level during the leaching process.

Note: 1/ A saturated solution of pure gypsum contains 3.0 meq. of gypsum per 100 g of water at 25°C. The solubility of gypsum increases considerably in the presence of other salts and more than 7.0 meq gypsum per 100 g can be dissolved in a 10 percent NaCl solution.

The dosage of gypsum used for soil improvement can be determined by the laboratory method (USDA Handbook 60, See A.6.10.), and also it can be estimated by the calculation based on the theory that the dosage of gypsum must be equivalent to the quantity of exchangeable sodium to be removed. the gypsum requirement for the alkali soils can be calculated from the following formula;

$$\text{Gypsum Requirement in meg/100g soil} = \frac{(\text{ESP} - \text{ESP final})}{100} \times \text{CEC}$$

Here, the ESP final of 10 is considered as not resulting in any noticeable peptisation of the soil.

Assuming that the surface layer in the Project Area soils weighs in average 3,900 ton/ha (bulk density averages 1.30), the total gypsum requirement for the soils in order to reduce the ESP below ten can be further calculated.

Tables A-4, and A-5 show the comparison and the calculation of requirement and content of gypsum for the Project Area soils.

A shown in Table A-4, the gypsum requirements are ranging from zero to 3.93 tons/feddan and the gypsum requirements can be classified into three categories, that is, 0, 2, and 4 tons/feddan and Figure A-17 show the gypsum requirement by location.

The quality of gypsum depends largely on its fineness, that is, the optimum particle size for gypsum is about 2 mm.

Table A-4 Comparison of Requirement and Content of Gypsum

(0-30 cm)

Pit No.	Gypsum Content		Gypsum Requirement
	%	ton/feddan	ton/feddan
P-1	3.9	37.6	3.4
P-2	1.3	24.2	0.2
P-3	4.5	46.4	3.5
P-4	4.4	61.8	0.3
P-5	1.4	13.5	-
P-6	0.5	10.2	3.2
P-7	4.3	52.9	-
P-8	2.2	15.7	0.1
P-9	3.3	54.3	0.6
P-10	3.5	55.0	-
P-11	3.3	23.0	3.9
P-12	1.5	34.0	-
S-4	1.2	19.0	2.4
S-6	1.8	29.5	2.0
S-27	2.3	37.3	0.8
S-28	3.5	55.8	0.2
S-35	0.9	15.4	0 3
S-44	1.3	21.4	2.1

Note: 1/ Bulk density = 1.30

$$\text{Weight of soil feddan (kg)} = 4200^{sq.m} \times \frac{\text{thickness(cm)}}{100} \times 1.30$$

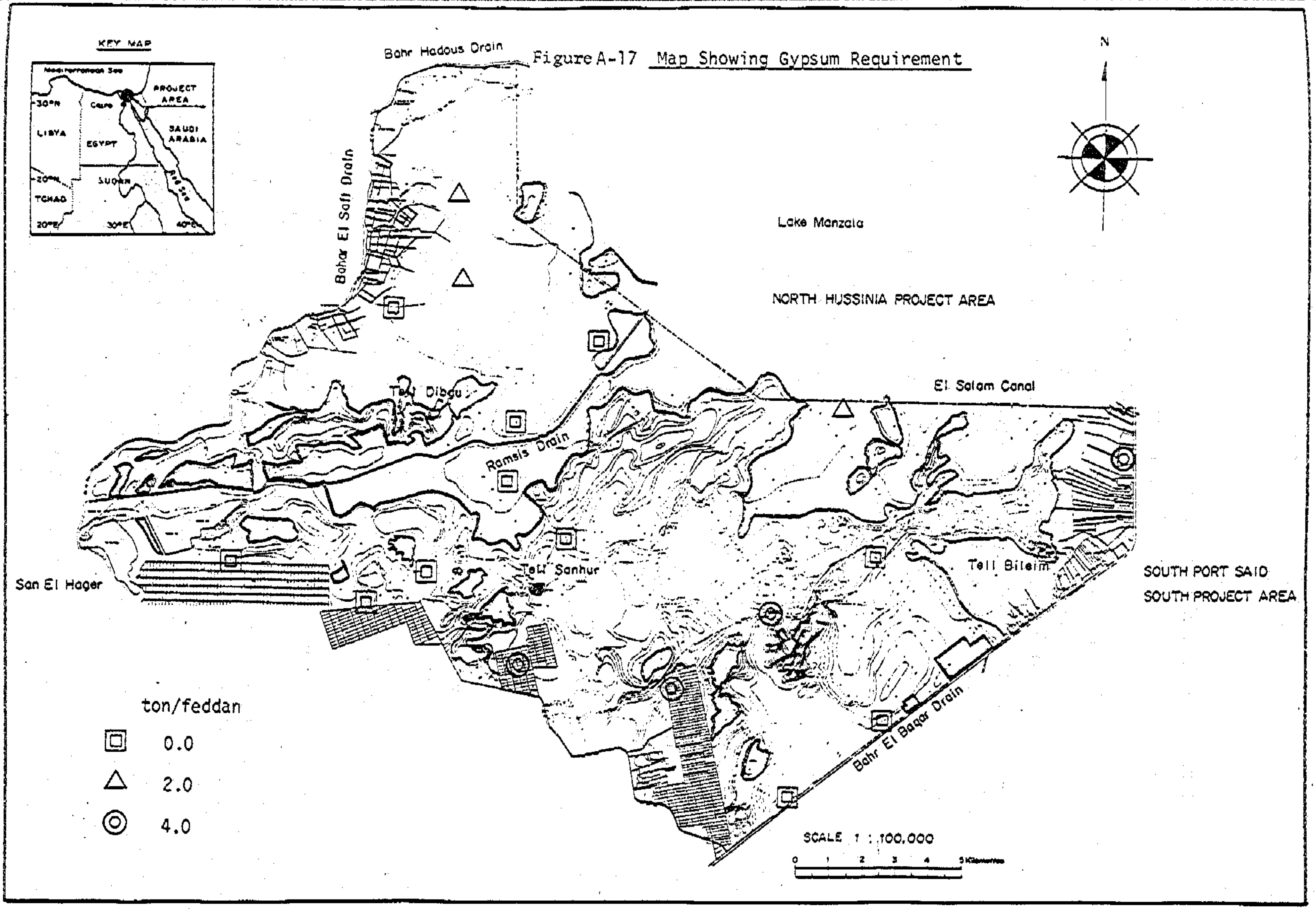
$$\text{Gypsum content (ton/feddan)} = \frac{\text{gypsum content(\%)}}{100} \times \frac{\text{wt. of soil per feddan(kg)}}{1,000}$$

