THE ARAB REPUBLIC OF EGYPT

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GENERAL AUTHORITY FOR REHABILITATION
PROJECT AND AGRICULTURAL DEVELOPMENT

MINISTRY OF DEVELOPMENT, STATE
FOR HOUSING, AND LAND RECLAMATION

FINAL REPORT
ON
FEASIBILITY STUDY
FOR
THE SOUTH HUSSINIA VALLEY
AGRICULTURAL DEVELOPMENT PROJECT PHASE II

(APPENDIXES-A)
VOLUME-1

MAY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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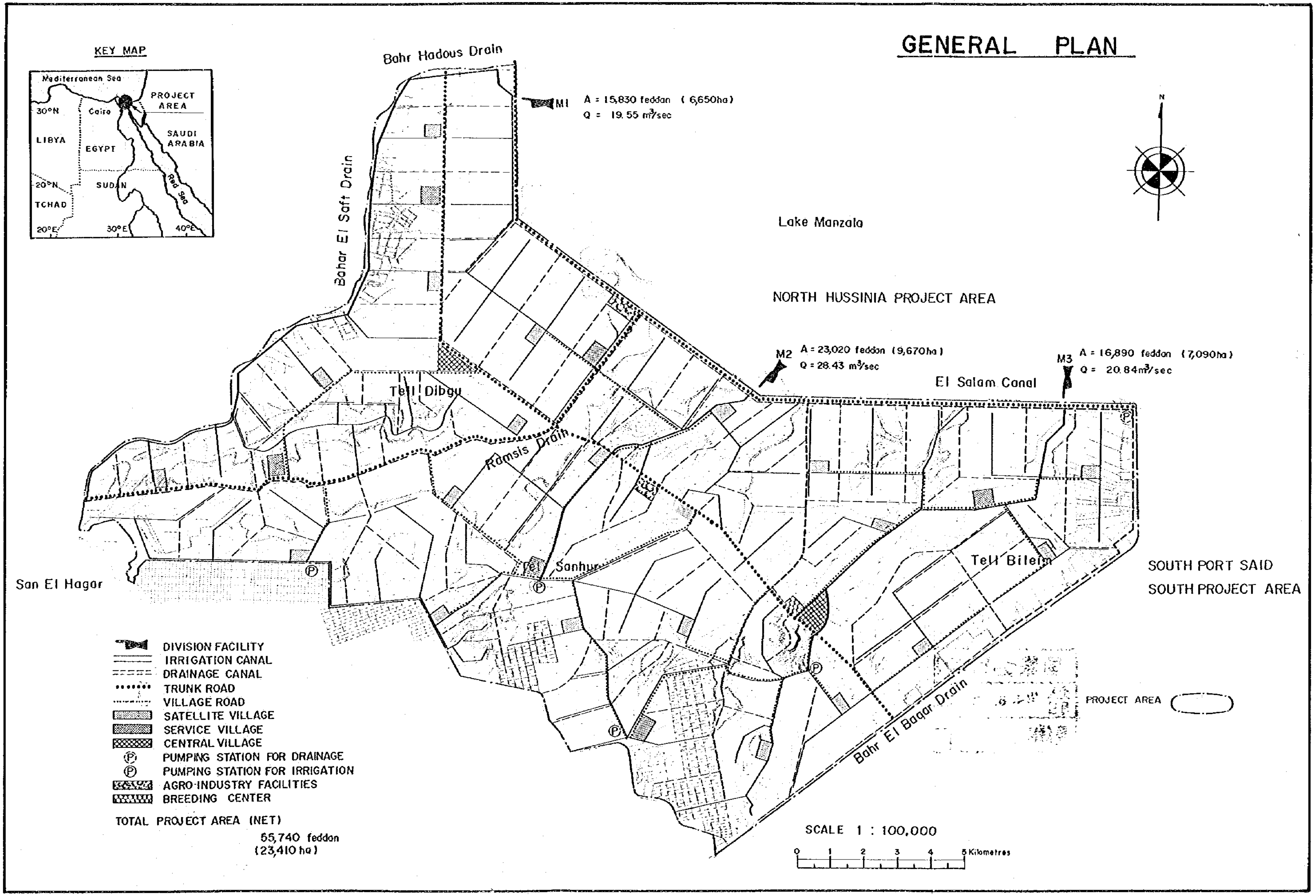

GENERAL PLAN
KEY MAP
Mediterranean Sea
PROJECT AREA
30°N
Cairo
LIBYA
EGYPT
SAUDI ARABIA
20°N
SUDAN
Red Sea
TCHAD
20°E
30°E
40°E
Bahr Hadous Drain
M1
A = 15,830 feddan (6,650ha)
Q = 19.55 m³/sec
N
Bahar El Saft Drain
Lake Manzala
NORTH HUSSINIA PROJECT AREA
M2
A = 23,020 feddan (9,670ha)
Q = 28.43 m³/sec
M3
A = 16,890 feddan (7,090ha)
Q = 20.84m³/sec
El Salam Canal
Tell Dibgu
Ramsis Drain
Tel Sanhur
Tell Bilem
San El Hagar
SOUTH PORT SAID
SOUTH PROJECT AREA
Bahr El Baqar Drain
PROJECT AREA
DIVISION FACILITY
IRRIGATION CANAL
DRAINAGE CANAL
TRUNK ROAD
VILLAGE ROAD
SATELLITE VILLAGE
SERVICE VILLAGE
CENTRAL VILLAGE
PUMPING STATION FOR DRAINAGE
PUMPING STATION FOR IRRIGATION
AGRO-INDUSTRY FACILITIES
BREEDING CENTER
TOTAL PROJECT AREA (NET)
55,740 feddon
(23,410 ha)
SCALE 1 : 100,000
0 1 2 3 4 5 Kilometres

VOLUME I

ANNEXES A SOIL

Appendix A Soil

LIST OF TABLES

LIST OF FIGURES

A.1. General

A.1.1. Natural Environment

a. Location and Topography

The Project Area of 74,700 feddan in total is located in the northeastern edge of the Nile Delta, and extends 25 km from east and 15 km from north to south, encompassing around the coordinates of 31°N latitude and of 32°E longitude.

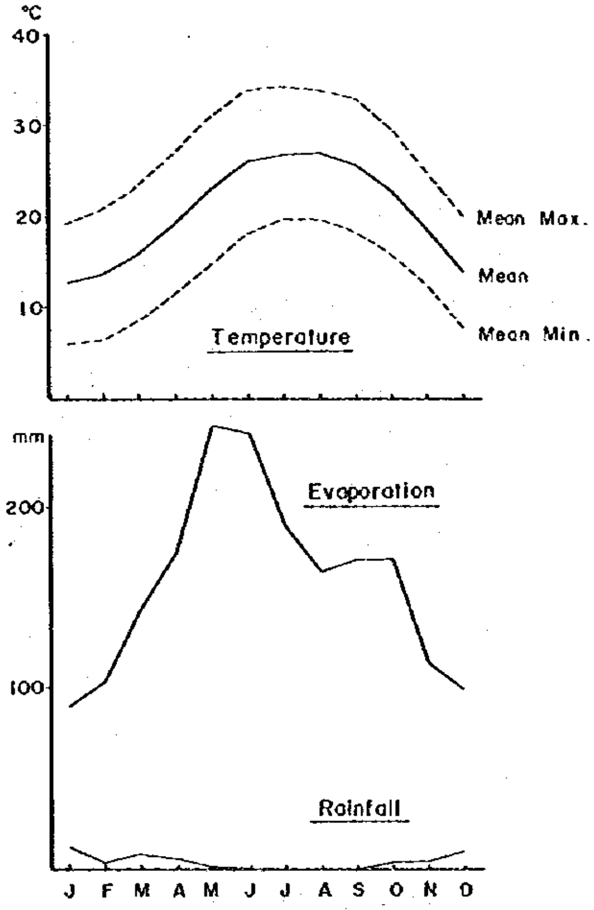
The Project Area predominantly consists of low lying nearly level clay flats including swamps and inundated area, having a gentle slope of about 1/5,000 to 1/10,000 towards the northeast between the elevations of one and three meters. The Lake Manzala which is shallow and still in the process of silting up owing to the inflow of muddy and saline water from drains, while the occasional intrusion of seawater of the Mediterranean. The location and topography of the Project Area were described in the Phase I Report. Since 1980 when the Phase I Study was made, construction of the El Salam Canal has been progressed and excavation of the Canal at most parts within the Project Area has been completed with the exception of crossing works.

b. Climate

The climate of the Project Area is characterized by its hot and dry summer, that is, the "dry, hot desert" category in the Koppen's classification system.

The main meteorological data are shown in Figure A-1. The mean annual temperature is 20.4°C with the highest mean maximum temperature of 34.1°C in July and the lowest mean minimum temperature of 6.0°C in January. The average annual

Figure A-1 Meteorological Conditions of the Project Area



At El Mansoura (1969-1978)

evaporation exceeds 1,900 mm, on the other hand, the average annual rainfall is less than 50 mm. There is no rainfall during the summer from July to September. Northwest winds prevail in ordinary times except for the dry stormy winds (Khamsin) from the southwest in the spring seasons.

According to the Soil Taxonomy's definitions, the moisture and temperature regimes of the Project Area soils fall into "torric" and "thermic" categories, respectively.

Torric - The moisture control section in most year is;

- dry in all parts more than half the time (cumulative) that the soil temperature at a depth of 50 cm is above 5°C; and
- never moist in some or all parts for as long as 90 consecutive days when the soil temperature at a depth of 50 cm is above 8°C. Soils that have a torric moisture regime are normally in arid climates. There is little or no leaching in this moisture regime, and soluble salts accumulate in the soil if there is a source of them.

Thermic - The mean annual soil temperature is 15°C or higher but lower than 22°C, and the difference between mean summer and mean winter soil temperature is more than 5°C at a depth of 50 cm.

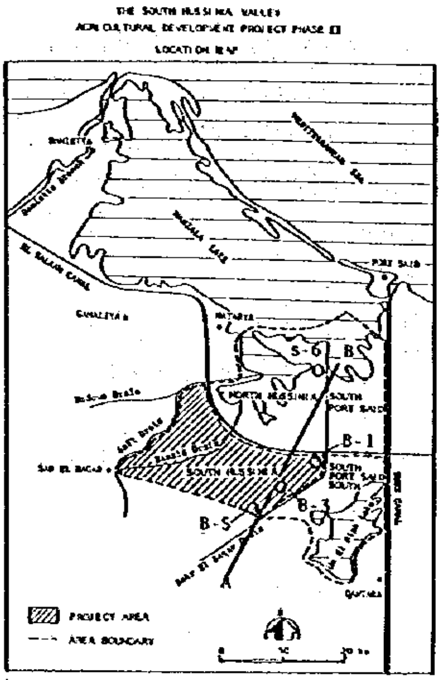
In the swamp and inundated areas, on the other hand, the soil moisture regime falls into the "aquic (per-aquic)" category as follow:

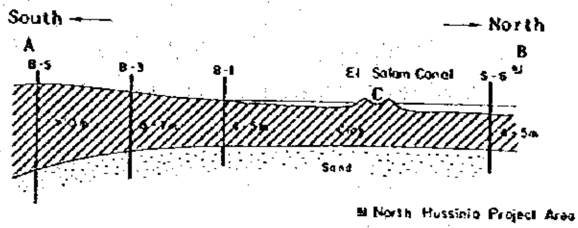
Aquic - The aquic moisture regime inplies a reducing regime that is virtually free of dissolved oxygen because the soils is saturated by groundwater or by water of the capillary fringe. Usually, the level of groundwater fluctuates with the seasons. There are soils, however, in which the groundwater is always at or very close to the surface. A tidal marsh and a closed, land-locked depression fed by perennial streams are examples of this type. The moisture regime in these soils is called "per-aquic".

c. Geology and geomorphology

The Project Area as a whole is composed of Quaternary fluvio lacustrine deposits which are fine-textured and recent origin. Through the sedimentation of materials transported by the Nile River, fine or coarse deposits have been stratified alternately in the profiles.

The substratum varies considerably by location within the Project Area as a consequence of the different degree of the fluvial and marine influences. Generally, clay or silty clay layer overlies the sandy substratum at various depth. In some substrata, in addition, many shell fragments are found at five to seven meters below the surface. These shell-rich layers prove that they are situated on the former coast line. The thickness of overlying clay or silty clay layer shows the general tendency of decreasing towards the Lake Manzala, and the sandy substratum appears at shallower depth as shown below;





Geomorphologically, the Project Area comprises fluvio-marine deposits and includes the following characteristic landscapes;

- Fluvio-Marine Marshes (Land slope less than 0.3%)
  - Clay Swamps
  - Clay Flats

- Plains (Land slope between 0.3 and 1.0%)
  - Clayey Plains

- Wind blown Deposits (Land slope greater than 1.0%)
  - Medium - High Clay Dunes

The vast clay swamps which are frequently or periodically submerged are found around the peripheries of Lake Manzala. The largest portion of the Project Area belongs to the clay flats. Towards the lake, the elevation gradually falls and the drainability becomes worse. Along the course of the El Salam

Canal, noticeable shore ridges with somewhat higher elevation occur, which indicates the former lake coast lines. The soils are coarse than surrounding lands and include shell fragments. Owing to the better drainability, these soils support natural vegetation of Phragmites and Salicornia.

The clay dunes and hummcky accumulations consist of wind blown fluffy clay derived from the topsoil of the adjacent clay flats. Several ancient man-made dwelling mounds called "Tell" are found in the Project Area. The largest one is Tell San El Hagar.

Figure A-2 shows the geomorphology and land slope classification of the Project Area, and the acreage of each class is as below;

Class	Slope (%)	Area (feddan)	Area (%)
1	< 0.1	31,310	41.9
2	0.1 - 0.2	14,190	19.0
3	0.2 - 0.3	20,740	27.8
4	0.3 - 0.5	6,600	8.8
5	0.5 - 1.0	1,310	1.8
6	> 1.0	550	0.7
	Total	74,700	100.0

As shown in the figure and table, the fluvio-marine marshes (clay flats and clay swamps) occupy about 90 percent of total area. The clayey plains occupy the southern fringe of the Project Area of which elevation is higher than other portions.

d. Water Quality

The quality of various water sources was determined using a pH meter and an EC meter, moreover, some water samples were sent to the laboratory for chemical analysis. Quality of the flowing water fluctuates widely depending on the discharge rate at the measuring time. In general, the concentrations of total soluble salts can be summarized as below;

Flowing Water	Total Soluble Salts (ppm)
° Drain water (Bahr Hadous, Bahr Saft, Ramsis, Bahr El Baqar)	1,200 - 2,700
° Nile river water (Downstream)	700 - 1,000
Stagnant Water	
° Lake Manzala	about 2,000
° Fish Ponds	4,000 - 8,000
° Depressions	10,000 - 150,000
Groundwater	20,000 - 150,000

Thus, the stagnant water of depressions as well as the groundwater include total soluble salts at extremely high level. Further details concerning water quality with respect to land reclamation will be discussed in Section A-5.

e. Natural Vegetation and Land Use

Because of the water scarcity as well as the soil salinity, natural vegetation is limited to peripheries of the swamps and inundated areas where the species of Salicornia and Phragmites are grown predominantly. The vast clay flats are barren, and only the xerophytic shrubs, Tamarix sp. are grown on the foot of clay dunes, where the soil drainability is moderately well.

