Irrigation and drainage systems in Basrah province, Iraq

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IRRIGATION AND DRAINAGE SYSTEMS
IN BASRAH PROVINCE, IRAQ

By

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TO MY MOTHER, BROTHERS AND SISTERS

ABSTRACT

This study of the irrigation and drainage systems in Basrah province analyses the factors affecting these systems, such as the water resources, soil conditions, management and crops and then shows the effects of these systems on crop yields and soil salinity.

In such a study it is necessary to discuss the physical characteristics of the province and the hydraulic aspects of Iraq which have direct and indirect influences on the irrigation and drainage systems in the province. In accordance with the variations in the irrigation and drainage systems, the province has been divided into four regions, namely : the Western, Southern Tigris, marshes and the Shat Al-Arab.

One of the findings of this study has been the spatial differences between the levels of salinity in the irrigation water which ranges from moderate in the southern Tigris, marshes and the upper section of the Shat Al-Arab to excessive in the western region and the lower section of the Shat Al-Arab. The salinity of the irrigated soils has also been shown to vary from region to region, from a very low level in the marshes to a strongly high level in the southern Tigris . Throughout the province it was found that the farmers continued to rely on their traditional skills and inherited experiences in carrying out cultivation and irrigation operations which have resulted in over-irrigation and low efficiency of use of irrigation water. This, together with the inadequate drainage and high evaporation rates has led to exacerbation of the soil salinity problem and the consequent abandonment of large areas of cultivable lands in the western, southern Tigris and the Shat Al-Arab regions. Additionally, in the marshes and the Shat Al-Arab regions the presence of aquatic vegetation forms an important obstacle to irrigation and drainage operations. Moreover, it is likely that in the future the province will face a

serious shortfall in irrigation water availability.

The province, however, still remains an important agricultural area, providing the Iraqi markets with tomatoes during winters and contributing 11.8% of the country's total date production. Improvements in irrigation and drainage and in soil-water management are therefore vital.

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INTRODUCTION

Iraq, located in south west Asia, known as the Middle East, on the eastern edge of the Arabic world, is divided into eighteen administrative units (provinces) called Muhafadat (sing. Muhafadha), (see Fig.0.1). Basrah province occupies the south-eastern corner of Iraq, at the head of the Arabian Gulf, and extends between latitudes 29°5' and 31°20' N. and between longitudes 46°4 and 48°30' E. The province is bounded by Thi-Qar and Muthanah provinces to the west, Iran to the east, Messan province to the north and Kuwait to the south. The south-eastern boundary is formed by the 90 km coastline along the head of the Arabian Gulf. Administratively, Basrah province is divided into seven sub-divisions (Qadha), see Fig. 0.2, which are further divided into seventeen smaller units (Nahia). The province has an area of 19070 km^2 or 7,628,000 donums(*) and a total population of 1,008,626 in the 1977 census.

In Iraq agriculture forms one of the most important sectors within the National Economy, contributing about 17.67 per cent to the National Income in 1975 (excluding oil).(1) The total cultivable area in Iraq is 48 million donums : one third consists of rain-fed lands in the northern part of the country where precipitation is sufficient to sustain plant growth and the other two thirds composed of irrigable lands in the Mesopotamian Plain in the central and southern parts of Iraq, where precipitation is insufficient for plant growth. In 1980 it was estimated that the total irrigated area was 14,840,000 donums, (see sect. 2.2.3).

The ancient "hydraulic" civilizations in the Mesopotamian Plain were dependent on agriculture, where the favourable environment of a

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(*) donum equals 2,500 m^2.

Fig 0·1 Administrative Units (Muhafadha) of Iraq, 1980

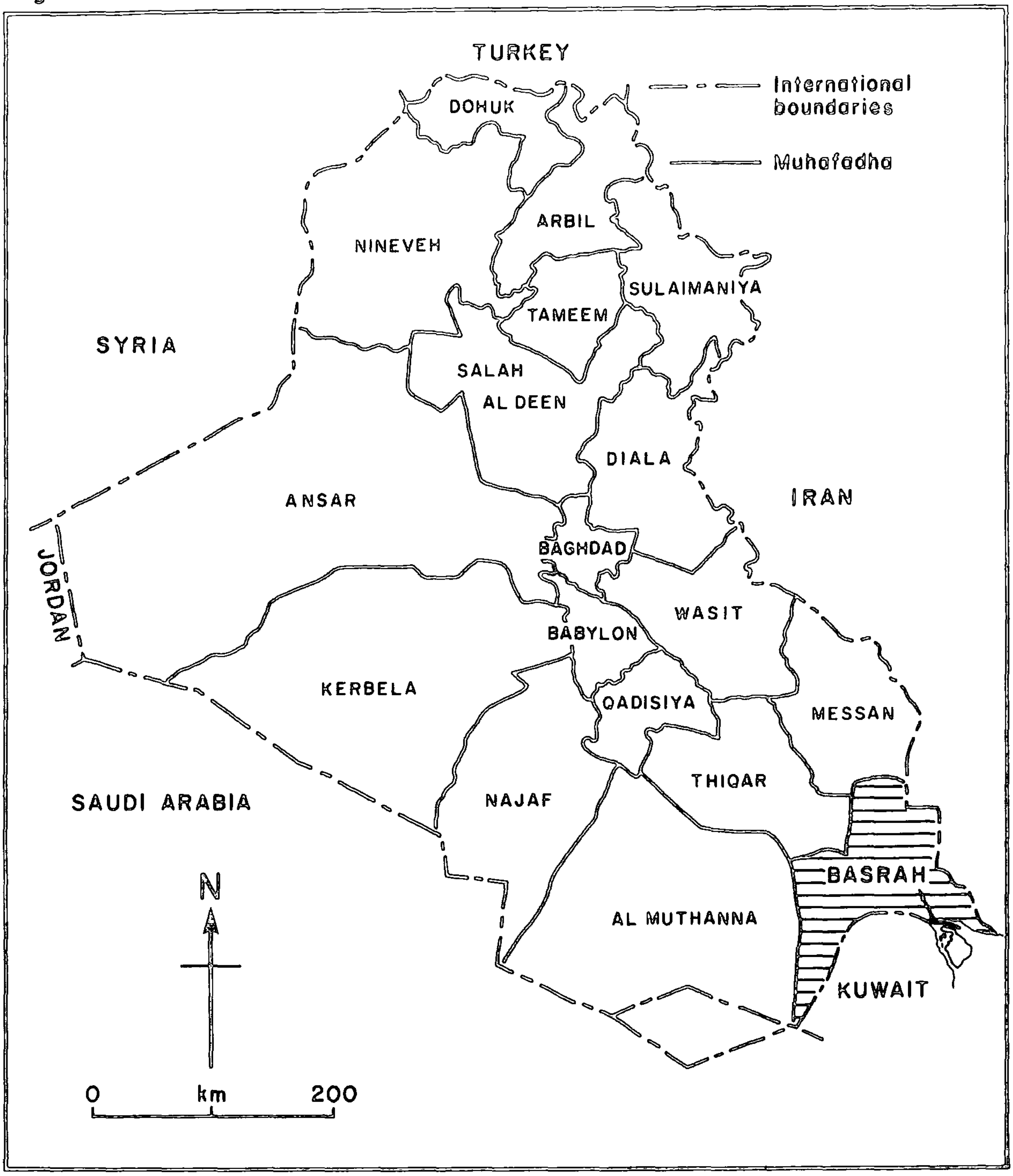
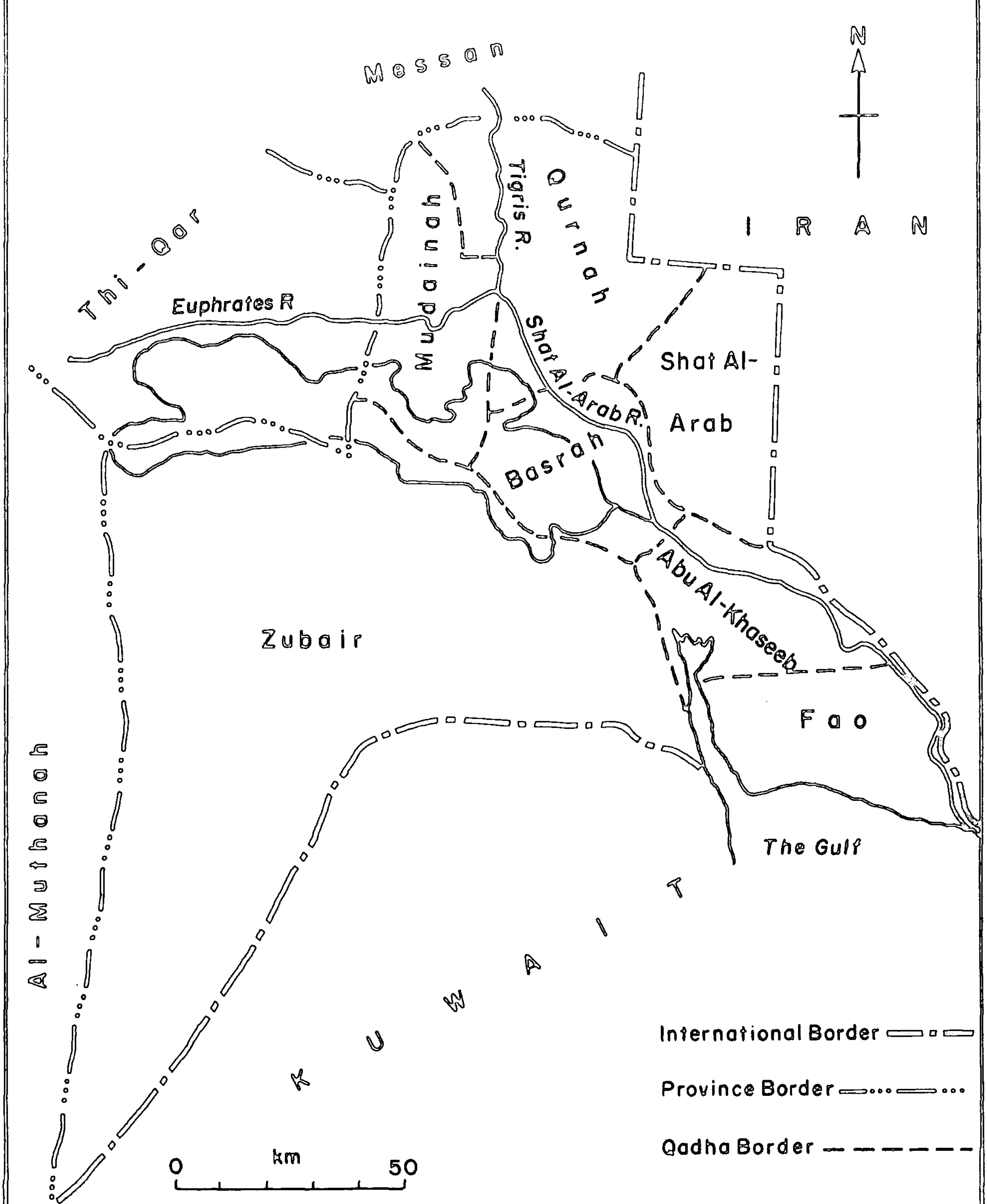


Fig Q2 ADMINISTRATIVE UNITS OF BASRAH PROVINCE



suitable climate, good productive soils and abundant water resources encouraged the people to cultivate the lands. However, throughout the history of the plain irrigated agriculture has been practised with poor drainage - there exists no evidence of the construction of drains and until recently, people did not concern themselves with the need for proper drainage. This fact has been associated with the Iraqi farmers belief that the more water they use for irrigation, the higher yield they will obtain, whereas in fact they use more water than is actually required by the plants. It is well known, however, that in arid and semi-arid regions in particular, such as the Mesopotamian Plain, irrigation cannot be practised with ecological safety unless there is drainage which removes excess water from the soils. Consequently, the soil salinity has increased and the crop yield declined. This has led the farmers to practise a bare fallow system of cultivation, a system by which half of the farmland is cropped in winter and the other half left fallow, the cultivated halves alternating from year to year. These factors, together with the seepage from rivers and canals have led to waterlogging, but of even more importance is the indirect effect of soil salinization. The Mesopotamian Plain is of marine origin, see sect. 1.1, and the sub-soils consequently saline. Due to the high groundwater table caused by over irrigation capillary action raises sub-soil water into the rooting zone. Evaporation takes place leaving behind the salt content of the groundwater in the soil. This process is a continuous one so long as the high groundwater table is maintained, and the salt concentration in the root zone frequently rises to toxic proportions affecting crop productivity, leading in extreme cases to the abandonment of once cultivated land. In recent years the Mesopotamian Plain has faced a serious soil salinity problem which has led to the abandonment of some areas and a decline in agricultural production. It has been estimated that 20 - 30 per cent of the cultivable land in the irrigated area of the Mesopotamian Plain has been abandoned during the last three decades and the decline in crop yields has been between 20 - 50 per cent. (2) This problem is particularly pronounced in the southern part of the Mesopotamian Plain where the lands are low and flat and the drainage is poor. Therefore, about 70 per cent of the soils of the lower Mesopotamian Plain are moderately to strongly saline and most of them have been abandoned.

Basrah province is located in the extreme south of the Mesopotamian Plain. Before the 1950s the province was one of the most important agricultural areas in Iraq. This importance has decreased gradually during the last three decades as the province has been developed as an industrial and commercial area, while the cultivated area has decreased continuously due mainly to increasing soil salinity. In 1958 the cultivated area in the province was 278,149 donums; this had decreased to 184,864 donums in 1980.(3) Soil salinity has caused not only abandonment of the land but also a decrease in crop yield and consequent low profits. Therefore, large numbers of the agricultural labour force have migrated from the rural lands to the urban areas seeking non-agricultural jobs from which they can obtain higher wages.

In considering the problem of soil salinity, irrigation, the artificial application of water to soil for the purpose of crop production, and drainage, the disposal of excess water from soil to provide healthy conditions for plant growth, are of paramount importance. This thesis aims to analyse the factors affecting the irrigation and drainage systems in Basrah province and to show the effects of these systems on soil salinity and crop yield. The subject of this thesis has been chosen for the following main reasons:

1. A personal wish to investigate the effects of irrigation and drainage practices on shrinkage of agricultural land in the province as noted by the author throughout his life in the province.

2. A familiarity with irrigation and drainage systems, obtained through many field visits to different parts of the province undertaken since 1968.

3. A demonstration for the first time in detail of the complexity and variety of the irrigation and drainage systems in this relatively small region which is often regarded as homogeneous.

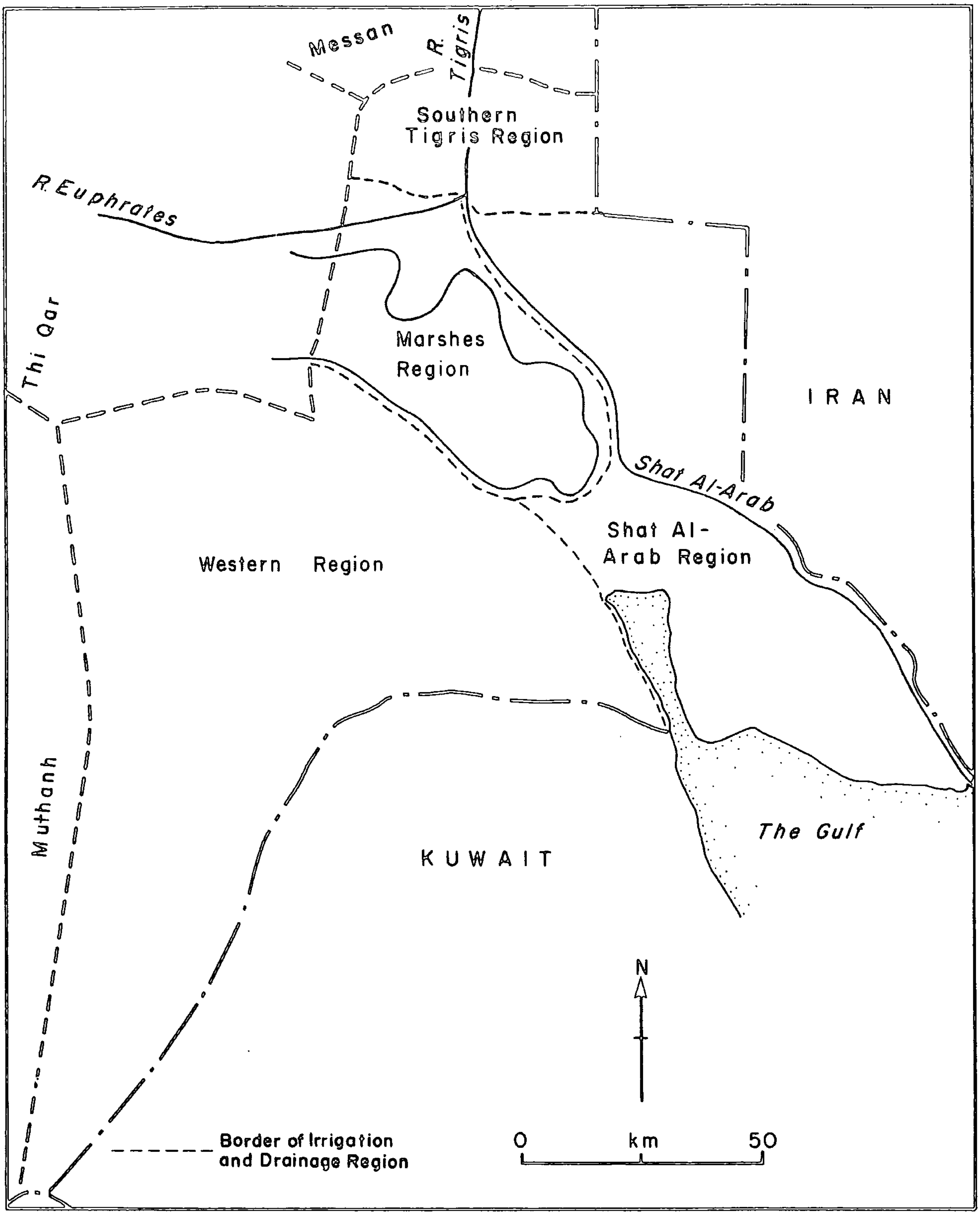
4. Recognition of the need to know the theoretical water required and the actual water applied to farms in the province to identify the scale of water wastage, this in relation to the present deficit of water resources in Iraq.

5. The provision of a more coherent geographical background to the irrigation and drainage systems as practised in the province for the planners and engineers developing the agricultural area with the object of increasing food production to meet the needs of the growing population in the province and the country.

Because of insufficient rain in the province agriculture in the eastern part of the province depends on surface water diverted from the lower sections of the Tigris and Euphrates as well as from the Shat Al-Arab river, all of which pass through the province, (see Fig. 0.2). In the western part where surface water is absent, agriculture depends entirely on the groundwater.

Basrah province can be divided into four regions on the basis of the differences between the irrigation and drainage systems practised in the province. These regions are the Western or Zubair, the Southern Tigris, the Marshes and the Shat Al-Arab, (see Fig.0.3). To deal with these regions the thesis will be divided into six chapters. The first chapter will be devoted to a discussion of the general physical aspects of the province as relevant to irrigation and drainage. These include geological developments, stratigraphy, topography, climate, soil, vegetation and water resources. Since there are three irrigation and drainage systems in the province dependent on irrigation water from the Tigris, Euphrates and the Shat Al-Arab, the second chapter deals with the hydraulic aspects of Iraq as a whole to show their effects on the quantity and quality of water available in the province. Included in this is a discussion of a) the surface water resources (Tigris and Euphrates) in terms of discharge, quality, suspended sediments, lakes and marshes, dams and reservoirs and irrigation and drainage in Iraq and the future of surface water resources; and b) the groundwater resources - levels, flow and quality. The other four chapters will deal with the irrigation and drainage systems in the province's sub-regions; the Western region, the Southern Tigris region, the Marshes region and the Shat Al-Arab region, (see Fig.0.3). In each of the four systems the water conditions - surface and ground waters - their availability and suitability for irrigation purposes will be considered. Following this the soil conditions will be dealt with - with reference to both the irrigated and abandoned soils. The irrigated soils will be discussed in terms of their physical and chemical properties and their suitability for irrigation. The abandoned soils are dealt with after the discussion of the irrigation and drainage system in each region; this is because abandonment is a consequence of soil salinisation, which in turn is a result of the practising of irrigation in each region. Management as a factor

Fig. O·3 Irrigation and Drainage Regions in Basrah Province



affecting the irrigation and drainage systems will be evaluated on the basis of the socio-economic and educational status of the farmer in each region to show his ability to regularise the relationships between water, soil and plant. The crops will be discussed in terms of their types and growth stages in order to show their influences on the distribution system, consumptive use and water supply. The influence of the climate will be emphasised in the consumptive use. Natural vegetation will be dealt with only where it grows profusely and has an effect on the irrigation and drainage practices, as in the Marshes and the Shat Al-Arab regions. These provide a basis for the consideration of the distribution systems, the design of and layout of the irrigation canals. The theoretical water requirements, consumptive use and leaching requirement - and the actual amount of water applied are then discussed in order to show the differences between them. Next, drainage conditions will be considered. Each system is evaluated on the basis of irrigation water efficiency and its effects on soil salinity and crop yield. Finally, the abandoned soils will be investigated as providing evidence of the results of practising a given system. It was impossible for a single research worker to undertake an individual study of all the farms in the province's regions; instead, following extensive reconnaissance, a sample farm was chosen in each region. These sample farms were selected as being typical of average conditions - farm size, distribution system, water supply and crops.

The irrigation and drainage systems in Basrah province have never been the subject of detailed study, the present work therefore can be considered as the first comprehensive study of the irrigation and drainage systems in the province. Some previous localised investigations have been carried out on the water and soil conditions such as those by T.A.M.S. Co. in 1957 in small areas of the province, Nippon Koie Co. in 1972 on the Shat Al-Arab region, and the last carried out in 1977-1978 by Polservice Co. also on the Shat Al-Arab region, where relevant the consequent data has been used.

Unfortunately, the continuing war conditions in Iraq, affecting in particular Basrah province, have posed many obstacles to the collection of field data concerning the irrigation and drainage in the province. The author has therefore had to supplement his own research from the other few data sources wherever suitable. Most of the available statistical data in this field concerned Iraq as a whole, a little deals specifically with the province and none is obtainable on the specific irrigation and drainage regions. Some official but unpublished data have been obtained from government offices. Unfortunately, not all the meteorological data ideally required for this study were available. There are only two meteorological stations in the province, the first, in the Western region, providing only limited data on temperature and precipitation, the other at Basrah near the location of three of the irrigation and drainage regions, provided sufficient data and was considered sufficiently reliable for calculating the consumptive use in these regions.

Thus, due to the difficulties above mentioned, field work became an essential source for this study but also associated with several difficulties. For example, some parts of the province were inaccessible due to the war conditions. In addition, transportation was difficult in the Marshes and Western regions.

The author has also drawn on work carried out as an undergraduate and member of staff at Basrah University (since 1968 and 1975 respectively). In 1981 and 1982 field visits enabled the collection of soil and water samples (which were analysed at Basrah and Baghdad Abu Graib laboratories), the direct measurement of irrigation systems, the selection of sample farms and extensive interviews with the farmers.

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and see

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CHAPTER 1

THE PHYSICAL CHARACTERISTICS OF BASRAH PROVINCE

The physical characteristics of the province are considered here in relation solely to their relevance to irrigation systems. They include geological structure and stratigraphy, topography, agroclimatology, soils, vegetation and water resources.

Geological factors affect the groundwater resources, soil properties and topography. There is a relationship between the topography and the irrigation and agricultural operations, soil drainability and groundwater resources, whilst soil characteristics are clearly relevant to the irrigation operations. Agroclimatological aspects are especially important in terms of precipitation effectiveness, the consumptive use of water by plants and water losses. Water resources govern the availability of irrigation water for crops.

These factors are discussed in general in this chapter and some, such as soil conditions, water resources and vegetation which have direct effects on the irrigation operations will be further analysed in Chapters 3,4,5 and 6.

1.1 GEOLOGICAL DEVELOPMENT

It is believed that in the Permian age the territory now included in Iraq was submerged by the Tethys Sea, which was surrounded by old land masses, Anatolia to the north, Arabia to the south and west and Iran to the east. These land masses represented small and large tectonic plates which were slowly moving in relationship to each other. Organic skeletal remains were deposited as horizontal layers of calcareous sediments on the sea floor, later forming limestones, interspersed with coarse detrital sediments from the adjacent land masses which constituted the shales and sandstones.[1]

During the beginning of the Mesozoic and Tertiary Eras, many geoanticlines and geosynclines were formed in the marine deposits due to epeirogenic movements. Consequently, from zones where the geoanticlines were rising, an immense quantity of sediments were carried by erosional processes to the geosynclines.[2]

During the Miocene age, tectonic movements compressed the sedimentary formation between the above mentioned land masses and caused a rapid rise of land and mountain building in the east and north of what is now Iraq. As a result further detrital sedimentation occurred in the remaining marine depression.[3] The Western region of Iraq (now the Western Desert) which forms the northern extension of the Arabian plate has been relatively unaffected by these tectonic movements whilst the area between the north-east mountains on one side and the resistant Iranian plate on the other was further depressed in a broad geosyncline. This area (now the Mesopotanian plain) continued to receive immense quantities of erosional products from the adjacent high lands.[4]

In the Quaternary Era, Pleistocene and Holocene periods, the sea which occupied the geosyncline transgressed and receded several times. During transgressions layers of coarse sand, marls and limestones were deposited in a marine environment, whilst during recessions sand, gravel and conglomerates were deposited in continental dryland conditions. These depositions, on balance, forced the sea to recede gradually southwards, leaving many islands, shoals and lagoons. The water in these depressions became more and more saline as a result of evaporation and then dried up. Thus layers of salts, gypsum and limestone were deposited in the trough.[5]

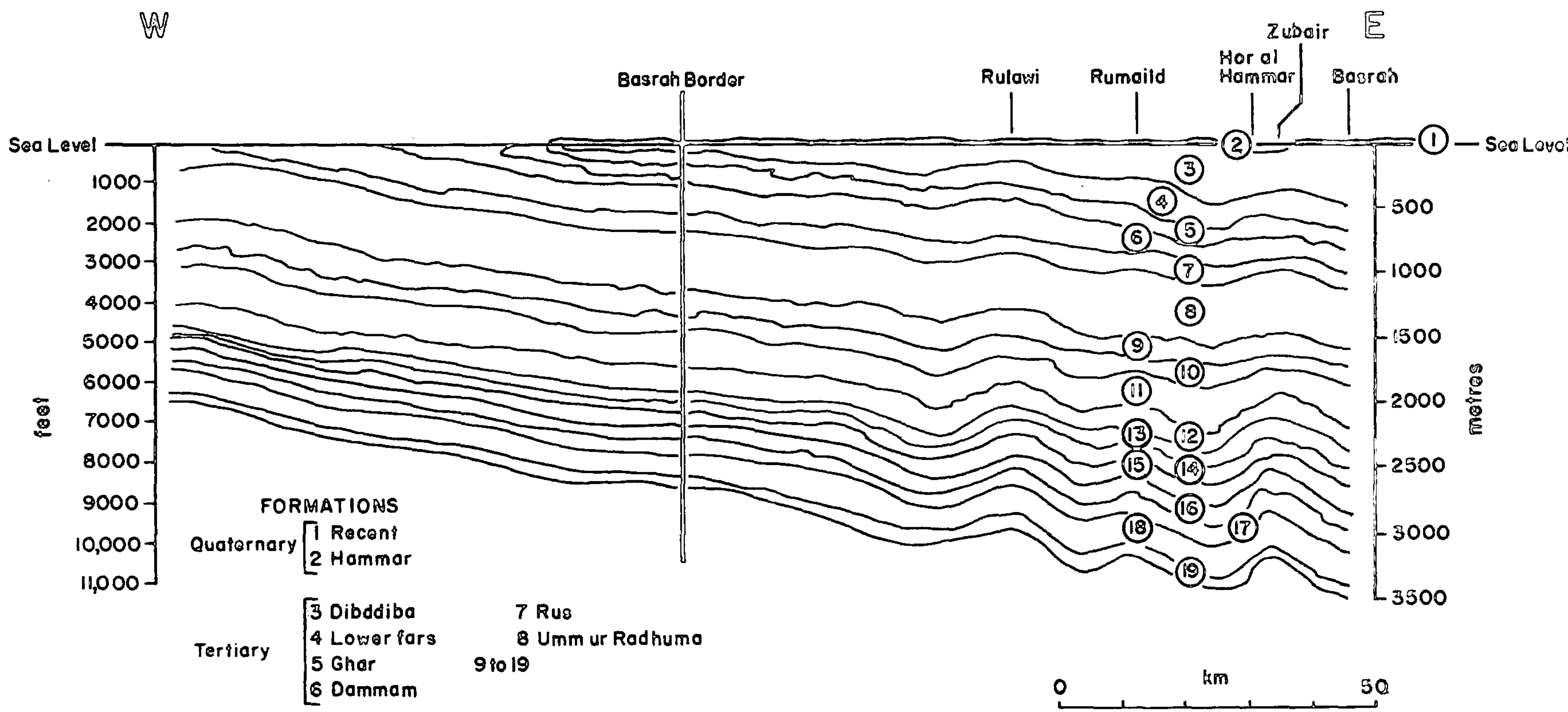
Consequently, the Mesopotamian Plain has finally been built up by the river by deposition of alluvium such as sand, clay, silt and gravel which overlie the earlier sedimentary sequence. These river deposits have been brought by the Tigris, Euphrates, Karkha and Karun, in addition to those carried by floods from the Western region during rainy periods, and also wind carried silts and sands.

The origins of the lower Mesopotamian Plain and the marshes are in dispute. Before 1952 many geologists, archaeologists and geographers agreed that the plain occupied a former northern extension of the Arabian Gulf which had been filled by sediments carried by the above rivers, valleys and winds, forming a large delta which extended rapidly into the Gulf. This sedimentation process caused the Gulf to gradually recede southwards. As for the Hammar Marsh, it was believed to have been separated from the northern part of the Gulf by a bar formed by the Karun delta from the east and the Al-Batin Valley sediments from the west.[(6)]

However, a different interpretation of the origin of the lower Mesopotamian Plain and the marshes was put forward by Lees and Falcon (1952) [(7)] who emphasized that the plain has been built up by sedimentation processes in a tectonic basin which occupied the former geosyncline. They stressed that subsidence is the dominant geological process behind the plain formation : it is not just a static depression being filled by river sediments, but it is the long continued subsidence which has allowed the sedimentation to continue. They maintained also that the Hammar marsh is a specific synclinorium, formed by slight synclinal movements which cause sedimentation to continue in this area. Figure 1.1 illustrates some of the synclines and anticlines, particularly in the lower layers, which appear on the surface as shallow depressions and slight rises.

Geologically, Basrah province occupies both the southern part of the lower Mesopotamian Plain in the east and the more and longer

Fig. 1·1 GEOLOGICAL SECTION ACROSS SOUTHERN IRAQ



Source: Al-Naqib, K. M., Geology of the Arabian Peninsula and South Western Iraq. Geological Survey Provision Paper 560, plate H elevated lands of south western Iraq (see Figure 1.2). Both zones have the same basic stratigraphical makeup except for the fact that the most recent sediments are restricted to the eastern part as will be shown later.

1.2 STRATIGRAPHY

The most important formations in the province are those deposited during the Tertiary and Quaternary eras because (a) they are exposed in the western part of the province and (b) some of them contain important aquifers.

The Tertiary formations (oldest-youngest) are as follows (Figure 1.1) :

1.2.1 Umm Ur Rudhuma Formation

With a thickness of between 396 and 487 m this is found at a depth of between 910 and 1,366 m and lies at depth in all areas to the west of the Euphrates and the Shat Al-Arab rivers. It was deposited during the Eocene to Pliocene periods in a neritic environment,[8] and therefore consists of anhydritic, dolomitic and marly limestones. It is generally permeable in character and contains groundwater which varies in quality according to its detailed composition. It frequently contains sulphur, gypsum and phosphate that consequently affects the groundwater quality.