Table A-5 Calculation of Gypsum Requirement (0-30cm)

Pit No.	ESP 1 %	CEC 2 meq/100g	$(\frac{ESP-10}{100}) \times CEC$ 3 meq/100g	Gypsum Requirement 3 x 3.35 ton/ha 1/	Gypsum Requirement 3 x 1.43 ton/feddan
P-1	17.4	33.0	2.422	8.19	3.44
P-2	10.5	23.4	0.117	0.39	0.16
P-3	19.4	26.4	2.482	8.33	3.49
P-4	10.7	26.3	0.184	0.62	0.26
P-5	7.9	33.0	-	-	-
P-6	17.4	31.0	2.294	7.70	3.23
P-7	8.4	24.4	-	-	-
P-8	10.3	29.8	0.089	0.29	0.12
P-9	11.6	24.9	0.398	1.33	0.56
P-10	10.1	30.6	0.031	0.11	0.04
P-11	20.4	26.8	2.787	9.35	3.93
P-12	10.1	25.8	0.026	0.09	0.03
S-4	16.6	25.8	1.703	5.71	2.40
S-6	15.0	28.4	1.420	4.77	2.00
S-27	11.8	31.8	0.572	1.92	0.81
S-28	10.4	25.8	0.0103	0.35	0.15
S-35	10.7	33.1	0.232	0.78	0.33
S-44	15.3	27.4	1.452	4.87	2.05

Note 1/ Since 1 meq of gypsum per 100g of soil equals 860 ppm of gypsum, for 1 ha to a depth of 30 cm (roughly 3,900 tons, assuming 1.30 of bulk density), the amount of gypsum required (ton/ha) is (gypsum requirement in meq/100g) $\times 860 \times 10^{-6} \times 3.9 \times 10^{3}$

Figure A-17 Map Showing Gypsum Requirement



A.5.2. Leaching of Saline Soils

Leaching for removal of soluble salts excessively accumulated in soils is called "initial" or "capital" leaching in order to distinguish from the leaching during irrigation for maintaining the salt balance. Simply, a term of "leaching" is used as the meliorative leaching in this section.

The effective leaching is entirely dependent on the elaborated designing such as water dose, time, method and procedures based on data obtained by pre-investigation.

The effectiveness of leaching has been confirmed by prominent works, even though there have been numerous cases of failures due to various technical defects, insufficient care, and insufficient experience.

a. Leaching Water Requirement

The amount of water required for capital leaching depends upon the quantity and quality of salts in the soil, groundwater and irrigation water; depth to be leached; soil permeability and type of leaching.

In USSR, L. Rozov (1936) proposed the following empirical formula to estimate the leaching water requirement;

$$M = FC - m + n\,FC$$

where, M = amount of water (cum/ha)
FC = field capacity (cum/ha)
m = water reserve in the soil before leaching (cum/ha)
n = coefficient (0.5 - 2.0 depending on the salinity and the mechanical composition of the soil)

Applying this formula for the anticipated Project Area soils just after drainage improvement, the coefficient n is 2.0 because of the highly accumulated salts and the heavy texture of the soil. Here, providing the field drains will not basically change the soil salinity and mechanical composition of the soil.

$$M = 6,825 - 3,900 + 2 \times 6,825 = 16,575 \text{ cu.m/ha}$$

where, leaching soil depth .... 1.5 m

bulk density 1.3

weight of soil (1 ha x 1.5 m deep)