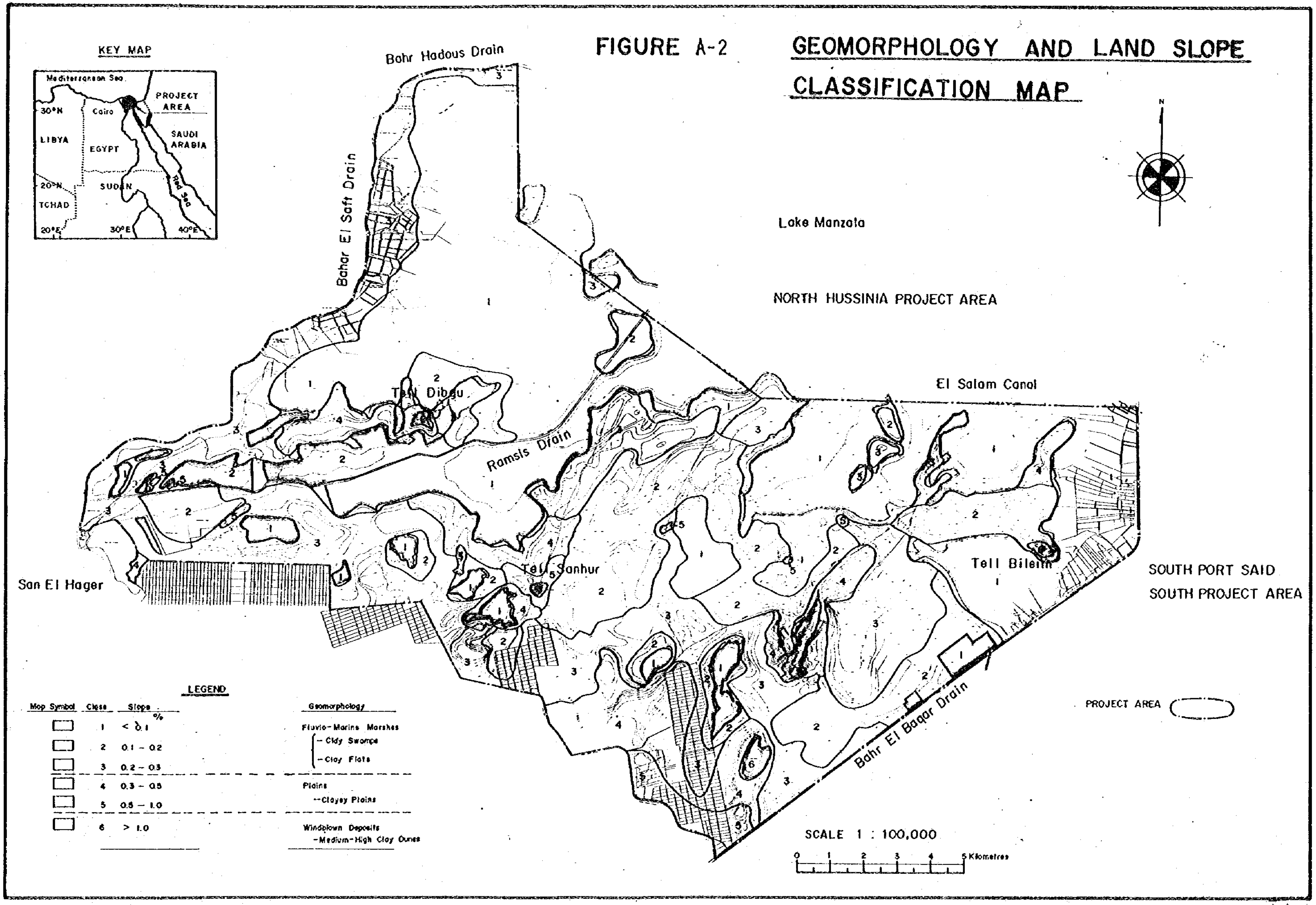


FIGURE A-2 GEOMORPHOLOGY AND LAND SLOPE CLASSIFICATION MAP

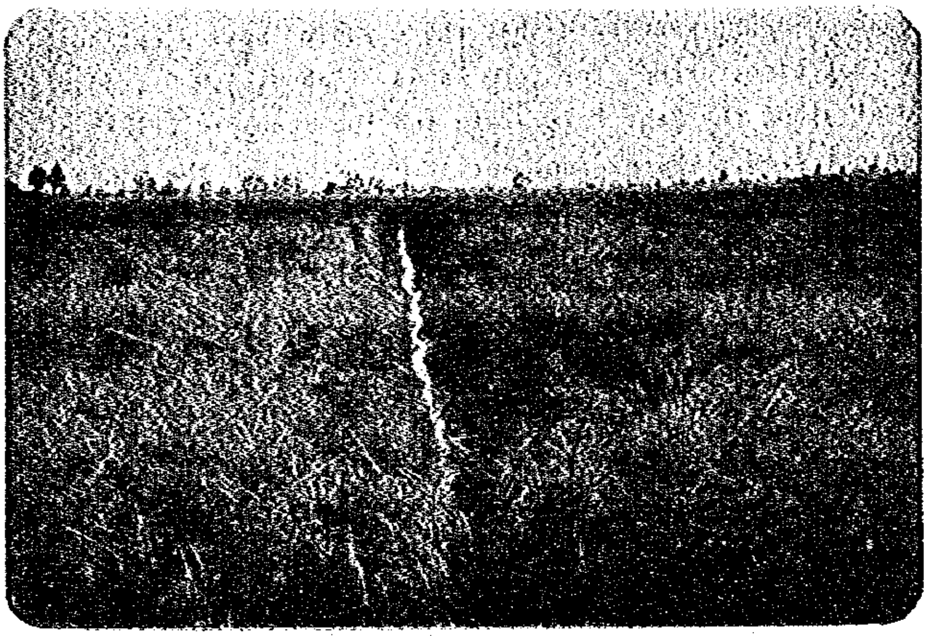
As regards agricultural activities in the Project Area, the Phase I Report mentioned that there was no active agriculture at that time, except for farm lands of about 6,000 feddan in total along the Bahr Saft drain and the southern fringe of the Project Area. The present survey has revealed the extention of agricultural activities especially along Bahr El Baqar, Ramsis, and Bahr Hadous drains, as well as Bahr Saft.

The limits of cultivated lands are not always exact, but it is estimated that there are about 7,800 feddans of cultivated areas including the lands where cultivation is discontinued at present. In addition, the Project Area includes two reclaimed areas of about 2,000 feddan executed by the government, that is, the Taimoor and the Hanon Projects.

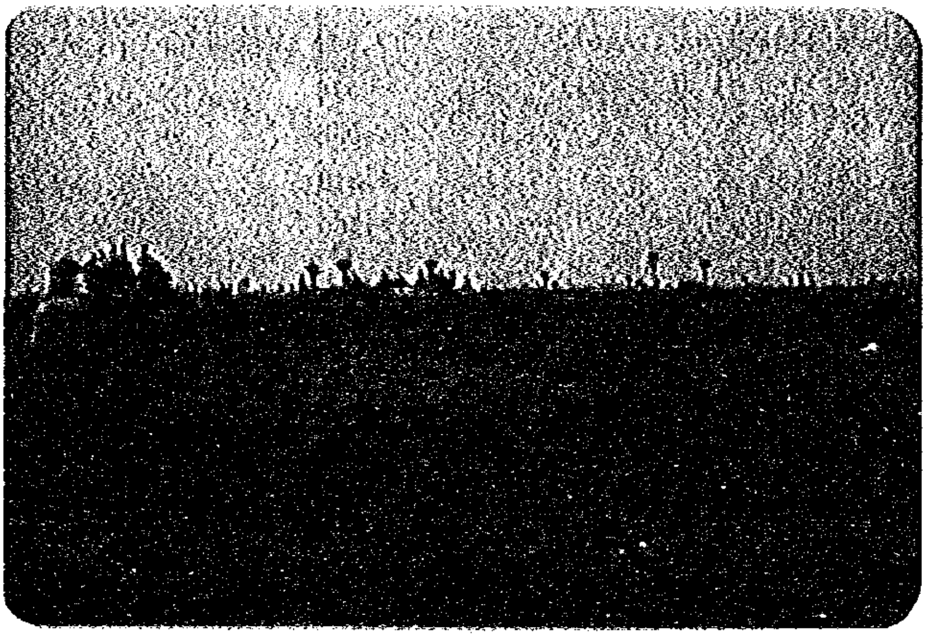
The present land use in the Project Area is shown in Figure A-3, and the acreage is as below;

Present Land Use	Area	
Agricultural Lands	7,800 feddan	10.5%
Ancient Sites (Tell)	370	0.5
Desert	34,080 1/	45.6
Fish Ponds	4,810	6.5
Inundated Lands	27,560	36.9
Total	74,700	100.0

Note: 1/ Including about 2,000 feddan of reclaimed lands.

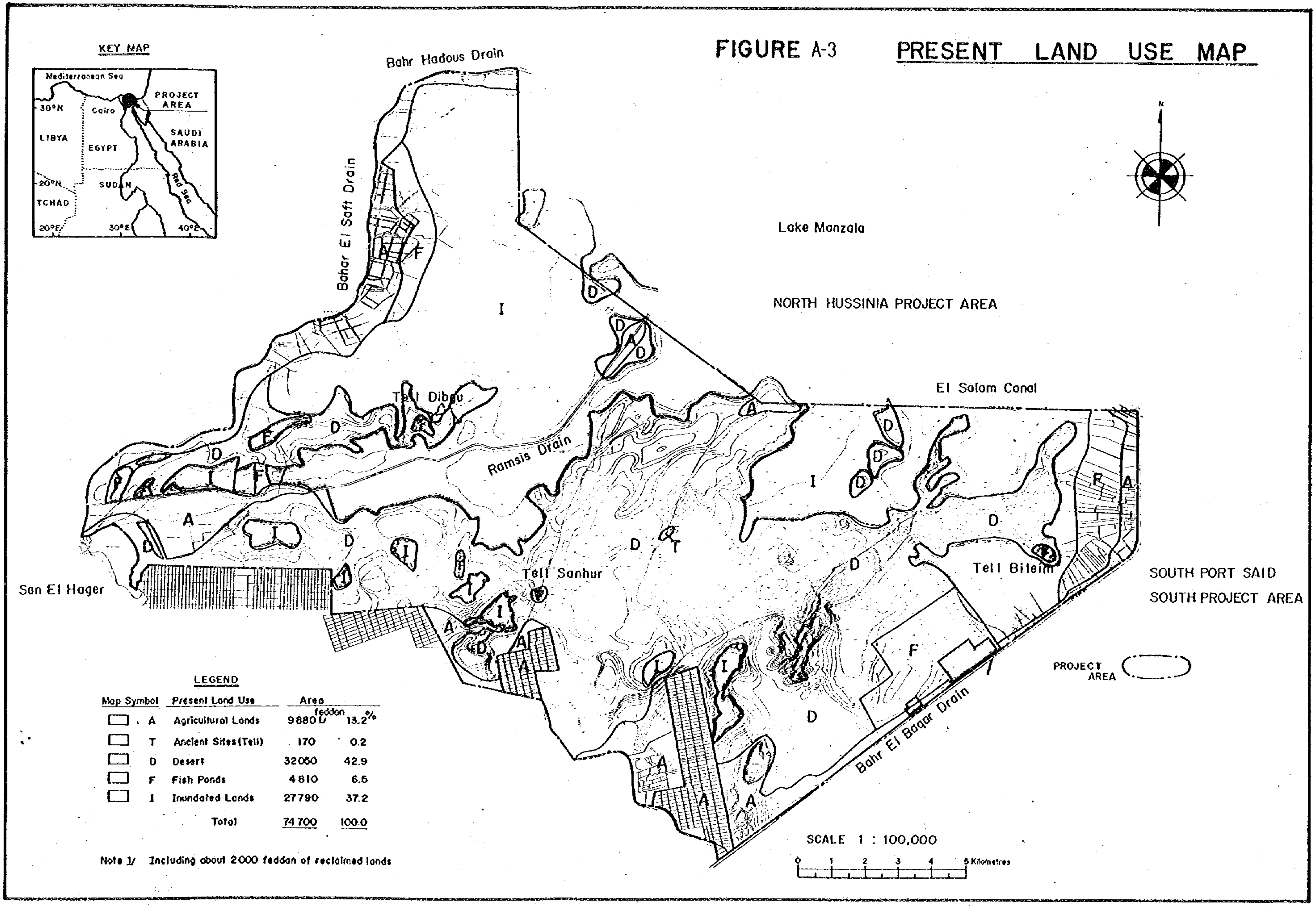


Present Rice Cultivation



Growing Berseem

FIGURE A-3 PRESENT LAND USE MAP



A.1.2. Objectives and Methods of Soil Survey

a. Objectives

The soil survey in the Phase II Study was carried out during the period from October 15 to December 4, 1983 in order to supplement the Phase I Report (1981) and to obtain the sufficient information to classify the drainability and reclaimability of Project Area soils.

The main aim of the present study was to prepare the land drainability and reclaimability classification maps which could be used for determining the most optimal land reclamation method under the prevailing condition of the Project Area, that is, the detailed planning of the reclamation and drainage works, including the soil improvement measures. In order to assess the drainability and reclaimability of the Project Area, systematic soil profile investigations to identify the permeable and impermeable layers as well as hydraulic conductivity measurement were carried out.

Another aim of the study was to adjust the principle of classification systems with the under going North Hussinia and South Port Said Project.

The soil survey was composed of the following studies;

- Soil profile investigation
- Hydraulic conductivity measurement
- Laboratory soil analysis
- Leaching experiments
- Clay mineral identification
- Geotechnical Survey (Deep boring)

The procedures and method of each study are outlined in this section, and the location of the soil profiles investigated is shown in Figure A-4.

b. Soil Profile Investigation

In order to carry out the systematic soil profile investigation for the entire Project Area of 74,700 feddan, two survey teams for the upland area and one for the swamp and inundated area were organized. Each team was composed of a consultant, an assistant, and several laborers.

Following the short-term field reconnaissance to grasp the general condition, especially accessibility within the Project Area, the soil profile investigation was carried out by making auger holes and open pits using the topographical maps scaled 1:10,000 as the base map. An overall density of soil profiles investigated was one per 180 feddan (about 75 ha) after adding the number of open pits made during the Phase I Study. The investigation was carried out following to the "Soil Survey Manual" of USDA, and each soil profile was described in accordance with the standards, in the "Guidelines for Soil Profile Description" of FAO. Furthermore, when the groundwater table appeared, its depth and rate of upward movement were observed visually. For survey in the swamp and inundated area, two amphibious cars were provided.

Auger Boring: Using various edges of hand auger, soil profiles up to two or three meters deep were investigated. A post-hole type was commonly used for sampling and a screw type or a closed spiral type was specially used for

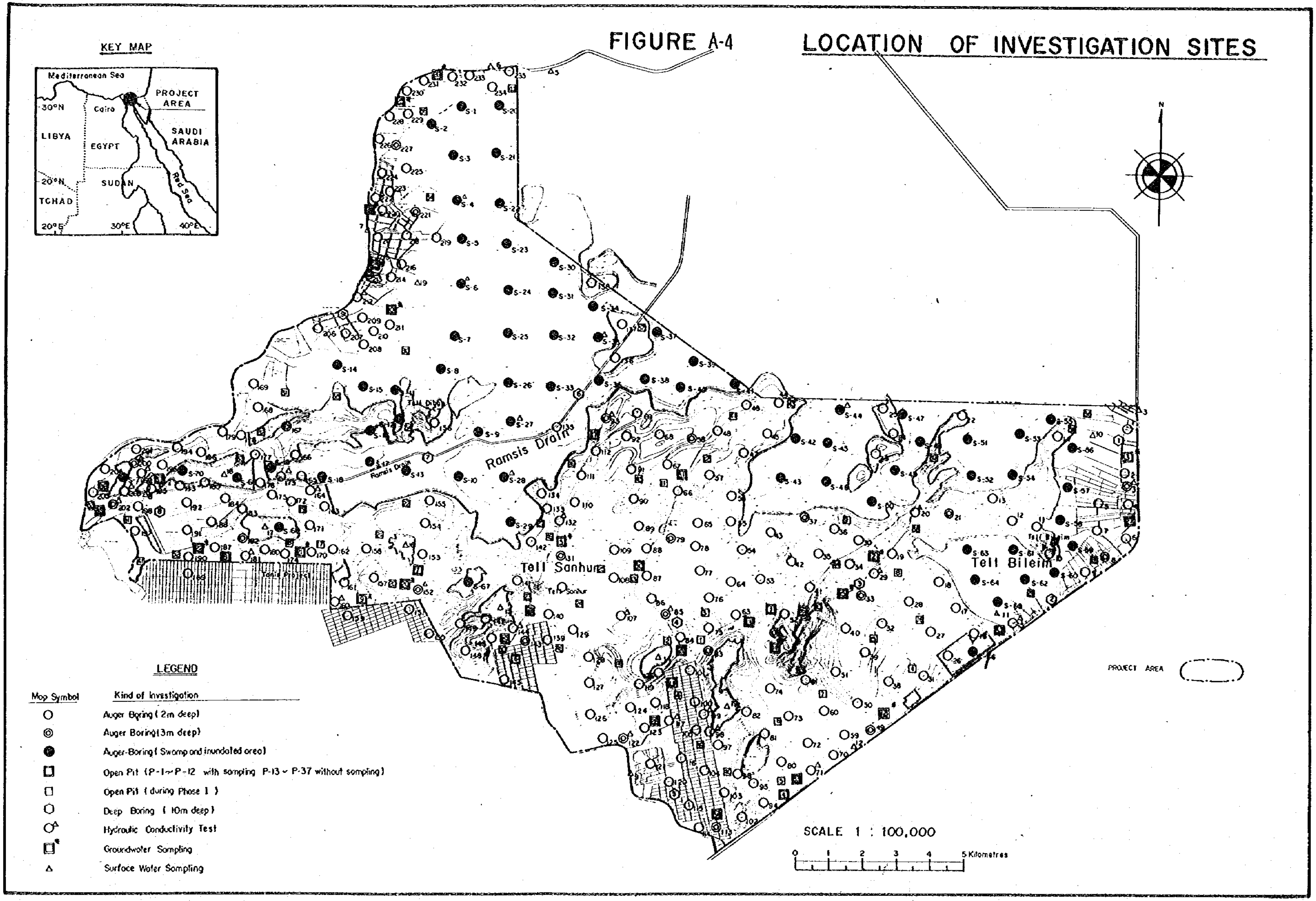


FIGURE A-4 LOCATION OF INVESTIGATION SITES

boring hard soils. In the swamp and inundated area, a thin-wall sampler or a porter sampler devised specially for this area was used. Quantities of the performed boring survey were as follows;