1.2.2 Rus Formation

This overlies the above formation at depths ranging from 820 to 900 m and with a thickness of between 75 and 200 m. It was deposited during the Eocene when the sea was transgressing. This formation consists of anhydrites and limestones with some slate and marl,[9] and varies from region to region in aquifer potential.

1.2.3 Dammam Formation

This is found covering the Rus formation at depths between 600 and 800 m and with a thickness of 180 and 250m, outcropping in the west of the province in a zone some 200 km wide. Its age ranges to the Middle Eocene, and it consists of dolomitized limestone and shales. It therefore has a porous character and is considered as a good aquifer i.e. containing groundwater resulting from recharge by rain water which percolates downwards.(10) However, its water contains salts and sulphur which are the result of the solution of materials by the percolating water.

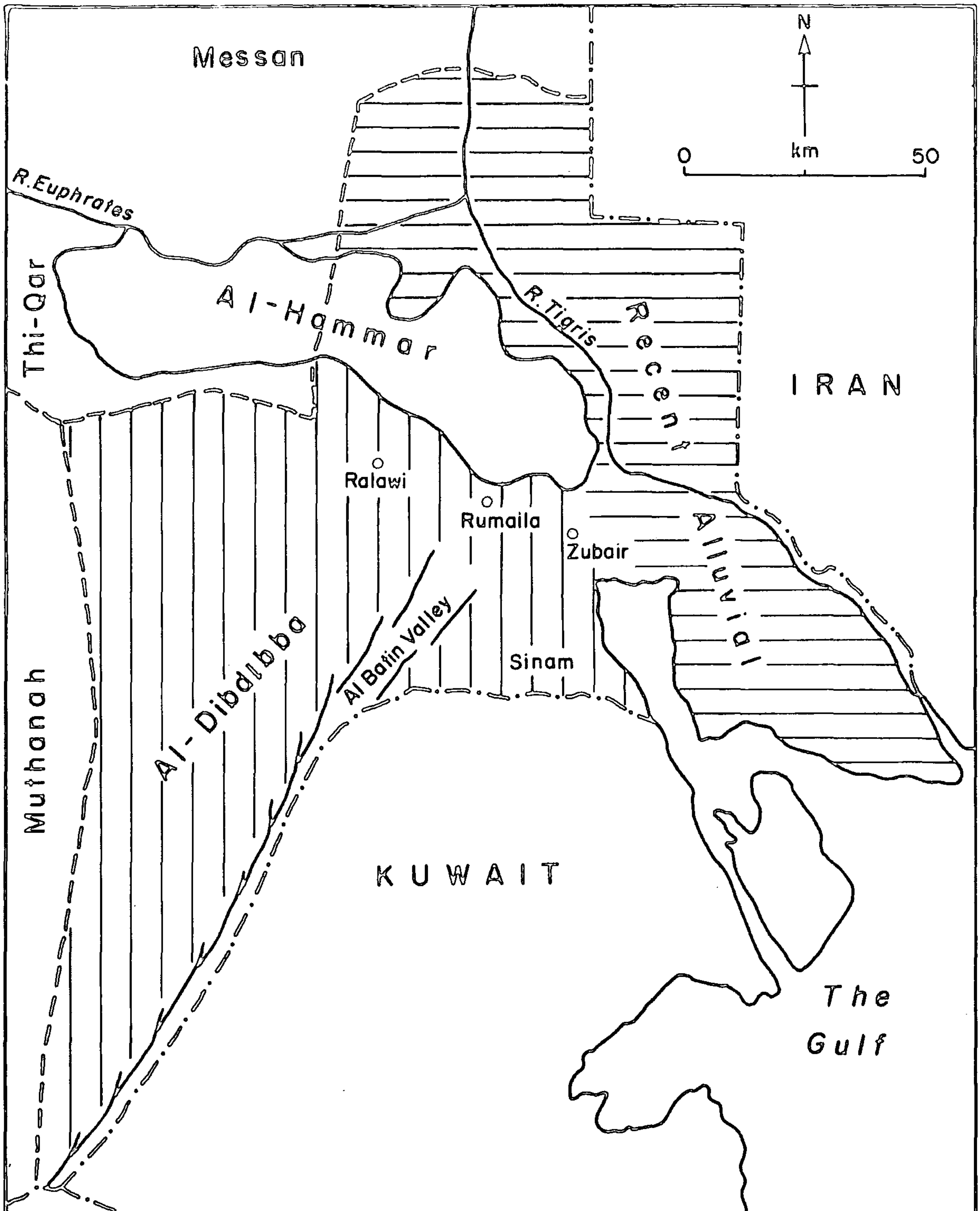
1.2.4 Ghar Formation

This overlies the above formation and is found at depths ranging from 460 to 590 m and with a thickness of between 90 and 170 m, which increases southwestwards. This formation is exposed in the west of the province. Its age ranges between the Oligocene and Low Miocene eras. It was deposited near the sea shores during its transgression on the area under discussion and therefore it consists of coarse sand, pebbles with locally a calcareous cement : sandy limestone, clay and anhydrite giving it a permeable character which allows water to flow.(11)

1.2.5 Lower Fars Formation

This overlies the previous formation at depths between 330 and 640 m and with a thickness of between 100 to 300 m. This formation outcrops in the west of the province and was depositedduring the Middle Miocene in a restricted basin forming a sea-arm, consisting mainly of mudstone, gypsum, limestone, clay and sand.(12) Consequently it has a porous property and can contain groundwater.

Fig. 1·2 SURFACE GEOLOGICAL LAYER



Source: Al-Naqib, K.M. Op. cit. p. 560, plate I.

The Quaternary formations are as follows:

1.2.6 Dibdibba Formation

Figure 1.2 shows that this formation extends over a large area in the western part of the province, while it underlies the recent sediments in the eastern part. Its depth ranges from ground surface to 360 m. the depth increasing towards the east and it also slopes in the same direction. This is a continental formation eroded and redeposited by surface flows from Arabia during the period from the Miocene to the Pleistocene.[13] It consists mainly of sand and gravel with subsidiary clay, silt and occasional calcareous and gypsum. Because of the high porosity of this formation, large quantities of water may percolate through and be stored. Its groundwater flows in accordance with the general slope towards the Shat Al-Arab and the Euphrates.[14]

Some specific geological features in the Dibdibba Plain should be noted, such as the Jebal Sinam and Wadi Al-Batin. As for the first, it is a symmetrical anticline affected by erosional processes and consisting of limestone, gravel, gypsum, marl and a little clay which were deposited during the Jurassic to Pleistocene ages, and formed by a slight anticline movement.[15] The Al-Batin valley was formed by water erosion during the pluvial periods in the Quaternary era. It slopes with the same gradient as the Dibdibba Plain.

1.2.7 Al-Hammar Formation

This is restricted to the eastern part of the province, it overlies the Dibdibba formation and underlies the recent river alluvia. Its thickness averages 4 m and it is found at a depth ranging from 6 to 12 m. It consists of clay and shale in the upper 2 m and sand and silt in the lower depths. These were deposited in recent periods.[17]

1.2.8 Recent Alluvium

This formation covers all the land surface of the province to a maximum of about 7 m depth. It is formed from deposits brought by the Tigris, Euphrates, Karkhah and Karun rivers, as well as by other water flows and wind action. The deposition processes which began in recent times are still continuing at present. Generally, silt, clay and sand have been deposited in the eastern region and mainly sand in the western region. (18)

From the foregoing it is apparent that most of the formations in Iraq were deposited in a marine environment and that they consist mainly of limestone and contain a high percentage of salts, whilst the others deposited in continental conditions consist of coarse sediments. The subsurface formations in the province contain salts and they have a permeable character and include groundwater. However, the surface formations consist of coarse sediments in the western part of the province and finer deposits in the eastern part. Accordingly, the province consists of two main geological regions : the Western region, which is covered mainly by sands and slopes from west to east, and the Eastern region which is covered by the alluvial sediments, silt, clay and sand, and slopes from north to south. All the above mentioned strata have been affected by slight anticlinal and synclinal movements. These movements and the river deposition processes have dominated the formation of the present topography.

1.3 TOPOGRAPHY

It has been stated that the geological development has resulted in a characteristic of flatness and low altitude of the land surface in Basrah Province. But although the tectonic movements have allowed continuous sedimentation processes without significant changes on the land surface, these processes had important local variations which have had effects on the drainage and agricultural activities.

Topographically, two regions in the province can be recognized, coincident with the geological regions, see Chapter 1.2., These regions are as follows (see Figure 1.3) :

1.3.1 The Western Plateau Region

Also called the Zubair Desert, this region occupies an area of more than 50% of the total 19,070 km^2 area of the province.[19] The eastern boundary of this region is represented by the contour line 6 m above sea level; the elevation of this region increases to 244 m in the west and south west (see Figure 1.4). Thus, the land generally slopes gently to the east and north. The land surface is generally flat but some subdued features and undulations can be distinguished. They result from local differences in the underground structures and erosional processes.[20] Some shallow wide depressions can be noticed in this region such as Safwan, Najmy, Berjsiyah, Rumaila and Arfajia. These generally have axes which dip slightly to the north and north west and have interior drainage. These depressions play an important part for agriculture in this region because in them the groundwater table is near the surface.

There are, in addition, several poorly defined ephemeral and shallow valleys which were formed during periods of heavy rain when rain temporarily exceeded infiltration rates. These valleys originate in the relatively higher parts and, following the general and local slopes, terminate in the depressions. The most important valleys are Al-Batin, Muwailhat, Al-Luwaihidh and Shaikh. The largest of these is the Al-Batin which originates in Central Arabia and running to the north east, terminates in the Berjsiyah depression,(see Figure 1.3).

Fig. 1·3 TOPOGRAPHIC REGIONS

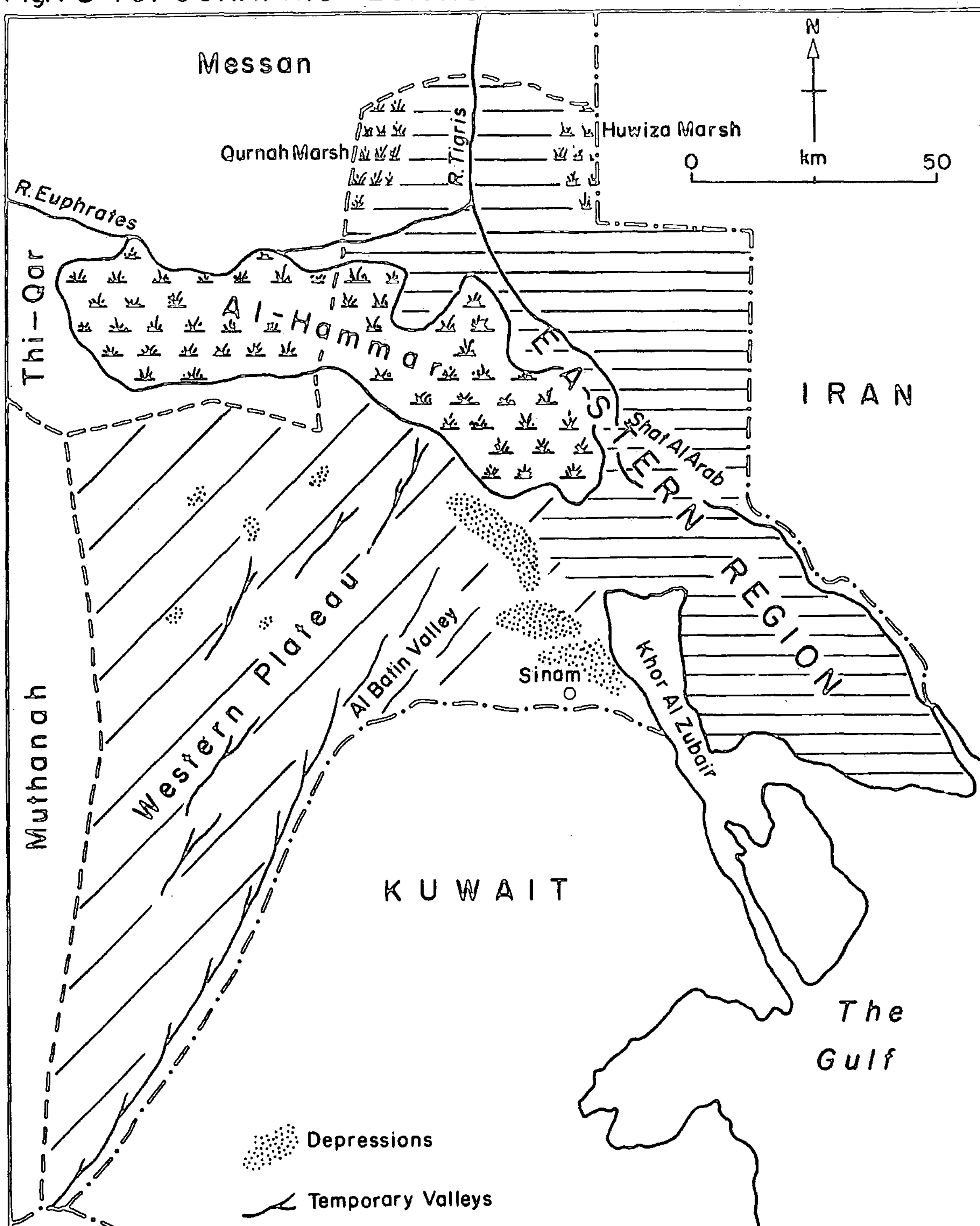
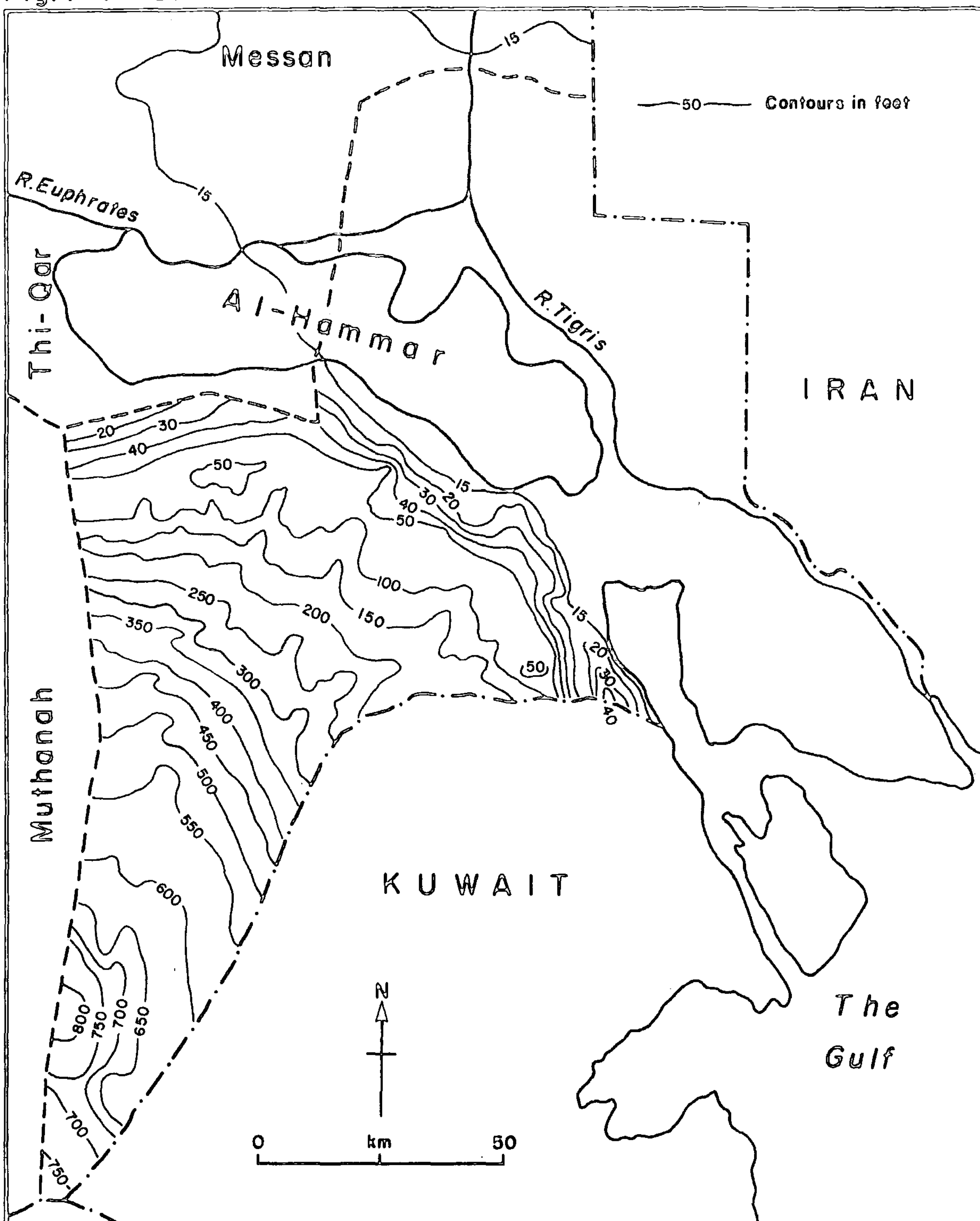


Fig. I·4 CONTOUR LINES



Source: Iran, Iraq, Kuwait map, produced by GSGS in 1947, June 1942, No. H-38L

It drains an area of $1,295,000\ km^2$, [21] and in width ranges from 2.5 to 13 km. The associated water flows contributed to the deposition of the Dibdibba formation.

Low anticlinal ridges with gentle slopes border the depressions with axis which dip to the north and north west. Also isolated subdued hills can be noticed and these have slight declivity and an elevation of less than 5 m. The highest hill in the region is Jabel Sinam which is located just near the Iraqi-Kuwaiti borders and appears as an inselberg or a solitary hill with an elevation of 156 m a.s.l.

1.3.2 The Eastern Lowland Region

Occupying the southern part of the Mesopotamian Plain it is characterised by low and flat topography and slopes from 4 m. a.s.l in the north to less than 2 m in the south. This is due to the decreased amounts of sediments carried by the Tigris, Euphrates and the Shat Al-Arab in this direction. Its slope is about 1 in 1000.[22] In addition there is a slight slope from the river levees to the surrounding lowland areas.

Based on topographical features, this region can be subdivided into three distinct units as follows (see Figure 1.3).

1.3.2.1 The Hammar Marsh : this is the most prominent physical feature in the region. It consists of the eastern part of the Hammar marsh which is located within Basrah province. This part is composed of temporary and permanent marshes which extends in the flood season and shrinks in the dry season. Its total area under normal conditions is about $2,000\ km^2$ of which 56% is located within the province. Its depth averages 2 m and in some places reaches 8 m.[23]

This marsh is fed by the Euphrates river and Qurnah marshes and drains its water into the Shat Al-Arab through the Germat Ali, Shafi and Omaitsh channels. This area is covered by aquatic vegetation - reeds and papyrus which grow extensively in this environment.

1.3.2.2 The Tigris Plain : this unit occupies the northern part of the region under discussion, on both sides at the lowest section of the Tigris river. It consists of the Tigris levees and the surrounding lowland areas, large parts of which are occupied by the Qurnah and Huwaizah marshes. Thus it slopes generally from north to south 4 to 2.5 m a.s.l. and from the Tigris banks to the surrounding areas 3 to 2 m a.s.l. (24) This plain is formed mainly by sedimentation from the Tigris river.

1.3.2.3 The tidal estuary plain : this unit consists of the rest of the area in the region under discussion. It includes the Shat Al Arab levées, which are affected by tidal movements, and the adjacent low areas. The western part of this plain was formed by the sedimentation processes of the Shat Al-Arab and the Old Euphrates which flowed in the western marginal area of this plain. The eastern part was formed by the Shat Al-Arab and Karun rivers. The levees are higher than the surrounding areas and they are intersected by many man-made irrigation canals.

In the southwestern part of this plain lies Khor Al-Zubair which represents the lowest and last section of the Old Euphrates before it changed its course in the 19th century to that of the present time. In addition, many shallow, swampy and salty depressions can be noted in the western part of this plain. These were fed by the flood water from the Hammar marsh, tide water from the Khor Al-Zubair and by rain.

Remains of old irrigation canals can be distinguished in the western part of this plain. These abandoned canals which date to Abbasid Age (758 to 1258 BC), (25) were excavated to join the Shat Al-Arab and the Old Euphrates and to irrigate the lands which were located between them, (see sect. 6.13).

From what has been said it can be concluded that the province consists of two main topographical regions : the western desert and the eastern lowlands. The western desert is flat, slopes from south and west to the east and north and contains some wide low depressions. The eastern lowlands consist of three regions : the Hammar marsh, the Tigris plain and the Shat Al-Arab plain. These are flat, low and slope mainly from the north to the south.

1.4 CLIMATE

Basrah province contains only two meteorological stations : Shuaiba station in the western region and Basrah station in the eastern region. However, the records of the first are restricted to temperature and precipitation, while the second provides most of the climatic data. Although these stations are only 16 km apart there are recognisable differences, particularly in precipitation, between them.

This area is affected by marine influences from the Mediterranean and the marshes in the north and the Gulf in the south, as well as being affected by the continental influences from the neighbouring Arabian, Persian and Anatolian plateaux. Thus, all the marine and continental influences seasonally affect climatic conditions in Basrah province because there are no barriers to air mass movement. Moreover, the low topography, latitudinal and longitudinal location and the distribution of the pressure centres influence the climatic conditions of the province as appears from an analysis of its climatic elements.

1.4.1 Duration of Sunshine

Duration of sunshine depends on cloud cover and Table 1.1 shows that the mean sunshine hours decrease in winter due to the onset of the rainy season. In December and January they fall to 7.1 h and 7.3 h respectively. However, the maximum hours of sunshine in these months do not drop to less than 10 hours. In summer the mean increases and reaches 11.1 h in June, due to the cloudless conditions in these months. The maximum hours in May, June and July are 13.9, 14.3 and 14.1 respectively.

1.4.2 Cloud

Table 1.2 shows that the mean daily cloud in winter months is higher than that during summer; this is due to variation in the passage of the Mediterranean depressions across the province between these seasons. These depressions increase in winter months and decrease in summer. Consequently the mean cloud in February, March and April reaches 2.5, 2.8 and 2.9 oktas* while it decreases in the summer months :June, July and August to 0.2, 0.3 and 0.2 oktas respectively.

1.4.3 Radiation

Generally, global radiation decreases in the winter months due to the frequency of cloudy days and the atmospheric turbidity which is caused by the southeastern winds that blow in front of the Mediterranean depressions. Table 1.3 shows that the global radiation reaches 482 and 513 cal/cm^2/day** in December and January respectively. It increases in summer months : June, July to 1001 and 990 cal/cm^2/day respectively due to absence of cloud

1.4.4 Temperature

It can be seen from table 1.4 and figure 1.5 that in both Shuaiba and Basrah stations the mean annual temperature is high 24.0^{o}C.

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* Okta is used in meteorological reports to describe the prevailing cloudiness, and it equals $\frac{1}{8}$ of the whole sky in the given area.

** FAO conversion 1 cal/cm^2/day = demand of 59 mm/day water.

Table 1.1 : Mean monthly sunshine duration at Basrah[1] (1941-1970)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
7.3	7.7	8.4	8.5	9.9	11.1	10.4	10.6	10.3	9.4	7.6	7.1

Table 1.2 : Total cloud (oktas) in Basrah[2] (1941-1970)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
2.7	2.5	2.8	2.9	1.8	0.2	0.3	0.2	0.2	1.1	2.6	3.0

Table 1.3 : Global Radiation (cal/cm^2/day) in Basrah[3] (1941-1970)

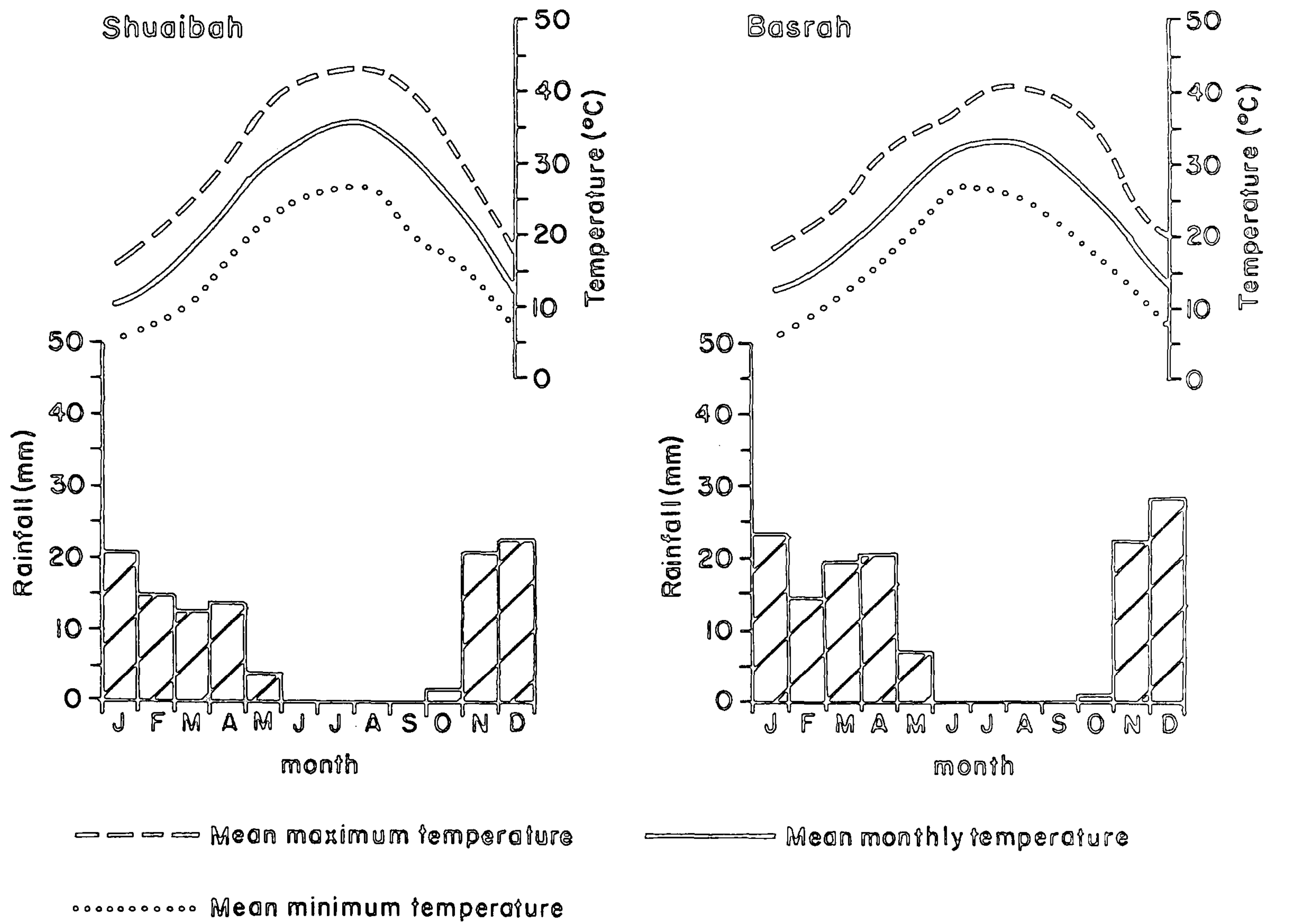
Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
513	624	770	892	974	1,001	990	923	816	679	553	482

Source: (1) Iraqi Meteorological Organization, Baghdad, Table No.4 (unpublished data)

(2) Ibid, table no.7.

(3) Ibid, table no.9.

Fig. 1·5 TEMERATURE and RAINFALL



This can be attributed to the high level of radiation together with the high sunshine hours.

Temperatures in both Basrah and Shuaiba stations are characterized by large daily and monthly ranges. The mean monthly minimum temperature reaches 17.8 and 17.0 °C respectively, while the maximum is 31.1 and 32 °C. In Basrah, the extreme minimum temperature reached - 4 °C as recorded on the 22nd of January in 1964 and the 3rd of February in 1967. The extreme highest temperature reached 50.6 and 49.2 °C as recorded on the 26th of July in 1951 and the 8th of August in 1974. The large monthly range of temperature is due to the fact that during summer the completely cloudless skies, the long days and dry hot CT (continental tropical) air masses, in association with the high radiation, intensify the high temperatures. On the other hand, in winter the relatively short days, and the predominantly cold dry CP (continental polar) air, along with low radiation bring low temperatures to the province.(26)

There are two main seasons - a hot summer and a relatively cool winter. Summer begins gradually from late April onwards and lasts until the beginning of November. The mean monthly temperature in this season is 32 °C at both Basrah and Shuaibah stations, with a mean monthly maximum temperature of 40 °C and a mean monthly minimum temperature of 23 °C at both stations. This gives a mean monthly range of 17 °C. The hottest months are July and August, in which the mean temperature is 36 °C in Shuaibah and 34 °C in Basrah stations. Autumn, a short period of about 20 days, follows with mild temperatures of around 19 °C.

Winter consists of four months from December to March in which the mean temperature decreases to about 15 °C at both stations. The mean monthly maximum temperature in this season is about 20 °C while the mean minimum decreases to about 9 °C. Thus, the mean monthly range of the temperature is 11 °C, less than in the summer. This can be attributed

Table 1.4 : Mean Monthly Temperature ^{o}C 1941 - 1970

Month	Shuaiba			Basrah		
	mean	min. mean	max. mean	mean	min. mean	max. mean
Jan.	11	6	17	13	7	19
Feb.	14	8	20	15	9	21
March	18	11	25	19	12	25
April	24	17	31	24	18	31
June	33	25	42	32	27	37
July	36	27	44	34	27	41
Aug.	36	27	44	34	26	41
Sept.	32	22	42	31	22	40
Oct.	27	18	35	26	18	35
Nov.	20	13	27	19	13	26
Dec.	13	7	19	14	8	20
Annual	24.5	17	32	24	17	31

Source: Iraqi Meteorological Organization, Baghdad, table 3 (unpublished data) to the high relative humidity and prevailing cold air masses in this season compared with those in summer. The coldest months are December and January in which the mean temperature is 12 and 13°C in Shuaiba and Basrah stations respectively. The extreme maximum temperature of 30°C has been registered, the extreme lowest, below zero, recorded in some nights in December and January. This season is followed by a short spring with relatively high mean temperatures of around 24°C.

Generally the province can be described as having high mean and wide monthly and daily ranges of temperature. This undoubtedly contributes to the increase of water losses through the intensification of the evaporation and evapotranspiration rates.

1.4.5 Pressure and winds

The different winds which blow on the province are a result of the variations of pressure values in the surrounding areas.

In winter, relatively high pressure of 1021 mbs, dominates the Anatolian, Armenian, Persian and Arabian plateaux. The lower pressure of 1019 mbs [27] extends from Syria across the province to the south of Iran. Therefore the cold air masses and the Mediterranean depressions are attacted from the high pressure areas, across the province to the lower pressure area in the Gulf.

In summer, the pressure distribution is the same as in winter but its values vary. The higher pressure of 1011 mbs dominates on the plateaux and the lower of 1003 mbs is on the Gulf. [28] The range between these pressures is 8 mbs in summer which is higher than that in winter at 2 mbs. This has an effect on the wind speed between these seasons.