10,000 sq.m x 1.5 m x 1.3 = 19,500 tons

field capacity (27 - 39%) - 35% average

FC = 19,500 x 0.35 = 6,825 cu.m/ha

moisture content before leaching .. 20% estimated

m = 19,500 x 0.20 = 3,900 cu.m/ha

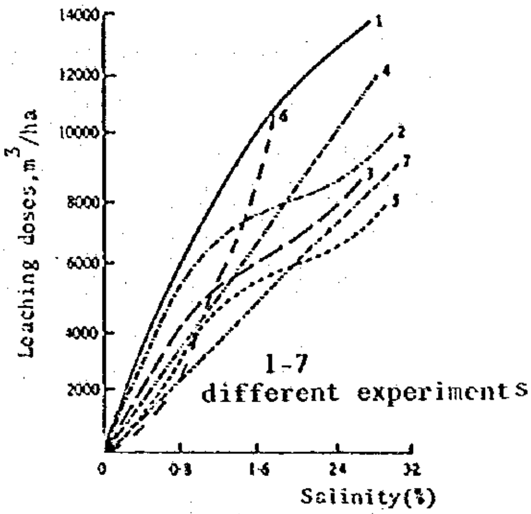
coefficient n = 2.0

As a rough estimate, a unit depth of water will remove about 80 percent of the salts from a unit depth of soil. According to the US Salinity Laboratory's guide, an approximation of the amount of water required for leaching 1.5 m depth of soil by flooding can be made as below;

Salt Removal	Depth of Water Needed
50%	750 mm
80%	1,500 mm
90%	3,000 mm

For the Project Area, for example, about 2,000 mm depth of low-salt water is needed for leaching the soils having ECe of 40 mS/cm to 6 mS/cm (85 percent of salt removed). In practice, however, the amount of water required depends upon the quality of the leaching water and soil conditions.

Based on the relation between leaching application and salinity obtained by generalization of data from many experiments, in the USSR, V. Kovda (1957) established the following empirical formula;



Connection between Leaching Application and Salinity
V.Volobuev (1947)

$$y = n_1 \cdot n_2 \cdot n_3 \cdot 400x \pm 100$$

where, y = depth of leaching water (mm)

x = mean salt content soil profile (%)

n_1 = coefficient depending on soil mechanical composition (sand = 0.5, loam = 1.0 , clay = 2.0)

n_2 = groundwater table depth (1.5 - 2.0 m = 3.0, 2 - 5 m = 1.5, 7 - 10 m = 1.0)

n_3 = groundwater salinity (weak or medium = 1.0, strong = 2.0, very strong = 3.0)

Applying this formula for the Project Area soils, the depth of leaching water is calculated as below[1/];

$$y = 2.0 \times 1.5 \times 1.5 \times 400 \times 1.25 \pm 100$$
$$= 2{,}250 \pm 100 \text{ mm}$$

where, n_1 = 2.0 (clay)

n_2 = 1.5 (2-5 m deep groundwater)

n_3 = 1.5 (medium to strong groundwater salinity)

x = 1.25% average(1.0 - 1.5%)

Thus, the effectiveness of leaching, expressed in terms of the quantity of salts removed by a given quantity of water from a given unit of soil increase sharply and progressively with the salinity in the soil. V.R. Volobuev (1960) suggested the relation between the leaching dose and the soil salinity is not rectilinear but logarithmic. And he made the equation on the basis of the degree and type of salinity and the mechanical composition of the soil being leached as below;

$$N = K \log \left(\frac{Si}{S_o} \right)^a$$

where, N = leaching water norm (cu.m/ha)
Si = soil salinity in 0 - 100 cm layer (%)
So = permissible residual soil salinity (%)
K = coefficient for recalculating per ha (10,000 sq.m)
a = parameter depending on soil salinity and on the proportion of chlorides in its salt

For chloride salinity type and clayey soils as the Project Area soils, the parameter "a" was considered to be in a range from 0.9 to 1.5. Accordingly, the leaching dose was calculated as follows;

$$N = 10{,}000 \log \frac{1.25}{0.25} \times 1.5$$

$$= 10{,}485 \text{ cu.m/ha for 1.0 m deep soil to be leached.}$$

For 1.5 m deep soil to be leached, the total leaching requirement was calculated as below;

$$10{,}485 \times 1.5 = 15{,}728 \text{ cu.m/ha} = 1{,}573 \text{ mm}$$

According to the calculation using the empirical formula, the leaching requirement for the Project Area soils was estimated to be in a range from 1,573 to 2,350 mm. In practice, the requirement fluctuate depending on the degree of soil drainability, salt accumulation, and quality of leaching water etc. For design of the Project, in conclusion, the maximum value of 2,350 mm by Kovada's formula was adopted taking a certain allowance into consideration.

To determine the total depth of leaching water, the leaching curves were made for the salt affected soils in Iraq as a result of prominent study conducted by Dutch soil hydrologist in 1963. They made the leaching curves which shows the decrease in the ECe in relation to the amount of leaching water over different soil depths.