° <u>Upland Area</u>

Depth 2 m : 211 sites

Depth 3 m : 24 sites

° <u>Swamp and Inundated Area</u>

Depth 2 m : 71 sites

<u>Open Pits</u>: Following the auger boring, twelve open pits for the representative soil types were made in order to take samples for laboratory analysis. In addition, 25 open pits were dug for the detailed profile descriptions. When the groundwater appeared, samples were taken for pH and EC measurements. Quanties of open pit survey were as follows;

° <u>For Sampling</u>

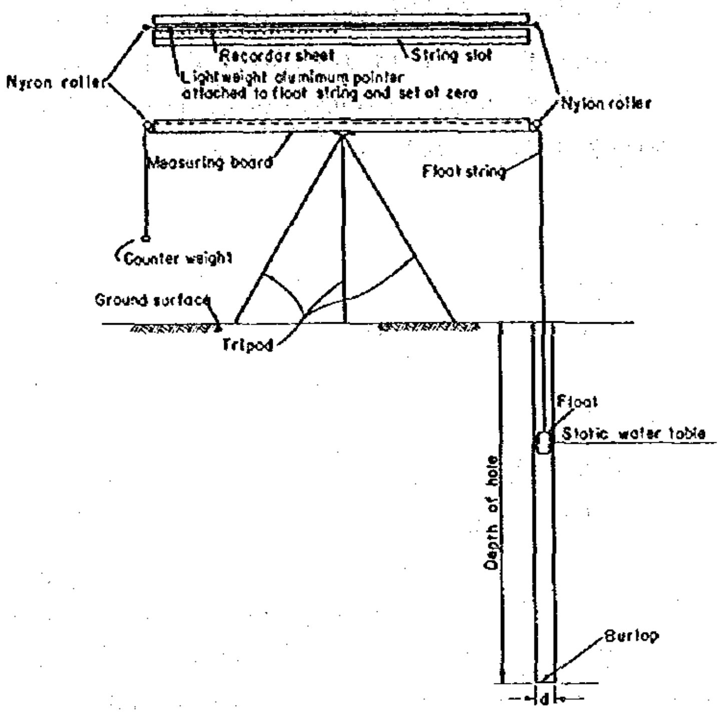
Depth 2 m : 12 sites

° <u>For Profile Description</u>

Depth 2 m : 25 sites

c. Hydraulic Conductivity Measurements

<u>Hydraulic Conductivity Measurement in the Field</u>: For the upland and swamp areas, the hydraulic conductivity of soil was measured on the site by auger-hole method referred to "In-Place Permeability Tests and Their Use in Subsurface Drainage" of USBR. The device used for the measurement is as shown below;



K = hydraulic conductivity (cm,per sec.),

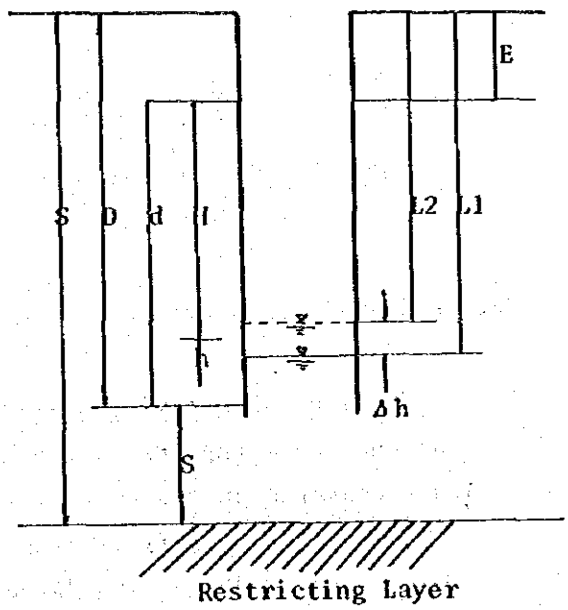
$\Delta h=L_1-L_2$ = increment of rise of water level in the hole (cm.),

$\Delta t=t_2-t_1$ = increment of time (sec/) required for increment of rise Δh,

R = radius of the hole (cm.),

$(L_2+L_1)/2-E$= average distance H (cm.) of water level in the hole below the water table during time of measurement, and

A = geometry factor (cm.) which is a constant depending on R,d,h, and s where s is the distance of the imperme-able layer below the bottom of the hole, h is the average depth of water in the hole during the measurement interval and d is the depth of the hole below the water table.



Soil Survey by Auger Boring

Measuring Hydraulic Conductivity by Auger-hole Method

Quantities of measurements were 23 sites for the upland, and two sites for the swamp areas.

<u>Laboratory Hydraulic Conductivity Measurement</u>: For the inundated areas, the hydraulic conductivity of soil was measured in the laboratory. Twenty-four undisturbed core samples were collected from six sites using a core sampler and delivered to the GARPAD's laboratory. The method described in the USDA Handbook No.60 was used for the measurement of hydraulic conductivity of soil cores and calculated by the following formula;

$$\frac{Q}{t} = k\, A\, \frac{\Delta H}{\Delta L}$$

where Q (cm^3): volume of water passing through the core in time, t (hrs)

A (cm^2): area of the core

k (cm/hr): average hydraulic conductivity in the soil interval (Δ L), over which there is a hydraulic head difference of ΔH.

In order to estimate the horizontal water transmissivity of the permeable layer and vertical water resistivity of overlying poorly permeable layer, twenty undisturbed undisturbed soil samples were collected in horizontal or vertical direction from the representative layers of five sites. The laboratory measurements were carried out by the same method as mentioned above at the Desert Institute.

d. Laboratory Analysis

<u>Sampling</u>: Soil samples for the soil analysis were taken from open pits dug in the representative soils. Generally, the disturbed samples were taken from four layers. Soil samples for the ECe and pH measurements were collected from surface soils and subsoil at every auger hole. Quantities of soil samples were as below;

Complete Analysis

Upland Area	48 from	11 sites
Swamp and Inundated Area	18 from	6 sites

ECe and pH Measurements

Upland Area	426 from	213 sites
Swamp and Inundated Area	86 from	43 sites

In addition, undisturbed core samples were taken from the open pits for determining the physical properties of soil, that is, three-phase distribution, field moisture content, bulk density etc. In order to determine the groundwater salinity, groundwater appeared in the open pits were sampled, as well as the surface water samples.

Preparation of Saturated Soil Paste and Saturation Extract: The soil samples were air-dried and sieved through a 2 mm screen to separate the coarse fraction. The fine fraction was used for saturated soil paste preparation according to the procedure outlined in the USDA Handbook No.60. After the pH measurement, the saturated soil pastes were vaccum filtrated to collect the saturation extract.

Analytical Methods: The procedures and methods of soil analysis are summarized in Table A-1.

e. Clay Mineral Identification

The soil samples for identification of clay minerals were collected from three locations: No.122, P-21, and S-25.

Table A-1 Procedures and Methods of Soil Analysis

Analytical Items		Procedures and Methods	Remarks (USDA Handbook No. 60)
1. pH		By pH meter with glass electrode in the saturated soil paste.	Method 21a
2. ECe		By conductivity bridge in the saturation extract.	Method 4b
3. Soluble Ions	Na and K	By flame photometer	Methods 10a and 11a
	Ca and Mg	By titration with versenate	Method 7
	CO_3 and HCO_3	By titration with sulfuric acid	Method 12
	Cl	By titration with silver nitrate	Method 13
	SO_4		
4. Exchangeable Cations	Na and K	By flame photometer in the ammonium acetate extract	Method 18
5. Cation-Exchange-Capacity		By sodium acetate/ammonium acetate method	Method 19
6. Total Nitrogen		By Kjeldahl distillation in the potassium sulphate extract	
7. Available Phosphate		By colorimetry with ammonium molybdate	
8. Organic Matter		By wet combusion method	Method 24
9. Gypsum		By increase in soluble calcium plus Magnesium content upon dilution	Method 22c
10. Lime		By titration with hydrochloric acid neutralization	Method 23c
11. Mechanical Analysis		By Bouyoucos hydrometer with using sodium hexametaphosphate carbonate as a dispersing agent	

Clay fraction (diameter less than 2 micron) was collected by sedimentation method from the soil samples which had been dispersed in water using a ultra-sonic machine. After the deferration by Mehra and Jackson's method, each fraction was divided into two portions and saturated with either K- or Mg-ions. After being oriented on a slide glass, they were X-rayed by a diffractometer.

f. Leaching Experiments

Originally, two types of leaching experiments had been planned; one is the field leaching experiment on the site and another is the laboratory experiments on soil columns. These experiments are especially useful in the diagnosis of saline-alkali soils, as the characteristics of these soils usually change markedly upon being leached.

Field Leaching Experiment: The field leaching experiment had been proposed in order to improve the practicability of the results obtained from the laboratory experiment. The field experiment is especially useful in the estimation of capital leaching of excess soluble salts which is to be practiced in the Project Area as well as in the demonstration of plant growth response. The plan of approach for the experiment, which is attached to Section A.6.7, was prepared, however, the experiment has not started yet due to the delay of building-up the experimental plots.

Laboratory Leaching Experiments

The laboratory leaching experiments by soil columns were carried out in order to estimate the amount of leaching needed for removal of excess soluble salts, to determine the response of soils to the addition of amendments, and to determine the changes in such soil properties as permeability, pH reading, and ESP that take place upon leaching.

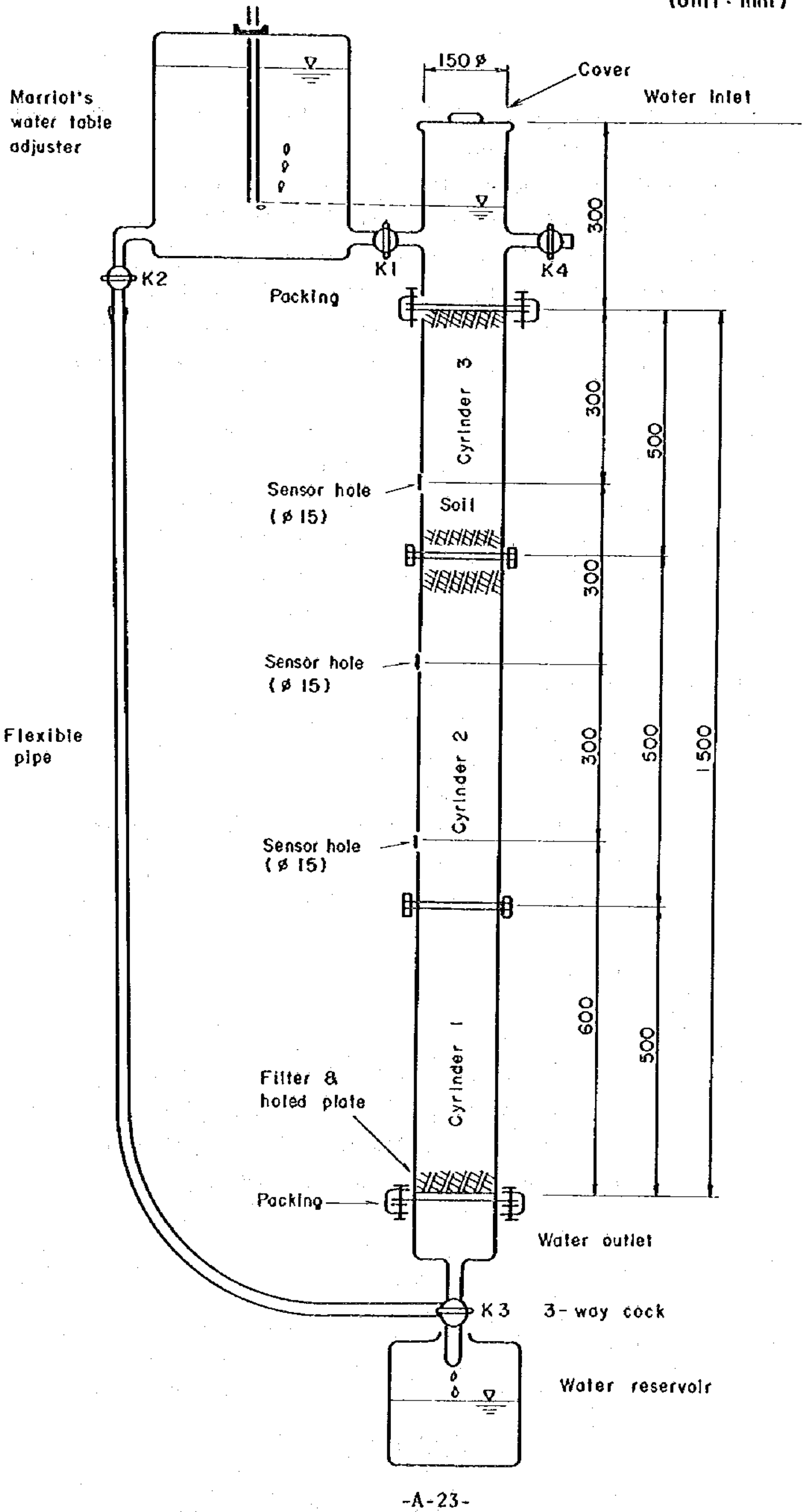
The experiments were conducted at the GARPAD's laboratory in two different scaled soil columns, that is, a large-scale leaching test apparatus and a small-scale leach test apparatus. For the leaching experiments, about 50 kg of surface soils (0 - 20 cm) were sampled from six pits. The methods of the laboratory leaching experiments are as follows;

Large-Scale Laboratory Leaching Experiment: Figure A-5 shows the large-scale leaching test apparatus which has similar function to a lysimeter. The apparatus consists of three parts, that is, a constant-head water inlet (Mariot's device), a soil column, and a leachate collector. The soil column is a cylinder of 15 cm diameter and 150 cm long. The soil column has three small holes to insert the EC sensor at an interval of 30 cm from its top. To suspend the load of soil in the column, a holed plate with a membrane filter having holes of 0.4 micron in diameter is provided at the bottom of soil column. Having a three-way cock (K3), the water outlet can control the amount of leachate from the soil column. A leachate collector is put under the soil column.

Approximately 30 kg of air-dried soil sample was placed in the column to have the same bulk density as the field. The soil was gradually poured into the column by 10 cm thick to compact with a rammer. For the leaching experiment, the soil in the column should be kept under the saturated infiltration condition. There are two methods for this purpose, that is, the downwards wetting front method and the capillary upwards saturation method.

Figure A-5 Apparatus of Leaching Tests (Large Size)

(unit : mm)



In Downwards Wetting Front Method: water is supplied from the top of the artificial soil layers in the soil column so as to saturate the soil layers with water infiltration. Water is supplied until the wetting front reaches the bottom of soil column, while Cock K3 is opened to release air which is pressed down by descending water. Air which remains in the soil through the course of infiltration makes it difficult to keep the soil under the complete saturated infiltration condition.

In Capillary Upwards Saturation Method: water is supplied from the bottom of soil layers in the soil column so as to saturate them by capillary attraction. Cocks K2 and K3 are opened to supply water of Marriot's device to soil through a flexible pipe. This method may require a longer time to complete the saturated condition than the former method.

When the saturated infiltration condition is attained, Cock K1 is opened to supply water to the water inlet so that the constant-head takes place in the column. then Cock K3 is opened to discharge the leachate to the collector. Discharge rate of the leachate is controlled by the adjusting Cock K3. The discharge rate directly affects the effect of leaching, therefore, the Cock K3 should be carefully and accurately adjusted. The following soil properties were analyzed before and after leaching[1/];

Note: 1/ Soil analysis results mentioned above can be used as analytical values before leaching. Therefore, at the laboratory, soils after leaching shall be taken out from the column and analyzed.