Table 1.5 and figure 1.6 show that the prevailing wind on the province is the north-westerly. The mean annual frequency of this

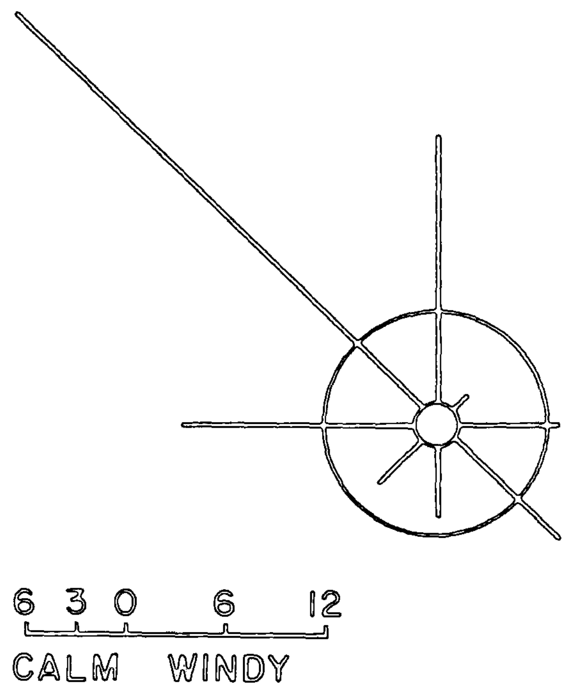
Table 1.5 : Mean monthly wind speeds (m/s) and direction frequencies for Basrah 1941-1970

Month	Mean speed m/s	Calm	N	NE	E	SE	S	SW	W	NW
						Direction				
Jan.	2.7	2.7	11.4	4.2	9.1	9	8	2.3	19.1	24.2
Feb.	3.1	9.6	11.6	4.5	7.3	11.5	9.1	2.7	17.6	26.2
Mar.	3.4	9.5	15.3	4.9	8.3	10.6	10.6	2.8	12.8	25.2
Apr.	3.3	9.4	14.1	6.1	7.9	12.0	12.2	3.7	11.4	23.3
May	3.4	9.5	17.4	4.9	5.0	3.0	7.1	2.8	11.6	36.9
Jun.	4.2	5.0	15.2	1.3	1.2	1.0	1.7	1.3	14.8	58.5
July	3.6	7.4	8.6	0.9	1.2	2.0	3.3	1.6	19.7	56.0
Aug.	3.4	7.2	10.1	1.1	2.0	2.1	3.4	2.4	17.7	54.0
Sept.	2.9	9.1	13.6	1.9	2.0	2.0	4.0	2.5	18.1	46.8
Oct.	2.4	12.3	15.5	0.7	5.7	5.9	8.7	3.1	15.1	29.1
Nov.	2.5	11.3	13.3	4.9	7.7	8.5	6.6	2.7	17.8	27.2
Dec.	2.5	12.8	1.5	3.7	7.1	8.1	6.4	2.4	20.0	28.1
Mean		9.7	13.1	3.6	5.4	6.4	5.8	2.5	16.3	36.3

Source: Iraqi Meteorological Organization, Table 9.

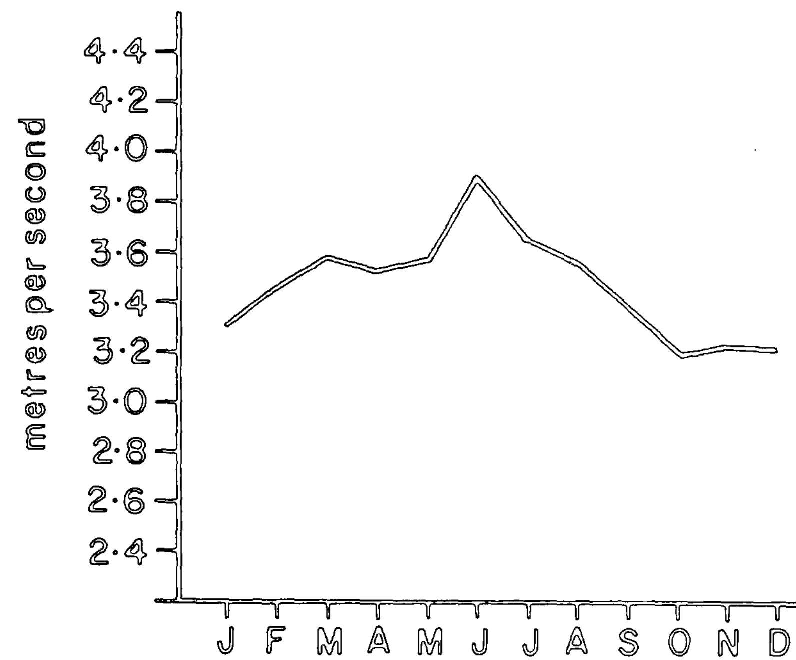
Fig 1·6 WIND

(A) Basrah Station Wind Rose



Frequency of calm % 9·7

(B) Basrah Station Wind Speed



wind is 36% of the total winds blowing on the province. This wind, called Al-Shammal, blows from the high pressure centres down to the Gulf. Therefore, it is most likely to be dry and cold in winter but it picks up some moisture when it crosses the marsh region, and it is interrupted occasionally by the Mediterranean depressions that travel to the Gulf across the province causing rain. In summer it becomes dry and hot. The westerly wind blows from the high pressure on the Arabian mass to the Gulf. So, it is dry and cold in winter and hot and dry in summer. Its mean annual frequency is 16.3%. The northerly wind is similar to the westerly wind and its mean annual frequency is 13% Frequency and speed of the above winds increase in summer and decrease in winter because the value variations between the pressure centres in winter are less than in summer as previously mentioned. The south-easterly wind, annual frequency 6.4%, blows occasionally from the Gulf to the province as a result of temporary variation in the pressure between them and it also blows in front of the Mediterranean depressions causing cloudy skies and rain and brings warmth and high humidity in winter for 1-4 days. It raises the humidity in summer.

Monthly average wind speed increases in summer and decreases in winter due to the value differentials between the pressure centres as earlier mentioned. The average reaches 3.5 m/s in summer and the highest at 4.2 m/s in June, while in winter it falls to 2.9 m/s.

As a result of the rather strong and dry winds which predominate particularly in summer along with the absence of rain, duststorms are quite common in this season with a maximum frequency during the period from June to August, in which they blow nearly every day.

The hot and dry winds, particularly in summer, contribute to an increase in water loss through evaporation and evapotranspiration. Additionally, their direction and speed have strong effects on water levels and irrigation operations in the Shat Al-Arab region (considered in detail in Chapter 6). The strong northerly winds decrease the water level of the tide and ebb in the Shat Al-Arab and then in the irrigation canals because they blow opposite to the water flow during the tide in the Shat Al-Arab. Thus, the water does not reach the marginal areas in this region efficiently enough and the drainage water is pushed into the Shat Al-Arab quickly. However, the southerly winds have the reverse effect - they push the tide water into the canals enabling it to reach the marginal areas while they disturb the excess water which drains into the Shat Al-Arab.

1.4.6 Precipitation

A Mediterranean rainfall region with rainfall maximum in autumn, winter and spring results from depressions from the Mediterranean crossing the province to the Gulf. During their passage across Iraq, the southerly winds blowing in front of them cause cloudy skies and rainfall. In summer the travel route of these depressions lies further to the north and they no longer have an effect on the country.[29]

It can be seen from table 1.6 and figure 1.5 that rainfall is confined to the seven cooler months : starting as scattered showers in October and increasing steadily until May. In this period the annual mean of the rainy days is 31 days. The annual average rainfall is 140 and 113 mm. in Basrah and Shuaibah respectively. The wettest months of the rainy season are November, December and January in which the average amount is 75.6 and 65.0 mm. in Basrah and Shuaibah respectively, equivalent to 56.8% and 57.5% respectively of the annual total. However, the remaining four months June to August are extremely dry. These low precipitation levels are insufficient for rainfed agriculture which has to be sustained by irrigation water.

Table 1.6 : Mean monthly precipitation (mm) 1941-1970

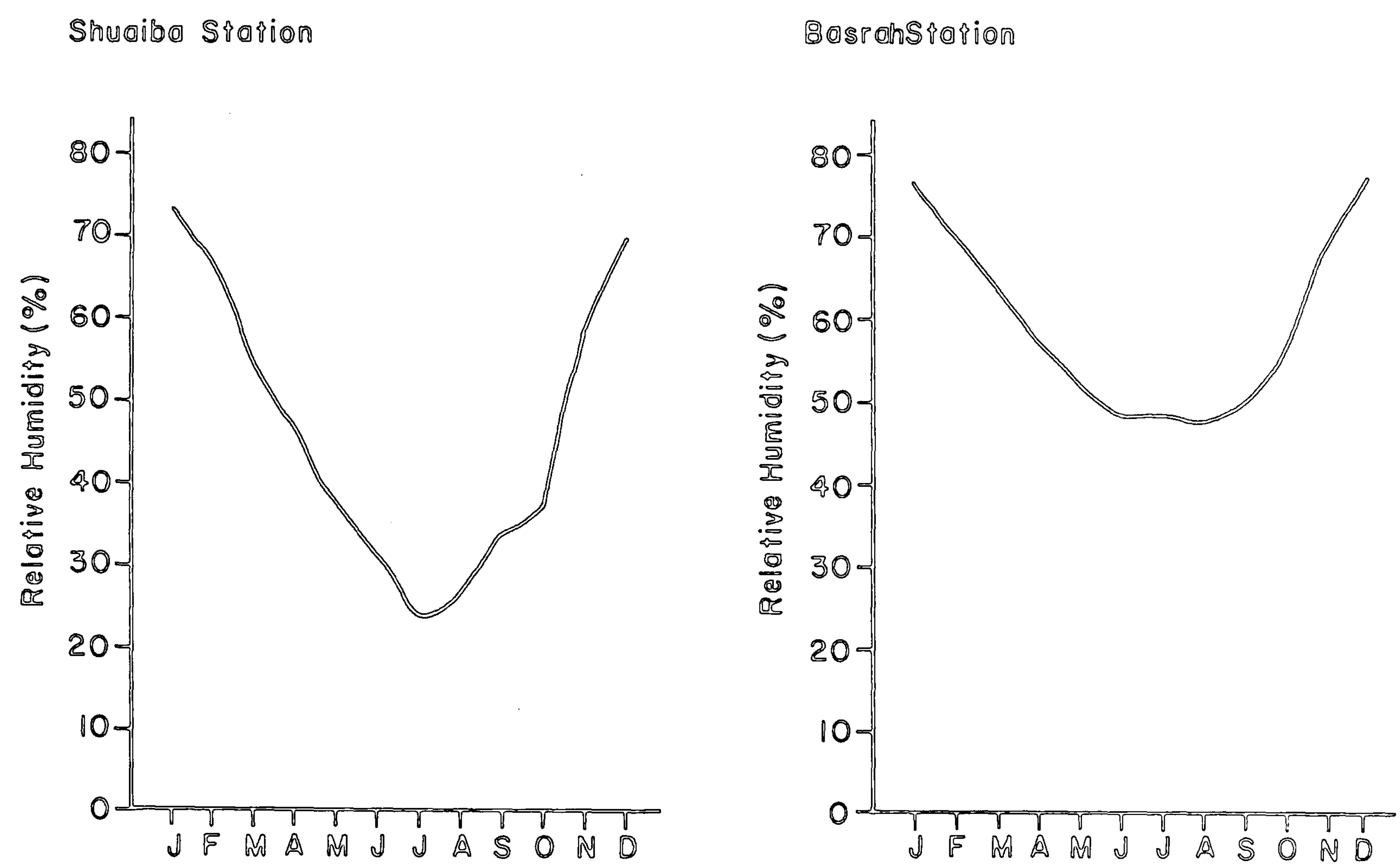
	Shuaibah	Basrah
January	21	24
February	15	15
March	13	20
April	14	21
May	4	7
June	0.0	0.1
July	0.0	0.0
August	0.0	0.0
September	0.0	0.1
October	2	1
November	21	23
December	23	29
Annual	113	140

Source : Iraqi Meteorological Organization, Baghdad, Table 8 (Unpublished data).

1.4.7 Relative Humidity

Table 1.7 and figure 1.7 show that the average annual relative humidity is generally high at 60% in Basrah station because it is affected by the marine influences from the Gulf and the marshes as well as by the vegetative areas. In Shuaibah the average falls to 45% due to the desert character of the western region. The average monthly relative humidity increases in winter to 72.5% with the highest percentage recorded in January and December due to increased rainfall, cloudiness and prevailing southerly winds. In summer the average decreases to 50.8% due to the cloudless conditions and predominantly hot-dry winds.

Fig I·7 RELATIVE HUMIDITY



1.4.8 Evaporation*

In the light of the high temperature and the rather strong dry winds, high evaporation rates are to be expected. Table 1.7 shows that the annual pan evaporation rate is 2053 mm which is equivalent to 15 times the mean annual rainfall at Basrah station. In Shuaibah the evaporation rate rises to 3679 mm (30) which is 32 times its mean annual rainfall. The monthly mean evaporation increases in summer to 1430 mm at Basrah station and the maximum mean occurs in the hottest months, June and July in which the means reach over 270 mm. This is equivalent to 2 times its mean annual rainfall. In Shuaibah the evaporation rate rises to over 300 mm in these months and this equals 3 times its mean annual rainfall.

Table 1.7 : Mean relative humidity and mean monthly evaporation rates at Basrah

Months	Mean monthly open pan evaporation (mm) * (1966-1970)	Mean monthly relative Humidity % (1941-1970)
January	65.1	77
February	90.8	71
March	137.2	64
April	186	59
May	253.2	53
June	276	50
July	282.1	49
August	263.5	48
September	201	50
October	155	55
November	78	68
December	65.1	78
Annual	2053	60

Source : Iraqi Meterological Organisation, Table No.2 and 5.

* There are no data available about the evaporation rates with the exception of 5 years (1966-70) and these cannot validly represent the statistical average from the viewpoint of meteorological studies.

In winter, the monthly mean evaporation rate decreases to 440 mm with a minimum mean of 65 mm in each of the months of January and December due to cold winds, high relative humidity and the cloudy conditions.

From what has been said it should be noted that the evaporation rates are generally high and greatly exceed the annual mean rainfall. Irrigation is therefore essential. Additionally, the high evaporation rates increase the consumptive use of water for the plants and stimulate the upward movement of the groundwater by capillary action in surface layers. Moreover, high evaporation causes an increase of salt concentration in both the soil and irrigation water.

1.4.9 Evapotranspiration

This refers to the consumptive use of water by plants and is defined as the quantity of water required to satisfy the evapotranspiration (Et) of a vegetative area. Different methods are used for predicting the consumptive use, some indicating the potential (Et) rates, whilst others measure the actual Et which may or may not be at the potential rate. Various formulae have been devised to calculate Et from standard meteorological data; however, the use of evaporation pans, class (A), is usually recommended as they give more reliable and accurate results compared with those obtained from climatic derived formulae.

Until recently in Iraq, calculation of the consumptive use has been carried out experimentally only in the central region, while in the rest of the country it has been calculated using the formulae of Thornwaite and Blaney-Criddle. However, the range of available meteorological data has recently increased, and other formulae such as Radiation and Penman have been used. This extra data, including radiation, relative humidity and wind velocity has been recorded only at Basrah Station which is located in the centre of the eastern region while only temperature and sunshine hours are presented in the Shuaibah Station which is located in the western region. Therefore, the Blaney-Criddle formulae will be used for the western region as it is suitable for the hot, arid conditions and the limited meteorological data available, while the modified Penman formula will be used for the eastern region.

The Blaney-Criddle equation is as follows:[31]

$f = \frac{t \times p}{100} \times 25.4$ where (f) is the consumptive use, (t) indicates the mean monthly fahrenheit temperature and(p) is the percentage of the day-light hours.

Table 1.8 shows that the theoretical consumptive use values vary greatly through the year. The values decrease during winter and reach the lowest at 96 mm in January, while they increase in summer and reach the highest at 260.2 mm in August. This is due to variations in the temperature and the sunshine duration,(see sect. 1.4.1 and 1.4.4)

The Penman formula (1948) has been used in Iraq in a modified form by Kettaneh and others (1974)[32] in an attempt to fit it more closely with the hot,arid conditions which prevail in Iraq. The Kettaneh modification depends on a study which was done by Gangopadhyaya and others to calculate the Et for Jodhpur, India, which has climatic conditions somewhat similar to those of Iraq. Gangopadhyaya used the Penman formular with some modifications. The original values of (a) and (b)* in the Penman formula were 0.18 and 0.55 respectively, satisfactory in U.K. climatic conditions. However, Gangopadhyaya

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* (a) and (b) values indicate the radiation coefficients.

Table 1.8 : Calculation of consumptive water use in the western region (mm)

month	t C(1)	t F	P(2)	f
January	11	51.8	7.3	96.0
February	14	57.2	7.7	111.8
March	18	64.4	8.4	137.4
April	24	75.2	8.5	163.3
May	30	86.0	9.9	216.2
June	33	91.4	11.1	257.6
July	36	96.8	10.4	255.7
August	36	96.8	10.6	260.2
September	32	89.8	10.3	234.4
October	27	80.6	9.4	192.4
November	20	68.0	7.6	131.2
December	13	55.4	7.1	99.9

Source: (1) Iraqi Meteorological Organization, Baghdad (Unpublished data) ,p.11.

(2) Ibid , ibid.

used the values 0.307 and 0.4898 for (a) and (b) respectively to be more representative of Jodhpur climatic conditions. This modification was used because the (a) and (b) values vary considerably from place to place as a result of variations in latitude and the general climatic conditions (see appendix 1.1). By comparing the actual observed total global radiation values in Iraq with computed ones using the modified values of (a) and (b), Kettaneh tested their validity for Iraq and they yielded good results. Therefore, Kettaneh suggested that use of these values in calculating the Et by the Penman formula yields better results than the other formulae mentioned above.

Penman formula is as follows : $Et = W \cdot Rn + (1-w)\, f(u)(ea-ed)$

where : w is the temperature related weighting factor

Rn is the net radiation = incoming radiation (Rns) - outgoing radiation (Rnl) in equivalent evaporation in mm/day.

Rns = (1-25) solar radiation (Rs)

Rs = (0.307 + 0.4898 n/N)Ra (modified)

Ra = extra-terrestrial radiation

n/N = ratio between actual and maximum bright sunshine hours

Rnl = f(t) f(ed) f(n/N)

f(t) = correction for temperature on long-wave radiation Rnl

f(ed)= correction for vapour pressure on long-wave radiation Rnl

f(n/N)= correction for the ratio between actual and maximum bright sunshine hours

(ea-ed)= differences between saturation water vapour pressure at mean air temperature and the mean actual water vapour pressure of the air, both in mbar.

This formula can be applied by using the meteorological data of functions as given in tables 7 to 17 in F.A.O. (1971) [33] and the results are then adjusted according to the above source to provide more accurate estimates of the potential evapotranspiration in the eastern region.

Table 1.9 shows that the mean Et increases in summer and reaches the highest value of 259.5 mm in July. The average falls in winter and reaches the lowest of 52.6 mm in January.

To summarize the foregoing it can be said that the prevailing hot and dry conditions in the province do not allow agriculture to be practised unless sufficient irrigation water can be supplied.

Table 1.9 : Mean evapotranspiration rates at Basrah (1941-1970) calculated using the modified Penman formula

month	min. RH% (1)	max. RH% (2)	wind min. m/s (3)	wind max. m/s (4)	max. hours of sunshine (n) (5)	actual vapour pressure mbar (6)	saturated vapour pressure mbar (7)	Et mm/month
Jan.	68	85.5	2.3	3.2	10.2	11.19	14.35	52.6
Feb.	60.5	80.5	2.4	3.8	11.0	11.59	16.57	78.4
Mar.	54.2	73.0	2.7	4.1	12.0	13.61	21.49	128.5
Apr.	49.2	67.5	2.6	3.9	13.0	17.35	29.92	164.7
May	45.2	60.5	2.7	3.9	13.9	22.05	41.6	221.4
Jun.	44.2	55.2	3.5	4.6	14.3	24.16	49.32	256.5
Jul.	42.5	55.0	3.2	4.1	14.1	26.0	53.05	259.5
Aug.	41.0	55.0	2.8	3.8	13.4	24.89	51.88	242.2
Sept.	42.2	57.2	2.4	3.3	12.4	21.65	43.82	193.4
Oct.	46.5	64.0	2.2	2.7	11.4	18.67	33.35	137.2
Nov.	59.5	76.7	2.1	2.8	10.5	15.41	22.33	84.3
Dec.	70.0	85.5	2.0	2.9	10.0	12.11	15.53	53.5

Source: (1) Iraqi Metereological Organization, Baghdad, Table No.2 (Unpublished data)
(2) Ibid
(3) Ibid, Table No.8.
(4) Ibid, Ibid
(5) Ibid, Table No.10
(6) Ibid, Table No.9. (7) Ibid, Ibid.

1.5 SOILS

Surface formations in the province are deposits transferred by rivers from the upper basins of the Tigris, Euphrates, Karkah and Karun rivers to an area of limestone, and by winds from the Arabian plateau. Therefore the soils are affected mainly by these formations which can be classified into two classes on the basis of the sedimentary processes and the topography.

1.5.1 Soils of the Western Region

These are formed by erosional products of the sandstone area in the Arabian plateau and are carried to this region by ephemeral streams and winds. Their parent materials contain more than 95% sand and gravel.[34] The sand content of these soils ranges from 87 to 96% with a small proportion of silt, clay, pebbles, gypsum and lime. They thus range between sandy, sandy-loam and loamy sand textures and overlie extensive areas of sandy gravel. Being generally coarse textured, they have a rapid infiltration rate, high permeability and a low water holding capacity. They are also extremely dry and low in organic matter due to the low rainfall and the scarcity of vegetation.

1.5.2 Soils of Eastern Region

They compose the southern part of the Mesopotamian Plain soils , as explained in Section 2.1. These soils are formed from the alluvium of the Tigris-Euphrates rivers, the Shat Al-Arab, Karun, Karkhah and the Old Euphrates. These soils are underlain by marine and estuarine deposits. They consist mainly of the same materials as the surface geological layer i.e. silt, clay and sand together with about 5% gypsum and 20-30% lime ($CaCo_3$).[35] Their texture is finer than in the Western region, organic matter content of these soils is generally low with the exception of the marsh soils where vegetation cover is considerable. They are deep soils formed on low gradient land and, consequently, have poor drainage with the exception of the river levees. The soils are affected by salinity and waterlogging to a varying extent due to the absence of an adequate drainage system along with over-irrigation as will be explained later.

1.6 WATER RESOURCES

Although the climate of the province is arid, there is available sufficient water for irrigation, of both groundwater and surface water.

In the Western region due to the absence of surface water the only source of water which can be used for irrigation is the groundwater. This water is more easily available in the depressions than in the surrounding higher land areas and can be found at shallow depths of about 20 m in the Dibdibba formation. It flows in the same general direction as the ground surface gradient, i.e. from the west and south to the north and east.

In the Eastern region groundwater is abundant due to its location in the lowest part of the southern Mesopotamian Plain and its low topography which helps the water to flow from the surrounding area and concentrate in this region. This water can be found at a few metres depth, and in the marsh region also the water table reaches ground level. However, this ground water is not used for irrigation due to its high salinity on the one hand and the availability of true surface water on the other.

Surface water in this region is derived from the Tigris river in the north and the Euphrates river in the marsh region, the Hammar marsh and the Shat Al-Arab. The régime of these surface flows follows the rainfall and snow melt sequence system as earlier mentioned.

Therefore river water discharge increases in the flood season which occurs at the beginning of and in mid summer, while the water discharge decreases in the dry season (see chapter 2).

1.7 VEGETATION

Natural vegetation grows in the province wherever sufficient moisture is available. Therefore, vegetation is scarce in the western region and concentrated in the depressions and the bases of the valleys where the groundwater table is shallow. It consists of shrubs scattered at low density. In the eastern region where there is water from the Tigris, Euphrates, Shat Al-Arab and in the marshes, vegetation grows at higher density and in greater variety. In the marsh and the irrigation canals in the Shat Al-Arab region it grows sufficiently thickly, particularly the aquatic species, to hinder the irrigation and cultivation operations in both regions. Shoks (Lagonyehium), alfalfa and agol (Alhagi maurorum) grow in the Tigris and the Shat Al-Arab region.

1.8 CONCLUSION

Geologically, topographically and pedologically, Basrah province consists of two main regions : the western and the eastern. The former is characterized by higher elevation, coarse formation and sandy soils while the latter is lower and consists of finer sediments and loamy soils. The western region contains some depressions which are particularly important for agricultural use. The flatness of the eastern region provides widespread suitability for agricultural activities but it has poor drainage.

Climatic conditions in the province are hot and dry, and the irrigation which is vital for agriculture depends on the groundwater in the western region and on the surface water resources - the Tigris, Euphrates, Shat Al-Arab and the Hammar marsh in the eastern region. However, temperature characteristics mean that opportunities are available to grow different types of crops in different seasons, but the general high mean of the temperature contributes to an increase in the evapotranspiration and water loss. Additionally, the high temperatures together with availability of surface water in the Hammar marsh and the Shat Al-Arab allows aquatic vegetation to flourish which is an obstacle to the irrigation and agricultural operations.

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CHAPTER TWO

HYDRAULIC ASPECTS OF IRAQ

Basrah province, located in the southern extremity of Iraq, lies at the end of a large river catchment area which includes the remainder of Iraq and some parts of Turkey, Syria, Iran and Saudi Arabia. Water precipitated in this catchment area is discharged through the province into the Gulf, in part through groundwater flow, but most importantly in relation to irrigation through the surface flows of the Euphrates and Tigris rivers, the eastern part of the Hammar marsh and the Shat Al-Arab. The water resources available and utilised for irrigation in Basrah province are,therefore,determined predominantly by hydrological factors within the catchment basin as a whole.

In this chapter therefore are discussed the hydraulic aspects of Iraq outside Basrah province such as surface and groundwater conditions, the hydraulic works and constructions, water uses and irrigation and drainage, in order to show their effect on the water resources in the province.

2.1 THE GENERAL PHYSICAL SETTING

2.1.1 Geology

As noted in Chapter 1.1 Iraq can be divided into three major structural zones as follows :

(a) The folded zone which characterizes the mountain area of the north east where strata have been strongly folded in a series of north-west to south-east oriented anticlines and synclines. The area consists of Cretaceous and Eocene limestones and shales with some Paleozoic strata exposed in the cores of eroded anticlines.

(b) The Western desert represents the north western extension of the Arabian Shield. This area has not been affected by the Miocene tectonic movements and presents a very gentle topography formed on sandstone and gravels.

(c) The geosynclinal Mesopotamian Plain in Central and Southern Iraq, is characterized by a broad structural depression of down-folded sedimentary formations associated with the tectonic movements of the middle Miocene.

2.1.2 Topography

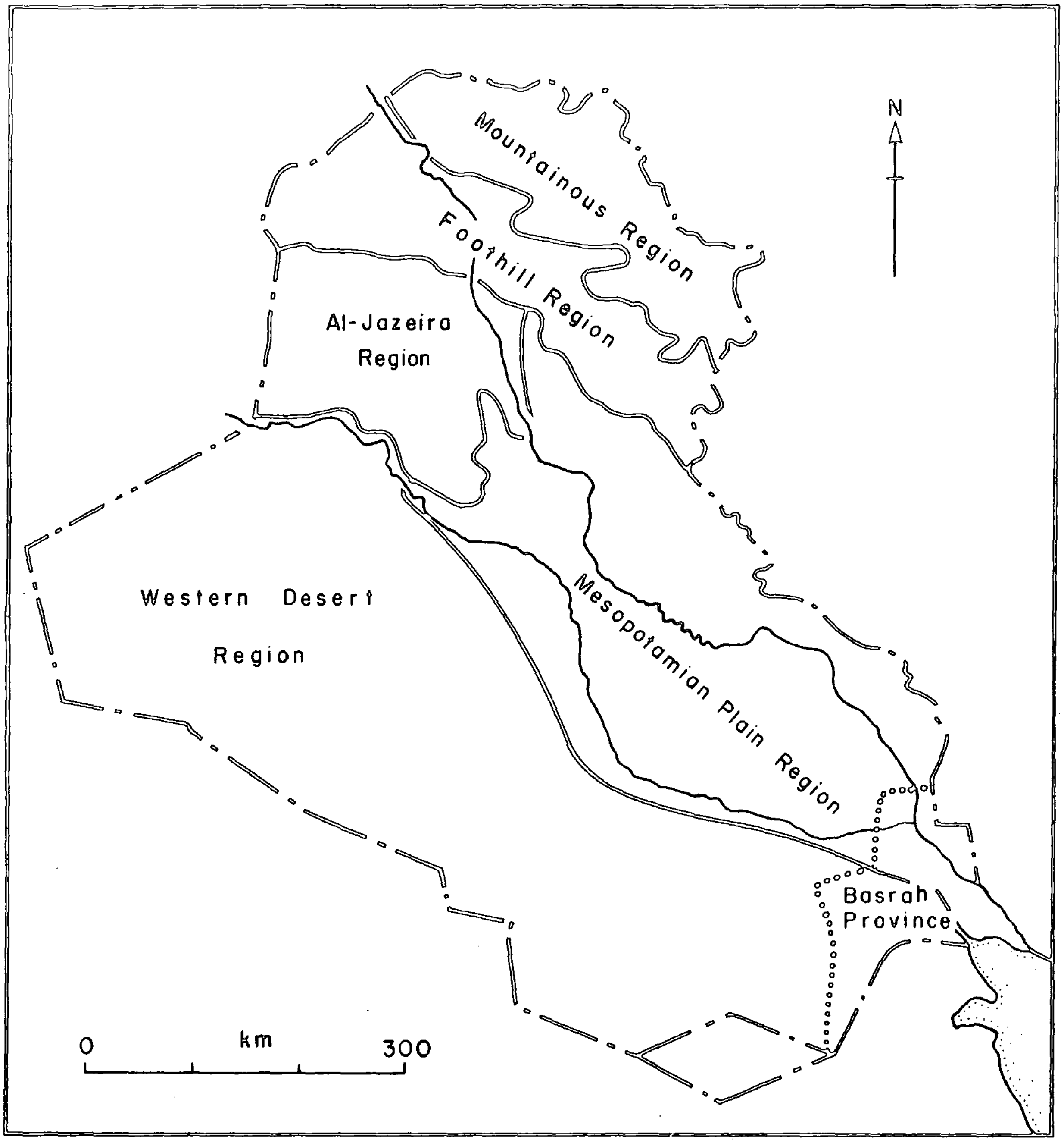
Topographically, Iraq can be divided into five distinguishable regions as follows, [1] (see figure 2.1).

2.1.2.1 The mountain region : Located in the north-east of the country has peak altitudes ranging from 2,000 to 3,600 m above sea level, the valleys situated at 500 to 800 m elevation. This area consists of a series of parallel anticlinal ranges trending north-west to south-east.

2.1.2.2 The foothills region : This is located to the south of the above region; a transition zone between the mountains in the north-east and the Jezira and Mesopotamian Plains in the south. The general elevation of the land varies from 200 m to 500 m and the area forms a fairly hilly landscape with low parallel ridges and rather extensive valleys and plains.

2.1.2.3 The Jezira region : This represents the northern section of the geosycline which is filled by alluvial sediments with considerable formations of gypsum. It is an undulating plain or low plateau, lying at an altitude of 150 to 350 m above sea level, with a number of small closed basins, the largest of which is the Wadi Tharthar.

Fig. 2.1 The Topographical Regions of Iraq



2.1.2.4 The Western desert : As the name suggests lies in the western part of Iraq. This region is a barren and monotonous plain rising in broad low steps to the Arabian plateau. It includes many shallow basins and valleys which generally slope towards the Euphrates river. This region is dominantly calcareous with recent aeolian surface deposits.

2.1.2.5 The Mesopotamian Plain : This is a vast, flat, low alluvial plain in central and southern Iraq which slopes gently from north to south. It is built up by thick layers of sediments laid down mainly by the Tigris and the Euphrates with a little admixture of wind blown deposits.