Furthermore, M. Afili et al (1977) made a laboratory leaching study for the Clay Swamp (Ms) and Port Said (Ps) soil series. They concluded that the Clay Swamp (Ms) series shows too slow percolation to make the leaching efficiently, that is, leaching is limited by their permeability and will be tedious unless proper amendments are applied. For Port Said (Ps) series of which texture is silty clay to clay, it was found that depth of leaching water as well as time required for leaching these soils varies widely due to the layer thickness, percolation rate as well as salt content and type.

Figure A-18 shows the result of laboratory leaching experiments carried out during this Study period.

Figure A-18-1 Leaching Curve of Project Area Soil

(By Large Scale Experiment)

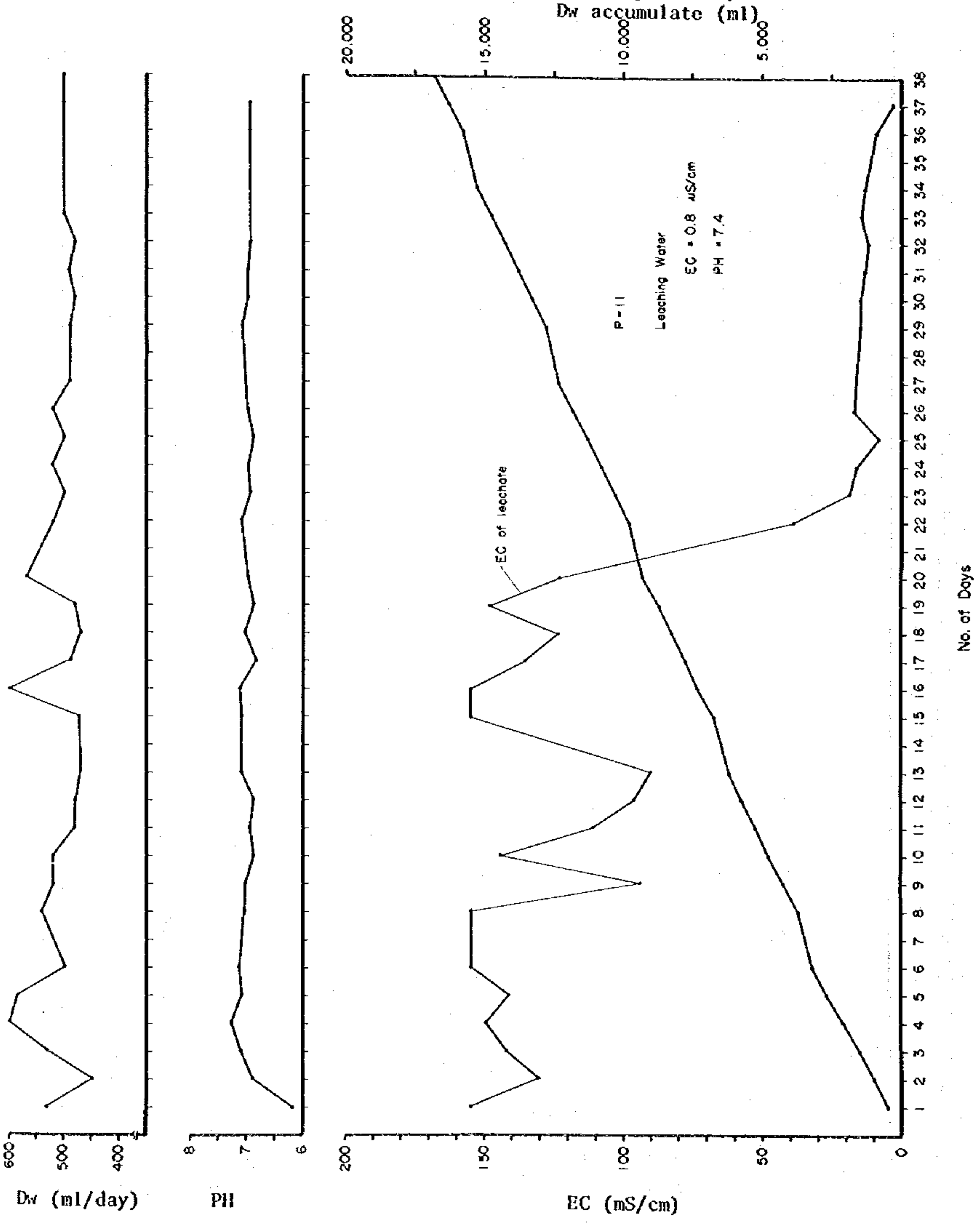
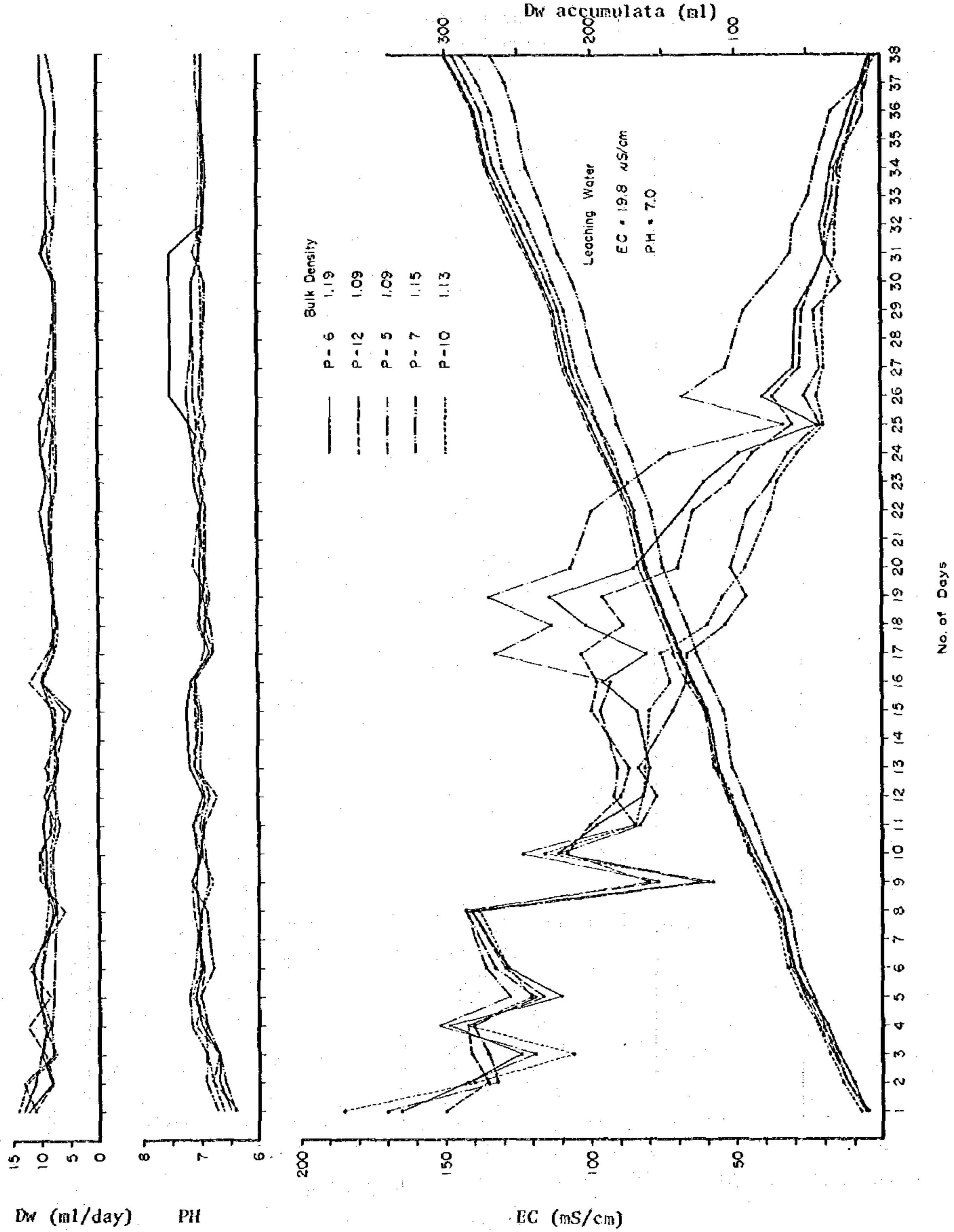