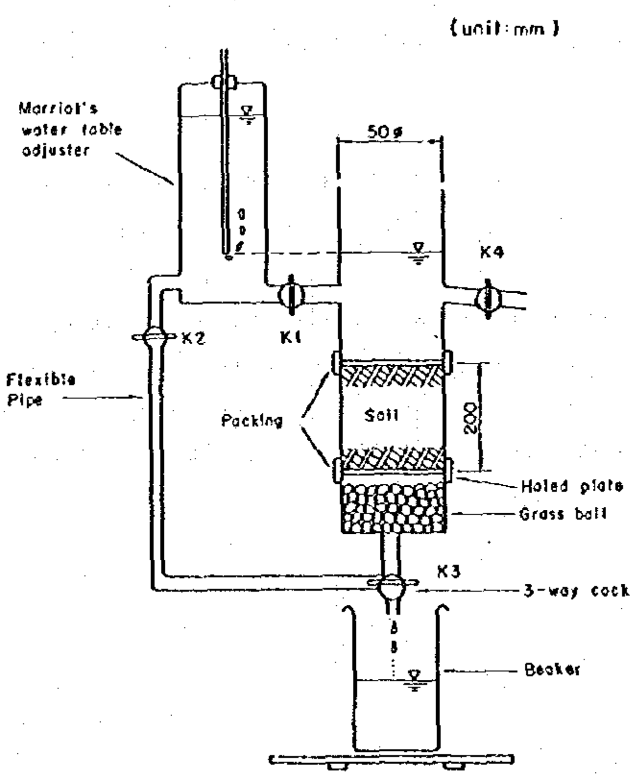
° pH
° ECe
° Soluble Salts
° ESP

For the leaching water and leachate, the following items were analyzed;

° pH
° EC
° Soluble Salts
° adj SAR

Small-Scale Laboratory Leaching Experiment The small-scale leaching test apparatus has similar function to the large-scale one except for its size, as shown below:

Apparatus of Leachiq Tests
(Small Size)



The apparatus has five soil columns of 5 cm of diameter and 20 cm long in a row. The experiment was carried out by the same procedures as mentioned above.

g. Geotechnical Investigation

Drilling and Sampling: A set of equipment consisting of a derrick and a winch were introduced for drilling boreholes of 7.5 cm diameter and 10 m depth. In clay and silty soils, a clay cutter and an auger were used to excavate the boreholes. Above the groundwater table, water was poured into the hole to make a slurry. Below the water table, the clay cutter and rods were periodically removed from the borehole and a shell or bailer was used to extract the slurry. In sandy and gravelly soils, on the other hand, the shell was used directly to excavate the borehole and a sinker bar was also used if necessary. The borehole was cased with steel pipes to protect its side from collapse.

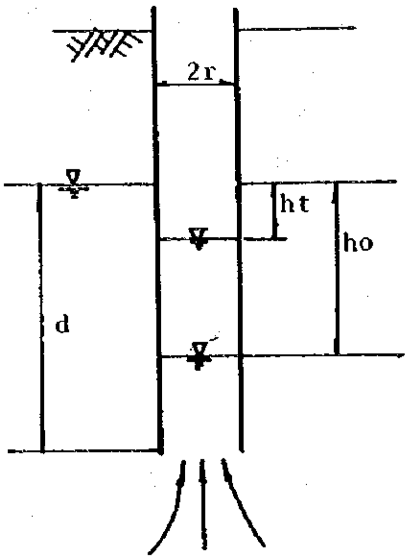
Representative soil samples were taken by using thin wall tubes or auger and they were sent to the GARPAD's laboratory for ECe and pH measurements.

Field Tests; The standard penetration test was carried out by the method according to "Terazaghi" criteria.

The permeability test was carried out by drilling 1.0 to 1.5 meter below the casing and measured the raising water table with time elapsed immediately after the drying the hole. The permeability coefficient (k) was calculated by the following formula;

$$k = \frac{2.30\ \pi\gamma^2}{Et} \log_{10}\left(\frac{h_o}{ht}\right)$$

E: coefficient as shown below;



$\frac{d}{2r}$	E(cm)						
	2r(cm)						
	2.5	5.1	7.6	10.2	12.7	15.2	20.3
1						39.6	53.1
2					33.2	39.4	52.9
3				26.2	33.0	39.4	52.6
4			19.6	26.2	32.8	39.2	52.1
5			19.6	25.9	32.8	38.9	51.8
6		13.0	19.3	25.9	32.6	38.6	51.6
7		13.0	19.3	25.6	32.2	38.6	51.3
8		13.0	19.1	25.6	32.2	38.4	51.0
10		12.7	19.1	25.2	31.8	37.9	
12	6.4	12.7	18.8	24.9	31.5		
15	6.1	12.5	18.3	24.6			
25	5.8	11.7	17.3				
40	5.3	10.2					
60	4.8						
100	3.8						

A.2. Soil Classification

A.2.1. Classification System

In the World Soil Map scaled 1:5,000,000 compiled by FAO/UNESCO, the Project Area as a whole is covered with Gleyic Solonchaks.

a. Phase Phase I Study

In the Phase I study the Project Area soils were classified into three soil series which had been used in the High Dam Soil Survey Project (FAO 1963), that is, Clay Swamp (Ms), Port Said (Ps), and Manzala (Ma) series. This system was based on actual drainage status, reflected in the depth of groundwater table which is closely related to the land elevation. Each series was further subdivided into soil types according to the properties such as degree of salinity, visual features of the surface (salt crust, puffy structure etc.), and texture.

These soil series correspond to the following families of subgroups in the Soil Taxonomy system, which was applied in the present study.

Clay Swamp series (Ms):	very-fine clayey, montmorillonitic, thermic family of Sulfic Hydraquents, or fine clayey, montmorillonitic, thermic family of Typic Salorthids
Port Said series (Ps):	fine clayey, montmorillonitic, thermic family of Typic Salorthids, or very-fine clayey, montmorillonitic, thermic family of Typic Gypsiorthids
Manzala series (Ma):	fine-loamy, montmorillonitic, thermic family of Typic Torriorthents

b. Soil Taxonomy

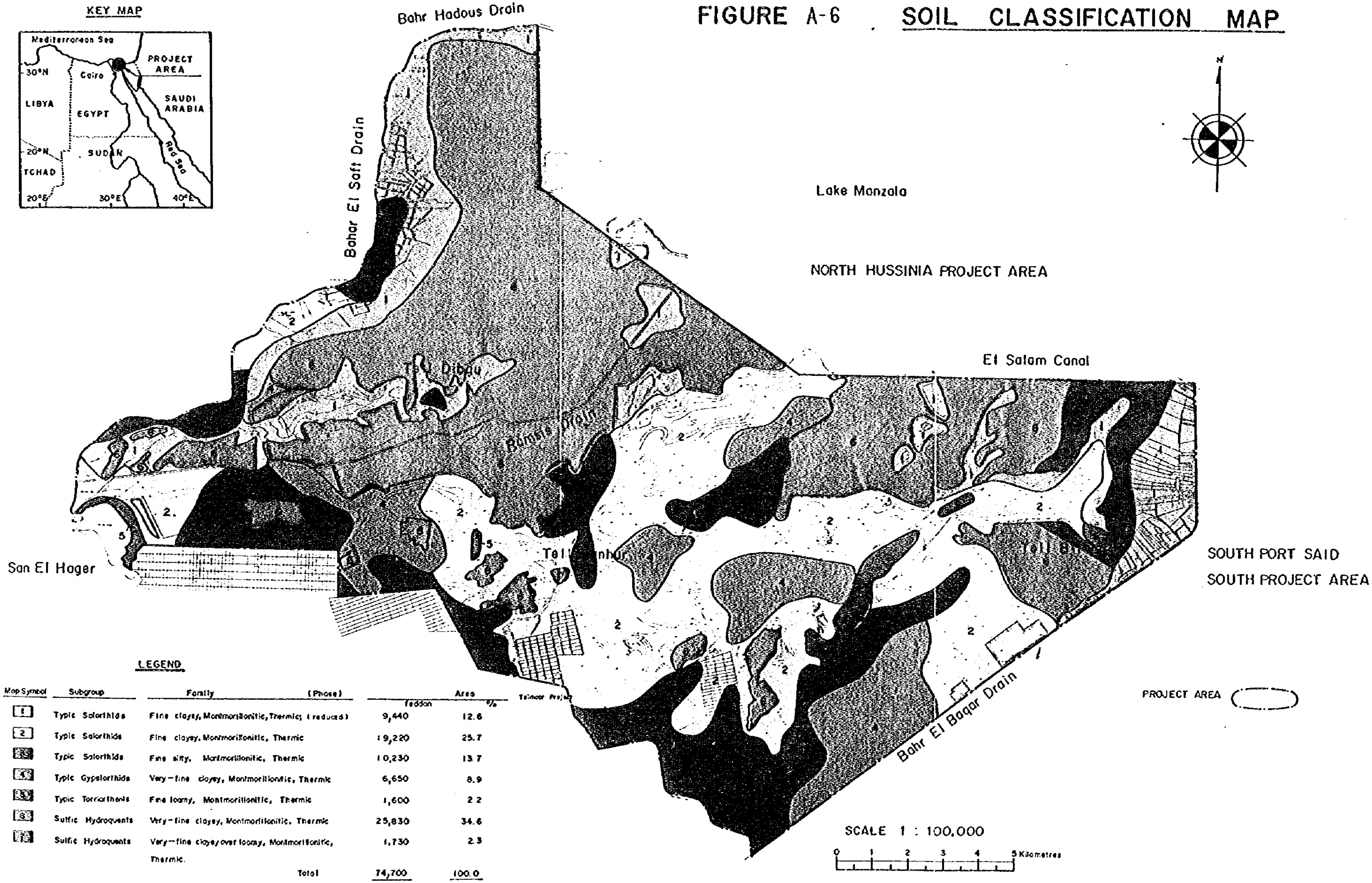
In the present study, the Project Area soils were classified in accordance with the system described in the Soil Taxonomy by the USDA. This system is adopted in the Land Master Plan Project of Egypt. In principle, the system classifies the soils depending on the presence of diagnostic horizons. For the Project Area, the following diagnostic horizons were distinguished of which definitions are put at the end of this volume.

Salic horizon
Natric horizon
Gypsic horizon
Sulfic horizon

The Great Groups found in the Project Area are Salorthids, Gypsiorthids, Torriorthents and Hydraquents. Figure A-6 shows a soil classification map of the Project Area, and the acreages by mapping units as indicated on the map are as below;

Subgroup	Family	Area (feddan)	Area (%)
Typic Salorthids	Fine clayey, Montmorillonitic, Thermic (reduced)	9,440	12.6
Typic Salorthids	Fine clayey, Montmorillonitic, Thermic	19,220	25.7
Typic Salorthids	Fine silty, Montmorillonitic, Thermic	10,230	13.7
Typic Gypsiorthids	Ver-fine clayey, Montmorillonitic, Termic	6,650	8.9
	Sub-total	47,140	63.1
Typic Torriothents	Fine loamy, Montmorillonitic, Thermic	1,600	2.2
Sulfic Hydraquents	Very-fine clayey, Montmorillonitic, Thermic	25,830	34.6
Sulfic Hydraquents	Very-fine clayey over loamy, Montmorillonitic, Thermic	1,730	2.3
	Sub-total	27,560	36.9
	Total	74,700	100.0

FIGURE A-6 SOIL CLASSIFICATION MAP



LEGEND

Map Symbol	Subgroup	Family (Phase)	Area Feddan	Area %
1	Typic Salorthids	Fine clayey, Montmorillonitic, Thermic; (reduced)	9,440	12.6
2	Typic Salorthids	Fine clayey, Montmorillonitic, Thermic	19,220	25.7
3	Typic Salorthids	Fine silty, Montmorillonitic, Thermic	10,230	13.7
4	Typic Gypsiorthids	Very-fine clayey, Montmorillonitic, Thermic	6,650	8.9
5	Typic Torriorthents	Fine loamy, Montmorillonitic, Thermic	1,600	2.2
6	Sulfic Hydraquents	Very-fine clayey, Montmorillonitic, Thermic	25,830	34.6
7	Sulfic Hydraquents	Very-fine clayey over loamy, Montmorillonitic, Thermic.	1,730	2.3
		Total	74,700	100.0

A.2.2. Soils of Dry Lands

The dry lands extend along the southern border of Lake Manzala, and the low-lying, nearly level clay flats and clay swamps are poorly drained, and partly flooded frequently. The soils are characterized by the strong salt accumulation. The soil profiles are predominantly deep clayey, sometimes with coarser textured subsoils or layers and locally wind blown fluffy clay dunes have been formed. The slightly higher portions with clay or silty clay accumulation of fluffy structure have a better drainage, on the other hand, very wet depressions with salt crusts occur in between.

The clay soils are of recent age so that they show no distinguished profile development except for salt accumulation and gleization in general. Originally these clayey soils have been deposited by water but also more or less marked aeolean accumulation.

The salt accumulation in the surface soils is a principle pedogenic process, and prominent features of the soils prevailing in the dry land areas are summarized as below;

1. Thick montmorillonitic clay texture beneath a thin wind-blown silt,
2. Salt accumulation on the surface and/or in the surface layer by capillary upward movement of saline groundwater under high evaporation,
3. Strongly cemented subsoil,
4. Gypsum rich layers in various form.

The soils of dry lands were classified into three subgroups, that is, Typic Salorthids, Typic Gypsiorthids, and Typic Torriorthents.

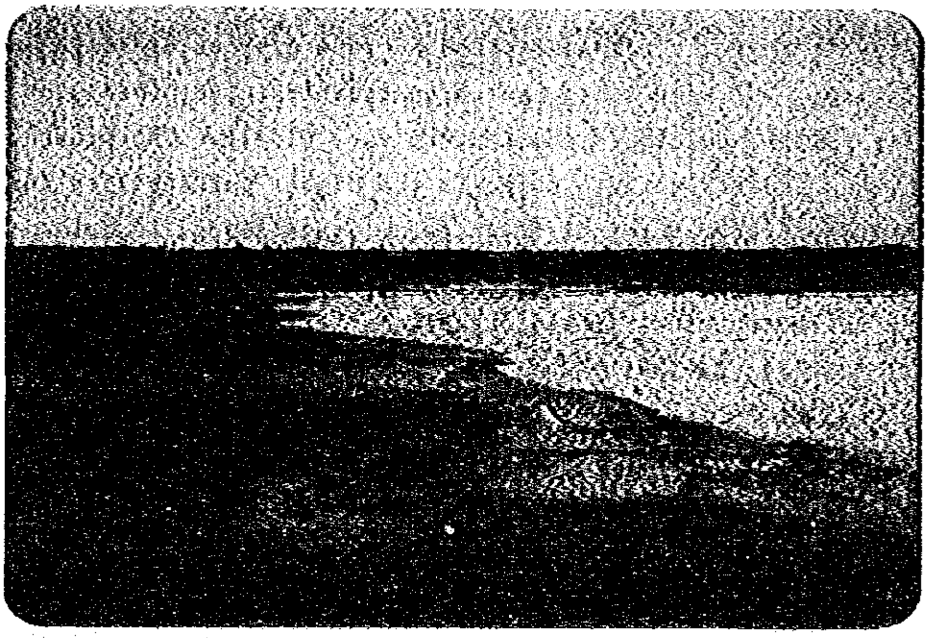
Note: The Phase I Report has made the detailed descriptions of general features of dry land soils, therefore, those which were mentioned in the Phase I Report are omitted in this report in order to avoid repetition.

a. Typic Salorthids

About 80 percent of almost flat, low-lying dry land area were classified into Typic Salorthids (38,890 feddan, corresponding to a half of total Project Area) because of having a salic horizon. Typic Salorthids are very saline soils formed on somewhat lower wet portions in the desert where capillary upward movement and evaporation of water accumulate salts into a salic horizon. The accumulation of salts is within 75 cm below the surface, and usually it is very near the soil surface. Commonly, there is a saturated zone by capillary water. If the groundwater table is shallow, the water moves upward through capillary spaces and reaches the surface. The dissolved salts precipitate owing to the evaporation of water is continuous, as the results, the soluble salts are accumulated at the surface and/or the upper portion of profile. When the salts precipitate at the soil surface, white salt crusts are formed. In the lower wet patches where the groundwater table is shallow and the saline water gathers from the surrounding areas, thick hard salt crusts (2 - 3 cm thick) cover the surface locally, and numerous fine white salt crystals (NaCl) are found in the surface soils. In a depression located at the center of the Project Area, the salt crusts are sufficiently thick to collect for sale.

In the slightly higher portion than depressions, the fluffy structure including many fine needle-like crystals are found just below the surface. The salts fill the fine pores and pressed the soil particles when crystalizing, and the soil structure swells and becomes fluffy consequently.