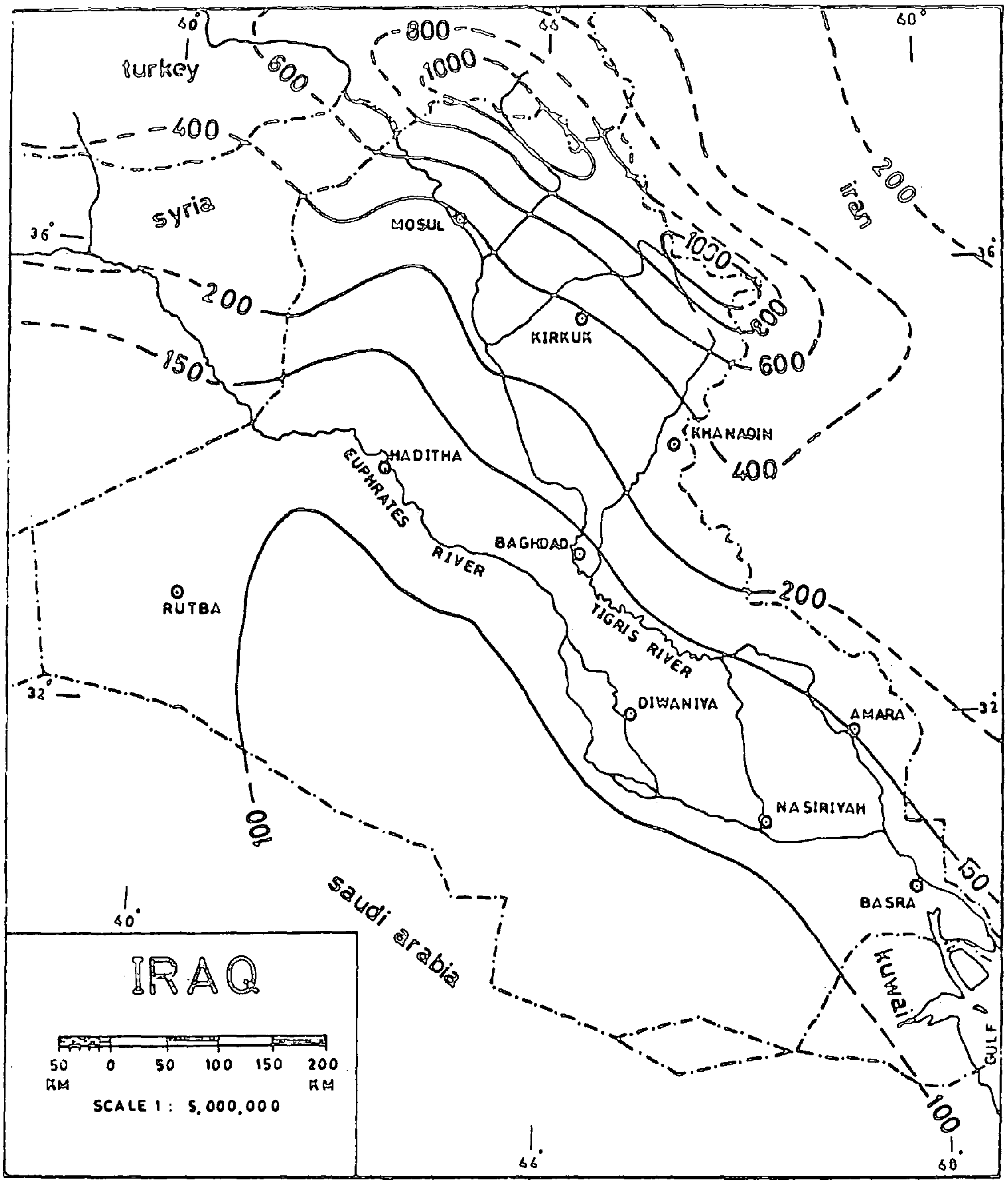
Thus the general slope of the land surface in Iraq is from the north to the south and from the west to the east.

2.1.3 Climate

The climate of Iraq is predominantly hot semi-arid, with dry, hot summers and mild winters. In summer Iraq is one of the hottest countries in the world. Generally, the temperature increases from the mountain region in the north to the lower Mesopotamian plain in the south. The mean annual temperature at Mosul in the north is 19°C increasing to 22°C at Baghdad in the centre and further increasing to 24°C at Basrah in the south. Consequently, the mean annual evaporation rate increases in the same direction from 1,000 mm in the north to about 2,400 mm in the south.(2)

Rainfall, generally associated with the passage of Mediterranean depressions is low and decreases southwards. The annual average reaches 1,000 mm in the mountain region and decreases to about 125 mm in the lower Mesopotamian Plain, (see figure 2.2). Generally, the precipitation in northern Iraq and the adjacent areas supplies the

Fig. 2.2 MEAN ANNUAL RAINFALL(mm) *based on 15 years or more data-period 1941 - 1970*



Source : UNESCO (1976) : Iraq – Contributions on Natural Resources Research, UNDP/IRQ/71/545, Paris, p. 21 twin rivers with 70% of their total inflow while the balance is provided by the precipitation in central and southern Iraq.[3] The annual rainfall varies from one year to another, for example, at Mosul, the totals were 220 and 515 mm in 1929 and 1939 respectively, and in Baghdad the totals were 44 and 249 mm in the same years respectively.

In northern Iraq, winter crops are fed by rain while the summer crops require irrigation water, whilst the lands of central and southern Iraq are irrigated throughout the year.

2.1.4 Soil

Generally, the soils of Iraq have a coarse to medium texture in the mountain region and become finer southwards due to the sedimentary processes of the twin rivers. Subsoils are more permeable than the surface soils[4] and this leads to an increase in the infiltration and percolation of the surface water through the soils and consequently leaching of the surface soils and replenishment of the groundwater.

The soils of the Mesopotamian plain, which includes Basrah province consist mainly of silt, clay and sand and attain a thickness of several metres; and given the flat low terrain they have poor drainage. They are characterized by quite strong stratification with horizontal and vertical differentiation in texture, mineral composition, structure, consistency and permeability.[5] The surface soil layers are generally not favourable for root ramification and microbial growth because of high compaction (volume weight > 1.40 gr/cm^3 and porosity less than 47%).[6] These soils contain high amounts of lime ($CaCo_3$) at 20 to 30% and lesser amounts of gypsum at 5% with a low content of organic matter at about 2%.[7] Many of these soils have been cultivated and irrigated for a long time but without adequate drainage. This, together with the high evaporation and high water table has led to an increase in soil salinity and waterlogging in the low lying areas.

2.2 WATER RESOURCES

In addition to groundwater these consist of surface water - the Tigris and the Euphrates, their tributaries, marshes and lakes.

2.2.1 Surface water

As both the Tigris and the Euphrates are the principal sources for irrigation, industrial and domestic purposes for Basrah province. Their fluvial conditions upstream have a significant effect on the quality and quantity of the water in the province.

2.2.1.1 The Euphrates River : This river rises in the mountainous region of Eastern Turkey and originates from the junction of two streams : the Korosy (western Euphrates) and Murat (eastern Euphrates). The river flows down past Keban City where it is controlled by the Keban Dam. The river then turns to the south entering Syria where it is joined by its tributaries the Belikh and Sajoor, flowing on past Tabka Dam near Tabka City. Downstream from this dam it is joined by its last tributary, the Khabour, and after that flows south eastwards to enter Iraq just below Al-Bu-Kamal City. Downstream from this city up to the Ramadi Barrage in Iraq the river flows through the western desert from which it gains periodic stream discharges.

Many irrigation distribution canals branch from the river in the Baghdad area - Saqlawiyah, Abu-Graib, Latifiyah, Yusifiyah, Eskenderiyah and Musaib. All these canals branch off from the right bank and flow eastwards and terminate in the irrigated lands. Upstream of Hindiyah Barage the river bifurcates into two channels, Shat Al-Hillah which also bifurcates into two channels, Ifaq and Diwaniyah, and Hindiyah which again bifurcates into two smaller channels : Abu Skhair and Shawiyah. The Al-Hillah and Hindiyah channels rejoin each other at Shunafiyah City, once more forming the Euphrates river,(see figure 2.3). Some 1,500 m downstream from Shanafiyah City the river again bifurcates into two channels - Sammar and Swear - which combine once more at Akhadher village. Downstream from Suq-Al-Shuokh City the river splits into five branches terminating in the Hammar marsh. The largest (the Euphrates river) flows through the northern parts of the Hammar marsh and finally joins with the Tigris at Qurna City.

The total catchment area of the Euphrates is about 289,300 km^2, extending over Turkey, Syria, Saudi Arabia and Iraq. Its total length is about 2,900 km. (8)

2.2.1.1.1 Water Discharge : The annual average discharge of the Euphrates river is about 672 cumecs at Keban Dam in Turkey. This average increases to 1,200 cumecs downstream in Syria as a result of water received from tributaries.(9) Table 2.1 and figure 2.4 shows that the annual average water discharge at Hit falls to 909 cumecs with an average annual water flow of 28.67 milliard cubic metres, both figures for the period 1932-1975. The reduction in discharge during the flow through Syria is caused by the withdrawal of water for irrigation and by losses from evaporation from the Tabka Dam. The annual average discharge of the river further decreases downstream of the Hindiyah Barrage to 593 cumecs as a result of the many irrigation canals which branch off from the river in the Baghdad area - Saqlawiyah (24 cumecs), Abu-Graib (23 cumecs), Yusifiyah (23 cumecs), Latifiyah (30 cumecs), Eskenderiyah (6 cumecs), Musaid (34 cumecs) and Shat Al-Hillah (236 cumecs). At Nasiriyah the annual average discharge has fallen to 457 cumecs, some 52% of the average discharge at Hit,(see figure 2.5).

Fig 2·3 Tigris and the Euphrates rivers

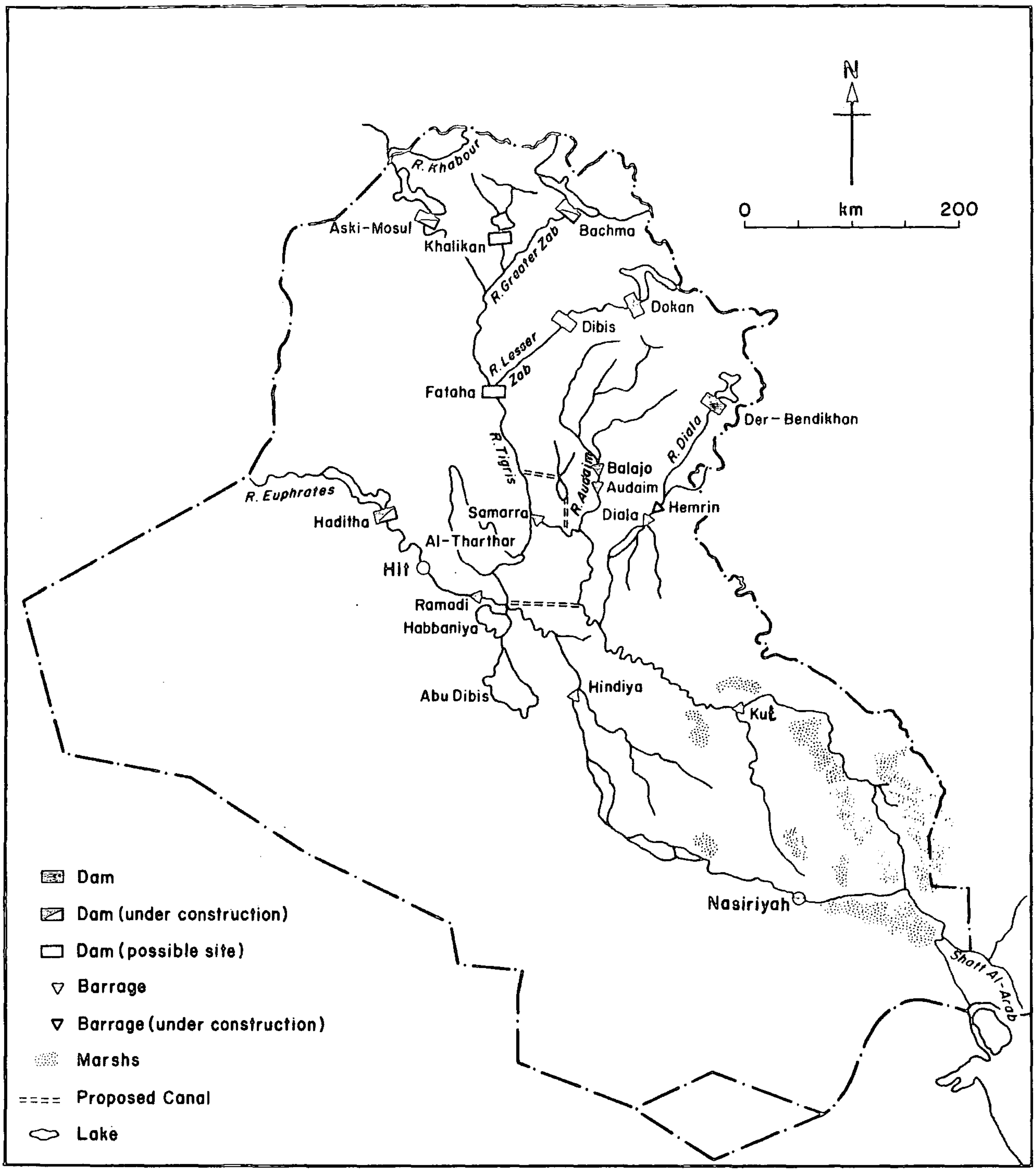


Fig 2·4 ANNUAL AVERAGE DISCHARGE OF THE RIVER EUPHRATES AT HIT, 1932-74

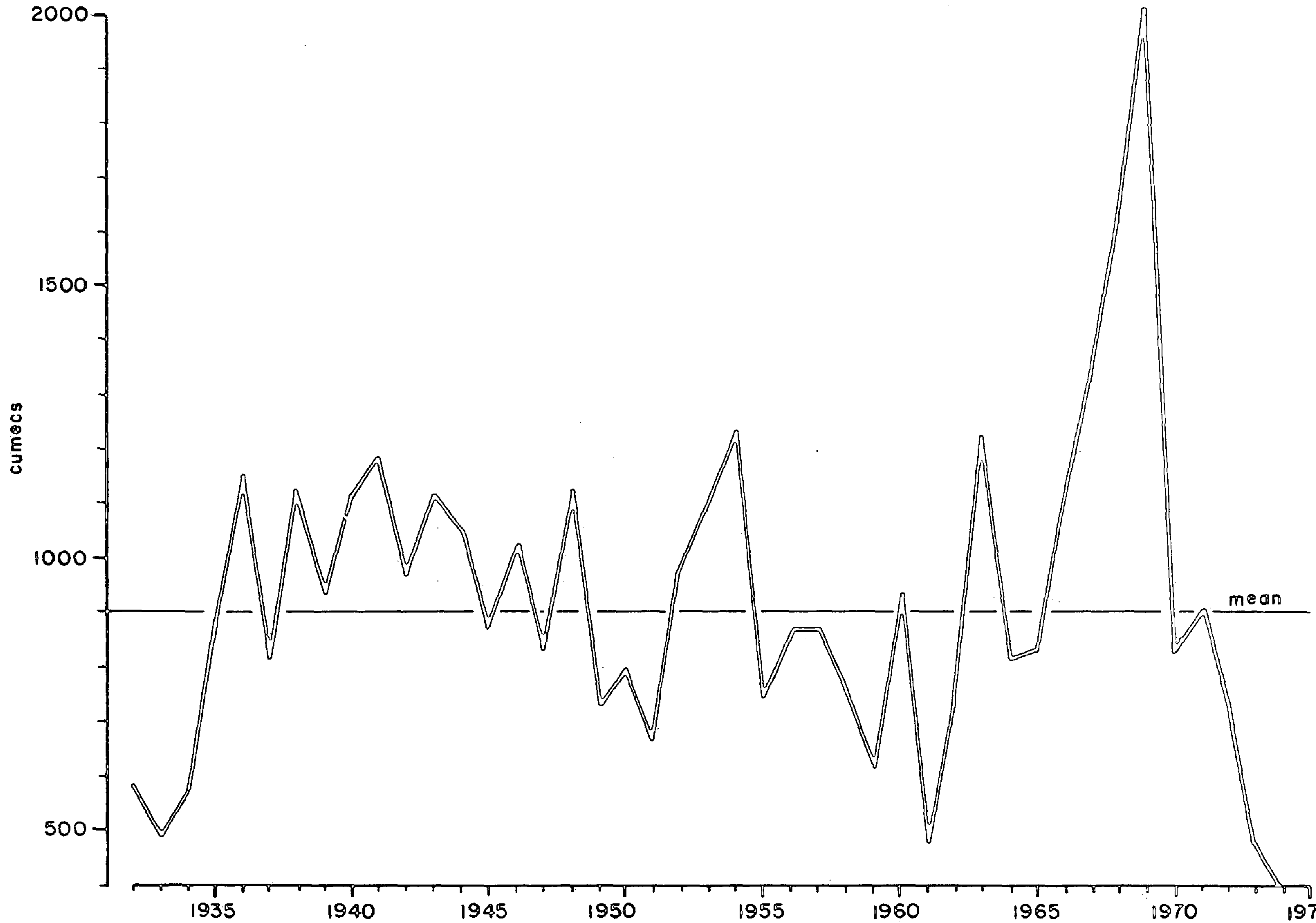


Fig.2·5 HYDRAULIC CONSTRUCTIONS AND WATER DISCHARGE OF THE EUPHRATES

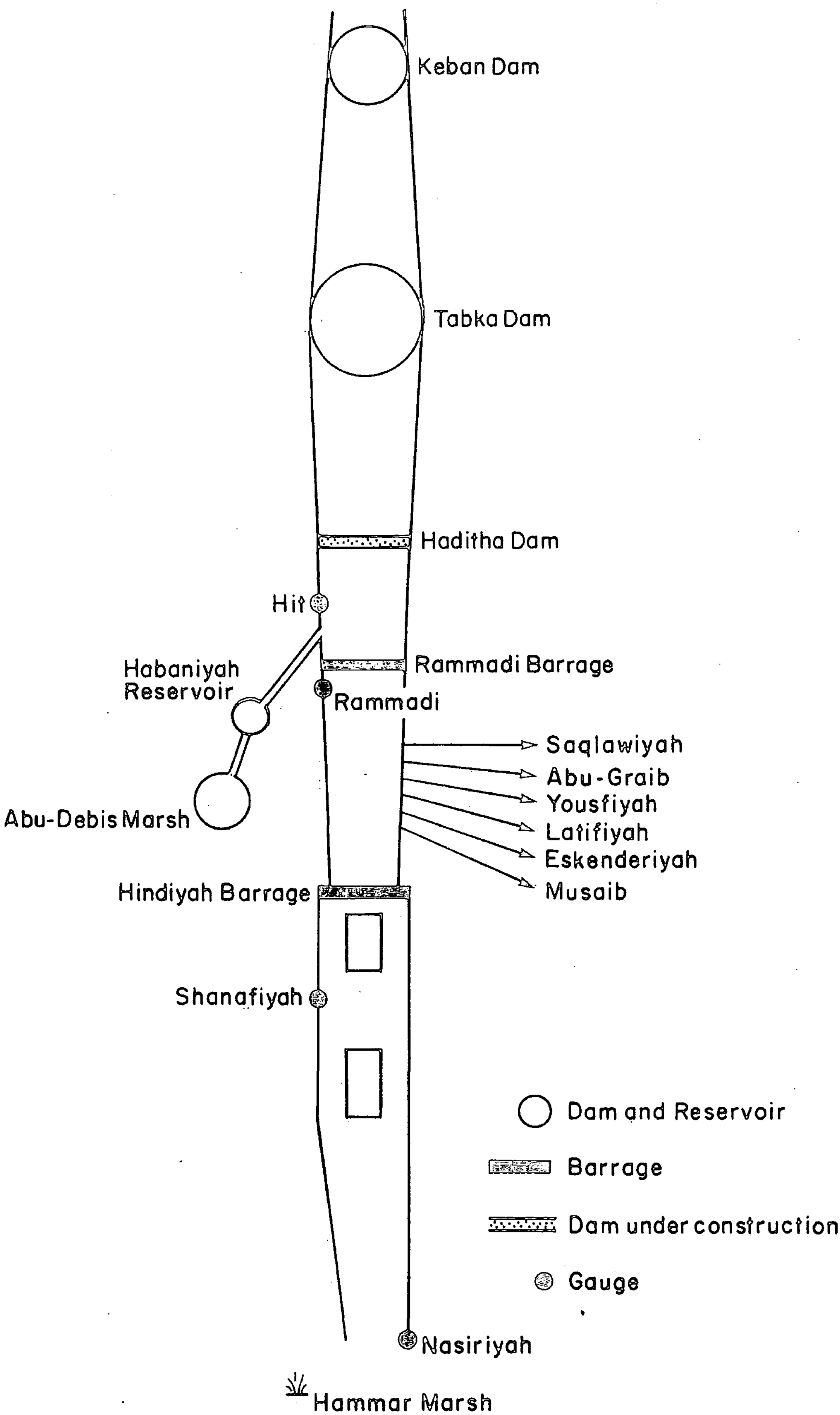


Table 2.1 : Euphrates River Discharges at Hit 1932-1975 (cumecs)

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Mean
1932	303	308	350	343	350	750	1270	1620	834	375	242	213	580
1933	232	250	270	275	313	481	501	1600	1110	443	236	215	495
1934	209	231	317	398	448	687	1530	1270	930	413	306	242	582
1935	236	341	268	681	885	1260	2560	2330	939	528	397	250	889
1936	356	747	1310	879	1140	1290	2250	2530	1630	811	519	331	1140
1937	321	382	757	525	620	1070	2080	1800	1090	558	343	275	819
1938	291	679	1090	1130	971	966	2220	3200	1450	778	461	355	1130
1939	359	491	528	731	761	1120	2000	2530	1230	685	452	375	939
1940	352	395	586	1010	1080	1270	3060	2950	1330	700	418	343	1120
1941	407	708	908	922	1300	2700	2700	2420	1040	549	303	321	1190
1942	341	417	390	603	821	1220	2640	3030	1190	451	281	238	969
1943	329	919	1210	1220	979	990	2350	2990	1190	573	376	309	1120
1944	330	482	485	666	754	1650	2250	3210	1400	622	394	359	1050
1945	374	634	513	904	726	847	1670	2120	1420	630	358	290	874
1946	304	371	574	580	656	1130	2160	3100	1660	705	463	376	1020
1947	591	612	473	870	900	1560	2080	1140	745	449	301	261	830
1948	281	549	575	554	1160	919	2560	3560	1950	749	408	349	1130
1949	356	368	495	407	542	585	1670	2200	1120	472	319	273	734
1950	283	311	355	448	354	1010	1970	2520	1130	494	311	264	789
1951	315	401	373	554	503	764	1870	1580	836	371	246	226	670
1952	399	471	576	451	1270	1140	2940	2350	1160	558	334	281	991
1953	308	343	416	537	1030	1310	3010	3110	1660	712	397	342	1100
1954	359	485	478	644	890	1630	3830	3380	1670	761	423	336	1240
1955	373	508	617	1090	706	899	1419	1720	777	340	228	228	742
1956	282	318	521	751	819	988	1750	2730	1230	558	314	269	877
1957	328	370	402	362	441	1580	1640	2690	1520	588	293	238	874
1958	300	417	649	679	644	1080	1820	1560	1140	414	219	196	760
1959	281	345	456	461	436	626	1670	1490	983	335	210	201	624
1960	308	417	390	856	615	1220	2670	2660	1050	462	283	244	931
1961	331	390	383	462	537	434	1300	1170	443	192	86	93	483
1962	223	419	882	691	939	1200	1730	1370	774	279	143	149	730
1963	250	289	452	685	1170	1240	2460	4330	2800	914	437	330	1280
1964	459	601	520	446	518	1300	2710	1560	969	349	160	175	812

Cont.

Table 2.1 (Cont.)

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Mean
1965	312	352	614	484	904	1300	2210	2090	971	401	214	187	835
1966	367	485	621	1300	2090	1490	2160	2550	1410	570	292	271	1130
1967	457	553	760	907	885	1180	2700	4880	2090	912	410	333	1340
1968	566	1020	1210	1260	1200	2400	3810	4250	2280	852	411	383	1630
1969	478	650	1540	2450	1660	2760	4660	5790	2320	875	454	404	2010
1970	585	637	639	732	895	1420	2390	1400	684	252	150	167	826
1971	309	348	660	413	368	999	3210	2320	1270	435	251	259	904
1972	375	411	511	404	399	692	1460	2240	1330	508	224	239	734
1973	329	457	412	317	340	595	1130	1280	608	192	81	89	485
1974	270	292	407	356	316	649	351	166	124	72	152	279	286
1975	276	273	277	297	291	264	259	252	334	393	356	312	299
av. cu-mecs	343	465	596	699	787	1150	2150	2390	1220	530	310	270	909
av. mill-iards	0.92	1.21	1.60	1.87	1.90	3.08	5.57	6.40	3.16	1.42	0.82	0.70	28.67

Source : Republic of Iraq, Ministry of irrigation, Directorate General of irrigation, Discharges for selected stations in Iraq, Baghdad, 1976, p. 48.

This is due to the extensive withdrawal of water for irrigation, as well as the water losses by seepage and evaporation along the river course.

2.2.1.1.2 Annual Water Regime : Table 2.2 shows that the annual cycle of the river water régime has two pronounced periods : first, the flood period between November and July with a flow of about 9,987 m^3, about 91% of the Euphrates annual flow. In this period the flood hydrograph has a multi-peaked character. Secondly the low water period between August and October during which only 9% of the annual run-off of the river is discharged.[10] Figure 2.6 shows that the average water discharge starts to increase from the beginning of November until May due first to the winter rainfall and later to the snow melt in the highlands. The flood peak most often takes place in April, May or more rarely in June. The mean monthly discharge of the river at Hit during April and May is 2,150 and 2,390 cumecs respectively, and the total water discharge of these two months is equivalent to 41% of the annual total discharge at this station. The average discharge decreases during the remaining months as a result of the absence of rainfall and disappearance of mountain snow. The

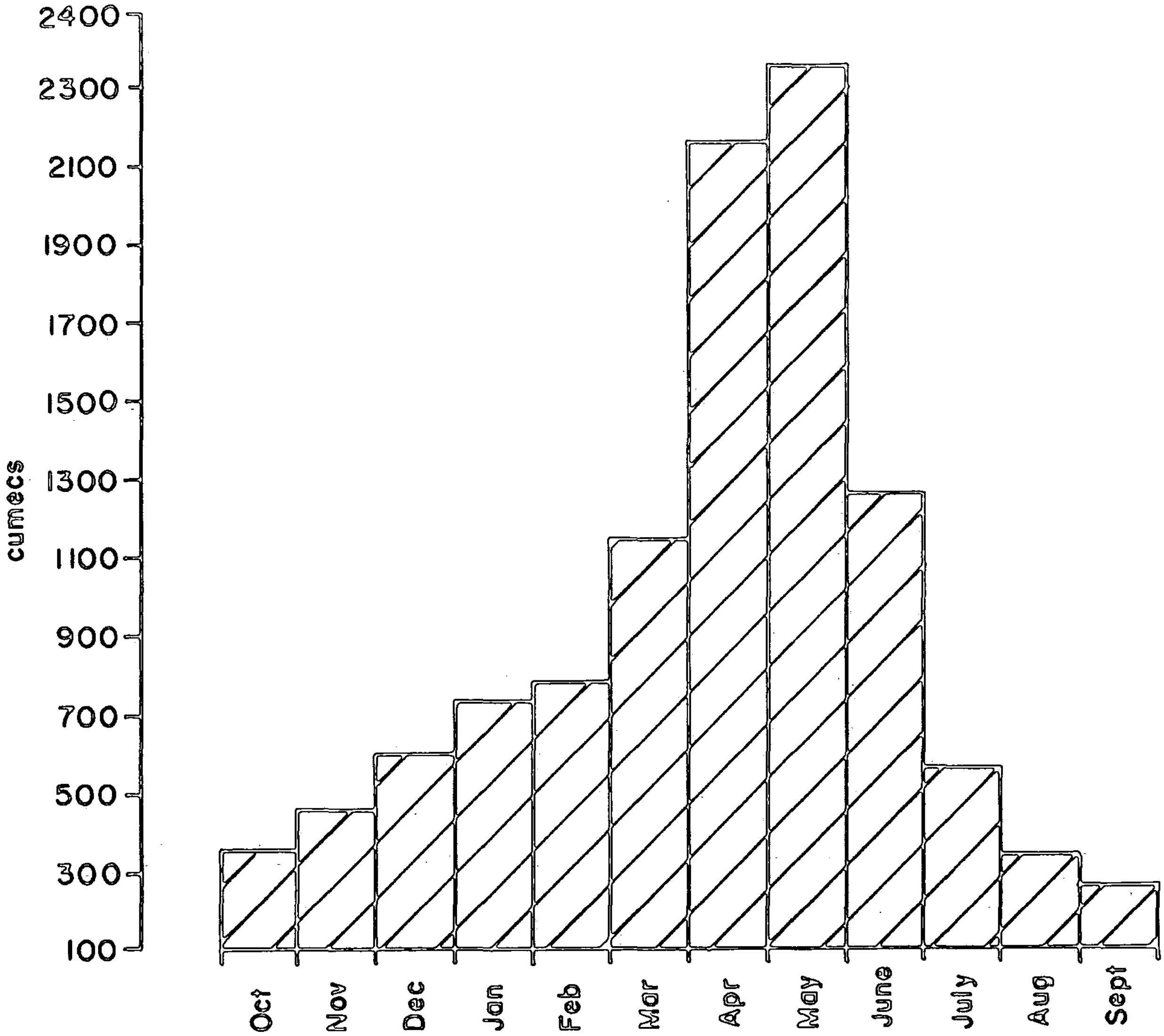
Table 2.2 : Mean monthly discharge of the Euphrates river 1932-1975 (cumecs)

gauge	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.
Hit[1]	343	465	596	699	787	1150	2150	2390	1220	530	310	270
Nasiriyah[2]	215	225	280	388	430	529	761	997	896	373	192	192

Source : (1) Ministry of Irrigation, op.cit., p.49.

(2) Ministry of Irrigation, General Establishment for Studies and Design, The Shat Al-Arab project, Polservice Co., Basrah, 1978, p.11.

Fig 2·6 MEAN MONTHLY DISCHARGE OF THE EUPHRATES RIVER 1932-1975 AT HIT GAUGE



river flow in this period comes from groundwater seepage, the remaining snow melt in the upper basins as well as from reservoirs such as Keban, Tabka and Habaniyah.

The natural river regime is clearly further distorted in the lower section of the river because of extensive water withdrawals for irrigation and partial runoff regulation by Habaniyah reservoir and other barrages. This is in addition to the natural regulation of a part of the flood runoff by marshes and depressions such as Baher Al-Najaf, Sahib, Najim and Abu-Hejar located on both sides of the river. Therefore, the flood peak of the Euphrates river at Nasiriyah takes place in May and June,(see table 2.2). The average water discharge at this gauge during these months is 997 and 896 cumecs respectively. The total discharge in these two months forms 34% of the annual water discharge at the same gauge.

Although the average annual discharge of the Euphrates river at Hit is 909 cumecs, decreasing to 457 cumecs at Nasiriyah, actual discharge is characterized by considerable fluctuation depending on the amount and type of precipitation in the upper basins. The maximum water discharge recorded at Hit reached 2,010 cumecs in 1969, double the annual average. Other years in which the water discharge was significantly higher than the annual average were 1954, 1963, 1967 and 1968. The discharge in so-called dry years such as 1933 and 1961 is less than the annual average. However, river discharge also fell in 1974 and 1975 due to the filling of the new reservoirs in Syria and Turkey as well as extensive water withdrawal for irrigation for new agricultural projects in these countries. All these fluctuations have had considerable effects on surface water volume and quality in Basrah province as will be explained in following chapters.

2.2.1.1.3 Marshes and lakes which occupy the natural depressions and low lying areas play various roles in the hydrology of the river. Since they receive water both from the river and from irrigation canals they act as reservoirs storing the flood water and providing the river with water in the low water season . In this respect the following lakes and marshes are important:-

a) Habaniyah lake is located to the west of the Euphrates and south west of Ramadi City and occupies a large depression some 25 km long and 12 km wide.(11) It is used for flood control and provides the Euphrates with water during the low water seasons.

b) Abu-Debis marsh extends to the south of Habaniyah lake and drains excess water from the lake.

c) Hammar marsh is located in the northern part of the Basrah province and south east part of the Thi-Qar province. It has a total area of about 5,200 km^2 in the flood season and shrinks in the dry season into two parts - the western in the Thi-Qar province and the east in the Basrah province. It is supplied with water mainly by the Euphrates river and partially from the Tigris river. It drains its water into the Shat Al-Arab river through the Euphrates, Omatish, Shafi and Germat Ali channels.