Figure A-18-2 Leaching Curves of Project Area Soil

(By Small-scale Experiment)



The experience in Egypt shows that at least 2,000 mm of water need to pass to the drainage system for effective leaching of the salts from a depth of 1.5 m of a soil with an average salt content of 2.3 percent using good quality water.

According to B. Zikri, in Abis Project where the soil permeability is relatively well owing to the presence of shell layer in the subsoil, tatally 2,525 mm of leaching water decreased the salinity from 46.4 to 4.4 mS/cm in 0 - 30 cm of soil and from 66.0 to 11.8 mS/cm in 30 - 60 cm of soil, respectively.

Using the result, the leaching requirements were calculated as below;

Large-Scale Laboratory Leaching Experiment

Soil Sample	:	P-11
Radius of Soil Column (r)	:	7.5 cm
Thickness of Leaching Soil	:	1.5 m
Change in EC of Leachate	:	155 ---> 6 mS/cm
Amount of Leachate (Dw)	:	16,025 ml
$Dw/\pi r^2$ = 16,025/176.6	:	90.7 cm

Small-Scale Laboratory Leaching Experiment

Soil Sample	:	P-5, 6, 7, 10, 12
Radius of Soil Column (r)	:	2.5 cm
Thickness of Leaching Soil	:	20 cm
Change in EC of Leachate	:	155 ---> 6 mS/cm (average)
Amount of Leachate (Dw)	:	278.8 ml (average)

$Dw/\pi r^2$ = 278.8/19.6 = 14.2 cm

In case that the thickness of leaching soil is 1.5 m, the leaching requirement is,

14.2 cm x 7.5 = 106.5 cm

According to the laboratory leaching experiments, the leaching requirements range from 907 to 1,065 mm, while the statistical analysis was impossible because of insuficient number of samples as well as lacking of replication. The laboratory experiment made the least water loss, therefore, the actual requirement in the field should be obviously larger than these figures.

b. Period and Type of Leaching Treatment

The adequate period for effective leaching of saline soils under the conditions prevailing in the Project Area is in late autumn to winter when the sufficient amount of water source is available and the evaporation is least.