The chemical analysis showed that ECe values of most soils was found to range from 16 to 64 ms/cm. Thus, both morphological features and chemical properties proved the presence of salic horizon.



Salt Crust in Depression

Salt Accumuration on the Surface

The texture is predaminantly montmorillonite clay or silty clay, which have been less ripened because of poor drainage condition. But some soils have a coarser textured subsoil or layer. Depth, thickness and texture vary widely. The presence of such a coarser texture supports the higher permeability and relatively better internal drainage.

These soils contain a little organic matter, but have extremely small portion of vapor phase. The structure development is very weak. The groundwater saturate soils at some times of the year in some subhorizone within one meter of the surface. As the result, soil profiles show the gley layer due to the reduction status at various depth depending upon the groundwater table. These soils hold the water at relatively lower teasion, however, the high osmotic pressure due to the dissolved salts makes the soils physiologically dry.

In rather larger considerable portions, the soils have a compact clay subsoil of very low permeability. As a consequence, these soils are very poorly drained and show salt accumulation in the upper part or at the surface of soil. At present, small portions of these soils are used for agricultural lands where rice and berseem are mainly cropped. On low-lying lands near swamp and inundation area where water is available throughout year, salt tolerant plants, Salicornia Chenopodium and Tamarix Nilotica Ehrenb are predominantly growing. However, vast clay flats are nearly barren because of the high salinity of these soils. Only dwarf Tamarix Nilotica Ehrenb grow sparsely.

These soils were subdivided into families by their particle-size, mineralogy, and soil temperature classes as below;

- Fine clayey, montmorillonitic, thermic 1/
- Fine silty, montmorillonitic, thermic

The followings are the descriptions of representative profile of each family.

Note: 1/ For mapping, the soils belonging to the fine clayey, montmorillonitic, thermic family were further divided by the depth of reduced layer.

Description of Representative Profile

Information on the Site

Profile No.:	P-25
Soil Name:	Typic Salorthids, fine clayey, montmorillonitic, thermic; (reduced)
Date of Investigation:	November 24, 1983
Location:	El-Bayaa, cultivated area along Hadous drain
Elevation:	0.6 m
Landform and Slope:	Flat, low-lying flat
Vegetation and Land Use:	Salicornia and scattered Tamarix, near paddy field

General Information on the Soil

Parent Material:	Fluvio-lacustrine deposits
Drainage:	Poor
Depth of Groundwater Table:	35 cm below surface
Presence of Stones, Shells etc.:	None
Evidence of Erosion:	None
Surface Features:	Cracking

Profile Description

0 - 10 cm	Very dark brown (10YR 2/3) clay, moist, firm, many narrow cracks, moderate coarse platy structure, very sticky and very plastic when wet, many fine roots and many organic matter, many brown cloudy mottling, weakly calcareous, hard (16.0)1/, clear smooth boundary to;
10 - 35 cm	As above layer, but includes common gley spots light gray (2.5 GY 8/1), predominant brown cloudy mottling and few manganese black spots, clear smooth boundary to;
35 - 45 cm	Black (10YR 2/1) clay, moist, structureless, very sticky and very plastic, common shell fragments, common distinct reddish brown nodules, slightly hard (10.6), clear smooth boundary to;
45 - 95 cm	Dark brown (10YR 3/3) silty clay, moist, weak coarse angular blocky, sticky and plastic, few fine roots, common fine pores, few white salt spots, compacted, hard (14.6), clear smooth boundary to;
95 - 110 cm	Dark olive gray (5GY 4/1)2/ fine loamy sand, water spring out from pores, non-sticky non-plastic, few yellowish brown mottling, hard (13.8), clear smooth boundary to;
110 + 200 cm	Dark greenish gray (10GY 3/1)2/ clay, wet, very sticky and plastic consistency, many small shell fragments, few fine roots with distinct reddish brown iron coating, compacted, hard (16.0)

Note: 1/ Soil hardness: Soil hardness indexes determined by Yamanaka's tester were classified into five categories as below;

	Hardness Index	(kg/cm^2)
Soft	< 8	(0.98)
Slightly hard	8 - 12	(1.93)
Hard	12 - 17	(4.04)
Very hard	17 - 23	(10.0)
Extremely hard	> 23	(10.0)

2/ Color name according to Japanese color charts.

Information on the Site

Profile No.:	P-5
Soil Name:	Typic Salorthids, fine clayey, montmorillonitic, thermic
Date of Investigation:	November 1, 1983
Location:	About 1.5 km north of Tell Sanhur, about 1 km west of lake shore
Elevation:	0.25 m
Landform and Slope:	Gently slope forwards the east, slightly hummocky relief
Vegetation and Land Use:	Very scarce dwarf Tamarix on a few fluffy accumulation

General Information on the Soil

Parent Material:	Fluvio-lacustrine deposits
Drainage:	Poor to very poor
Depth of Groundwater Table:	75 cm below surface
Presence of Stones, Shells etc.:	None
Evidence of Erosion:	None
Surface Features:	Weak salt crust (1 mm thick) and very thin wind blown silt on the crust

Profile Description

0 - 20 cm	Very dark brown (10YR 2/2) clay, saturated due to the crust, structureless, very sticky and plastic, slightly hard (9.0), many salt crystals, gradual smooth boundary to;
20 - 35 cm	Dark brown (10YR 3/3) clay, moist, weak medium angular blocky, friable, very sticky and plastic when wet, hard (16.6), common gypsum needles, common fine salt crystals, gradual smooth boundary to;
35 - 70 cm	Very dark grayish brown (10YRd 3/2) clay, moist, moderate medium angular blocky, friable, compacted, extremely hard (26.8), very few pores, few brown cloudy mottling and few manganese concretions, few fine salt cystals, gradual smooth boundary to;
70 - 110 cm	Very dark grayish brown (10YR 3/2) clay, wet, structureless, very sticky and very plastic, very hard (23.2), common yellowish brown cloudy mottling and common manganese concretions, few fine pores, gradual smooth boundary to;
110 - 200 cm	Very dark gray (10YR 3/1) clay, wet, structureless, very sticky and plastic, very hard (22.6), few fine pores, few manganese concretions, less mottled than above layer.

Information on the Site

Profile No.	P-20
Soil Name:	Typic Salorthids, fine silty, montmorillonitic, thermic
Date of Investigation:	November 23, 1983
Location:	About 500 m north of the boundary of Tanis Project, near swamp
Elevation	1.2 m
Landform and Slope:	Nearly flat with somewhat hummocky relief
Vegetation and Land Use:	Scattered *Tamarix* on a few fluffy clay mounds

General Information on the Soil

Parent Material:	Fluvio-lacustrine deposits
Drainage:	Moderately well
Depth of Groundwater Table:	1.0 m below surface
Presence of Stones, Shells etc.:	None
Evidence of Erosion:	None
Surface Features:	Puffed surface with salt efflorescene

Profile Description

0 - 5 cm	Very dark brown (10YR 2/2) silty clay, slightly moist, fluffy, slightly sticky and plastic when wet, many fine salt crystals abrupt smooth boundary to;
5 - 55 cm	Dark brown (10YR 3/3) silty clay, moist, structureless, few faint brown cloudy mottling, slightly hard (12.2), abrupt smooth boundary to;
55 - 65 cm	Very dark brown (10YR 2/3) clay, moist, weak fine subangular blocky, friable, very sticky and plastic when wet, hard (17.0), few small gypsum needles, common fine salt crystals, common manganese concretions, few yellowish white lime concretions (2 mm in diameter), abrupt smooth boundary to;
65 - 145 cm	Brown (10YR 4/3) sandy clay loam with several stratified fine sand layers (3 cm thick), slightly wet, firm, compacted, very hard (21.4), clear smooth boundary to;
145 - 200 cm	Very dark grayish brown (10YR 3/2) silty clay, wet, moderate columnar structure, sticky and plastic, ten pores, compacted, very hard (19.8), common manganese concretions, water coming from the pores, clear smooth boundary to;
200 - 270 cm	Very dark gray (10YR 3/1) clay without mottling, wet, massive and very compacted.

b. Typic Gypsiorthids

A gypsic horizon containing a large amount of gypsum ($CaSO4. 2H_2O$) in various forms was identified in some very-fine clayey soils. Because of the gypsic horizon as a diagnostic horizon of which upper boundary was found within one meter from the surface, these soils were classified as Typic Gypsiorthids. Mostly, they are found in the slightly depressed areas and occupy 6,650 feddan, namely, about 14 percent of dry land area (about 9 percent of total Project Area).

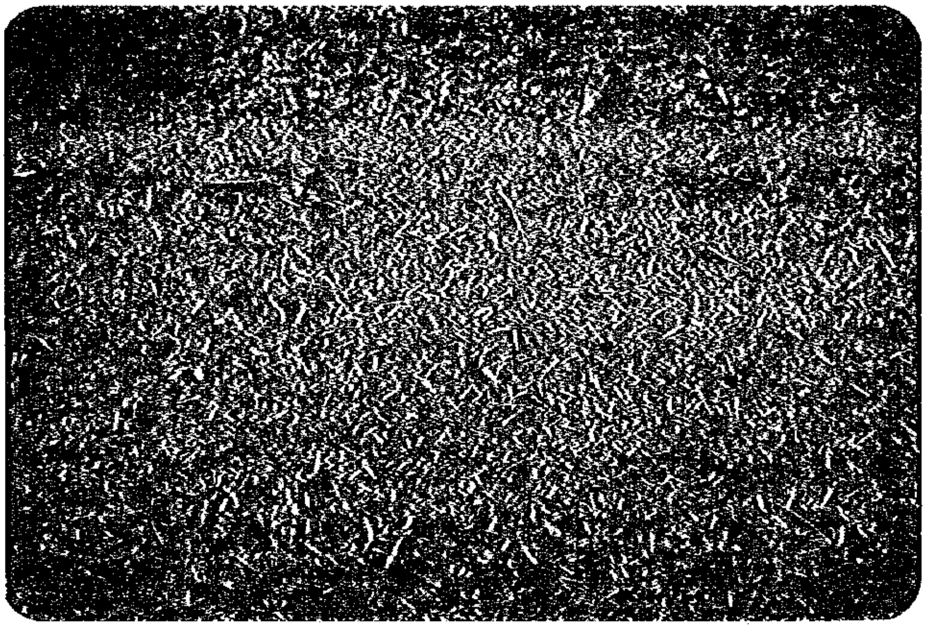
Many light yellowish brown transparent gypsum flakes or needles (2 - 20 mm long) on the surface and/or many fine white crystals in the surface layer are characteristic feature of these soils. According to the chemical analysis, these soils contain around five percent of gypsum.

The gypsum deposits are considered as sea bottom deposits. When the coastline moved north, the sea bottom became dry and, as a result of high evaporation under hot and dry climate, gypsum has crystallized at the surface. The greatest accumulation of gypsum occurs above the capillary water zone in the profile. The fact proves that the gypsum is of secondary origin and has been formed by precipitation through evaporation of the groundwater.

These soils contain little organic matter. There is almost no natural vegetation on these soils. The lands covered with these soils are used for fish farming to a limited extent.

These soils have constraint of drainage for irrigated agriculture. Also, subsidence problem under irrigation is affected by any important differences in bulk density as well as the percentage of gypsum by weight.

In the Project Area, a very-fine clayey, montmorillonitic, thermic family of Typic Gypsiorthids was found.



Gypsum Crystals on the Surface

Description of Representative Profile

Information on the Site

Profile No.	P-13
Soil Name:	Typic Gypsiorthids, very-fine clayey, montmorillonitic, thermic
Date of Investigation:	November 21, 1983
Location:	About 2 km southwest of Tell Khaiwanet
Elevation:	1.25 m
Landform and Slope:	Gentle slope with dune (3 m high) relief the pit was dug at the bottom of them
Vegetation and Land Use:	Scattered dwarf Tamarix on the hummocky accumulation

General Information on the Soil

Parent Material:	Fluvio-lacustrine deposits
Drainage:	Poor to very poor
Depth of Groundwater Table:	1.7 m below surface
Presence of Stones, Shells etc.:	None
Evidence of Erosion:	Somewhat susceptible to wind erosion
Surface Features:	Thin wind-blown silt (2 mm thick), fluffy structure, no cracks, scattered gypsum flakes and small shell remnant.

Profile Description

0 - 5 cm	Brown (10YR 4/3) clay, dry, loose, many gypsum flakes, many shell fragments, clear smooth boundary to:
5 - 20 cm	Very dark grayish brown (10YR 3/2) clay, moist, weak fine subangular blocky structure, very sticky and plastic when wet, many gypsum flakes, many fine salt crystals, few manganese concretions, compacted, very hard (20.6), gradual smooth boundary to;
20 - 50 cm	Very dark brown (10YR 2/3) clay, moist, granular and weak medium subangular blocky structure, few white gypsum veins, few fine salt crystals, very hard (21.4), gradual smooth boundary to;
50 - 105 cm	Very dark brown (10YR 2/2) silty clay with thin stratified silt layer, moist, structureless, sticky and plastic, compacted, extremely hard (23.6), common vertical white gypsum veins, common salt crystals, gradual smooth boundary to;
105 - 155 cm	Very dark brown (10YR 2/2) clay, moist, massive, compacted, extremely hard (23.6), sticky and plastic when wet, less gypsum veins and salt crystals than above layer, few manganese concretions, gradual smooth boundary to;

155 - 240 cm Very dark brown (10YR 2/2), silty clay with very thin stratified fine sand layer, wet, structureless, compacted, very hard (19.6), sticky and plastic, few magnanese concretions;

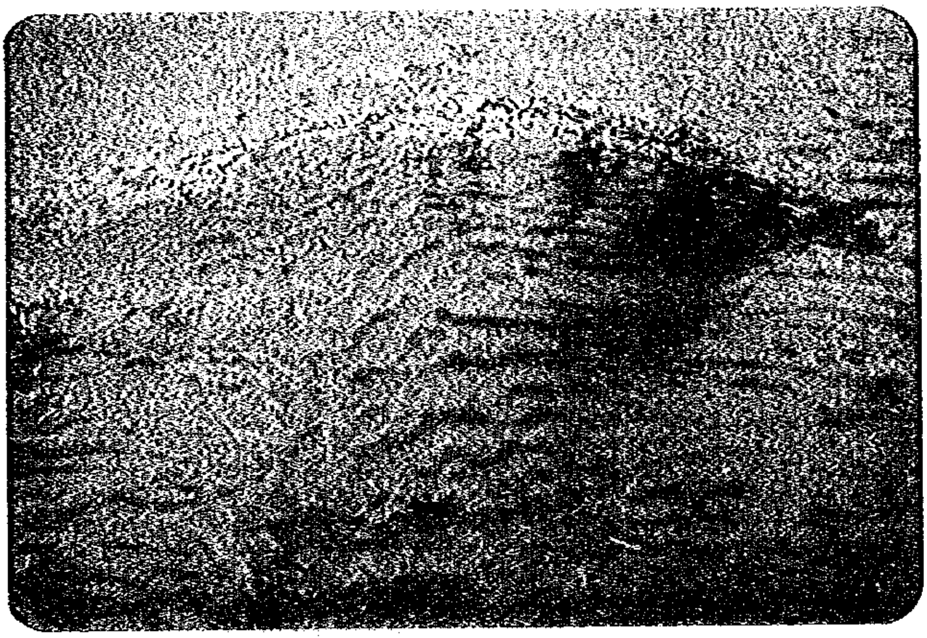
240 - 360 cm Very dark gray (10YR 3/1) clay without mottling nor concretions, wet, structureless, compacted, very hard.

c. Typic Torriotheats

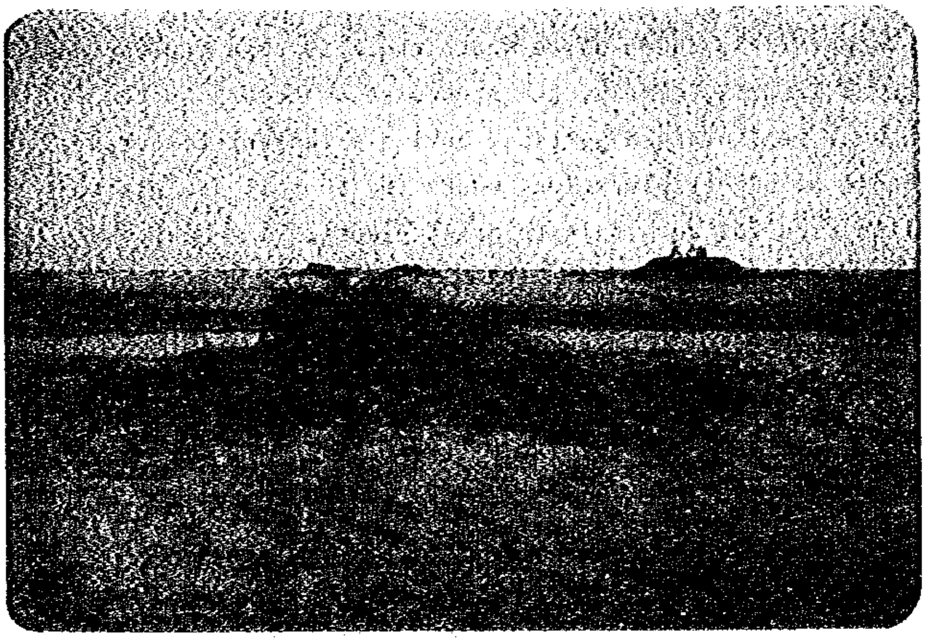
On clay dunes, no significant salic horizon nor any diagnostic horizons could be identified, therefore, the soils were classified as Typic Torriorthents. These soils are found on gentle or moderate slopes and have a limited acreage of 1,600 feddan, that is, about three percent of dry land area.