These marshes and lakes also have indirect effects on the water discharge and quality of the Shat Al-Arab and the last section of the Euphrates, as will be explained in following chapters.

2.2.1.1.4 Hydraulic works and structures : These constructions not only regulate flow and control floods but also affect downstream water quality through evaporation and abstraction and consequently the water quality and quantity of the last section of the Euphrates and the Hammar marsh within Basrah province. The four major structures influencing the Euphrates flow are as follows:-

a) Keban Dam and Reservoir are located on the Euphrates river in Turkey at a point 10 km downstream from the junction between the Murat and the Korosy. They were constructed in 1973 to supply irrigation water and to generate electricity. The total capacity of the reservoir is 3.61 milliard cubic metres and the annual average evaporation loss is some 0.6 milliard cubic metres.(12)

Additionally, the Turkish government plans to construct another three dams and reservoirs on the river. The first, Kara-Kayah, was begun in 1975 and the other two will be constructed during the next 40 years to irrigate an area of 2.8 million donums.* In addition, new agricultural projects in Turkey, involving 3.2 million donums will require about 10 milliard cubic metres per year from the Euphrates river.(13)

b) Tabka Dam and Reservoir are located on the Euphrates in Syria at Tabka village. They were completed in 1974 with a total storage capacity of 11.9 milliard cubic metres in the first stage. Improvements to them are under construction and these will be completed in 1985 at which time the total storage capacity will be raised to 18 milliard cubic metres. They are being constructed to provide 9.6 milliard cubic metres of irrigation water a year for an area of 20 million donums of cultivable lands.(14) The annual amount of evaporation loss from the reservoir is estimated at 1.5 milliard cubic metres.(15)

The hydraulic constructions and irrigation projects which are planned in Turkey and Syria will certainly affect the amounts of water entering into Iraq. The annual average runoff from the Euphrates at

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* Donum = 2,500 m^2

Hit during the 1932-75 period was 28.67 milliard cubic metres, and this will decrease to 15 milliard cubic metres by 1985.(16) Consequently, the water quantity and quality of the Hammar lake and the last section of the Euphrates will be adversely affected.

c) Haditha Dam and Reservoir : The Iraqi government started, in 1975, to construct the Haditha dam and reservoir near Haditha City to redistribute the seasonal water discharge of the river. This should be completed by 1984. Its storage capacity will be 9.8 milliard cubic metres; evaporation losses will be 1.5 milliard cubic metres per year.(17)

d) Habaniyah Reservoir : This is used to store the flood water from the Euphrates through Warar canal upstream from the Ramadi Barrage. Its total storage capacity is 3.34 milliard cubic metres and the evaporation losses are about 0.5 milliard cubic metres per year.(18) Since the reservoir capacity is often less than the whole surplus flood water, the excess water is diverted by the Majarah canal into the Abu-Debis depression.

Because the water discharge of the Euphrates falls during the dry season the Tharthar-Euphrates canal was excavated in 1976 to maintain river flow.

2.2.1.1.5 Water quality The electric conductivity of water Ec is very important in determining the irrigation water quality. Its importance stems from the correlation between the total soluble salts in irrigation water and soil solution on the one hand and plant growth on the other hand. Table 2.3 shows that the average Ec values at Hit is 0.600 mmhos/cm, this increases southwards and reaches 0.976 mmhos/cm at Nasiriyah. This average varies from season to season according to the water discharge i.e. increases in the dry seasons and decreases in the flood seasons when more fresh water is discharged. At Hit it reaches 0.776 and 0.470 mmhos/cm in the above seasons respectively. At Nasiriyah the average reaches 1.386 and 0.640 mmhos/cm respectively.

Table 2.3 : Water quality of the Euphrates 1967-1969

Gauge	EC mmhos/cm			SAR me /L		
	Dry season	Average	Flood season	Dry season	Average	Flood season
Hit	0.776	0.600	0.470	1.5	1.0	0.5
Nasiriyah	1.386	0.976	0.640	3.5	1.7	1.0

Source : Hanah, O.B. and Al.Talabany, K. Water qualities and their types in Iraq, First Technical Conference of the Arab Agricultural Engineers, Khartoum, 22-27 Dec. 1970, Baghdad, 1970, p.13 (in Arabic)

The U.S.D.A. Salinity Laboratory has classified irrigation water as follows:(19)

Class 1 Low salinity : < 0.250 mmhos/cm

2 Moderate salinity : 0.250 - 0.750 mmhos/cm

3 Medium salinity : 0.750 - 2.250 mmhos/cm

4 High salinity : 2.250 - 4.000 mmhos/cm

5 Very high salinity : 4.000 - 6.000 mmhos/cm

6 Excessively high salinity > 6,000 mmhos/cm

Thus, the water at the Hit gauge is classified as having moderate salinity (Class 2) while at the Nasiriyah gauge it is of medium salinity (Class 3).

The sodium adsorption ratio (SAR) of the Euphrates water at Hit averages 1.0 me/L, increasing in the dry season to 1.5 me/L and decreasing in the flood season to 0.5 me/L. The average SAR increases at Nasiriyah to 1.7 me/L, it decreases in the flood season to 1.0 me/L and increases in the dry season to 3.5 me/L. According to the U.S. Salinity Laboratory Staff (1954) [20] classification of water quality from the viewpoint of SAR and Ec values, (see figure 2.7) the Euphrates water is classified as having a low sodium hazard, (Class S1). The increase of the Ec and SAR values of the Euphrates water southwards is due firstly to the increasing amounts of drainage water which are discharged into the river and secondly, to the high evaporation along the course and in the reservoirs as well as increased flow of saline groundwater into the river.

The pH value ranges from 7.8 in the upper section to 8.0 in the lower reach.

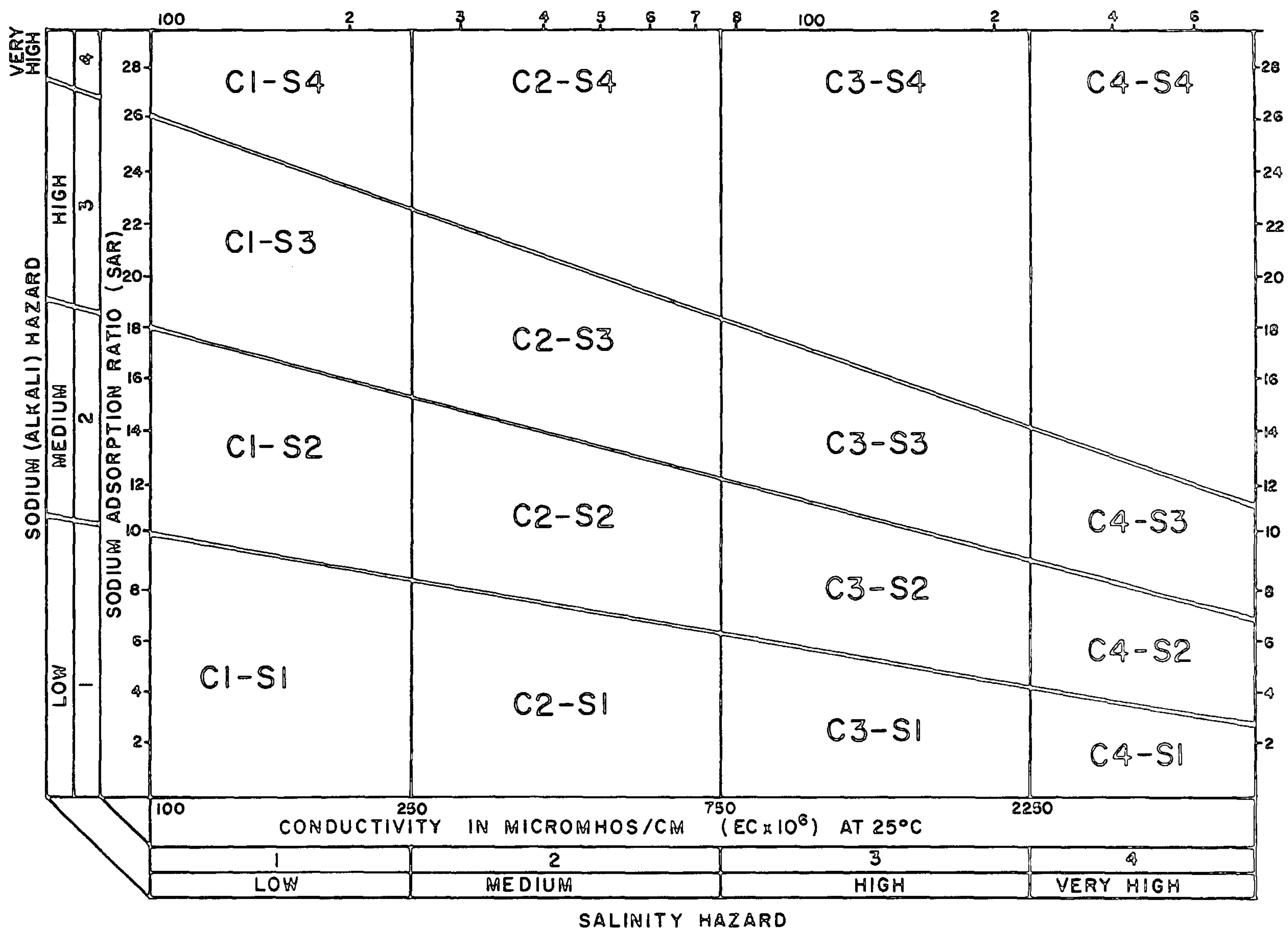
At Hit the predominant cation is calcium at 2.8 me/L while the predominant anions are sulphate and bicarbonate at 2.8 me/L,(see table 2.4). At Nasiriyah the predominant cation is sodium at 4 me/L and the highest anion is chloride at 4.6 me/L.

Table 2.4 : Soluble salts in the Euphrates water (me/L)

Gauge	Na	Ca	Mg	Cl	SO_4	HCo_3
Hit	1.7	2.8	2.3	1.9	1.8	2.7
Nasiriyah	4.1	3.3	3.3	4.6	3.1	2.8

Source : Hanah, O.B and Talabany, K. op.cit. p.14.

Fig. 2·7 CLASSIFICATION OF IRRIGATION WATERS WITH REGARD TO SODIUM AND SALINITY HAZARDS



Source: U.S.D.A. Handbook No. 60 op. cit., p-80

2.2.1.1.6 Suspended Sediments : The Euphrates water has relatively high turbidity. Table 2.5 shows that the annual average discharge of suspended sediments at Hit is 55 million tons. This has a seasonal variation according to variations in the water discharge. The total amount discharged in the flood season is equivalent to 80% of the annual amount and the highest quantity occurs in April and May at 22.44 and 15.75 million tons respectively. This falls in the low-water season to 0.06 million tons in September. The sediment load decreases downstream due both to deposition from river water in the irrigated lands which are located along its course and in the Habaniyah lake. The annual average therefore decreases to 11.4 million tons at Nasiriyah gauge, (see Table 2.5).

Table 2.5 : Suspended sediments of the Euphrates (million ton) 1933-1970

Gauge	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul	Aug.	Sep.	Oct.	Nov.	Dec.	Total annual
Hit	4.07	2.64	5.39	22.44	15.75	1.76	0.55	0.22	0.06	0.94	0.88	0.33	55
Nasiriyah	0.15	0.15	1.46	1.7	0.7	0.5	0.06	0.01	0.01	0.2	0.2	0.1	11.4

Source : Al-Sahaf, M. Water Resources of Iraq and their protection from pollution, Baghdad, Dar Al-Hiriyah, 1976, p.120 (in Arabic).

2.2.1.2 The Tigris River : The Tigris rises in the mountainous region in south eastern Turkey, occupying the basin to the east of the Euphrates. It originates from the junction of two streams : Diyar-Beker and Batman-Su which join some 100 km from the Iraqi border. From the confluence the Tigris river is formed and turns southward where it enters Iraq at Fiesh-Khabour village in which the first tributary, Khabour, joins the left bank of the river. Then the Tigris flows southward until it is joined by the second tributary, Greater Zab, 49 km downstream of Mosul City. The river continues to flow southward to a point 35 km downstream from Sharqat City where it is joined by the Lesser Zab. The fourth tributary, the Adhaim, joins the Tigris 15 km downstream from Baghdad City. The last tributary, Diyala, joins the Tigris at a point 15 km downstream from Baghdad. The above tributaries originate in the north east of Iraq and the adjacent areas of Iran and Turkey.

Downstream from the Tigris and Adhaim confluence the river enters the Mesopotamian plain where it receives no tributaries, with the exception of Diyala, until it joins the Euphrates at Qurnah City, (see Figure 2.3)

Upstream from the Kut Barrage, two channels leave from the right bank of the river : the Charaf and Dujaila. Numerous side escapes and outflows exist between Kut Barrage and Buteira channels, the largest, the Musandaq, is located some 48 km downstream from the Kut Barrage, and feeds Saniyah and Qurnah marshes with water particularly in the flood seasons. In addition, many irrigation canals leave the river in the Amarah area, the most important of which is the Nahar Saad which branches off at 32 km north of Amarah City, some 22 km upstream of which the Butaira channel branches off. The Musharah and Kahla channels both leave the left bank of the Tigris at Amarah City, and 22 km downstream the Taber and Great Majar branch off from the right bank of the river. The Machriyah channel leaves the left bank of the river 4 km upstream of Qalat-Saleh city. These channels take huge amounts of the flow from the Tigris and they terminate in the Huwaizah and Qurnah marshes which feed the Tigris during the low-water seasons by many outlets such as Kassarah, Rota, Swaib etc.

The total area of the Tigris river basin is about 375,000 km^2, distributed in Turkey, Iraq and Iran.[21]

2.2.1.2.1 Water Discharge : The annual average discharge of the Tigris river at Tusan in Iraq is 657 cumecs. [22] This average increases slightly at Mosul to 663 cumecs,[23] due to the water received from short tributaries upstream from Mosul City. The average increases markedly at Baghdad to 1140 cumecs, see table 2.6 and figure 2.8, due to the tributaries discharging into the river upstream from Baghdad, such as the Greater Zab(418 cumecs), the Lesser Zab (200 cumecs) and the Adhaim (25 cumecs). Downstream from Baghdad the average increases to 1322 cumecs due to the water received from Diyalah (182 cumecs).[24]

Downstream from the Diyalah tributary the annual average discharge of the Tigris river decreases gradually southwards. It reaches about 989 cumecs at Kut Barrage. As a result of the water discharges into the Gharaf (238 cumecs) and the Dujaila (18.5 cumecs) [25] as well as water withdrawal for irrigation purposes. The river discharge decreases continuously southwards and reaches only 35 cumecs at Qalat Saleh downstream from Amarah City. Thus, by this point the river has lost about 97% of its discharge at Baghdad gauge (see Figure 2.9). This is due to the branching off of many irrigation canals and channels in the Amarah area, such as Naher Saad (11 cumecs), Butaira (292 cumecs), Kahla (116 cumecs), Musharah (40 cumecs), Majar (71 cumecs) and Machriyah (9.5 cumecs), [26] as well as the water escape from the Musandaq outlet, the withdrawal of water for irrigation and the evaporation and seepage losses along its course. However, downstream from the Qalah Saleh the water discharge increases due to the water received from the Hwaizah and Qurnah marshes.

2.2.1.2.2 Annual Water Regime : The annual cycle of the Tigris water régime is similar to that of the Euphrates due to the similarity between the physical environments of their upper basins. The annual cycle can be divided into two periods : first, the flood period between

Table 2.6 : Tigris River Discharges at Baghdad (cumecs) 1930-1975

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Mean
1930	-	-	-	-	-	828	961	1040	545	286	199	179	-
1931	189	235	540	1200	1020	1450	2700	2100	1490	725	372	265	1020
1932	248	304	555	500	943	1860	1910	2080	1350	551	305	239	903
1933	225	377	328	611	915	1650	2120	2700	1470	697	353	252	974
1934	219	258	661	599	936	1090	2260	2040	1440	575	318	237	884
1935	223	240	276	816	1820	1760	2390	2050	990	458	256	216	953
1936	221	512	1030	431	1500	1500	2900	2670	1420	671	364	276	1120
1937	254	468	1030	816	1580	1790	2940	2320	1280	631	338	249	1140
1938	251	686	759	1550	1990	2010	3940	3450	1670	800	408	315	1480
1939	307	507	807	1380	1630	2440	3980	3360	1560	738	402	314	1450
1940	297	436	869	2200	3160	2360	4010	2870	1640	855	481	349	1620
1941	491	540	860	1600	3070	3600	3080	3220	1480	665	376	284	1600
1942	280	321	435	1350	1540	3170	3430	3560	1820	828	415	296	1450
1943	379	1400	1440	1330	1380	2370	3190	3560	1740	890	451	306	1540
1944	293	369	410	906	1000	1650	3610	3850	1560	699	372	244	1250
1945	258	771	426	1650	1190	1420	2150	2150	1370	580	332	241	1040
1946	236	431	588	1250	1710	3240	3900	4300	2280	1190	587	389	1670
1947	544	415	395	1170	1360	2000	1840	1440	906	410	249	210	909
1948	215	484	589	608	1210	1250	3010	3950	2240	926	413	278	1260
1949	268	278	402	423	1000	2420	4050	3700	1970	792	401	286	1330
1950	285	272	430	1180	889	3120	2840	3650	1710	787	423	270	1320
1951	316	306	361	790	848	1140	1460	1580	846	365	213	178	700
1952	368	369	521	510	2860	2510	3120	2850	1490	700	353	249	1320
1953	224	236	463	854	1940	3110	3690	2890	1760	860	420	269	1390
1954	246	516	527	1040	2010	4040	5240	4020	2260	1070	497	322	1816
1955	304	378	467	750	686	990	1470	1820	820	356	205	171	700
1956	181	301	1090	963	1650	2310	2190	2560	1710	817	363	238	1200
1957	231	266	451	492	861	3276	2520	2770	1910	926	437	307	1210
1958	300	473	611	960	1160	1790	2150	1640	1030	498	262	179	919
1959	207	266	590	572	455	1050	1960	2020	1030	512	314	246	769
1960	269	329	465	789	735	1230	2090	2220	859	437	286	296	834
1961	360	653	492	674	759	732	1450	1880	789	440	311	322	737
1962	318	531	997	1000	1290	1650	1740	1640	908	510	373	312	938

(Cont.)

Table 2.6 (cont.)

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Mean
1963	298	311	719	1020	1650	1820	2640	2320	2190	1290	781	525	1290
1964	428	535	811	708	1250	1910	1810	2350	1550	724	481	502	1090
1965	389	355	606	702	1210	1640	2080	2090	1530	724	460	376	1010
1966	453	490	781	1270	1420	1510	2090	1880	1110	536	423	394	1030
1967	469	409	591	884	1000	1780	2250	2500	1590	792	527	406	1100
1968	465	618	776	746	1230	2150	2580	2170	1670	801	575	505	1190
1969	416	564	1690	1680	1880	2100	2210	2650	2620	1430	1010	745	1580
1970	640	728	813	1090	1370	1500	1800	1240	774	507	433	381	937
1971	367	359	526	386	449	916	2580	1850	927	496	407	345	800
1972	412	445	777	622	960	1750	2840	2870	1870	383	572	490	1200
1973	515	690	612	579	1070	1230	1530	1760	978	527	485	390	861
1974	403	476	577	646	645	1460	2320	2530	1500	626	495	445	1010
1975	422	451	640	600	866	1370	1810	1740	903	477	382	334	832
av. cu-mecs	326	452	662	931	1340	1940	2620	2550	1470	704	415	321	1140
av. mill-iards	0.87	1.17	1.77	2.44	3.24	5.2o	6.79	6.83	3.81	1.89	1.11	0.83	35.95

Source :Republic of Iraq, Ministry of Irrigation, Directorate General of Irrigation op.cit., p.35.

Fig. 2·8 ANNUAL AVERAGE DISCHARGE OF THE TIGRIS RIVER AT BAGHDAD, 1931-1975

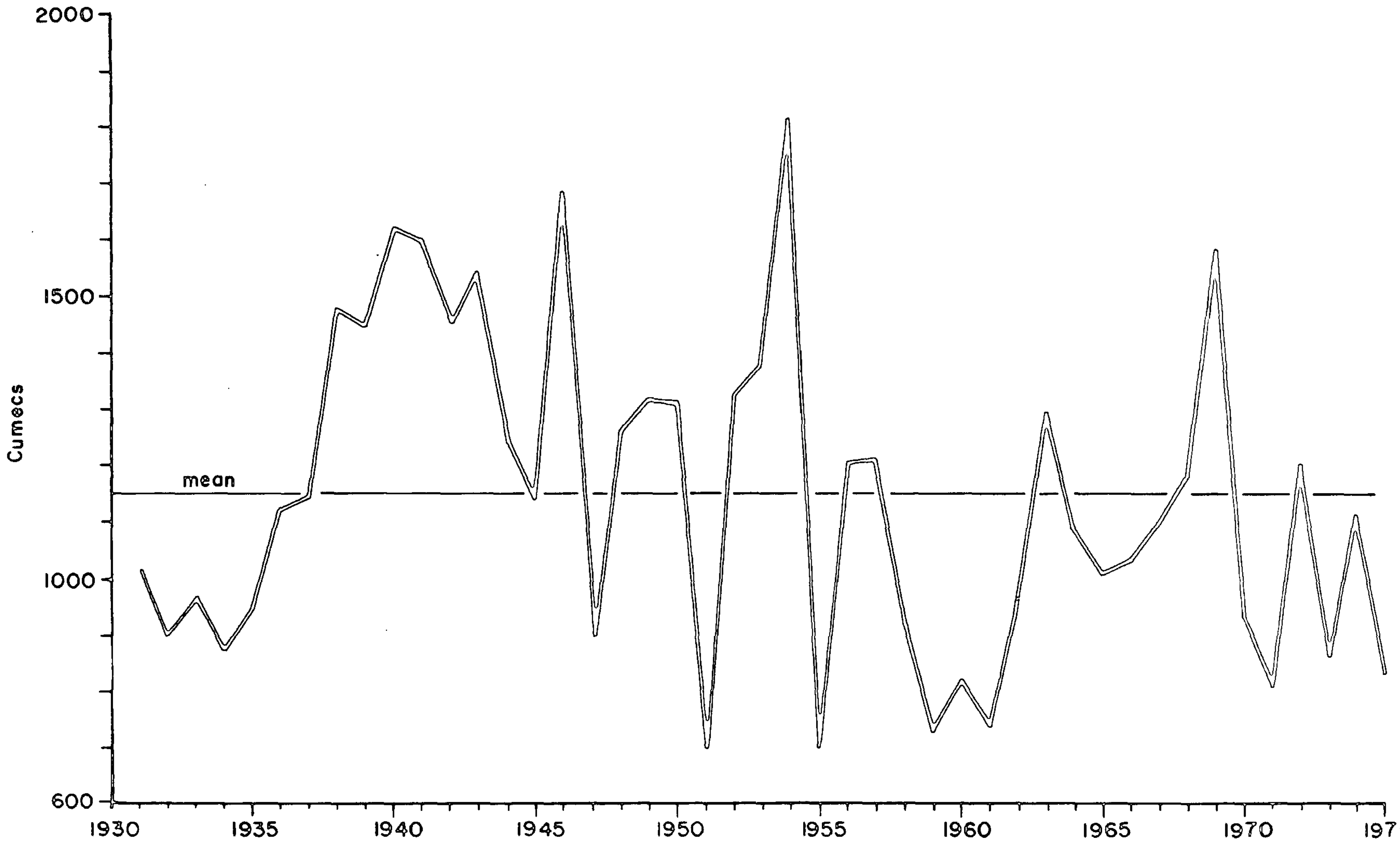
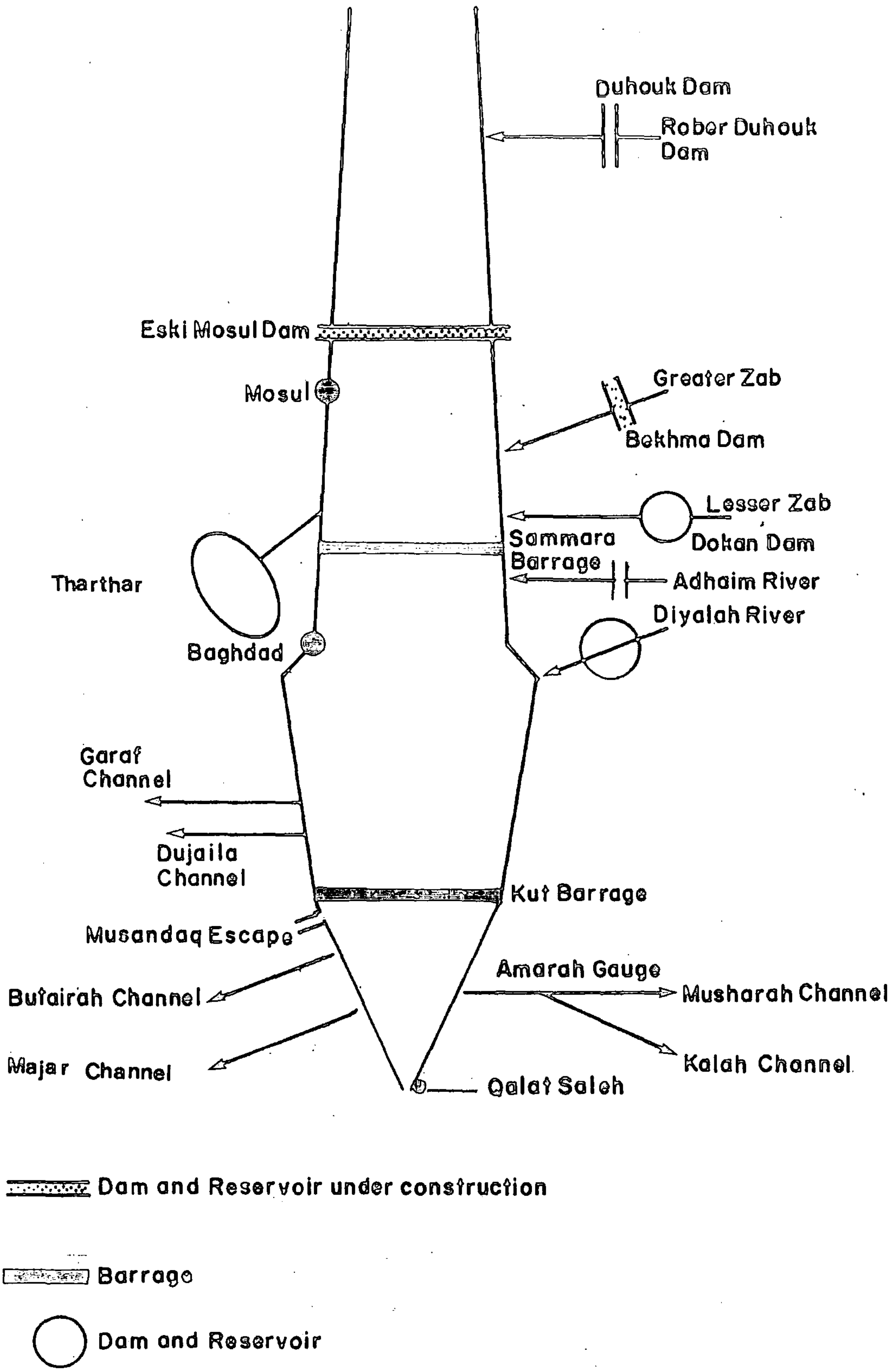


Fig. 2·9 HYDRAULIC CONSTRUCTIONS AND WATER DISCHARGE OF THE TIGRIS RIVER



November and June during which the river discharge constitutes about 87% of annual runoff. The flood hydrograph in this period shows a multi-peaked character as noticed for the Euphrates regime. Table 2.7 and figure 2.10 show that the average water discharges start increasing gradually from November until March as rainfall increases and snow melt begins in the upper catchment area. The flood peak takes place in April and May as a result of the combination of rainfall and increased snow melt. The average discharge of the Tigris at Baghdad in these months is 2,620 and 2,550 cumecs respectively, equivalent to 37% of the annual runoff of the river at this gauge. From July until October the average discharge decreases due to the lack of precipitation. In this period the river is fed by groundwater and the remainder of snow melt.

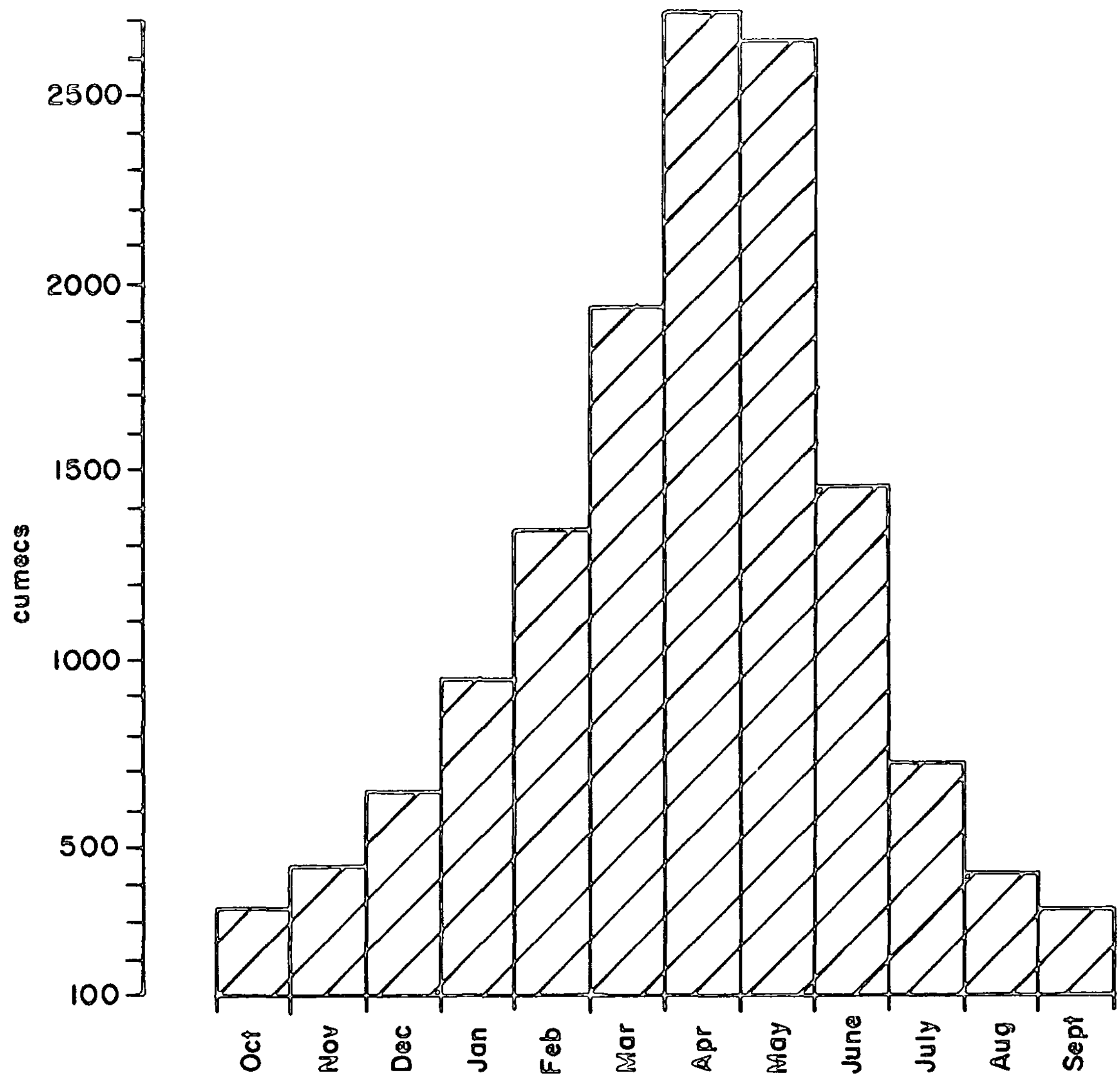
The annual average of the Tigris water discharge at Baghdad for the period of 45 years from 1931-1975 is 1,140 cumecs. However, this average varies from year to year due to variability of precipitation. The average water discharge reached 1,810 cumecs in 1954 and there were other wet years such as 1941 and 1969. The average discharge decreases in the dry years to less than the annual average, for example as in 1951 and 1961 (see table 2.6). These variations have an effect on the water discharge and quality in the Basrah province as will be explained in the following chapters.