During the summer season prior to the start of leaching, the lands are left fallow after deep plowing or subsoiling in order to dry the soils uniformly for making the infiltration of leaching water more easily and perfectly. In the next summer following to the leaching, rice cultivation is started to eliminate the risk of re-salinization under the dry and hot climate.

Types of leaching can be separated into two groups; that is, continuous flooding and intermittent flooding.

From the experiments carried out by Elgabaly et al, in low permeability salt-affected soils (Shalma Project), it has been found that continuous leaching is less effective than intermittent leaching in the removal of excess salts.

In intermittent leaching water is first added in quantities sufficient to dissolve the soluble salts (about 100 mm) followed by about 150 - 200 mm to leach the salts out. This is repeated at intervals, sufficient to prevent resalinization of top soil.

c. Procedures of Leaching Treatment

The following leaching procedures are recommendable for the Project Area.

Before leaching, the lands are cleared of the overgrowth of halophytes shrubs, and salt crusts on the surface are removed mechanically. Then the lands are levelled with an accuracy of 10 cm. The fields are plowed to a depth of about 20 - 40 cm. In case that cemented layer formed at the upper subsoil, subsoiling for breaking-up it is preferable.

After this, the fields are levelled again with an accuracy of 5 cm and devided into leaching plots which are separated from others by ridges.

Within a Block, leaching begins on lower-lying areas and works up gradually on to higher portion. Leaching water is poured on to the field with controlling the quantity by using a weir.

The leaching water is not poured on all at once, but in applications of approximately 150 mm at a time in order to minimize the loss. The first water application is done at the rate not exceeding the deficit in field capacity (approximately 100 mm on the average). This water spreads and soaks into the soil having virtually no downward flow, and gradually dissolves all the soluble salts accumulated in the soil. With respect to the solubility of salts, even with the most strongly salinized soils, the water depth, as mentioned-above, is enough to fully dissolve the salts.[1/]

Subsequently (after two or three days) further leaching will have to be done, with application of 150 mm, for removal of the salt solution. Each application is given time to soak in before the next is done.

Note :

1/ Solubility of NaCl is 26.38g in 100g saturated solution at 20°C. So 35.8g of NaCl can be dissolved in 100 ml of water as below;

$$26.38g / (100g - 26.38g) = 0.358$$

Applied 150 mm of water per sq.m can dissolve 53.7 kg of NaCl at the maximum as below;

$$0.15 \text{ ton} \times 0.358 = 0.0537 \text{ ton} = 53.7 \text{ kg}$$

Meanwhile, 2 percent of NaCl in 1.5 m deep soils is 39 kg of NaCl content.

$$1.5 \text{ cu.m} \times 1.3 \times 0.02 = 0.039 \text{ ton} = 39 \text{ kg}$$

Therefore, application of 150 mm of water is sufficient to dissolve the salts in 1.5 m deep soil.

During the leaching, the EC is measured regularly to check the amount of salts washed out. As the water soaks in, the easily soluble salts are gradually removed, that is, first NaCl, $MgCl_2$, and $MgSO_4$.

Using leaching water of greater than 500 - 700 mm, it is difficult to complete the leaching operations in a single season in general. Therefore, they are spread over two years. For the Project Area, the quantity was estimated to be more than 2,000 mm in total, therefore, the leaching period will be spread over two years. After leaching, rice and berseem are grown as the first crop in crop rotation.

For the Project Area, the designing items of leaching are as below;

- ° leaching requirement : 2,350 mm
- ° leaching period : 2 years (except for a period from April to August)
- ° leaching type : intermittent flooding
- ° water amount per application: 150 mm (100 mm at the first application)

  100 mm + 150 mm x 15 times = 2,350 mm
- ° leaching days per application: 21 days

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Daily evaporation (mm/day)	2.9	3.7	4.6	5.8	7.9	8.0	6.1	5.3	5.7	5.5	3.8	3.2

Average daily evaporation except for months from April to August	4.2 mm/day
Estimated daily percolation with open drain system	3.0 mm/day
<u>Total</u>	<u>7.2 mm/day</u>

150 mm ÷ 7.2 mm/day = 21 days

- drying days after leaching 4 days
- total necessary days for leaching
  (21 + 4) days x 16 times = 400 days (about 14 months)

d. Water Quality for Leaching

The interpretation of water quality for irrigation was quoted from FAO's guideline (Table A-6) and the water quality of possible water sources were analyzed and evaluated using the said guideline as Tables A-7 and A-8.

There is no significant difference among the water sources, namely, Bahr El Baqar, and Bahr Hadous drain and the Nile River. For every source, the water quality was evaluated as the degree of "increasing problem" for salinity and permeability problems.