These soils have a fluffy, hummocky or dune-like accumulations of aeolian deposits of various depth derived from the fluffy topsoils which were developed on moderately well drained clayey soils in the adjacent clay flats. The accumulation of wind blown materials takes place where there is some vegetations such as Tamarix, namely, the accumulation occurs on the somewhat well drained portions having a coarser textured subsoil of higher elevation, where the topsoil are not too saline even for such salt tolerant plants.

These soils are dry and saline, that is, the ECe is more than 2 mS/cm. However, because of relatively deep groundwater table which restricts the capillary upward movement of water, the salts have not accumulated in the surface layer. As the result, the soils do not have a salic horizon and the salinity is less than surrounding lands of other soils.



Aeolian Deposit Behind Dwaff Vegetation



Medium Clay and Tamarix Shrub

These soils have little organic matter because of sparse natural vegetation. Only xerophytic shrubs of Tamarix Nilotica Ehrenb are found. As mentioned-above, these shrubs contribute to form dune and hummocky relief. Actually, these lands are not used at present. These lands are highly susceptible to erosion.

A fine loamy, montmorillonitic, thermic family is found in the Project Area.

Description of Representative Profile

Information on the Site

Profile No.:	P-16
Soil Name:	Typic Torriorthents, fine loamy montmorillonitic, thermic
Date of Investigation:	November 21, 1983
Location:	On the hill ridge, about 2 km north of the summit
Elevation:	2.5 m
Landform and Slope:	Undulating with clay dunes (1 - 3 m high)
Vegetation and Land Use:	Tamarix on a foot of dune

General Information on the Soil

Parent Material:	Wind-blown deposits
Drainage:	Moderately well
Depth of Groundwater Table:	Deeper than 2 m below surface
Presence of Stones, Shells etc.	None
Evidence of Erosion:	Susceptible to wind erosion
Surface Features:	Coarse sand pavement, puffy surface, no cracks

Profile Description

0 - 10 cm	Very dark grayish brown (10YR 3/2) silty loam, dry, loose, fluffy structure, non-sticky and nonplastic, few salt crystals, clear smooth boundary to;
10 - 90 cm	Dark yellowish brown (10YR 3/4) silty clay loam, dry, structureless, non-sticky and slightly plastic, hard (15.8), few white powdery salt's small spots, clear smooth boundary to;
90 - 105 cm	Very dark grayish brown (10YR 3/2) silty clay loam, dry, structureless, a few thin stratified coarse sand layer (2 mm thick), few white powdery salts, hard (16.4), gradual smooth boundary to;
105 - 200 cm	Similar to the above horizon except this layer is moist.

A.2.3. Swamp and Inundated Lands

The swamp and inundated lands, which have an acreage of 27,560 feddan, about 37 percent of total Project Area, cover the northern half of the Area. These lands adjoin the North Hussinia Project Area with the El Salam Canal. The construction of the canal has not discontinued the soil distribution, therefore, the classification was made adjusting to those of the North Hussinia Project.

The lands are permanently submerged by brackish water the salt content of which ranges from 9,600 to 37,400 ppm. The profiles showed only gleization but no other diagnostic horizons. The profiles consist of mainly montmorillonite clay having a very sticky consistency, and have usually a compact substrata.

At the northeast corner near the former coastline along the El Salam Canal, the profiles consist of sandy materials such as sandy loam or sandy clay loam including shell fragments. The Salicornia vegetation is rather dense in shallow water portion.

Generally, the top layer has been strongly reduced and shows dark greenish or bluish gray color. Below the upper reduced layer, a grayish brown clay is found, and again a dark bluish gray reduced layer appears below 100 cm from the surface. Because the clay has deposited under the water, the bulk density is small and the moisture content is high, namely more than 100 percent by dry weight. On the top layer, very soft clay has deposited followed by a considerably hard layer having n-value of more than one. The profiles frequently have very compacted layer at deeper portion. Furthermore, according to the survey made for the North Hussinia Project, it was revealed that these sediments were rich in sulfidic materials.

For mapping, these lands were tentatively classified into the Sulfic Hydraquents because these profiles did not show any pedogenic diagnostic horizons except for the gleization, and the layer rich in sulfidic materials. Although there is a conflict about the adaptability of the Soil Taxonomy system for the permanently submerged lands, they were further subdivided into two families as below;

Very-fine clayey, montmorillonitic, thermic, and, very-fine clayey over loamy, montmorillonitic, thermic.

Salicornia Chenopodium and Phragmite are predominant natural vegetation. Fish ponds have been constructed at the fringe of the inundated area. Because the water content is high, the soil strength is low, commonly too low to support grazing animals unless strengthening by natural vegetation.

When the swamps and inundated lands are desiccated, the bulk density increases and the montorillonitic clay makes cracks. And the sulfidic materials are oxidized and show the sulphate-acid.

A.3. Drainage, Salinity, and Alkalinity

A.3.1. Drainage Problem

The Project Area is predominantly situated on clay flats formed of fluvio-marine deposits. The following interactive factors restrict the internal drainage of soils;

(1) Montmorillonitic clay,
(2) Undeveloped soil structure,
  - very low void ratio
  - low organic matter content
(3) Shallow groundwater table,
  - high water saturated zone

(4) Poorly permeable compact subsoil,
(5) High exchangeable sodium percentage in soil

In addition, the surface drainage is restricted the following reasons;

(1) Nearly flat geomorphological feature including depression,
(2) Limited infiltration into the dried puffed surface,
(3) Thick hard salt crusts on the surface

Thus, poor drainability has resulted in waterlogging here and there in the Project Area.

The drainability of lands plays a very important role in considering future land reclamation plans. The drainability was determined from the results of in-place hydraulic conductivity measurement, soil profile morphology and soil physical tests as well as taking into consideration of groundwater status and topographical conditions.

For the land drainability classification, the specifications were made as below;

Drainability Class	Hydraulic Conductivity Possible Rate in m/24 hrs	Soil Texture
1. Moderately well	> 0.5	SiL, SL
2. Moderate	0.25 - 0.5	SiCL, SCL, SiL
3. Moderately poor	0.1 - 0.25	SiCL, SiC
4. Poor	0.05 - 0.1	SiC, C
5. Very poor	< 0.05	C, HC

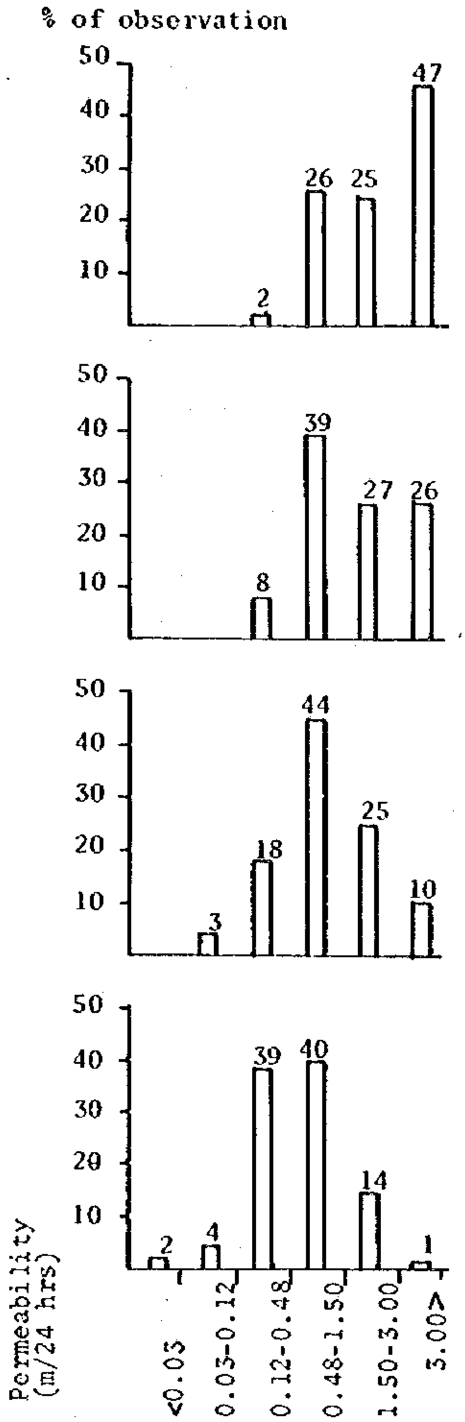
There is a correlation between soil texture and permeability as shown in the following figures made from the result according to the study in Iraq.

Figure A-7 shows a drainability classifiction map, and the acreage of each drainability class is as bellow;

Drainability Class	Area	
1. Moderately well	5,300 feddan	7.1%
2. Moderate	8,210	11.0
3. Moderately poor	9,560	12.8
4. Poor	16,730	22.4
5. Very poor	34,900	46.7
Total	74,700	100.0

About a half of the Project Area has very poor drainability under the prevailing conditions, therefore, the improvement of soil drainability is the most important for the reclamation of these lands, followed by leaching.

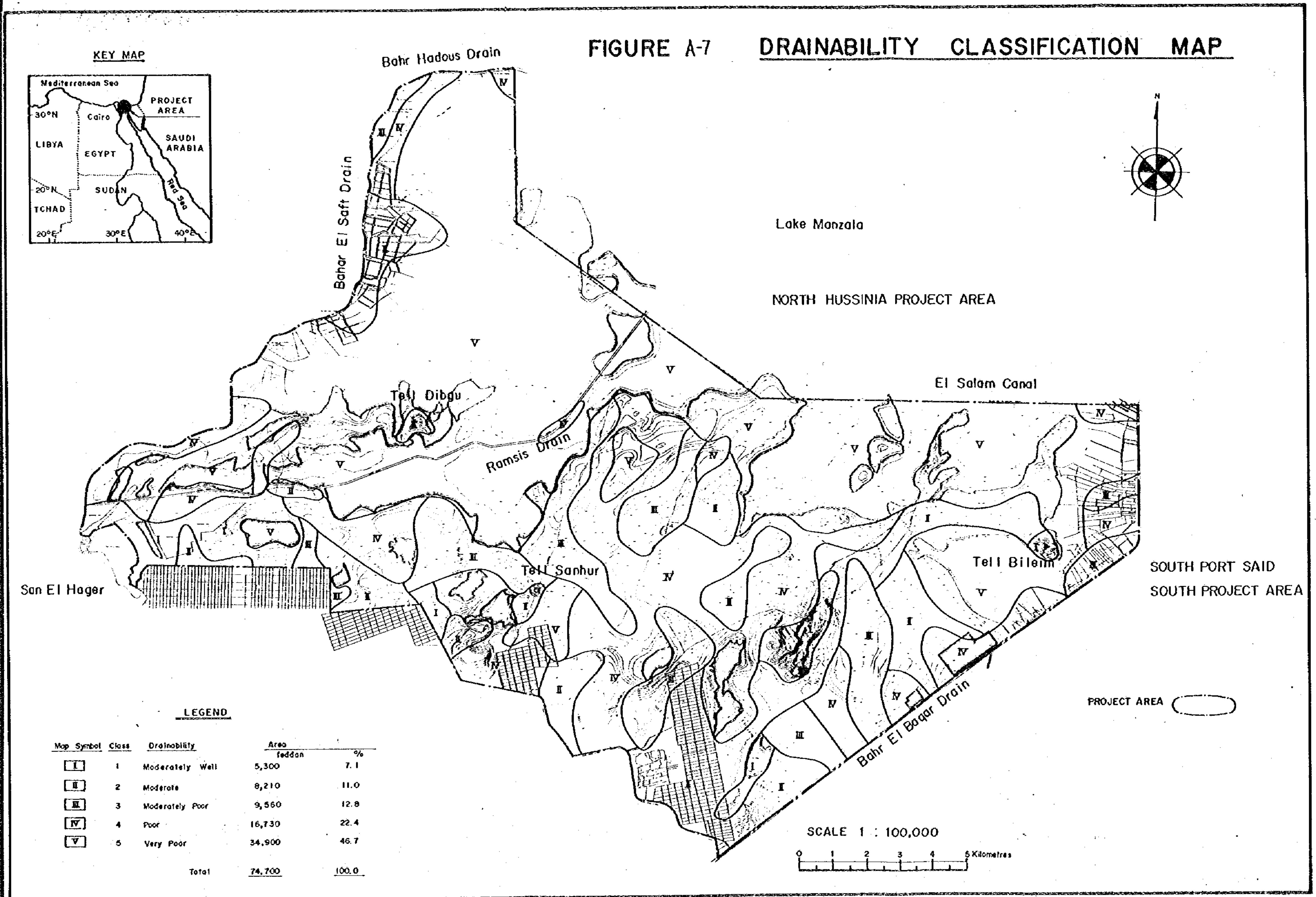
Note: Because the survey period was limited, the hydraulic conductivity measurements were carried out only at some selected sites; therefore, the visual observation of recovery of groundwater table and soil textural sequence in the profiles were used for compiling the land drainability classification map.



Soil Texture	Average Permeability m/24 hrs
S, LS, SL	3.18
SiL, L	2.20
SiCL, CL	1.40
SiC, C	0.80

Source ; CEKOP, Irrigation Improvement in the Amarah Area, Iraq

FIGURE A-7 DRAINABILITY CLASSIFICATION MAP



A.3.2. Soil Salinity

The soil salinity was estimated by measuring the electrical conductivity of saturation extract of the soil. Figure A-8 shows the correlation between ECe and total soluble salts (TSS).

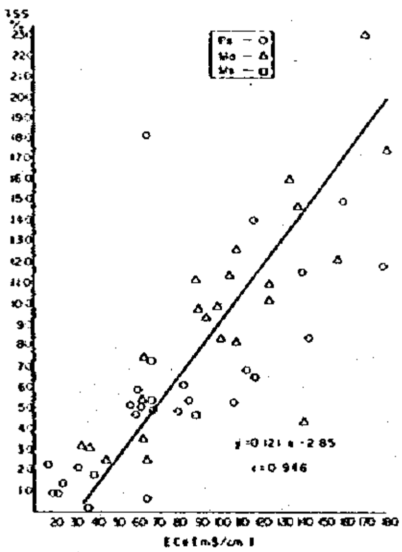


Figure A-8 Relation between ECe and TSS

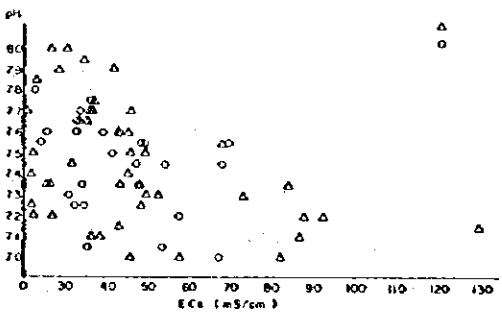


Figure A-9 Relation between ECe and pH

There is a highly positive correlation between ECe and TSS. And Figure A-9 shows the correlation between ECe and pH. There is a tendency of negative correlation between ECe and pH.