Table 2.7 : Mean monthly water discharge of the Tigris 1931-1975 (cumecs)

Gauge	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.
Baghdad (1)	326	452	662	931	1340	1940	2620	2550	1470	704	415	321
Qalat-Saleh (2)	16	15	18	22	27	36	45	47	35	20	15	14

Source: (1) Ministry of Irrigation, op.cit. p.36.
(2) Ministry of Irrigation, Shat Al-Arab project, p.11.

Fig. 2·10 MEAN MONTHLY DISCHARGE OF THE TIGRIS RIVER AT BAGHDAD, 1931-75



Downstream from Baghdad the Tigris water regime is affected slightly by the water received from the Diyala which has a flood peak in March and April as well as by the withdrawal of water for irrigation and discharge of huge amounts of water into the marshes as previously mentioned. Nevertheless, the annual cycle of the river water regime is retained at Qalat-Saleh but the average discharge has decreased considerably. The average discharge of the same flood peak months, April and May is 45 and 47 cumecs respectively. These amounts are equivalent to only 29% of the annual runoff of the river at this gauge.

2.2.1.2.3 Marshes and lakes : These play a similar role as those on the Euphrates, the principal ones are:-

a) Tharthar lake is located between the Tigris and the Euphrates some 160 km to the north of Baghdad. This lake occupies a large depression 110 km long and 25 km wide and its bed falls to 3 m below sea level. The drainage area of this lake is about 24,470 km^2.[27] It plays a significant role in the regulation of the water discharge from the twin rivers downstream from the lake, as will be explained later.

b) Huwiza marsh : This extends to the east of the Tigris in the Amarah area. Its area totals about 3,590 km^2 in the flood season shrinking in the dry season to about 948 km^2. It is divided into two parts - the eastern which is fed by the Karkhah, Dwairij and Teab and drained by the Rutah andSwaib channels into the Shat Al-Arab and the western part which is supplied with water by the Tigris river and drained by the Kassarah channel.

c) Qurnah marsh : Extendsin the Amarah area to the west of the Tigris river, and much of it is shallow swampy lands. Its total area is about 4,000 km^2 increasing in the flood season to about 6,400 km^2. It is supplied with water by the western branches of the Tigris river and drains into the Euphrates and the Hammar marsh by many small channels.

2.2.1.2.4 Hydraulic works and structures : As on the Euphrates these are playing an increasingly important role in controlling the total discharge of the river. At present there are some 8 structures affecting flow:-

a) Eski Mosul Dam and Reservoir, under construction on the Tigris river upstream from Mosul city will be completed by 1986 with a total storage capacity of 13.3 milliard cubic metres.[28] The evaporation losses will be about 0.6 milliard cubic metres per year. Their construction is in order to provide flood control on the river and supply irrigation water for an area of 1.25 million donums, as well as to generate electric power.

b) Duhouk Dam and Reservoir are planned for the Rober Duhouk, tributary of the Tigris, with a total storage capacity of 48 million cubic metres.[29] They will protect Duhouk city from flood and generate electric power.

c) Bekhma Dam and Reservoir are under construction on the Greater Zab. Their total storage capacity in the first stage will be 3 milliard cubic metres increasing in the second stage to 8 milliard cubic metres.[30] The first stage will be completed by 1988 and they will be used for flood control and electric power generation as well as the supply of irrigation water for a cultivable area of 6.6 million donums.

d) Dokan Dam and Reservoir were constructed on the Lesser Zab with a total storage capacity of 6.8 milliard cubic metres, and with evaporation losses of 0.35 milliard cubic metres per annum.[31] They are used for flood control and electric power generation and in addition they supply irrigation water for about a million donums of agricultural lands.

e) Tharthar Reservoir : since 1954 the Tharthar lake has been used as a reservoir to store flood water, into which the Tigris can be diverted through a canal upstream from the Samara Barrage. If the water flow of the Tigris river upstream from the Barrage exceeds 4,000 cumecs the surplus water is diverted into this reservoir in order to protect Baghdad City from flood.(32) Its total storage capacity is 78.8 milliard cubic metres and the evaporation losses are about 5 milliard cubic metres per year. The government has undertaken the excavation of the Tharthar-Tigris canal in order to provide the Tigris with water during low water seasons. This canal is scheduled for completion between 1981-1985.

f) Adhaim Dam and Reservoir : These are planned on the Adhaim tributary for flood control and regulation of the flow as well as the generation of electric power.

g) Derbandi-Khan Dam and Reservoir : These were constructed on the upper Diyala tributary with a total storage capacity of 3.25 milliard cubic metres and total evaporation losses of about 0.15 milliard cubic metres. (33) They were constructed mainly for flood control, by reducing the peak flood of the river by between 5,000-6,000 cumecs.(34) This is in order to protect Baghdad City and the agricultural lands from flooding and to provide irrigation water for an area of 50,000 donums of agricultural land.

h) Hemrein Dam and Reservoir are under construction on the middle section of the Diyala tributary with a total storage capacity of 3.95 milliard cubic metres and evaporation losses of about 0.25 milliard cubic metres per year. (35)

2.2.1.2.5 <u>Water quality</u> : Table 2.8 shows that like the Euphrates the Ec values also increase downstream, at Mosul reaching 0.404 mmhos/cm and increasing to 0.650 mmhos/cm at Amarah gauge, for the same reasons as noted for the Euphrates. At the above gauges Ec value increases in the dry seasons to 0.455 and 0.992 mmhos/cm respectively and decreases in the flood season to 0.350 and 0.475 mmhos/cm respectively. According to the U.S.D.A classification the Tigris water is considered as having moderate salinity, Class 2 at both stations,(see table 2.8).

The average value of the SAR at Mosul is 0.2 me/L and at Amarah is 1.0 me/L. According to the U.S. Salinity Lab. Staff (1954) classification, the water at both gauges is regarded as having a low sodium hazard, Class S1. The pH value ranges from 7.8 in the upper section to 8 in the lower reaches.

The predominant cation and anion in the Tigris water at Mosul are calcium and bicarbonate at 2.7 and 2.9 me/L respectively and the same components predominate in the Amarah gauge at 3.4 and 2.7 me/L respectively, (see table 2.9).

Table 2.8 : Water quality of the Tigris river (1967-1969)

Gauge	Ec mmhos/cm			SAR me/L		
	Dry season	Average	Flood season	Dry season	Average	Flood season
Mosul	0.455	0.350	0.404	0.5	0.3	0.2
Amarah	0.992	0.475	0.650	1.8	1.4	1.0

Source : Hanah, O.B. and Talabany, K. op.cit., p.11.

Table 2.9 : Soluble salts in the Tigris river 1967-1969 (me/L)

Gauge	Na	Ca	Mc	Cl	SO_4	HCo_3
Mosul	0.5	2.7	1.8	0.7	1.4	2.9
Amarah	2	3.4	2.1	2.1	2.4	2.7

Source : Hanah, O.D. and Talabany, K. op.cit., p.12.

2.2.1.2.6 Suspended Sediments : The Tigris river is characterized by high turbidity. The total annual amounts of suspended sediments at Mosul is 51 million tons, this quantity increases southwards and reaches 108 million tons at Fatha - north of Baghdad (see table 2.10). This increase can be attributed to the sediments brought to the river by its tributaries. The Diyalah tributary downstream from Baghdad also adds considerable quantities of sediment to the Tigris, but there is no data available about the exact amounts of additional sediments received. However, the quantity of sediment decreases southwards and becomes finer due to the absence of the tributaries and the nature of the sedimentary processes of the river. The quantity of sediments is affected by the water discharge, therefore in the flood season they are equivalent to 85% of the total annual amount, while the remaining 15% is discharged during the dry seaon, (see table 2. 10).

Table 2.10 : Suspended sediments in the Tigris water (million tons) 1933 - 1970

Gauge	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Mosul	1.32	3.12	7.59	20.6	15.7	1.06	0.12	0.04	0.02	0.04	0.95	0.58	51
Fatha	1.79	6.02	18.2	45.7	30.7	2.59	0.50	0.18	0.06	0.08	0.91	0.74	108

Source: Al-Sahaf, M. op.cit., p.128.

2.2.2 The present and future use of the Twin rivers' water

In 1972 the total water supply of the twin rivers downstream from the Diyalah tributary was estimated at 71 milliard cubic metres. However, this quantity varies from year to year according to variations in precipitation and other factors earlier mentioned such as the filling of new reservoirs and the irrigation of new agricultural projects. For example, in 1975 the total water supply decreased markedly to 48.56 milliard cubic metres due to the filling of the Tabka reservoir. However, the estimated annual water supply is expected to decrease to 50 milliard cubic metres during the period from 1985-1995 (36) as new reservoirs and agricultural projects are completed.

At the present time the total national water requirement is estimated at 42.35 milliard cubic metres,(see table 2.11). As a result of economic improvements and population growth in Iraq this will increase by 1995 to about 63.59 milliard cubic metres. This in turn means that a water shortage of 13.59 milliard cubic metres will be expected. Most of this deficit will occur in the Euphrates basin where Turkish and Syrian irrigation projects due for completion in 1995 are sited. Therefore, the volume of water deficit is assumed to be not less than 15% of the requirements.(37) This will have a serious effect on the water quality and quantity in Basrah province, as will be explained in following chapters.

2.2.3 Irrigation and Drainage

The irrigation and drainage practices upstream from Basrah have an indirect effect on the water quality and quantity in the province.

Irrigation practices in Iraq date back to about 4200 BC. (38) They began by using natural flow in a very primitive system of irrigation consisting of cuts in the river banks; since then a canal system

Table 2.11 : Water Requirements in Iraq (milliard m^3/year)

Details	Present requirements	Requirements in 1995	Notes
Domestic	0.58	3.52	add to the total
Industrial	0.45	1.90	13 milliard as
Fishing	0.03	2.64	evaporation and
Irrigation	39.53	52.10	conveyance
Power generation	1.76	3.43	losses
Total	42.35	63.59	

Source: Ministry of Irrigation, Water Conference of the South west Asia, Baghdad, 11-16 Dec. 1976, Baghdad, 1978, p.7.(in Arabic) has been gradually developed into a controlled canal irrigation system. The use of pump irrigation started about sixty years ago.

In 1980 the estimated irrigated area in Iraq was about 14,840,000 donums with a planned expansion of the irrigated area between 1985-1995 to about 15,480,000 donums .[39] Table 2.11 shows that the required water for irrigation at the present time is 39.53 milliard cubic metres; this will increase to about 52.10 milliard cubic metres during the period 1985-1995 with consequently adverse effects on the water discharges in Basrah province.

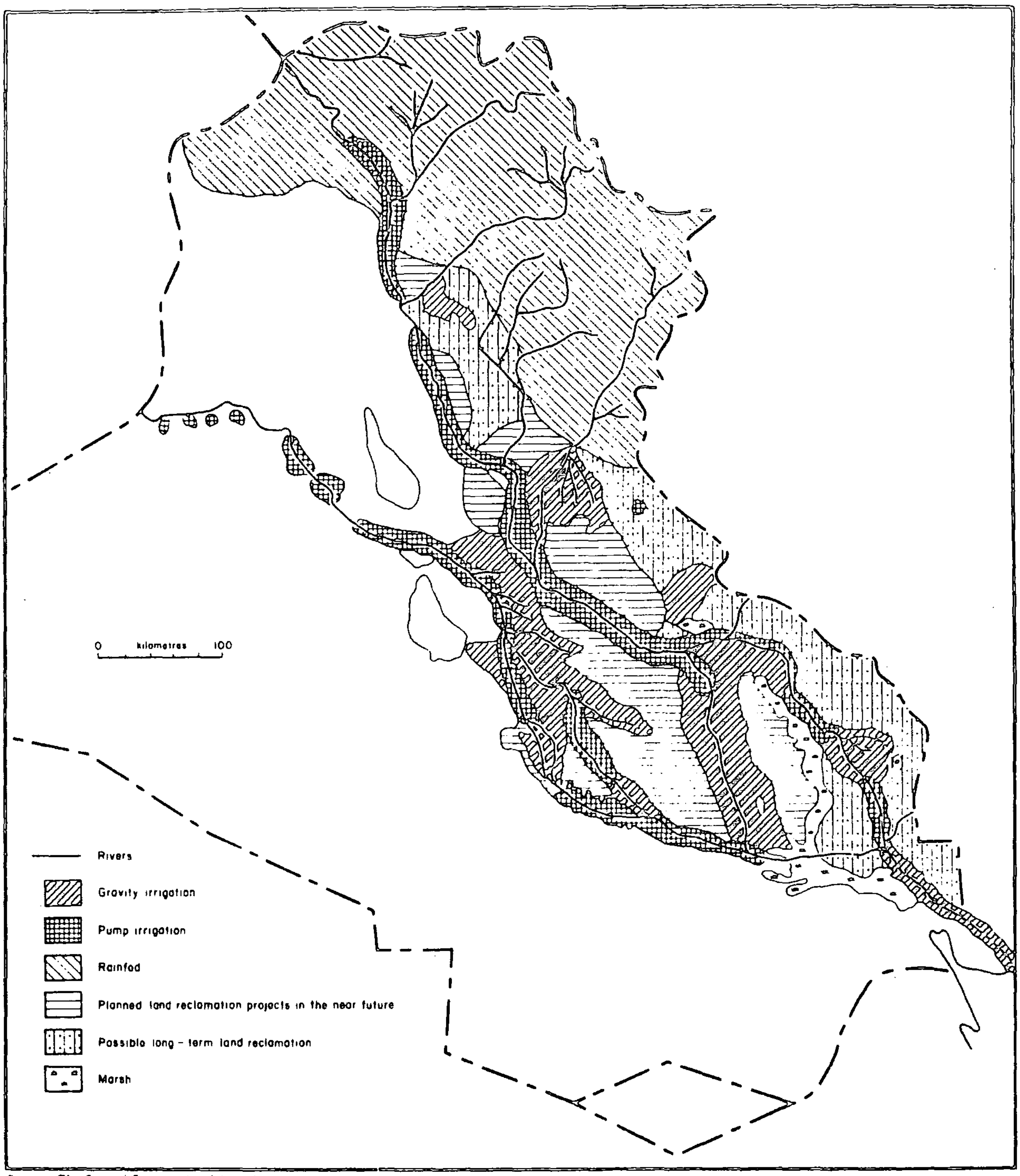
At present Iraq can be divided into two broad regions on the bases of irrigation water sources and uses as follows (see figure 2.11).

2.2.3.1 Northern Region : In this region the winter crops are rainfed while the summer crops depend mainly on irrigation water either from the Tigris and its tributaries or the groundwater which is lifted by pumps or wheels.

2.2.3.2 Central and Southern Region: This consists of the Mesopotamian plain, and Jazeira and foothill regions, in which cultivation depends entirely on water from the twin rivers and their tributaries. The irrigation water in this region is lifted by pump particularly on both sides of the twin rivers, or obtained by gravity as on both sides of the Garaf channel, the last section of the Diyalah river, the Euphrates branches in the central section and on both sides of the Shat Al-Arab (see figure 2.11).

Because irrigation activities have been practised since 4200 BC without any adequate drainage, soil salinity problems have developed, from at least 2300 BC. This deterioration encouraged a change from wheat to barley cultivation,[40] and the adaption of the Neir and Neir fallow system, in which half of the farmland is cropped and the other

Fig. 2.11 IRRIGATION METHODS IN IRAQ



Source The General Directorate of Irrigation half is left fallow to be cultivated in the following year. The farmers, therefore, have tended to use large quantities of irrigation water to leach and reduce the soil salinity but still without adequate drainage, thereby exacerbating the problem.

Figure 2.12 shows that there is virtually no salinity in the rain-fed region of northern Iraq, but it is very pronounced in the irrigated areas of central and southern Iraq. The degree of salinization varies, some areas being only slightly saline, others being highly to extremely saline. This variation may have various causes, such as differences in irrigation practices, in soils and in the occurrence of natural drainage. In this connection it should be noted that until 1950s no artificial drainage facilities existed. Thus, for example, the annual quantity of salt brought to the fields by moderate irrigation to a depth of 300 mm and with average salt content of water with an Ec of 0.600 mmhos/cm brings on the field 300 kg of pure salt per donum and if there is no natural or artificial drainage this salt remains in the soil and increases over the years to enormous quantities. (41)

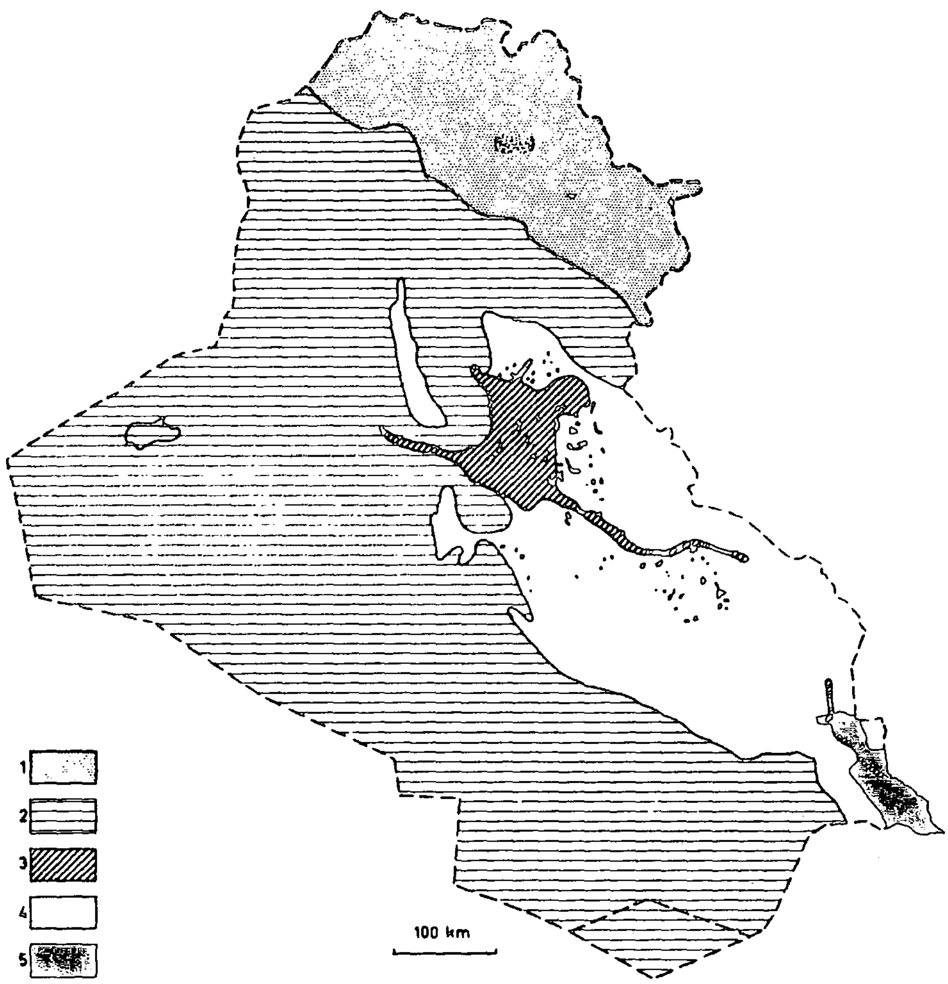
The salt affected soils in Iraq can be divided, on the bases of their leaching requirements, into three regions as follows.(42)

1. Less than 30% of the cultivable areas in the north of Baghdad require leaching at a norm of 2800-3600 m^3/donum/year.

2. Between 30-50% of the area to the south of Baghdad need heavy leaching at the norm 4800-6400 m^3/donum/year.

3. Between 50-70% of the cultivable lands in the south-eastern part of the country required very heavy leaching at the norm 5600-7200 m^3/donum/year.

Fig. 2.12 SCHEMATIC MAP OF SALINIZATION IN SOILS OF IRAQ



1. soils without salinization; 2. deserts and soils with some salinization locally; 3. soils with moderate salinization; 4. soils with severe salinization; 5. (and black dots) soils with salinization and solonization. (9.9)-area in 1000 km.².
Solonization processes have only been noticed in some small areas on Tigris terraces east of Samarra.

Source: *Buringh, P. (1960): Soils and soil conditions in Iraq, Ministry of Agriculture Baghdad, Iraq, p. 306*

Recently, many drains have been constructed and others are under construction to reclaim the salt-affected soils. These are as follows: (43)

a) The existing drains which discharge their drainage water into the Tigris river are as follows:

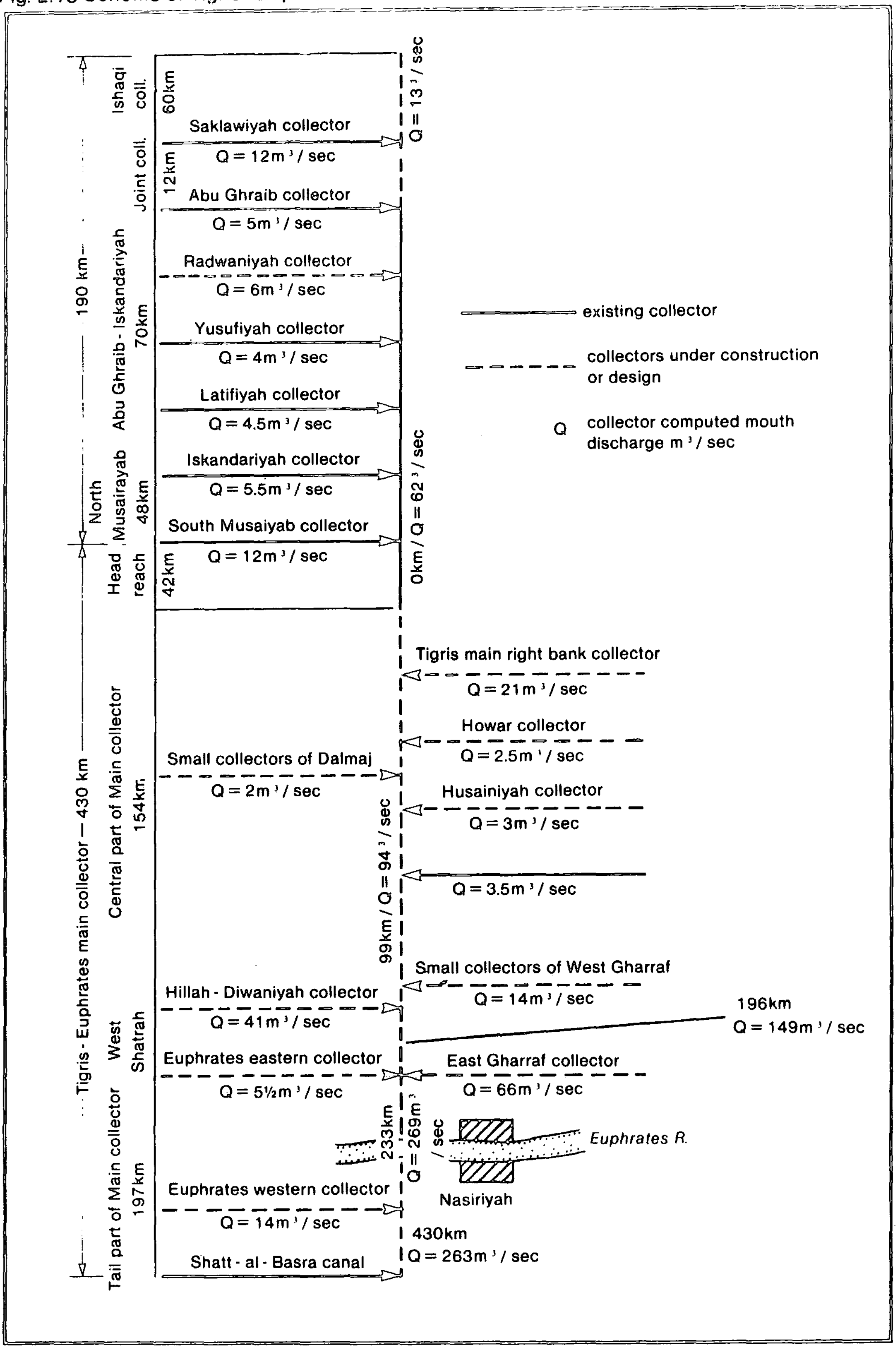
drains	outfall discharge (cumecs)
Ishaqi	13
Wahda-Jassimyah	5.7
Aziziyah	0.8
Saqlawiyah	12
Khalis-Dawoody	4
Salman pak	1
Washash	1.10
Total	36.6

b) The existing drains which discharge their drainage water into the Euphrates river are as follows:

drains	outfall discharge (cumecs)
Ramadi-Faluja	4.7
Rumaitha	15
Hilla-Kifel	6
Beni-Hassan	2.7
Husainiyah	1
Habaniyah	1.5
Twairiech	0.50
Azraqiyah-Abu-Akash	0.30
Total	31.7

The total drainage water discharged into the twin rivers is about 68 cumecs. This leads to a considerable increase in water mineralization which increases downstream as earlier mentioned, and consequently

Fig. 2.13 Scheme of Tigris - Euphrates Main Collector



Republic of Iraq, Ministry of Irrigation, General scheme of water resources and land development, Op - Cit, book 2 adversely affects the water quality in downstream Basrah province.

However, in order to prevent a further increase in mineralization of the river water, the Euphrates-Tigris main collector was constructed recently to discharge the drainage water from 5 million donums [44] of irrigated lands in the Mesopotamian plain directly into the Gulf, see figure 2.13. However, at the present time this collector discharges its water into the Hammar marsh and this will seriously affect water quality and the irrigation practices in this marsh and the Shat Al-Arab region. It is, therefore, a matter of urgency to construct the final part of the collector - which crosses the Euphrates at Ur Station and will extend parallel to the south border of the Hammar marsh and terminate into the Khor Al-Zubair which will prevent the saline water entering the Hammar marsh and the Shat Al-Arab.

2.2.4 Groundwater

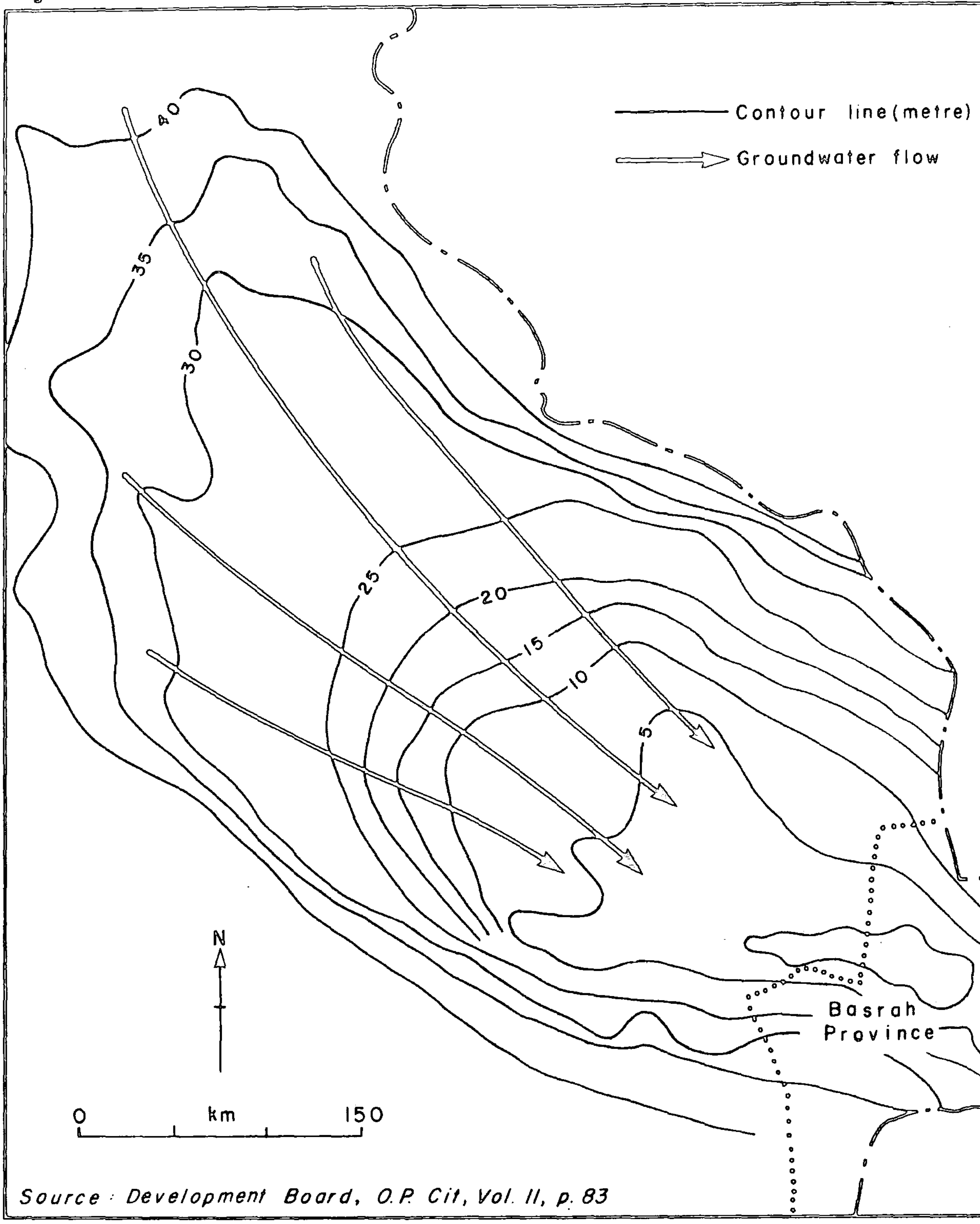
As Basrah province is located at the southern most part of Iraq and has a flat, low topography, the groundwater flows towards the province and concentrates there, creating waterlogging and salinity problems particularly in the eastern region.

Little attention has yet been given to a study of the groundwater in Iraq due to the fact that 80% of the irrigated land in the country depends on water from the twin rivers, while only the remaining 20% is irrigated by rainfall and groundwater.

The geological structure of Iraq is that of a long geosyncline which has a northwest southeast trend. This structure together with the permeable subsurface makes it suitable for groundwater storage and flow.

The groundwater is recharged mainly from precipitation and from the twin riversin the flood seasons, as well as by the deep percolation of irrigation water. Figure 2.14 shows that the general groundwater

Fig. 2.14 Groundwater Flow



Source: Development Board, O.P. Cit, Vol. II, p. 83

flow is from north to south with the general slope of the ground surface in the Mesopotamian plain and from west to east in the Western Desert. The gradient of groundwater from the northern border of the Mesopotamian plain to the central part is less than 0.2 m per km and from the central part to Basrah province is about 0.1 per km, while its gradient in the northern mountainous region is between 6-7%.[45]

The groundwater of the Western Desert discharges into the Euphrates, Hammar marsh and the Tigris river. The quantity which is discharged into the Hammar marsh is 1.4 cumecs and into the Tigris upstream from Baghdad about 12.5 cumecs.[46]

The depth to groundwater decreases from west to east and from north to south according to the general slope of the ground surface. Throughout the Mesopotamian plain the depth of the groundwater table averages 2 m below the surface, ranging from zero - the landsurface - to more than 16 m. The depth of the groundwater table varies from season to season according to variations in the precipitation and the water levels of the twin rivers. In the flood season the groundwater level rises in most areas when it is replenished by precipitation and the twin rivers, while it falls in the dry seasons due to the absence of precipitation and low water levels of the twin rivers. Generally the fluctuations in the groundwater levels do not exceed more than 1-2 m.