To avoid the cause of permeability problem in leaching soil, it is recommendable to use the slightly saline water for the initial leaching and then convert to the water having low salinity.

With respect to specific ion toxicity, sodium problem is the degree of "increasing problem", while chloride problem is severe except for the Nile River and the growth of sensitive crops will be inhibited.

Table A-6 Guidelines for Interpretation of Water Quality for Irrigation

Irrigation Problem	Degree of Problem		
	No Problem	Increasing Problem	Severe Problem
Salinity (affects crop water availability)			
ECw (mS/cm)	<0.75	0.75 -- 3.0	>3.0
Permeability (affects infiltration rate into soil)			
ECw (mS/cm)	>0.5	0.5 - 0.2	<0.2
adj. SAR			
Montmorillonite (2:1 crystal lattice)	<6	6 - 9	>9
Illite - Vermiculite (2:1 crystal lattice)	<8	8 - 16	>16
Kaolinite-sesquioxides (1:1 crystal latice)	<16	16 - 24	>24
Specific Ion Toxicity (affects sensitive crops)			
Sodium (adj. SAR)	<3	3 - 9	>9
Chloride (meq/l)	<4	4 - 10	>10
Boron (mg/l)	<0.75	0.75 - 2.0	>2.0
Miscellaneous Effects (affects susceptible crops)			
No_3-N (or) NH_4-N (mg/l)	<5	5 - 30	>30
HCO_3 (meq/l) [overhead sprinkling]	<1.5	1.5 - 8.5	>8.5
pH	[Normal Range 6.5 - 8.4]		

Table A-7 Results of Water Chemical Analysis

Sampling Place	EC mS/cm	Dissolved Ions (meq/l) HCO₃	Cl	SO₄	Ca	Mg	Na	K	pHc 1/	adj. SAR 2/
Bahr Baqar drain	1.45	1.6	12.3	0.8	5.5	1.5	7.5	0.10	7.55	7.40
Bahr Hadous drain	1.77	2.0	11.8	4.3	4.4	6.6	7.0	0.05	7.35	6.15
Nile River	1.07	1.6	4.9	4.6	2.2	2.8	6.0	0.05	7.70	6.46
Adjacent area	1.67	1.4	11.3	4.4	2.7	1.3	13.0	0.10	7.85	10.08

Notes: 1/ pHc = (pK'₂ - pK'c) + p(Ca+Mg) + p(Alk)

(pK'₂ - pK'c) is obtained from using the sum of Ca + Mg +Na in meq/l
p(Ca+Mg) is obtained from using the sum of Ca + Mg in meq/l
p(Alk) is obtained from using sum of CO₃ + HCO₃ in meq/l
} Obtained from water analysis

From Table (FAO, 1976, Water Quality for Agriculture, Irrigation and Drainage Paper 29)

Values of pHc above 8.4 indicate a tendency to dissolve lime from the soil through which the water moves; values below 8.4 indicate a tendency to precipitate lime from the water applied.

2/ $$\text{adj.SAR} = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}} \times [\,1 + (8.4 - pHc)\,]$$

Table A-8 Evaluation of Water Quality for Irrigation

Irrigation Problem		Degree of Problem: Bahr Baqar Drain	Bahr Hadous Drain	Nile River
Salinity				
	ECW	Increasing	Increasing	Increasing
Permeability				
	ECW	No	No	No
	adj. SAR	Increasing	Increasing	Increasing
Specific Ion Toxicity				
	Na	Increasing	Increasing	Increasing
	Cl	Severe	Severe	Increasing
	B	Not determined	Not determined	Not determined
Miscellaneous Effects				
	No₃-N	Not dtermined	Not determined	Not determined
	HCO₃	Increasing	Increasing	Increasing
	pH	*Normal*	*Normal*	*Normal*

e. Leaching Requirement after Land Reclamation

The careful water management is essential to prevent the leached soils from re-salinization (secondary salinization). In principle, the water management plan should be made to maintain the rational water and salt balances during irrigation.

Leaching requirement to maintain the salt balances during irrigation for the proposed crop rotation after land reclamation is discussed in Appendix B in Volume II .

A.5.3. Soil Improvement

The land reclamation consisting of drainage improvement and leaching salts can provide the arable lands, however, these lands cannot give an economically feasible agricultural produce unless the chemical and physical properties of topsoil are improved.

The fertility of surface soils is severely degraded after heavy leaching because the leaching washed essential nutrient elements including nitrogen and phosphate out from the topsoil as well as excessive harmful salts.

Application of organic matter is very beneficial for improvement of both chemical and physical properties of soils. During the early stage of crop rotation after land reclamation, the concentrated application of manure in combination with chemical fertilizer is done to compensate the nutrient loss by the leaching. The application of organic matter for the Project Area is required to be 15 - 20 tons/feddan.