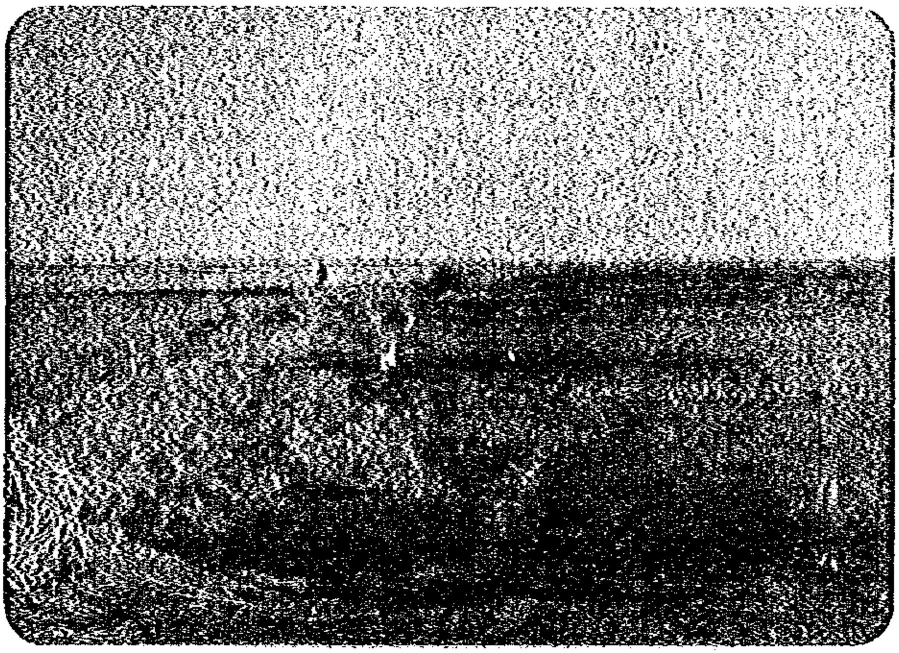
As is shown in the results of chemical analysis, the Project Area soils are characterized by their high salinity, namely, the ECe valves of most soils exceed 16 mS/cm. According to the definition made by the US Salinity Laboratory, the most Project Area soils belong to the category of saline soils.

US Salinity Laboratory's Definition

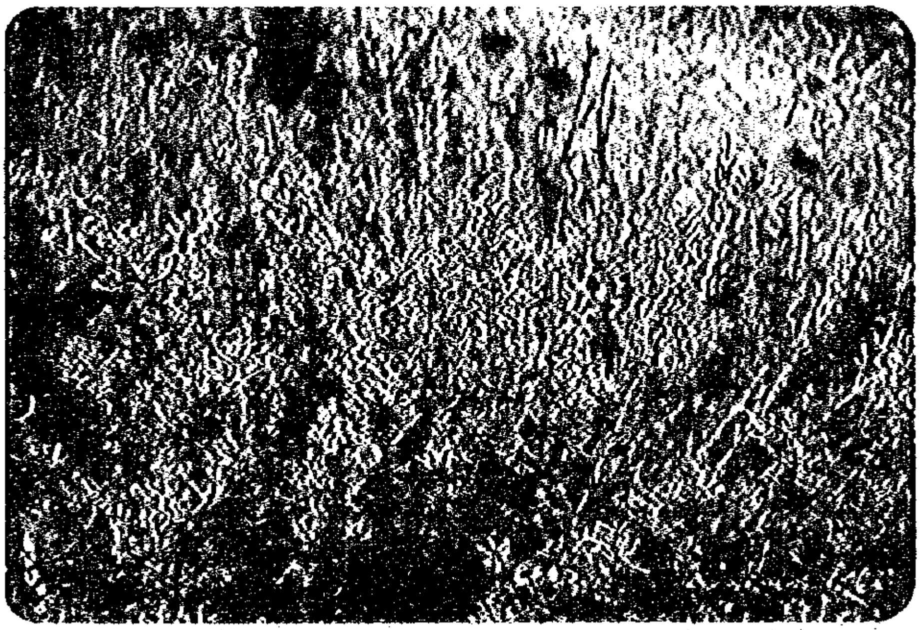
	ECe(mS/cm)	ESP(%)	pH
Saline Soils	> 4	<15	<8.5
Alkali Soils	< 4	>15	>8.5
Saline-Alkali Soils	> 4	>15	>8.5

Figure A-10 shows the vertical distribution of cations and anions, as well as ECe and ESP. As shown in this figure, sodium and chloride are the predominant cation and anion, respectively. The vertical salts distribution with depth in the cultivated lands(P-3, P-11, P-12). On the other hand, salts have been accumulated at a certain depth in the non-cultivated lands.

Natural vegetation of Salicornia is adaptable to the salinity by adjusting its growth, namely, it grows vigorously and blooms tiny yellow flower when the salinity is low, on the other hand, it stops growing and lingers with reddish color. Thus this wild plant indates a certain degree of the salinity.

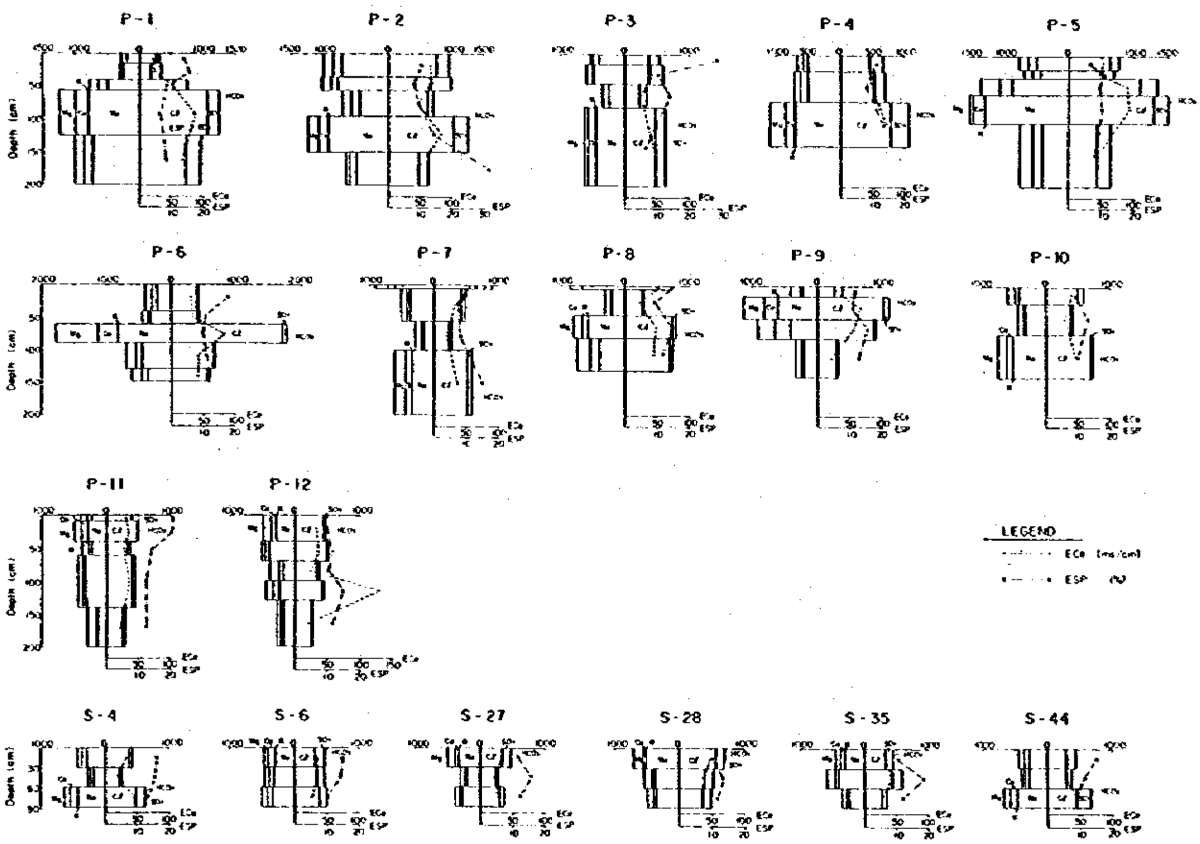


Salicornia Growing under Salin Condition



Salicornia Makes Flowers on less Saline Soil

Figure A-10 Cation-Anion Distribution, ECe, and ESP of Soil Profiles



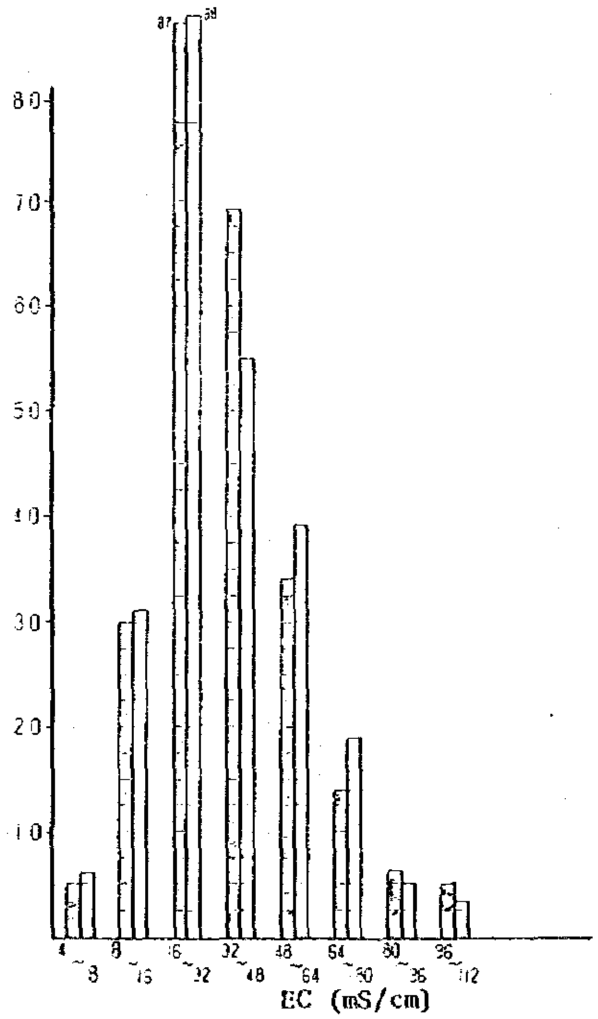
The salts in the surface soil have been accumulated by the capillary upward movement. The salt regime index proposed by Polynov (1956) was calculated by the following formula;

$$S = \frac{\text{Groundwater Cl/SO4}}{\text{Surface Soil Cl/SO4}}$$

When the index (S) is less than one, it points out that the capillary upward movement of soil solution is continuous and the process of salinization takes place.

Table A-2 and Figure A-11 show the results of calculation of the salt regime index for the Project Area. Most of Project Area soils are still under the salinization process with a few exceptions of some portions in the presently cultivated lands having coarser texture than clay flats.

Frequency distribution of the salt contents in surface soils and subsoils were shown in bar chart (below). The highest frequency is at ECe of 16-32 mS/cm or salt content of 1.0 - 1.5 percent.



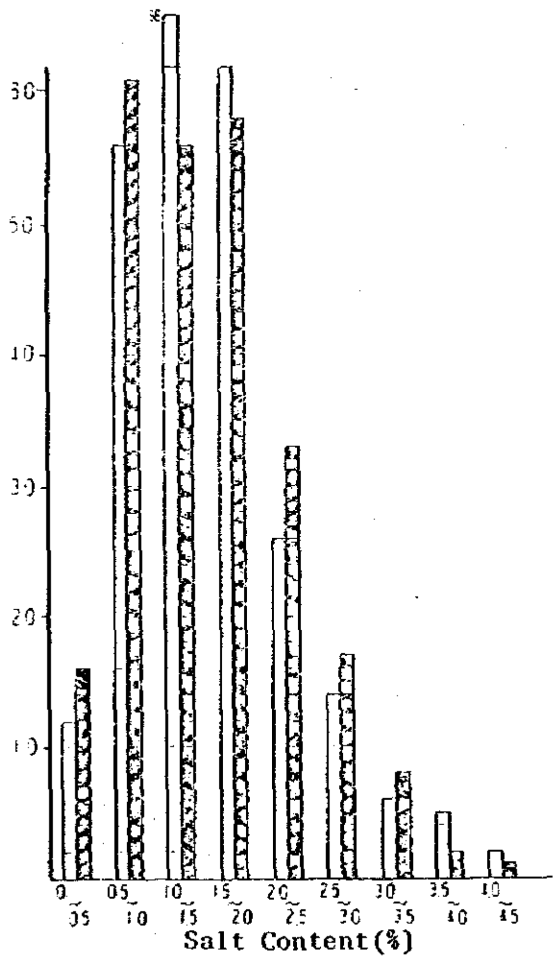


Table A-2 Calculation of Salt Regime Index

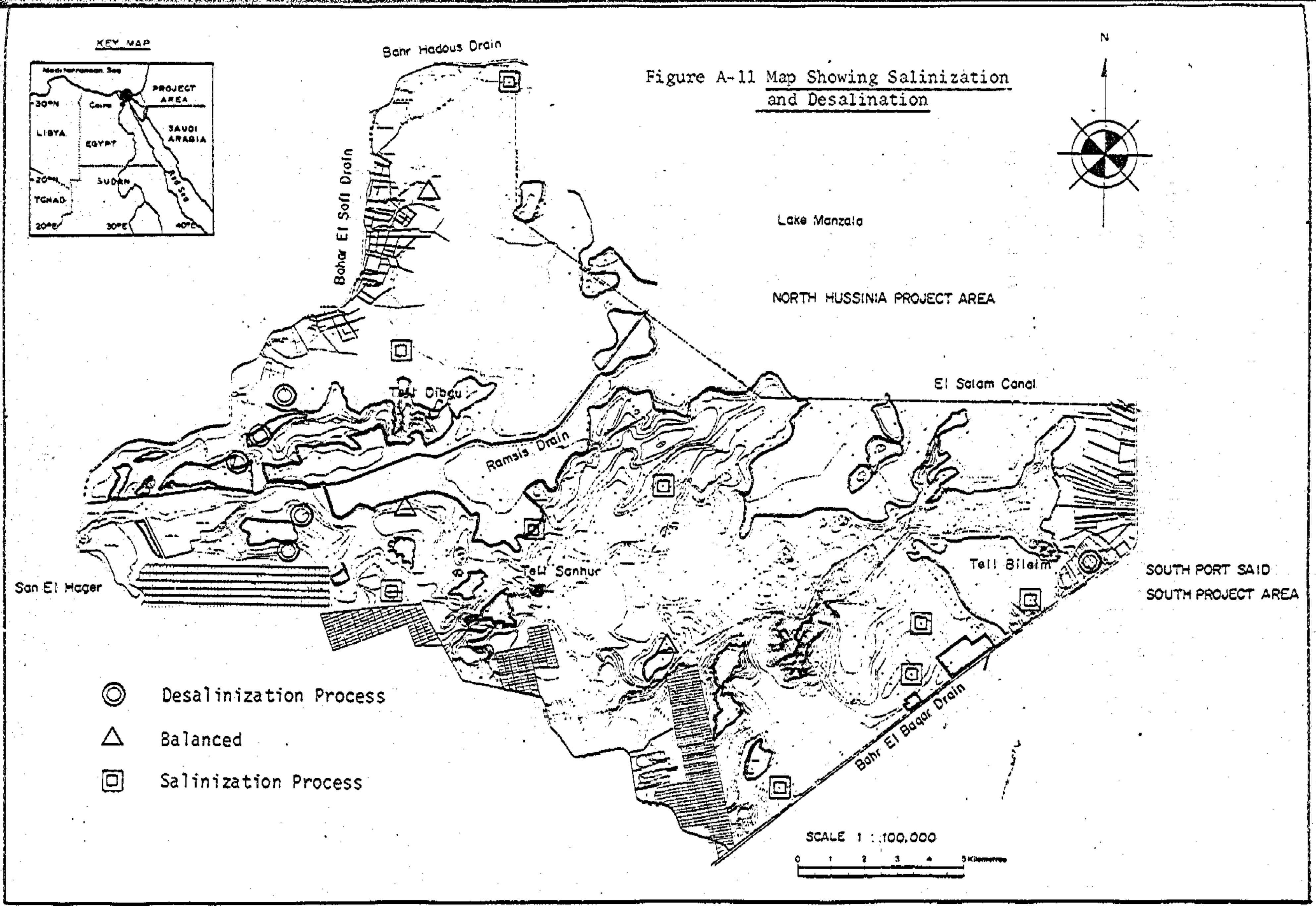
Pit No.	Groundwater			Surface Soil(0-30cm)			Salt Regime Index 1/	
	Cl	SO_4	CL/SO_4 ①	Cl	SO_4	CL/SO_4 ②	①/②	
34	1270	378	3.36	760	237	3.21	1.05	Δ
31	1617	449	3.60	1427	492	2.90	1.24	o
28	2290	488	4.69	590	212	2.78	1.69	o
30	441	268	1.65	319	136	2.35	0.70	×
42	343	292	1.17	172	98	1.76	0.66	×
5	2101	636	3.30	1863	467	3.99	0.83	×
14	1012	467	2.17	926	284	3.26	0.67	×
18	2154	365	5.90	1079	482	2.24	2.63	o
22	1797	270	6.66	700	231	3.03	0.95	Δ
27	1029	433	2.38	1997	491	4.07	0.58	×
29	1960	778	2.52	1145	421	2.72	0.93	×
2	2675	625	4.28	1411	327	4.31	0.99	Δ
11	980	198	4.95	1261	201	6.27	0.79	×
19	970	169	5.74	1480	527	2.81	2.04	o
26	1372	467	2.94	925	331	2.79	1.05	Δ
32	836	268	3.12	691	343	2.01	1.55	o
33	2103	581	3.62	642	312	2.06	1.76	o
16	2000	659	3.03	2263	573	3.95	0.77	×
20	2863	939	3.05	855	244	3.50	0.87	×