Iraq can be divided into five regions on the basis of the groundwater quantity and quality as follows :[47][48]

2.2.4.1 The Mountain Region : This area contains a large amount of fresh water which appears on the surface through artesian wells. This is due to the high rate of precipitation together with the existence of permeable bed rocks. Its soluble salt content ranges from 240 to 1000 me/L making it suitable for drinking and irrigation.

2.2.4.2 The Foothills Region : this area has less water than the mountain region. Due to lower precipitation and its soluble salt content ranges from 500 to 3,000 me/L.

2.2.4.3 The Jazeira Region : Located to the west of the foothills region has less groundwater of poorer quality than the above regions. Its soluble salts content ranges from 3,000 to 10,000 me/L.

2.2.4.4 The Western Desert Region : The groundwater level is deeper than that in the above regions and decreases eastwards. It has poorer groundwater and its quality decreases southwards along with the decrease in precipitation. Its soluble salt content ranges from 500 to 3,000 me/L in the northern parts and between 2,000 and 10,000 me/L in the southern parts. However, it becomes abundant and fresher in the depressions and valleys.

2.2.4.5 The Mesopotamian Plain Region : Groundwater here is sustained by flow from the surrounding above mentioned regions and by precipitation and percolation from the twin rivers and the irrigated lands. The groundwater flows southwards with the general surface gradient, see figure 2. 3 and concentrates in Basrah province on its way to the Gulf. It is of poor quality and the soluble salts content ranges from 4,000 to 5,000 me/L. This is because the subsurface sediments themselves were deposited in a saline marine environment and are also affected by percolation of saline leaching water from the irrigated lands. This saline groundwater becomes shallow in Basrah province and its depth level ranges from the landsurface in the Hammar region to about 2 m in the river levees. Therefore, it creates salinity and waterlogging problems particularly in the low lying areas through evaporation of this water which rises to the surface by capillary action.

Because of the high salinity of the groundwater in the Mesopotamian

Plain as well as the abundance of fresher surface water, it is not generally used for irrigation or any other purposes. However, in the depressions of the western region in the province this water is used for irrigation purposes as will be explained in Chapter 3.

2.3 CONCLUSION

It has already been pointed out that downstream the surface water discharge decreases and its quality becomes poorer and clearly this situation is likely to become worse with adverse effects on the water quality and quantity in Basrah province. More saline water will be discharged into the province and it will face a deficit of water quantity, seriously affecting the irrigation activities in the province. In addition, the groundwater is saline and concentrates in the province creating soil salinity and waterlogging. Therefore, it is necessary to construct an adequate drainage system which will lower the groundwater table and alleviate the salinity and waterlogging problems in the province. The traditional human responses through irrigation to natural river regimes are no longer as appropriate to the managed hydraulic systems which recently and today are being created.

The situation is further complicated by the fact that in Basrah province there is neither spatial uniformity in irrigation systems nor has there been simple continuity over time.

The detailed regional differences in the availability and type of water resources which can be used for irrigation, together with other variations in physical factors have themselves led to the evolution of a variety of different irrigation systems. During the whole of history, changes in the alignment of river flows and the physical changes in soil and water resulting from the practice of irrigation have combined to produce a series of non-static situations. The recent very large scale modification of the characteristics of surface and groundwater through the use of totally new technologies are accelerating the changes in the physical environments within which irrigation is set. Lastly, there are major socio-economic changes which differentially are affecting human motivations and attitudes towards irrigation farming.

Chapters 3 to 6 are devoted to four case studies which illustrate the complexity, sensitivity and changing nature of irrigation in Basrah province.

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CHAPTER THREE

IRRIGATION AND DRAINAGE IN THE WESTERN REGION

3.1 INTRODUCTION

This region, often called the Zubair region, is located in the western part of the province, and occupies the southeastern part of the Western Desert. The land surface which slopes gently to the east and north is mainly covered by sand over its flat and low surface. It is disrupted by some shallow depressions in which groundwater is accessible and used for agricultural activities. It is characterized by high temperatures and evaporation rates and a low annual average rainfall which is totally insufficient for the needs of the agriculture. Therefore, under these hot, arid conditions, cultivation can only be carried out by utilizing groundwater, and a traditional furrow irrigation system has been evolved by local communities for this purpose.

Apart from the survey which was carried out by T.A.M.S. Co. in 21 km^2 of the north eastern part of the region in 1954, no other investigations have hitherto been made about the methods of irrigation and drainage used in this region. This study is therefore almost entirely based on personal field research.

Since it was not possible to study each farm in the region separately, extensive reconnaissances were carried out in order to select for study a typical farm where average conditions prevail and which would indicate clearly the standard irrigation and drainage system of the region. The study will discuss the soil and water conditions, management, the crop distribution system, theoretical irrigation and leaching requirements; then the water supply to show the effects of the above on irrigation water efficiency, soil salinity and the crop yield, mainly with reference to the sample farm. Finally, this chapter will evaluate irrigation experiments carried out in the northern part of the region to measure their suitability for the physical and socio-economic conditions in the region.

3.2 SOIL CONDITIONS OF UNIRRIGATED AREAS

The soils have been formed under the hot, arid conditions summarised in Chapter 1. These conditions, along with the variations in daily and annual temperature, cause physical weathering of parent material, a process more important than the chemical and biological. The parent material consists of sandstone, gravels and limestone.

The influence of the vegetation cover on soil formation is very small because its very limited cover produces only small localised additions of organic matter to the soil. In addition, the effect of relief is relatively small due to its monotonous undulating surface. Its influence appears to be limited to the accumulation of wind carried sand in the depression (see Chapter 1.3).

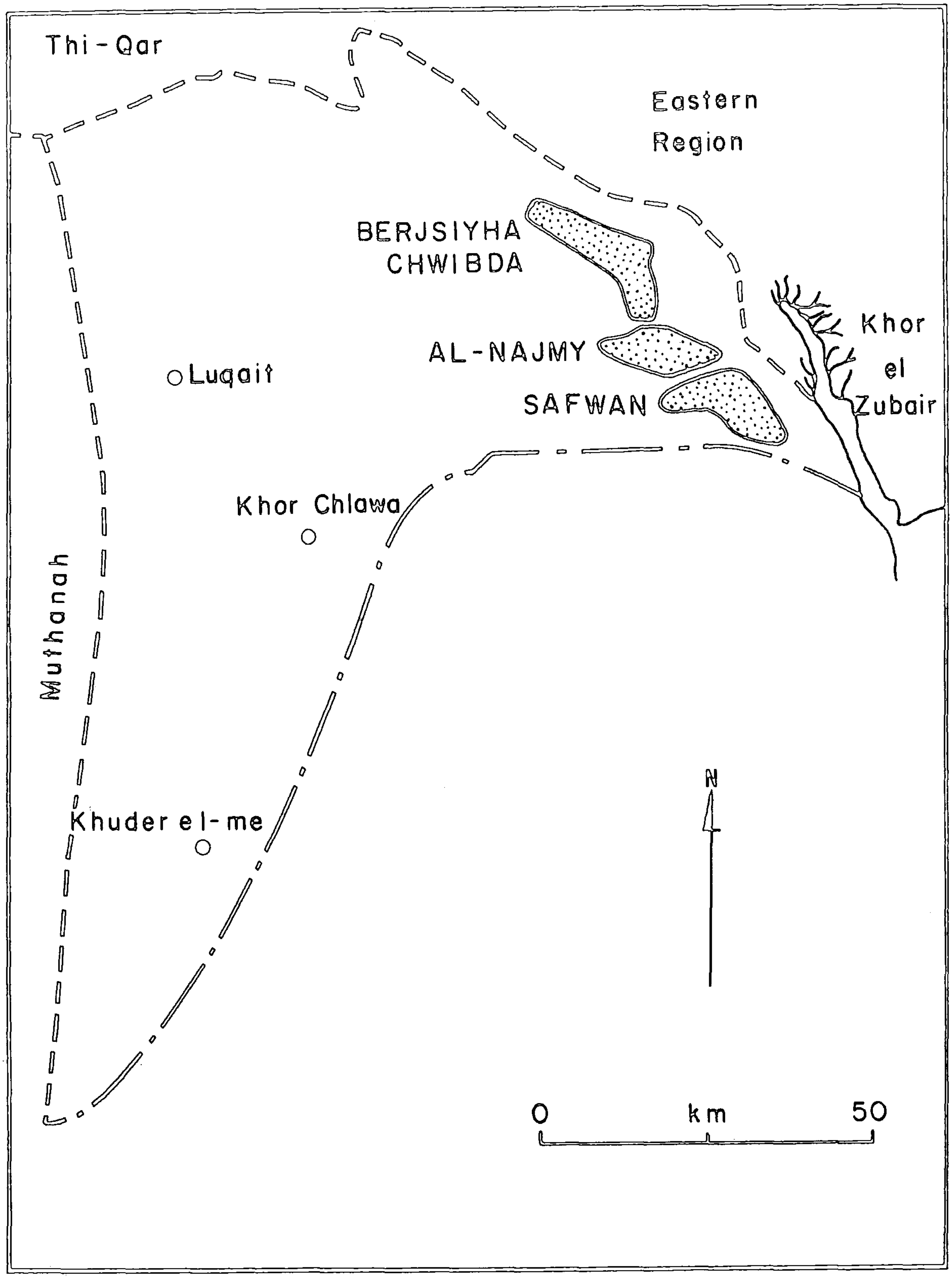
Since agricultural activities are only carried out in the depressions - Al-Berjsiyah-Chwibda, Al-Najmy and Safwan - their soils, therefore, will be given most attention (see figure 3.1). As many of the properties of the irrigated soils are related to irrigation practices, these will be discussed in a later section (3.16).

3.2.1 Properties of the Uncultivated Soils of the Depressions

The uncultivated soils of the depressions were first studied as control sites for later comparison with soils affected by irrigation. The soils were sampled and the samples collected subjected to routine laboratory analysis (see appendix 1 to Chapter 3).

3.2.1.1 Physical analysis : three soil samples were taken from unirrigated soils in each depression. Table 3.1 and soil samples nos. 1 - 9 (Appendix 2, Chapter 3) show that the average sand content is 74.6%, this percentage varying between 73% at Al-Najmy and 77% at Al-Berjsiyah-Chwibda. The sand content also increases with depth due to the parent material containing 95% sand and gravel.[1] Clay content averages 15.9% and the average silt content is 8.9%. Thus, these soils can be classified as sandy loam. Since soil water movement and aeration is closely related to soil texture, the presence of

Fig. 3.1 The Western Region -- Location of Main Depressions



high sand content generally imparts to these soils both rapid water and air movement. The infiltration rate of these soils, as measured by double ring infiltrometer, ranges between 12.7 and 24.5 cm/hr which according to F.A.O. criteria (1971): (2)

Infiltration rate cm/hr	Designation
<0 - 1	very slow
0.1 - 0.5	slow
0.5 - 2.6	moderately slow
2.6 - 6.3	moderate
6.3 - 12.7	moderately rapid
12.7 - 24.5	rapid
>24.5	very rapid

The infiltration rate can be classified as moderately rapid to the highest limit of the rapid class.

The high infiltration rates may lead to increased water losses through seepage and percolation. However, soils having infiltration rates of 10 cm/hr or more are not recommended for surface irrigation.(3)

Additionally, these soils are characterized by a low water holding capacity due to their coarse texture and low organic matter content. The field capacity is 10% and the wilting point is at about 6%. Thus, available moisture is generally low at 4%.(4) As a result of the coarse texture of these soils they have a permeability of 6.0 m/day. According to Soil Survey Manual (1951) criteria (5)

Permeability m/day	Designation
<0.03	very slow
0.03 - 0.12	slow
0.12 - 0.48	moderately slow
0.48 - 3.00	moderately rapid
3.00 - 6.00	rapid
> 6.00	very rapid

The permeability of these soils can be classified at the higher limit of rapid. The percolation losses of these soils average 42.5% and ranges between 33% and 52%.[6] This high percentage means that irrigation water may rapidly sink back to the aquifer.

The high infiltration rates coupled with the low water-holding capacity and rapid permeability of these soils lead to a high demand for irrigation water and frequent irrigations in order to retain soil moisture at field capacity and ensure healthy crop growth.

3.2.1.2 Chemical analysis : Table 3.1 and soil samples nos. 1-9 show that the average content of gypsum ($CaSo_4$) is 6.4% and the lime ($CaCo_3$) content averages 15.5%. The lime indicates the main source of calcium cations in the soil solution, even though its solubility is low.

The organic matter average is extremely low at 0.2% due to the scarcity of vegetation cover. Therefore, cultivation of these soils requires a high input of organic matter so as to increase the moisture holding capacity and the cation exchange capacity in the root zone. However, organic materials are subject to loss by leaching due to the frequent heavy irrigation as above mentioned, and rapid decomposition, so surface application of organic matter has an effect for a short duration only. Incorporation deeper into the soil, at the root zone of the cultivated lands, has better effects. These soils are often described as "droughty" and easily eroded by running water, which is regarded as one of the obstacles to successful surface irrigation.

The electric conductivity Ec of the saturation extract of these soils at 25 °C averages 4.3 mmhos/cm and ranges between 2.6 mmhos/cm at Safwan and 7.2 mmhos/cm at Al-Najmy. According to the U.S.D.A classification (1954) of the soil salinity,[7] these soils are regarded as slightly saline. The average pH value is 7.7.

Table 3.1 : The average results of soil analyses in each of three depressions

Depth	pH	Ec mmhos/cm	Sand %	Silt %	Clay %	Gypsum %	Lime %	Ex.Na me/100g	CEC me/100g	O.M %	Esp %	SAR me/L	Ca	Mg	Na	K	Cl	So4	HCo3
Al-Berjsiyah-Chwibda Depression																			
0-78	7.7	3.19	77.1	5.7	15.8	3.4	15.5	1.45	22.6	0.27	7.0	4.8	22.4	7.7	11.2	0.3	7.5	33.8	2.4
Al-Najmy Depression																			
0-85	7.6	7.2	73	10.9	16.1	9.9	18.3	0.9	27.3	0.27	4.0	6.4	29.7	17.3	28.5	1.3	28.8	49.3	2.4
Safwan Depression																			
0-88	7.7	2.6	73.9	10.2	15.9	5.9	12.9	0.45	20.6	0.1	2.3	2.6	17.1	6.6	10.3	1.4	7.2	25	2.6
Averages for the three Depressions																			
	7.7	4.3	74.6	8.9	15.9	6.4	15.5	0.9	23.5	0.2	4.4	4.6	23	10.5	16.6	1	14.5	36.0	2.46

For detailed analyses see Appendix 3.2.

The average cation exchange capacity (C.E.C) is 23.5 me/100 g. This average varies between 20.6 me/100 g at Safwan and 27.3 me/100 g at Al-Najmy. According to the I.L.A.C.O.Bv criteria (1981) [8]

Rating	C.E.C me/100 g
very high	> 40
high	26 - 40
medium	13 - 25
low	6 - 12
very low	< 6

The average cation exchange capacity is considered as medium due to the low organic matter and clay content.

The exchangeable sodium in these soils is generally low, averaging 0.9 me/100 g. However, the average sodium adsorption ratio (SAR) is 4.6 me/L varying between 2.6 me/L at Safwan and 6.4 me/L at Al-Najmy. The exchangeable sodium percentage (Esp) averages 4.4%, between 2.3% at Safwan and 7.0% at Al-Berjsiyah-Chwibda. The (Esp) in soil is used as a criterion of alkalinity. Soils with (Esp) less than 15% are regarded as free from alkalinity.

From what has been said, it is evident that these soils are slightly saline and free from alkalinity. This reflects the U.S.D.A (1954)[9] definition of saline soil that is used in connection with soil for which the Ec is more than 4 mmhos/cm at 25°C and the Esp is less than 15% and the pH of such soil is less than 8.5. According to the standards above mentioned, the soil of Al-Najmy is saline, and of Safwan and Al-Berjsiyah-Chwibda is non saline and the soils of all the depressions are free from alkalinity.

Calcium is the predominant cation at 23 me/L and sulphate is the predominant anion at 36.0 me/L.

According to the U.S.D.I. Bureau of Reclamation, the general soil conditions required for profitable sustained irrigation agriculture are as follows:[10] The soil

- must have a reasonably high available moisture capacity.
- must be readily penetrable by water to permit aeration, replenishment of the soil reservoir, the ready escape of excess water, and leaching of soluble salts.
- must have a slow enough infiltration rate to prevent excessive percolation and droughtiness.
- must be of sufficient depth to allow necessary root development and provide adequate storage for moisture and permit drainage.
- must be readily susceptible to cultural operation.
- must be free from an injurious amount of sodium or 'black alkali'.
- must be free of, or readily susceptible to, leaching of harmful accumulation of salines.
- must have an adequate supply of plant nutrients and a favourable cation exchange capacity.
- finally, must be able to resist excessive erosion under economical irrigation practices.

On the bases of the above requirements, the soils of the depressions are relatively unprofitable for sustained irrigation agriculture, particularly surface irrigation, due to their high infiltration rates, low water holding capacity, rapid permeability, excessive drainage and low organic matter content.

Also, according to the U.S. Bureau of Reclamation classification (1954)[11] of soil suitability for irrigation, which consists of four classes, the soils of the depressions include characteristics from both Classes 2 and 3. They include from Class 2, which indicates intermediate suitability for irrigation, the low available moisture capacity and they require heavy expenditure both to irrigate and to prevent erosion within the irrigation area. They also include some aspects from Class 3, which indicates the lowest suitability for irrigation, such as good topography, the requirement of a large amount of irrigation water or special irrigation practices and the demand for greater fertilization or more intensive soil improvement practices. It is convenient therefore to consider them as Class 3.

3.2.2 Unirrigated soils in the surrounding areas

Table 3.2 and samples nos. 10-12 show that these soils are similar to those in the depressions in terms of the mechanical and chemical properties, except that these soils are shallower and usually underlain by extensive gypsic horizons at varying depths. In addition, they contain more and larger gravel than the unirrigated soils of the depressions. They are not utilized in agriculture but only for gravel gathering and sand removal.

Table 3.2 : Uncultivated soils in areas surrounding the depressions

Depth	pH	Ecc mmhos/cm	sand %	silt %	clay %	Gypsum %	Lime %	Ex.Na me/100 g	C.E.C. me/100 g	O.M. %
0.60	7.5	2.1	74.3	18.6	7.0	18.4	10.0	1.44	8.4	0.2

3.3 WATER CONDITIONS

Groundwater is the only source of irrigation water in this region.

The importance of the groundwater has been most readily appreciated during the last 70 years when it has become utilized for irrigated agriculture.

The stratigraphy of the Western Region has already been discussed in section 1.2. The Dammam, Ghar, Lower Fars and Dibdibba formations are all of a porous nature and so are potentially good aquifers. However, the selection of usable aquifers depends on many factors, among which the depth of aquifer, its thickness and the water quality are important. The Dibdibba formation is of particular importance from the point of view of groundwater exploitation, due generally to its proximity to the surface and water purity in the upper part of the formation. This formation lies between 14 and 5 m below the surface in the Safwan depression, and 20-30 m in the Al-Najmy and Al-Berjsiyah-Chwibda depressions.

3.3.1 Water quantity

The quantity of fresh water in the Dibdibba depends largely on contemporary rainwater recharge of the upper parts of the formation. It is believed that about 90% of the total annual rainfall of about 113 mm on the corresponding catchment areas seeps into the upper part of the Dibdibba.(12) Therefore, the groundwater level varies from year to year according to the large fluctuation in the annual average rainfall,(see chapter 1.4). In addition, there are also seasonal fluctuations between 0.30 to 1.0 m.(13) The highest level is recorded during April and May, at the end of the rainy season, and the lowest at the end of the dry season in October and November.

The area of the agricultural depressions totals 472 km^2 - Safwan being 150 km^2, Al-Berjsiyah-Chwibda is 198 km^2 and Al-Najmy is 124 km^2. To determine the possible average recharge into the depressions, calculations could be made by multiplying the percentage of rain recharged to the groundwater, 90%, by the annual average of rain which is 113 mm and the total area of the depressions. The result is in the order of $48 \times 10^6 m^3$ per year for all depressions, or individually $15.2 \times 10^6 m^3$ per year at Safwan, $20.1 \times 10^6 m^3$/year at Al-Bersiyah-Chwibda and $12.6 \times 10^6 m^3$/year at Al-Najmy. The average recharge to the depressions is the figure above mentioned plus the unknown amounts of the water recharge by the ephemeral streams which terminate in these depressions.

The total amount of the groundwater stored in the usable part of the aquifer, in the upper part of the Dibdibba, is equal to the usable aquifer thickness, which averages 21.5 m multiplied by the total area of the aquifer and the effective porosity of the aquifer, 20%,(14) to give a minimum total of the groundwater storage under the depressions of about $202 \times 10^6 m^3$, or again individually, $43.5 \times 10^6 m^3$ for Safwan, $44.5 \times 10^6 m^3$ for Al-Berjsiyah-Chwibda and $62 \times 10^6 m^3$ at Al-Najmy. Thus, the probable total groundwater storage under the depressions is $202 \times 10^6 m^3$ plus the lateral movements of the groundwater within the aquifer from surrounding areas to the depressions.

3.3.2 Water Discharge

The average discharge of the fresher groundwater into the wells ranges from 0.75 to 0.84 m^3/min at Al-Berjsiyah-Chwibda, 0.73 to 0.87 m^3/min at Al-Najmy and 0.72 to 0.90 m^3/min at Safwan. The discharge falls in the surrounding areas, reaching 0.3 to 0.42 m^3/min at Khor Chlawa and from 0.28 to 0.40 m^3/min at Khuder-el-Mai,(15) (see figure 3. 1). Thus, the water discharge increases in the depressions where the groundwater is concentrated and decreases in the surrounding higher areas.

3.3.3 Water flow

The flow of groundwater in the region is in accordance with the general slope of the land surface. Therefore, the flow direction is from west and south-west in the north and east where the depressions and the low lands are located (see figure 3.2).

3.3.4 Water depth

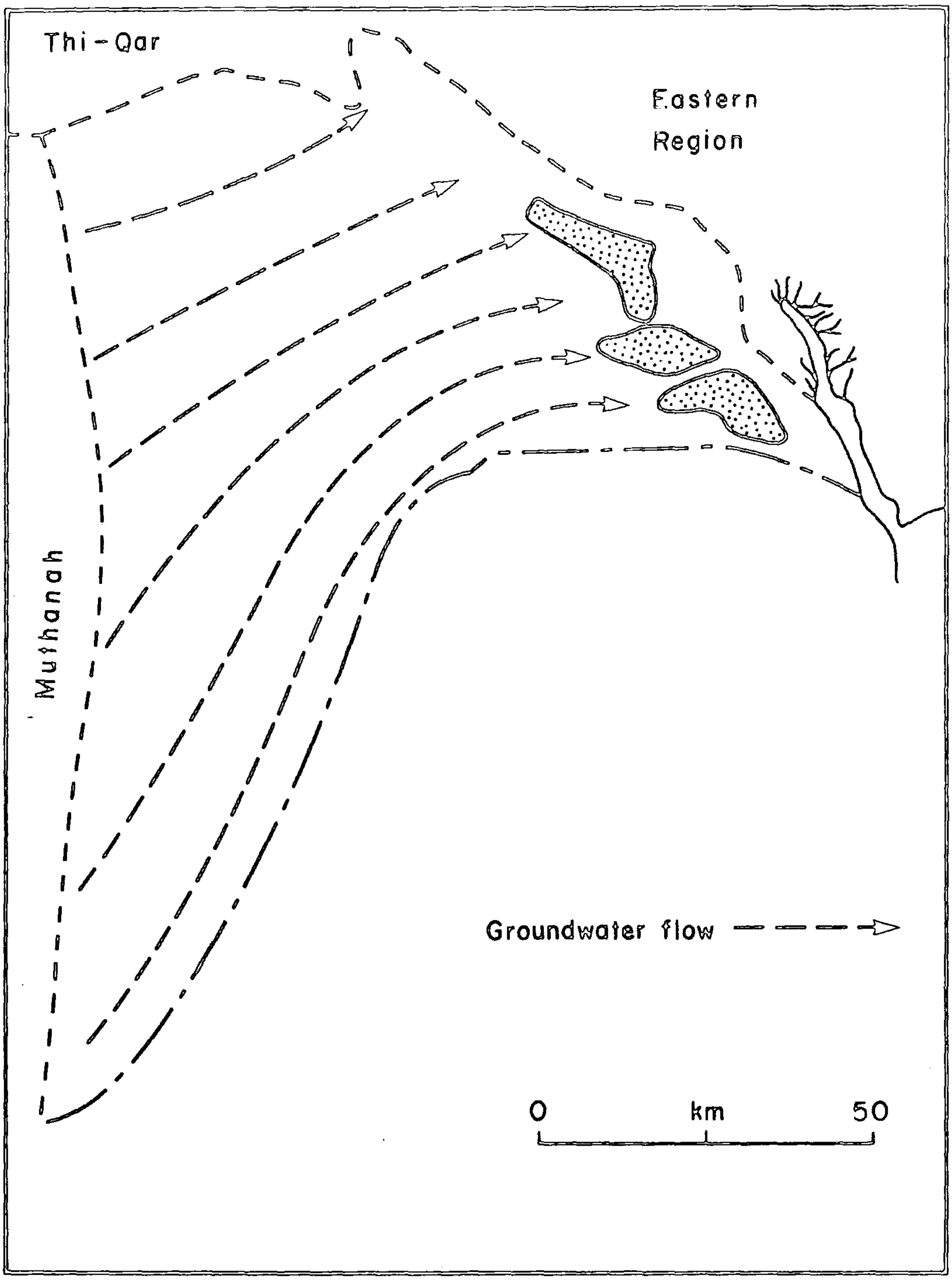
As a result of groundwater concentration in the depressions its depth is shallower in these depressions than in the surrounding higher areas. At Safwan the depths to groundwater range from 10 to 16 m and at Al-Berjsiyah-Chwibda between 15 and 25 m and at Al-Najmy from 15 to 20 m. However, in the surrounding areas the depths increases and reach 172 m at Khuder-el-Mai and 198 m at Khor-Chlawa.

3.3.5 Water quality

The quality of fresh water in the Dibdibba depends largely on the amount of rain received by the upper parts of the formation. The local farmers suggest that the quality of water becomes better at the end of the rainy season than at the end of the dry summer season. Therefore, it is convenient to cultivate crops which require a lot of water at the end of the rainy season.

Tables 3.3 - 3.6 show that the average Ec value of the groundwater varies from place to place. It reaches 7.8 mmhos/cm at Al-Najmy, increases to 8.6 mmhos/cm at Safwan and the highest value at 10.0 mmhos/cm is at Al-Berjsiyah-Chwibda. According to U.S.D.A classification of the water quality which was mentioned in Chapter 2.2.1.1.5, the waters of all depressions are considered as having excessively high salinity and should not be used for irrigation. This high water salinity can be attributed to three factors:

Fig 3·2 Groundwater flow and direction



Source: Institute for Applied Research on Natural Resources, Op.Cit.p.13

1. The Dibdibba formation which includes the usable part of the groundwater overlies the Ghar and Dammam formations which contain saline waters. The Dibdibba formation is separated from the above formations by clayey beds. These beds do not fully prevent hydraulic communication between the formations. So, as groundwater flows both in Dibdibba and the underlying formations, a continuous flow from one aquifer into another is possible. In other words, the saline water from Ghar and Dammam may pass through the separation beds and pollute the Dibdibba water. This occurs particularly in locations where fresh water is over-pumped through prolonged use.[16]

2. The irrigation water may dissolve the salts left in the soil by evaporation and carry them back to the aquifer causing an increase in the salt concentration of the original fresh water.

3. The third possible source of the salinity is that the coastal aquifer is renowned for discharging its saline water into adjacent aquifers which have low water levels. The saline sea water may be from Khor-el-Zubair which is located adjacent to the eastern parts of the region under discussion. The intrusion of this saline sea water to the adjacent groundwater basins in the depressions may cause pollution of their waters. The problems of saline sea water intrusion are acute not only in the coastal aquifers but also in many inland areas.[17] This is due to changes of pressure head where the two fluids - fresh and sea water - are hydraulically connected as a result of the destruction of natural barriers - those separating the two types of waters. The destruction occurs during drilling for water or oil,[*] or again by development of a steep pressure gradient towards the fresh water due to over-pumping.

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* There are many oil fields in this region.

A third possibility can be used to explain the saline water presence in the following cases:

a) Directly during well digging, particularly in wells dug at the low parts of the depressions where the static water level is below mean sea level. For example, some parts in the Al-Berjsiyah-Chwibda depression are 3 m below M.S.L. and some at Al-Najmy 4 m below M.S.L.

b) After heavy pumping of fresh water.

In addition, it can be noted that the Ec values of the groundwater do increase with increasing depth of the groundwater to the west and southwest. Its value at Khuder-el-Mai is 14 mmhos/cm, at Khor-Chlawa is 15 mmhos/cm and 10 mmhos/cm at Luqait. (18)

The groundwater analyses further show that it is rich in sulphate and sodium components at 54 and 52 me/L respectively. Thus, sulphates are dominant in the groundwaters of the region with 50 me/L in Safwan increasing to 52 me/L at Al-Najmy and escalating to 62.3 me/L in the Al-Berjsiyah-Chwibda. The amount also increases to the west-southwest as for example in Khuder-el-Mai where it increases to 72 me/L.

Of the cations responsible for water salinity, sodium is the most important because of its effect on the soil and hence plant growth through deterioration of the physical conditions - permeability and aeration of the soil. Tables 3.3 - 3.6 show that the average sodium proportionate to other cations is 54.5%, this varying between 51% at Al-Najmy and 60.3% at Al-Berjsiyah-Chwibda. According to Wilcox's classification (1955) (19) of the water from the viewpoint of the sodium percentage:

Designation	Sodium percentage
Excellent	< 20
Good	20-40
Permissible	40-60
Doubtful	60-80
unusable	> 80

Table 3.3 : Groundwater samples at Al-Berjsiyah-Chwibda

Sample	Year of well exploitation	Depth	Ec mmhos/cm	pH	Ca me/L	Mg me/L	Na me/L	K me/L	Cl me/L	SO_4 me/L	HCO_3 me/L	CO_3 me/L
1	1979	17	12.17	7.2	22	18	92	0.6	67.5	62	1.72	0.68
2	1978	16	11.15	7.6	20	34	81	0.8	54	78	2.58	0.86
3	1980	15	10.63	7.5	20	16	70	0.4	39	66	0.86	0.86
4	1961	25	9.34	7.8	28	12	64	0.7	48	54	1.72	0.86
5	1979	17	10.2	7.5	20	26	56	0.6	39	61	0.86	0.86
6	1980	19	10.95	7.8	38	4	78	6.0	54	70	1.72	0.86
7	1976	20	9.29	7.4	16	34	45	7.0	37.5	62	1.72	0.86
8	1981	17	6.79	7.7	24	2	46	0.4	24	46	1.72	0.86

Table 3.4 : Groundwater samples at Al-Najmy

Sample no.	Year of well exploitation	Depth m	Ec mmhos/cm	pH	Ca me/L	Mg me/L	Na me/L	K me/L	Cl me/L	So_4 me/L	HCo_3 me/L	Co_3 me/L
1	1980	20	6.68	7.65	28	12	35	0.7	36	37	1.72	0.86
2	1978	17	10.04	7.65	22	20	65	0.4	36	66	3.44	0.86
3	1981	20	5.67	7.8	16.8	15.6	30	0.3	12	48	0.86	0.86
4	1979	15	8.96	7.6	24	22	43	6.0	36	58	1.72	0.86

Table 3.5 : Groundwater samples at Safwan

Sample no.	Year of well exploitation	Depth m	Ec mmhos/cm	pH	Ca me/L	Mg me/L	Na me/L	K me/L	Cl me/L	So_4 me/L	HCo_3 me/L	Co_3 me/L
1	1974	12	12.15	7.4	36	14	74	0.8	63	58	2.58	0.86
2	1975	13	9.51	6.1	16	36	50	1.0	4.5	56	6.86	0.86
3	1981	16	3.65	7.65	4.4	16.4	17	0.2	4.8	30	1.72	0.86
4	1976	10	9.34	7.8	28	18	59	0.6	60	43	1.72	0.86
5	1980	11	7.61	7.7	22	34	55	0.7	42	67	1.72	0.86
6	1981	14	5.26	7.45	28	12	24	0.4	10.2	51	1.72	0.86
7	1981	16	6.73	8.0	34	4	35	0.4	30	41	1.72	0.86
8	1978	13	10.15	7.3	26	18	75	1.3	63	54	3.44	0.86

Table 3.6 : Average Results of Water Analysis

Depression	Ec mmhos/ cm	pH	Ca me/L	Mg me/L	Na me/L	K me/L	Cl me/L	So_4 me/L	HCo_3 me/L	Co_3 me/L	SAR me/L	Na %
Al-Berjsiyah-Chwibda	10.0	7.5	23.5	18.2	66.5	2.0	45.3	62.3	1.6	0.86	14.5	60.3
Al-Najmy	7.8	7.6	22.2	17.4	43.2	1.8	30.0	52.2	1.9	0.86	9.7	51.0
Safwan	8.0	7.4	24.3	19.0	48.5	0.6	34	50	2.6	0.86	10.4	52.4
Average	8.6	7.5	23.3	18.2	52.7	1.4	36.4	54.8	2.0	0.86	11.5	54.5

The groundwater in all depressions is considered as permissible from this stand point.