For the inundated area, sulfidic materials (pyrites) were found in the substrata in the course of survey for the North Hussinia and South Port Said Project. When the sulfidic materials will be oxidized by dessiccation of the inundation, they will be transformed to sulfuric acid and show strongly acid reaction (pH 4.5). This oxidation process can be expressed as below;

$$2\,FeS_2 + 7O_2 + 2H_2O \rightleftarrows 2FeSO_4 + 2H_2SO_4$$

In such case, the chemical amendment to neutralize it, calcium carbonate for example, would be required.

Prior to the dessiccation of the inundated lands, therefore, careful checking of the distribution of sulfidic materials is necessary. For quick identification in the field, a sample can be oxidized by boiling in concentrated H_2O_2 and measuring the drop in pH.

A.5.4. Work Programme of Land Reclamation

The land reclamation plan for the Project Area was made to aim at the following points;

1) to lower the groundwater table up to the level not induce the salt accumulation by capillary upward movement,

2) to improve the soil drainability and dessiccate the soil,

3) to leach the excess soluble salts from sufficient depth of soil,

4) to prevent the desalinized soil from re-salinization under the optimum water management,

5) to improve the soil fertility after leaching,

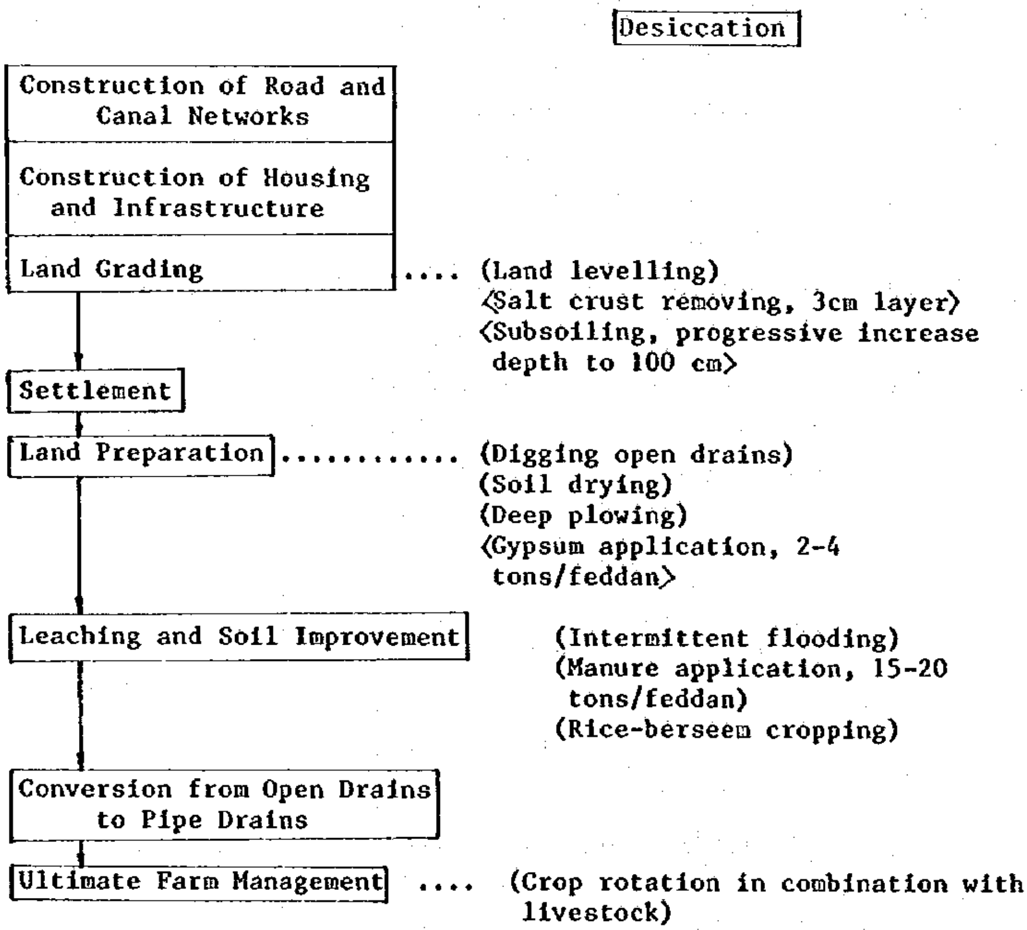
6) to introduce the efficient and productive farm management to avoid the soil degradation due to the over-cropping, over irrigation, and over-grazing.

The soil condition varies widely by location within the Project Area, therefore, the reclamation practices differ depending on the prevailing conditions. However, the general work programme of land reclamation for the Project Area can be summarized as shown in Figure A-19.

The farmer will settle in the Project Area immediately after the completion of infrastructural facilities such as irrigation and drainage, roads, housing etc., then employed to construct the field drains. Afterwards, leaching will be carried out for two years and crop rotation of rice and berseem will be started successively. When the soil salinity decrease to ECe 5 mS/cm, it can be expected to harvest of rice at around 75 percent of normal yield. The time of bilding-up period in which rice and berseem will be cropped. Duration of the building-up period varies with the land reclaimability class.

Figure 19. Work Programme of Land Reclamation

(Swamp and Inundated Lands)



( ) main works
〈 〉 works depending on the local condition