Note 1/ $S < 1$ Process of salinization

$S = 1$ Processes of salinization and desalinization are balanced

$S > 1$ Process of desalinization

Figure A-11 Map Showing Salinization and Desalination



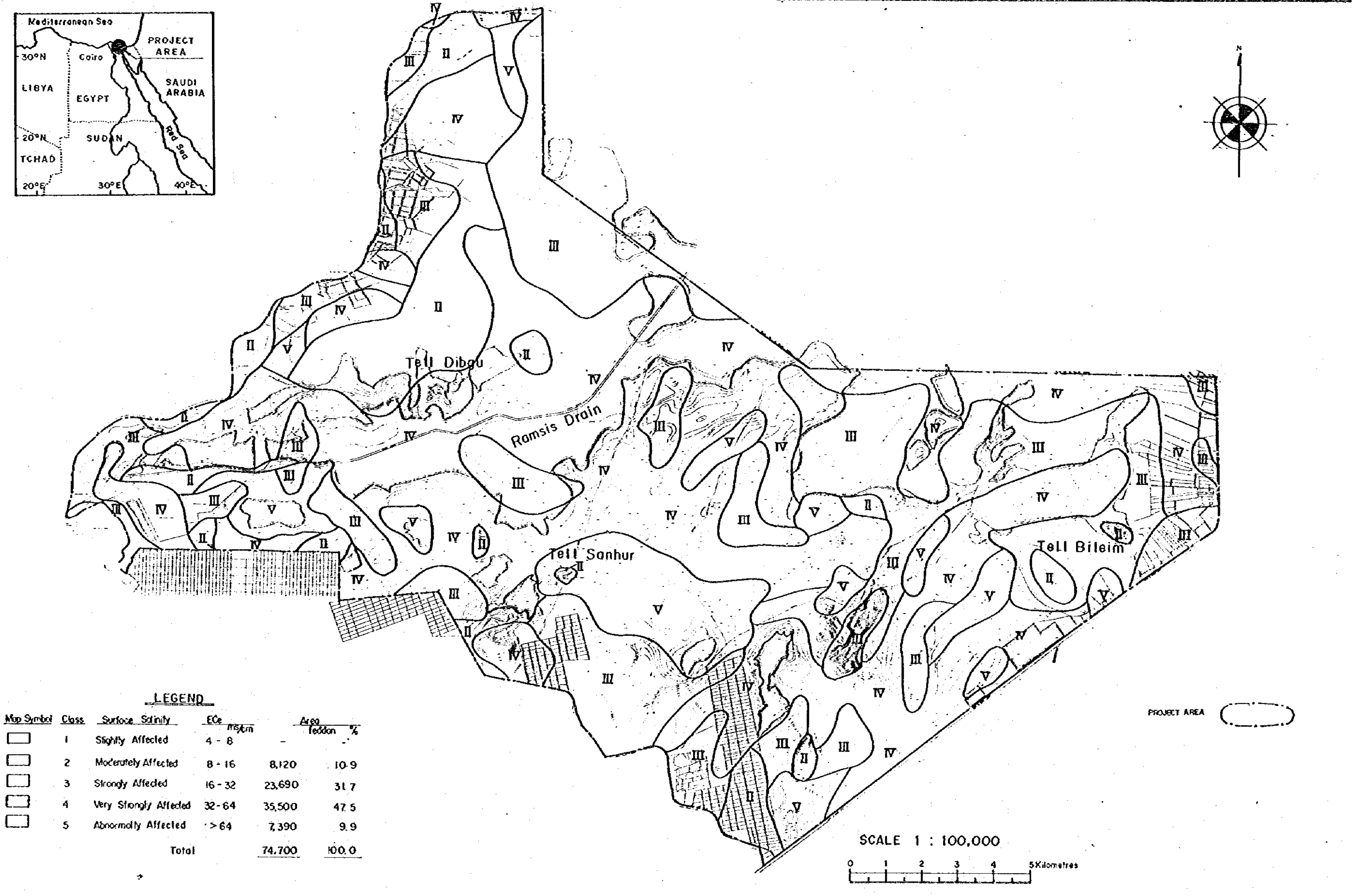
The salinity classifiction of surface soils and subsoils were made as shown in Figure A-12 and A-13, and the acreage of each salinity class was summarized as below;

Class	ECe		Surface Salinity Area		Subsoil Salinity Area	
		(mS/cm)	(feddan)	(%)	(feddan)	(%)
1.	Slightly Affected	4 - 8	-	-	1,290	1.7
2.	Moderately Affected	8 - 16	8,120	10.9	5,200	7.0
3.	Strongly Affected	16 - 32	23,690	31.7	37,580	50.3
4.	Very Strongly Affected	32 - 64	35,500	47.5	25,530	34.2
5.	Abnormally Affected	>64	7,390	9.9	5,100	6.8
	Total		74,700	100.0	74,700	100.0

For both surface and subsoils, about 90 percent of total area shows a strong salt accumulation; more than 16 mS/cm. Therefore, leaching of excess soluble salts is very important as well as improving the soil drainability for the land reclamation of this area.

Figure A-14 shows the depth of groundwater table and groundwater salinity. Most of groundwater have extremely high salinity, except for some shallow groundwater having connection with stagnant water in inundation area.

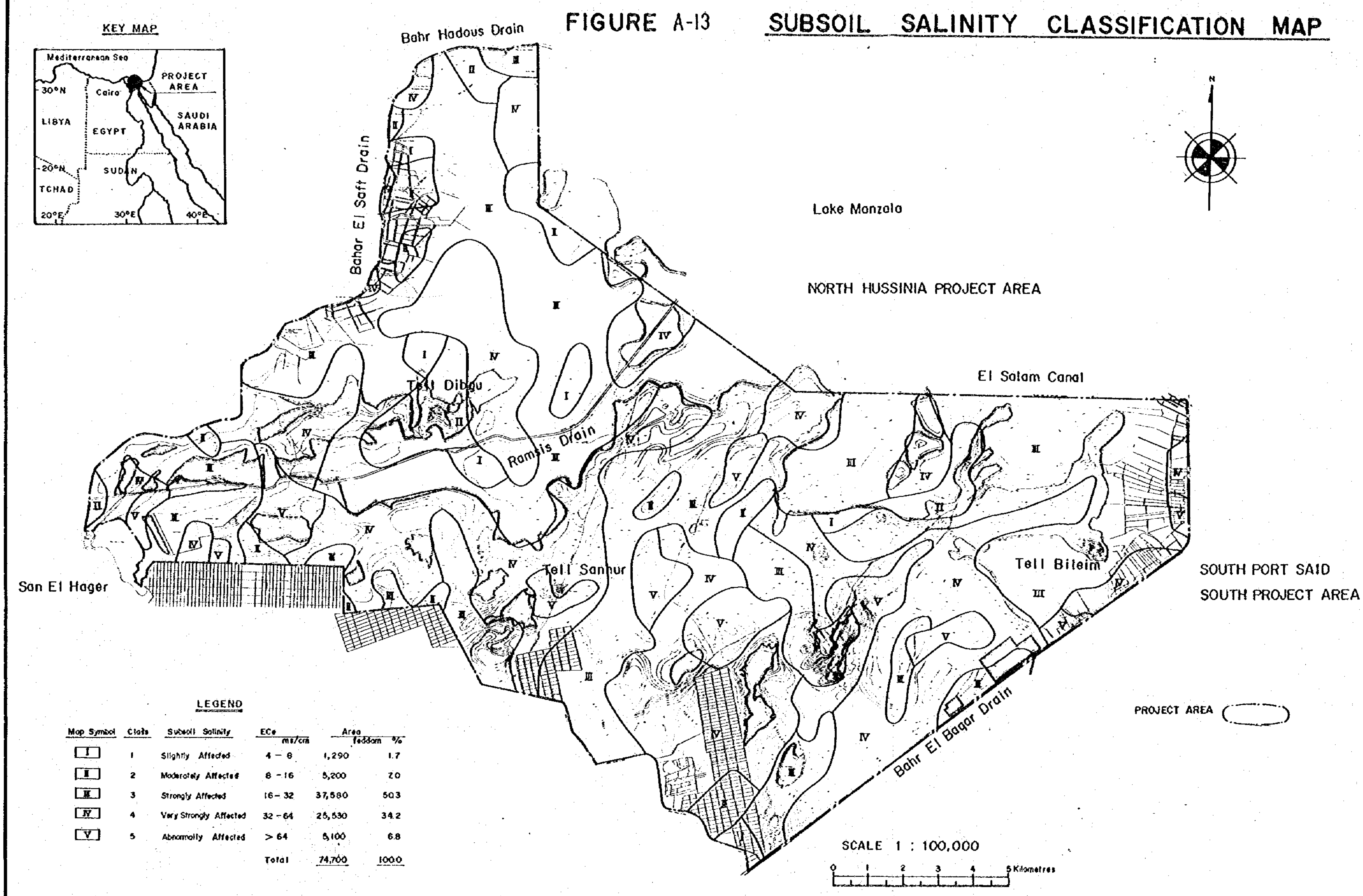
FIGURE A-12 SURFACE SALINITY CLASSIFICATION MAP



LEGEND

Map Symbol	Class	Surface Salinity	ECe mS/cm	Area feddan	%
	1	Slightly Affected	4 - 8	-	-
	2	Moderately Affected	8 - 16	8,120	10.9
	3	Strongly Affected	16 - 32	23,690	31.7
	4	Very Strongly Affected	32 - 64	35,500	47.5
	5	Abnormally Affected	> 64	7,390	9.9
		Total		74,700	100.0

FIGURE A-13 SUBSOIL SALINITY CLASSIFICATION MAP



LEGEND

Map Symbol	Class	Subsoil Salinity	ECe ms/cm	Area feddan	%
I	1	Slightly Affected	4 – 8	1,290	1.7
II	2	Moderately Affected	8 – 16	5,200	7.0
III	3	Strongly Affected	16 – 32	37,580	50.3
IV	4	Very Strongly Affected	32 – 64	25,530	34.2
V	5	Abnormally Affected	> 64	5,100	6.8
			Total	74,700	100.0

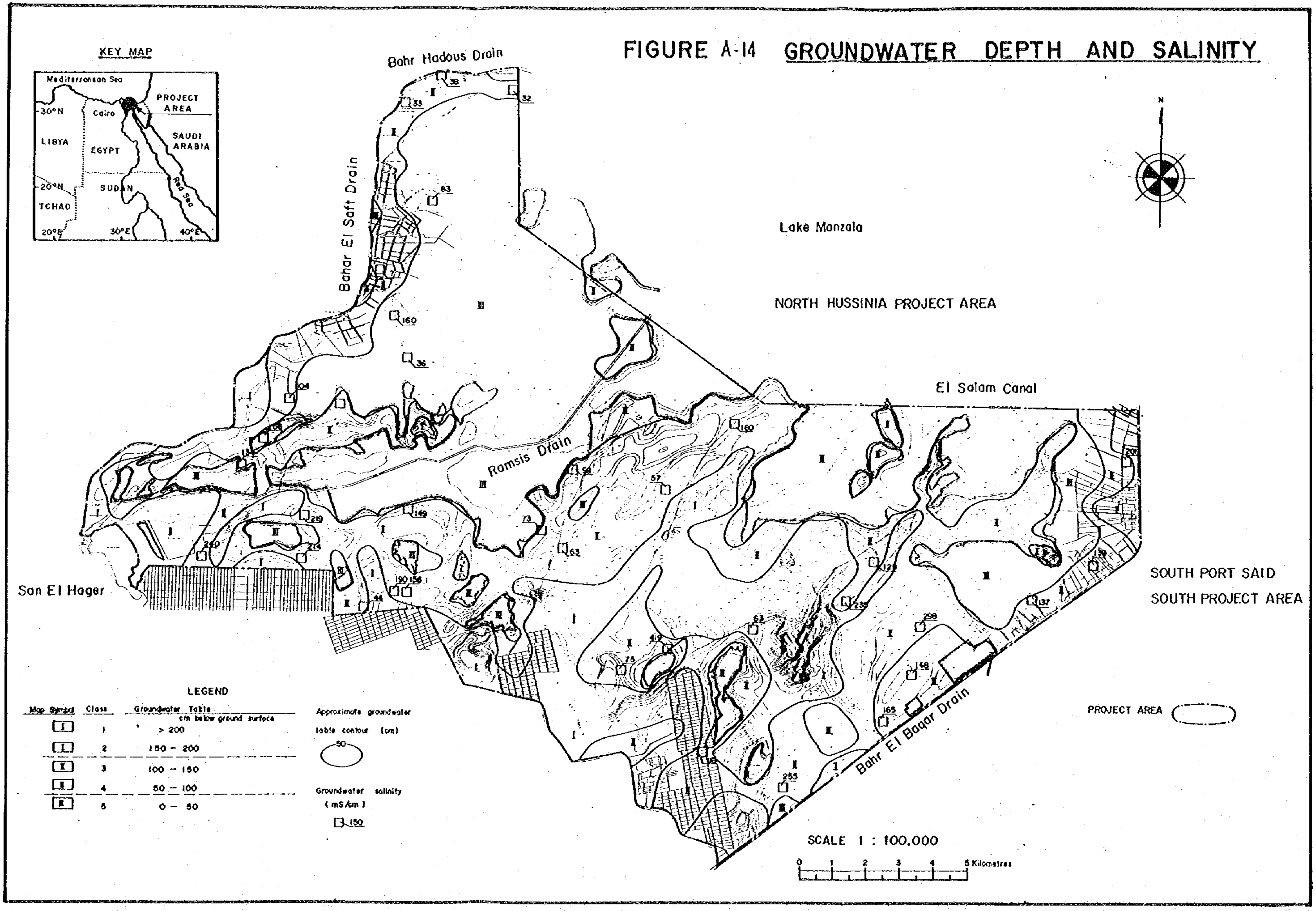


FIGURE A-14 GROUNDWATER DEPTH AND SALINITY

A.3.3. Soil Alkalinity

Soil alkalinity cause a severe soil permeability problems as well as toxicity problem of sodium. High exchangeable sodium induce the dispersion of clay fractions, as a result, the soil structure is degraded and the soil permeability reduced considerably.

Some parts of the Project Area fall into the category of saline-alkali soils according to the US Salinity Laboratory's classification, namely, the ESP values exceed 15. Roughly speaking, these saline-alkali soils extend in the cultivated areas where the lands have been irrigated.

The relation between soil pH and ESP is shown in Figure A-15. The pH values of Project Area soils do not exceed 8.5, but there is potentiality of soil alkalinity problem.

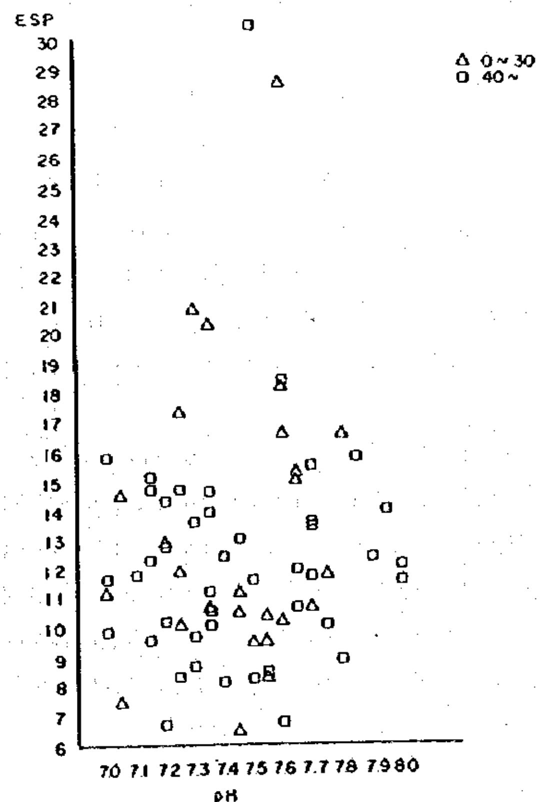


Figure A-15 Relation between PH and ESP