However, sodium hazard is determined by the absolute and relative concentration of cations and can be evaluated through the sodium adsorption ratio (SAR). The average SAR value is 11.5 me/L and varies from 9.7 me/L at Al-Najmy to 14.5 me/L at Al-Berjsiyah-Chwibda. According to U.S.D.A. Classification (1954) of the water quality from the viewpoint of the SAR (see sec.2.2.1.1.5), the groundwater of Al-Najmy is considered as Class 1 and of Al-Berjsiyah-Chwibda and Safwan as Class 2. The first class can be used on almost all soils with little danger of accumulation of harmful amounts of exchangeable sodium. The second class can be used readily on coarse-textured soils with good permeability.

The bicarbonate hazard may affect the soil solution concentration, since a high content of bicarbonate may lead to precipitation of calcium and to a lesser extent magnesium in the form of carbonates as the soil solution becomes more concentrated. This leads to an increase of the SAR of the soil solution and consequently an increase in its Esp. Eaton (1950) [20] developed this approach and assumed that all calcium and magnesium would precipitate as carbonates and introduced the term residual sodium carbonate (RSC). He considered that water with RSC higher than 2.5 me/L is not suitable for irrigation purposes and an RSC between 1.25 and 2.5 me/L as marginal and he regarded water with an RSC less than 1.25 me/L as safe. According to these measurements, the groundwaters of all depressions are considered safe because their RSC values are less than 1 me/L.

It is worth while mentioning that both the SAR and RSC methods have been used to evaluate the alkalinity hazard independently of each other. Bower (et al,)(1968) [21] suggested a new modification of

SAR including RSC. This modification is called adjusted sodium adsorption ratio (adj. SAR). However, this requires complex calculations and gives relatively the same results as previously explained for the components of the water quality.

Boron is essential for the plant growth, but in a large concentration it becomes toxic. Water containing 0.3 to 1 ppm boron can be used for sensitive crops, 1 to 2 ppm can be used for semi-tolerant crops, for example tomatoes, and 2 to 4 ppm can be used for tolerant crops.[22] Previous study showed that the groundwater of all depressions can be used for all crops.[23]

Determination of suitability of groundwater for irrigation is highly affected by soil texture and its drainability. The soils of the depressions as earlier mentioned are sandy with a coarse texture and rapid permeability. These properties allow even excessively highly saline water (USDA) to be used for irrigation. It is, therefore, possible, as indeed is currently practised, to use rather saline water for successful growth of vegetables, as will be explained later.

In the foregoing it has been pointed out that the fresher, usable groundwater exists within the upper part of the Dibdibba formation. The groundwater tends to concentrate under the depressions in which it becomes shallower than in the surrounding areas. Therefore, these depressions indicate the main water fields in the region.

3.4 MANAGEMENT

In relation to irrigated agriculture, sound management means the best utilization of the water and soil of the farm for the realization of optimum profits. In the present context a definition of management would include the knowledge and skills of the farmer and the availability of both labour and means of finance as factors which determine the relationships between soil, water and plant. These aspects depend for a large part on the farmer's socio-economic background and his level of education. To this end the following sections pursue the background and perceptions of the traditional farmer.

3.4.1 Socio-economic status

The majority of the farmers in the region do not live on their farms or even near them i.e. they live in the towns and cities of Zubair, Safwan and Basrah. From field investigations it is known that a potential agricultural labour force exists in farmers' families. However, the farmers and their families are affected by urban life; the children work in nonagricultural jobs in the above mentioned cities or attend urban schools, and the majority of farmers practice other non agricultural jobs and supervise their farms only through occasional visits. In effect, there is no farm resident rural society and little or no farm family labour available.

The farmer himself is the water well owner and the land is obtained from the government for a nominal sum as a means of encouraging agriculture in the region. In this region cultivation is practised only in one season per year and this provides essentially a secondary source of income for the farmers whose main occupations are in non agricultural activities. Therefore, agriculture practices concentrate on the cultivation of crops which provide the largest cash return e.g. tomatoes, which will cover the high wages of employed workers and provide a reasonable profit (see section 3.14).

The majority of the workers on the farm are Egyptians and others are drawn from the adjacent Thi-Qar province. They carry out all the irrigation and cultivation operations under supervision of the farmer and receive their wages monthly from the farmer. These workers live in small mud huts on the farm and are provided with food and water by the farmer. Two or three workers are employed on a permanent basis during the growing season only and another 2 or 3 are required for a short period during the establishment of the farm. The workers demand relatively high wages in compensation for the seasonal unemployment and the hot,arid desert conditions in which they have to work.

3.4.2 Educational Status

Cultivation activities in this region differ from those practised in the other regions in Iraq and require special skills (see sections 3.6 and 3.10). These traditional skills are handed down to the farmer from their fathers, and the farmers instruct their workers at the beginning of the growing seasons in e.g., the excavation, smoothing of the canals and how and when to irrigate the farm.

Most of the farmers know how to maintain irrigation pumps and a number of them have two pumps for each farm because pump-failure during the growing season would cause damage to the crops. They are also able to estimate the water quantity which is withdrawn from the well, when to irrigate and with how much water. They also realize the importance of the leaching requirement and how to improve soil properties. However, these skills are all based on traditional manual technology and farmers have not improved on irrigation methods which have been used for a long time. They also rely on annual bare fallow (see section 3.15) as a means of generating fertility.

3.5 WELLS

The wells are mainly concentrated on the water fields in the three depressions which provide the main source of the groundwater in the region.

Well sites are chosen by the would-be farmer and specialist well-digger. In the site selection and digging of the wells many factors have to be taken into consideration. First, the site is usually chosen to be near to roads. Secondly, since the manual digging of the wells is expensive it is preferable for them to be dug at the lowest points in the depressions where the water level is near to the ground surface. Thirdly, the presence of vegetation on other farms is used as evidence of the ground water availability in the area. Finally, the chosen site for the well should avoid the need to dig through hard compact strata. The digger would use his own experience in this matter or would carry out a trial excavation. Recently land digging of the trial excavation has been replaced by a mechanical shovel which can excavate to 3 m depth, the cost being about ID 150 (£260).*

After a complete agreement is reached with the owner of the well, respecting the site, the digger and three semi-skilled workers begin the excavation. The equipment involved includes ropes, a plastic basket, a horse, a shovel and an iron rod of 1.5 m length - tapered at one end and sharp and flat at the other. The digging group starts with a circular excavation about 4 m in diameter. The waste earth is removed in the basket, being passed to a worker standing on the well edge and then to another one who distributes it round the well and on a site which was previously chosen for the water reservoir basin and main canal. When the depth increases to more than 5 m below the bed of the large excavation, the horse is used to lift the waste earth-basket. During the digging the digger checks from time to time whether or not the well walls are consolidated. When their formation is found to be unconsolidated, a casing is necessary, and the walls are lined with bricks to prevent caving and collapsing. Only in consolidated strata can they be left uncased.

The well diameter decreases by 0.50 m for every 5 m of depth,

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* Prices in this chapter are converted to sterling at the mid 1981 rate of £1 sterling equals ID 0.575.

to provide support for the well casing and to ease the excavation operation in the deeper sections. Consequently, the well diameter will be 2 m at a depth of 20 m.

The digging is continued in order to penetrate the saturated zone which is located at different depths as previously mentioned. Generally, the well penetrates the saturation zone at a depth ranging from 4 m to 8 m, an increase in the thickness penetrated leading to an increase in the amount of water flowing into the well and vice versa. However, the digging rarely reaches more than 25 m depth in order to avoid the saline water which normally underlies the fresher layer. At the saturated zone, the digger applying his own experience will go on digging at the more moist spots in order to try to discover the small 2-8 cm diameter tube like zones of more permeable material which best conduct the groundwater. He continues the digging in order to find bigger tubes having a diameter ranging from 10 cm to 20 cm. When three or four are discovered, the digging may continue to only 3 m under these tubes, this extra excavation being used as a store for groundwater to feed the pump.

The well digging may be completed in about two months. During this period the wages for the digger total some ID 1200 (£2083) and those of the assistants total ID 900 (£1562), ID 600 (£1041) and ID 600(£1041) for each worker and ID 480 (£833) for the hire of the horse. Thus the total cost for well digging amounts to nearly ID 4000 (£6956).

In cases where the well proves to be unproductive, due to the groundwater conditions at the well site, the owner stands to lose the total amount of money outlayed on digging operations. Such cases occur :

1. When the digger cannot find narrow or larger water carrying tubular structures.

2. When the water discovered is of insufficient amount to feed the pump or to irrigate the farm three times a day.

3. When the discovered water is saline.

When the discovered water is sufficient and fresh, the well is surrounded by a brick wall of 0.50 m in height to protect it from sand falls. Then two iron rods, ranging between 7 m to 10 m in length, are placed across the well's diameter, and on these the turbine pump is installed at the central point of the well excavation. The engine installed near the well drives the pump by a drive belt. Two pipes are then connected to the pump; one of them 10 cm in diameter, used to withdraw the water from the well and the other 7 cm in diameter to discharge the water into the water reservoir which is located 3 m to 5 m from the well.

The availability of spare parts for the engine is crucial during the growing season because engine failure, even for 24 hours, would lead to serious problems for plant growth. Therefore, spare parts must be available to guarantee quick repairs during the irrigation season.

The cost of the turbine pump and the 8 horsepower engine which is commonly used in the region ranges between ID 350 (£607) and ID 450 (£781).

In the past, a centrifugal pump was used to boost the water flow from the well to the water basin. It was installed on the bed of a pit which was dug beside the well and connected by a gap to the well. Access to the engine was by means of steps cut into the side of the engine pit, (see figure 3.3). The use of a turbine removed the need for the constructions described above.

FIGURE 3.3 : Reconstruction of an old well

FIGURE 3.4 : An old well using animal power

Before the use of the pump and more recently the turbine, the water was lifted by using three donkeys which pulled up three leather buckets on three pulleys that were supported above the well, (see figure 3.4.).

From what has been said it can be concluded that hand dug wells are the only means of utilizing the ground water in the region. These are located at the low spots in the depressions. Discovery of plantiful and fresh water in the well is not certain. These wells are costly, so the farmer risks his money when adequate quantities of fresh water are not discovered. The wells penetrate to depths of no more than 25 m, avoiding the saline water. The turbine is a significant modern device which compensates for the effort and costs spent on the old constructions.

3.6 THE DISTRIBUTION SYSTEM

A typical farm in the region, where average conditions prevail, consists of 200 furrows or 9160 m^2 (3.66 donums). This area is determined by the water produced from the well as will be explained in Section 3.10.

The distribution system for irrigation water on a typical farm consists of a water basin, canals, division boxes and furrows, these being used for conveying irrigation water from the water basin to the furrows where the crops are planted.

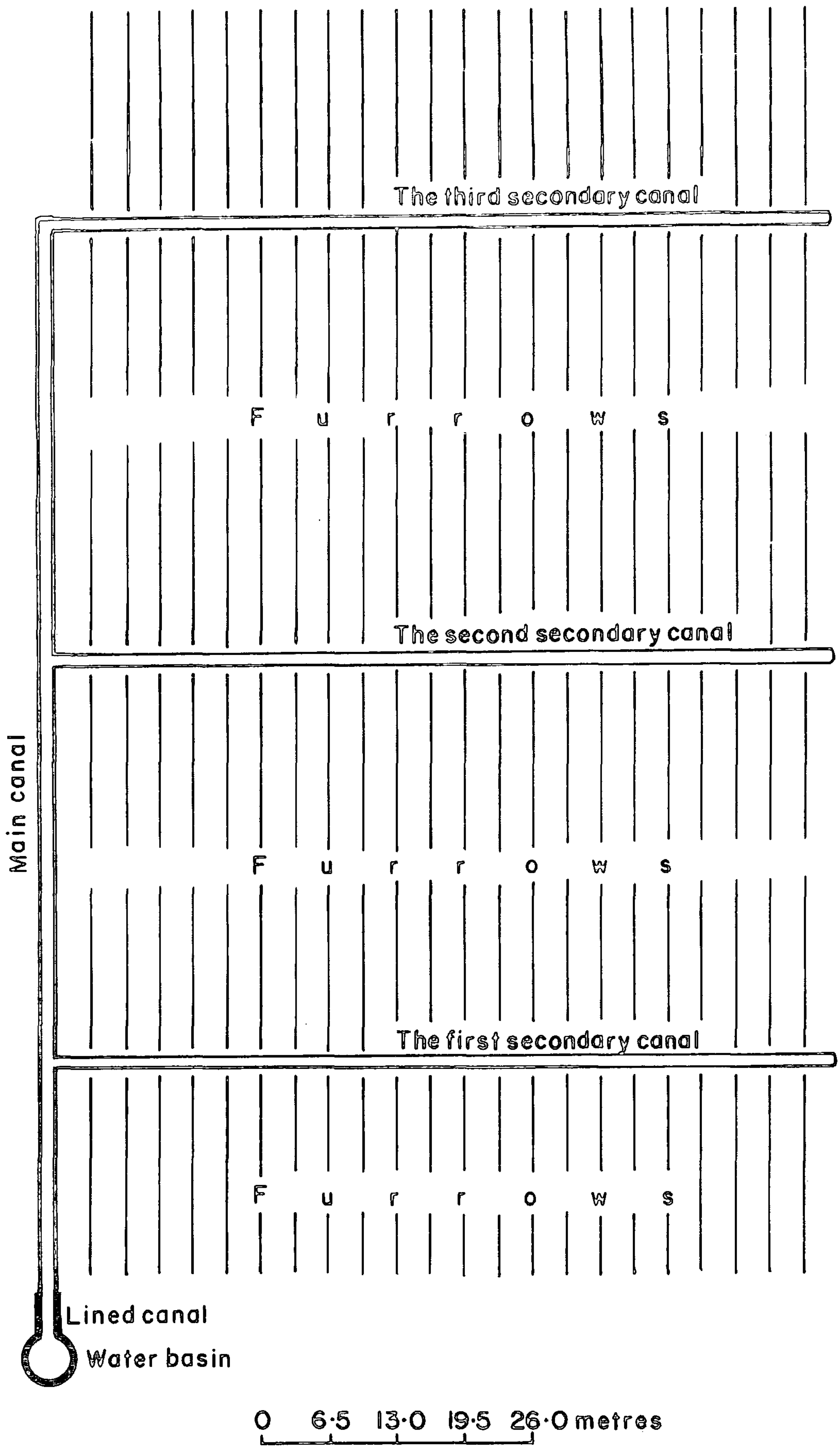
The concrete-lined spilling basin (Al-Bercha) is recharged with water from the pipe which is connected to the pump, the bottom of the basin measuring about 0.50 m, the diameter 2 m, hence the volume totals 1.5 m^3. It is built on an earth base which is more than 1.5 m above the adjacent farmland surface so that the water will flow into the irrigation canals by gravity force. Its construction costs about ID 35 (£60). A small aperture of 0.30 m depth and width, situated above the basin base, allows the water to spill from the basin into a concrete-lined ditch, for a length of 5 m. It is lined to prevent water erosion at the head of the main canal due to its relatively high speed in this section. The main canal (Al-Geuom) connected with the above canal is unlined and excavated on the surface of an embankment which is compiled of waste earth from the well excavation and sandy soil. Its elevation decreases from 1.5 m above the adjacent land surface near the water basin to about 0.20 m below the surface at the last section, (see figure 3.5.). It is usually built along one edge of the farm immediately above the irrigated land so as to divert the irrigation water into the secondary canals. The total length is about 180 m, consisting of two sections, the longer of 110 m is the highest and the other measures 70 m, being excavated on the land surface and constituting the third secondary canal, (see figure 3.6.). The first section has dimensions which average 0.35 m depth, 0.6 m width, this having an overall volume of 16.5 m^3. For the second section the measurements are 0.20 m depth, 0.40 m width and hence a volume of 5.6 m^3. The construction costs approximately ID60 (£104). Due to locally available materials used to construct this canal being unsuitable, seepage occurs and is noticeable on both sides of the canal. To combat this the farmer lines these parts with plastic sheets decreasing seepage losses and water erosion, (see figure 3.7).

Two secondary canals 42 m apart are constructed at right angles from the main canal. They are excavated by tractor as linear excavations being later planed by hand and shovel. Uniform flow in these canals is achieved by spilling water into them, the flow being observed by the irrigation workers as to where it stops or concentrates or moves quickly. In this way the workers moving soil, in baskets

FIGURE 3.5 : Elevation of the main canal

FIGURE 3.7 : Use of plastic sheets to line some portions of the main canal

Fig 3·6 DESIGN OF THE TYPICAL FARM IN THE REGION



from higher spots to lower ones, provide uniform flow for the irrigation water into these canals. These canals together with the last section of the main canal comprise the secondary canals for the farm. The dimensions for each are 70 m length, 0.35 m width and 0.20 m depth, the capacity therefore being 4.9 m^3. The cost of excavation of each canal by tractor is ID 0.150 (£0.25). The above open earth canals are characterized by high water losses due to seepage, evaporation and deep percolation, all of which with the large cross-section influences the water conveying capacity, its velocity and consequently the water discharge. In addition their sides are usually broken due to water erosion. However, the low initial costs are one of the major advantages of this type of canal, along with the ease of construction and maintenance.

The furrows (meshaieb) (sing. meshaab), branch at right angles from the secondary canals, 35 furrows from each side, at a regular spacing of 2 m, thus the typical farm consists of 200 furrows. The dimensions again measure an average of 20 m length, 0.30 m width and 0.20 in depth, the volume of each furrow being about 1.2 m^3 (see figure 3.8). The furrows are excavated and smoothed in the same way as the secondary canals. The costs of excavation for each furrow by tractor is ID 0.120 (£0.17).

Diversion boxes are constructed at the junction points of the furrows and the secondary canals. Their function is to divert irrigation water from secondary canals into the furrows. Each box is constructed from plaster or concrete slabs to prevent water erosion to the head of the furrows, (see figure 3.9). Each box has four gaps, two of which are used to pass water in the secondary canal through the box, the other two are used to divert the irrigation water from the sides into the furrows. Small coiled burlaps are placed in one or

FIGURE 3.8 : A furrow and side excavations

FIGURE 3.9 : Construction of the diversion boxes

two of the gaps to divert the water as needed. These burlaps however are not completely efficient barriers as a certain amount of irrigation water passes through causing a decrease in the water conveyance capacity. Therefore, the water discharge will decrease with increasing distance from the water basin.

It is clear that the distribution system of irrigation water is generally inadequate because of high water losses through the canals and diversion boxes. This inefficiency is accepted because construction costs are generally low and because the farmer is aware that the system will be abandoned after about three years as explained in section 3.15.

The distribution system discussed above is constructed to serve the particular types of crops which are to be cultivated and at the same time is influenced by soil conditions and husbandry. Hence, the crop types, stages of growth, consumptive use and leaching requirements have to be considered before water supply.

3.7 THE CROPS

Tomatoes are the only important crop cultivated in the region as they provide the greatest cash return.

When irrigation water was lifted by donkeys and pumps, the cultivated areas (farm area) were small consisting of 120 furrows or 4950 m^2 because of the small quantities of productive water which could be drawn. The produce of these old farms included melons, water melons, cucumber, aubergine and alfalfa in summer, and tomatoes, garlic, onions and squash in winter.

As a result of the continually increasing well digging costs, rising wages and falling prices for the summer crops, in addition to the recognition that as little water as possible should be used to avoid rapid deterioration of the soil, the majority of the farms now confine crop production to tomatoes as the main cash crop together with limited quantities of garlic and onions which are cultivated only in winter. This choice is firstly because in this region, which has moderate winters compared to other regions, tomatoes mature in a period from January to March and April when there is a distinct lack of tomates in the Iraqi markets with the exception of the tomatoes produced in the marsh region, thus ensuring high prices in winter months. Secondly, winter grown crops avoid the high temperatures of summer which lead to an increase in water supply. Thirdly, tomatoes are more tolerant to saline water than other high value crops.

According to the FAO classification (1975) [24] the crop growth stages and the average time of these stages in the typical farm can be stated as follows:

3.7.1 <u>The initial stage</u>

After digging and smoothing of the canals and furrows, small excavations of 0.30m depth and 0.20 m width are dug by hand shovel on both sides of the furrows with an average distance of 0.50m separating each pair of excavations,(see figure 3.8). So, the total number of such excavations on each furrow amounts to 80 and the total excavations in the typical farm numbers 16000. The spaces between these excavations are left for the extension of tomato root system and the cultivation of garlic and onions. These excavations require 3 workers for 14 days, working hours being confined to between 5 a.m. to about 10 a.m. per day due to the high temperatures in the summer months. Wage costs total ID 420 (£729).

As a result of the low organic content of the soil, both organic and chemical fertilizers (potassium, phosphorus and nitrogen) are placed in the excavations. They are mixed with the soil in order to provide nutrients for the roots and to increase the water holding capacity in the root zone. The total quantity of organic matter required for the typical farm is about 30 m^3 costing ID 450 (£781). Local farmers have suggested that if lower amounts of organic matter are used, the production will decrease because most of the nutrients will be leached from the root zones by the heavy irrigation applications. The organic fertilizer is manure brought from Basrah and Zubair cities.

About 20 tomato seeds are planted in each excavation in mid-July, this number being planted to avoid complete failure in production. The seeds are left to be irrigated three times a day until the seedlings reach a height of 0.15 m at the end of this stage; at this point the seedlings are thinned leaving only the most healthy to grow free from competition. This stage takes 30 days from the 15th July to the 12th August.

3.7.2 The developing stage

In this stage the tomatoes are also irrigated three times a day because the crop is still very sensitive to drought. Growth throughout this stage is vegetative and lasts for about 49 days from mid-August (13 August)to the end of September (30 September).

3.7.3 The mid-season stage

In this stage, irrigation is reduced to twice a day and the farm becomes green, and some of the lower leaves tend to be yellowish. Flowering takes place and the fruit begins to form at the end of this stage which lasts about 61 days from the 1st October to the 30th November.

3.7.4 The late stage

In this stage the crops are irrigated once a day and the fruits gradually become mature. This stage lasts about four months from December to March.

During this stage when temperature decreases at night in January and February, plastic cloches are constructed on the furrows to avoid frost damage. They are placed over the crops during night and removed during the day-time hours for two reasons : firstly, because the temperature rises during the day-time and secondly to remove the excessive moisture formed inside these cloches and expose the crops to needed sunlight.

3.8 CONSUMPTIVE USE

With available meteorological data in this region restricted to temperature, rainfall and day-time hours (see Section 1.4), the Blaney Criddle method is used to determine the theoretical consumptive use of water for the crops in this region (see Section 1.4.9). To find the consumptive use of the major produce of the region - tomatoes, the result of the equation is multiplied by k = 0.68 as the coefficient for tomatoes.[25] Table 3.7 and figure 3.10 show that the total consumptive use of the tomatoes on the typical farm is $8304m^3$. The mean monthly consumptive use varies according to variations of the temperature and daylength. It increases in the summer months and decreases in winter,(see table 3.7).

However, the actual water demand has to be measured in the light of the following factors:

High water losses through the coarse textured soils which have low water-holding capacity, high temperature, cultivation of the seedlings in

Fig 3·10 THE THEORETICAL CONSUMPTIVE USE AND THE ACTUAL WATER APPLIED ON THE TYPICAL FARM (m^3)

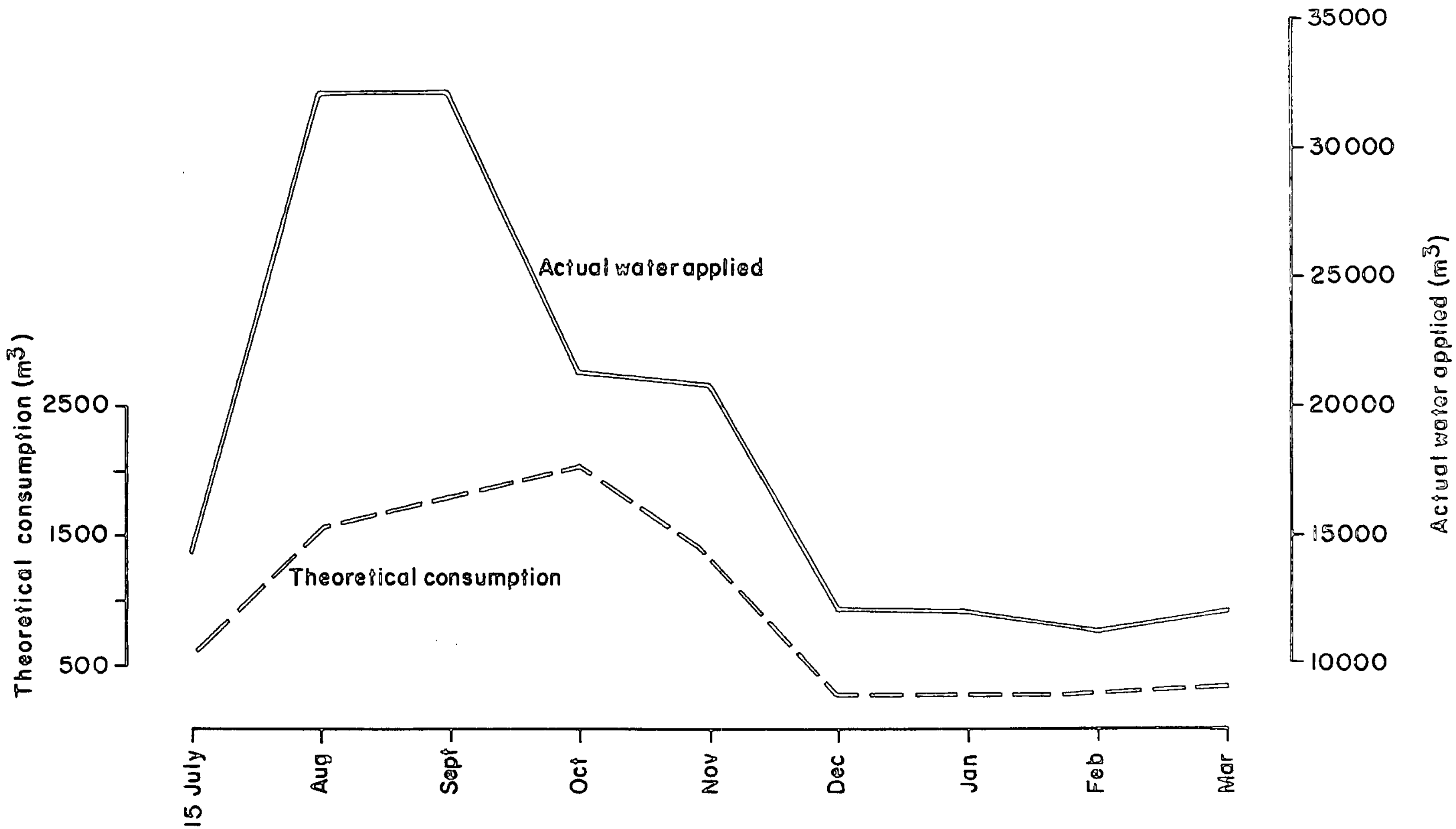


Table 3.7 : The consumptive use of water by tomatoes (m^3)

month	t= F°	p%	f mm/ month	Et of tomatoes k=0.68mm	Tomato area m^2	Et of tomatoes area in m^3	Remarks
Jan.	51.8	7.3	96	24	9,160	219	
Feb.	57.2	7.7	111	27	9,160	247	
Mar.	64.4	8.4	137	34	9,160	311	
Apr.	75.2	8.5	162				no crops
May	86.0	9.9	216				"
June	91.4	11.1	257				"
July	96.8	10.4	255	64	9,160	586	for 15 days
Aug.	96.8	10.6	260	171	9,160	1,566	
Sep.	89.8	10.3	234	192	9,160	1,758	
Oct.	80.6	9.4	192	221	9,160	2,024	
Nov.	68.0	7.6	131	150	9,160	1,374	
Dec.	55.4	7.1	99	24	9,160	219	
Total				907		8,304	

the hotter months and irrigation by saline water which therefore requires more frequent watering to prevent salts building up in the soil. For these reasons crops under the specific local conditions may need more water than the theoretical calculation indicates.

The farmers, therefore, know from their experience of the quantity of crop produced along with the greenness of the leaves how much water to apply and how many irrigations to carry out per day.

3.9 LEACHING REQUIREMENT

This is the amount of water required to reduce the Ec value of the soil in the root zone. Thorne and Peterson (1954) [26] produced the following equation to calculate the leaching requirement (LR) as follows:

$$LR = Ecw \div Ecs \times 100$$

Where Ecw is the Ec value of the irrigation water and Ecs is the Ec value of the soil. On applying this equation to the average Ec values of the soil and the water in the depressions, the result shows that 205% more water should be used than is actually required to bring the soil to field capacity and to maintain the average Ec of the soil at 4.3 mmhos/cm. Thus the leaching requirement would be 16,940 m^3 during the growing season in the typical farm. The total net irrigation and leaching water required for the typical farm per season amounts to 25,244 m^3. (consumptive use + LR).

However, adequate leaching is not taking place in these soils as is shown by the gradual increase of the Ec value. Table 3.15 shows that the mean Ec value of the soils which have been irrigated for one year is 7.19 mmhos/cm. The following section examines the actual water supply which is a reflection of the efficiency of management and in association with the soil, water and distribution system and will show the difference between theoretical irrigation requirements and actual practice.

3.10 THE WATER SUPPLY

The gross irrigation water applied cannot be known unless actual measurements are carried out on the farm. The gross irrigation water application consists of the consumptive use which is reduced by the amount of effective rainfall and increased due to water losses by deep percolation, evaporation and run-off from the farm, this in addition to the leaching requirement.

The pump used on the typical farm has an 8 horse power capacity with a maximum yield of 3 m^3/min. However, if the pump engine is used at full power the farmer recognises that the water can rapidly become saline. They therefore run it at a lower level giving an average yield of 0.97 m^3/min. The duration of pumping from the wells varies according to the need for water and the time of year. Discussions with local farmers suggested that the typical farm is irrigated three times a day in the first two growth stages and twice a day in the mid-season stage and once in the late stage.

3.10.1 The water supply in the first two stages

Irrigation during these stages consists of three successive irrigations per day.

The water discharges from the pump were measured at important points,(see figure 3.11 and table 3.8). However, measurements of water discharge in earth canals, where flows are affected by water erosion and deposition, were not easy. Because it was not possible to use the common water scales, weir or partial flume, the findings, therefore, may be considered to be less precise than those carried out in lined canals.

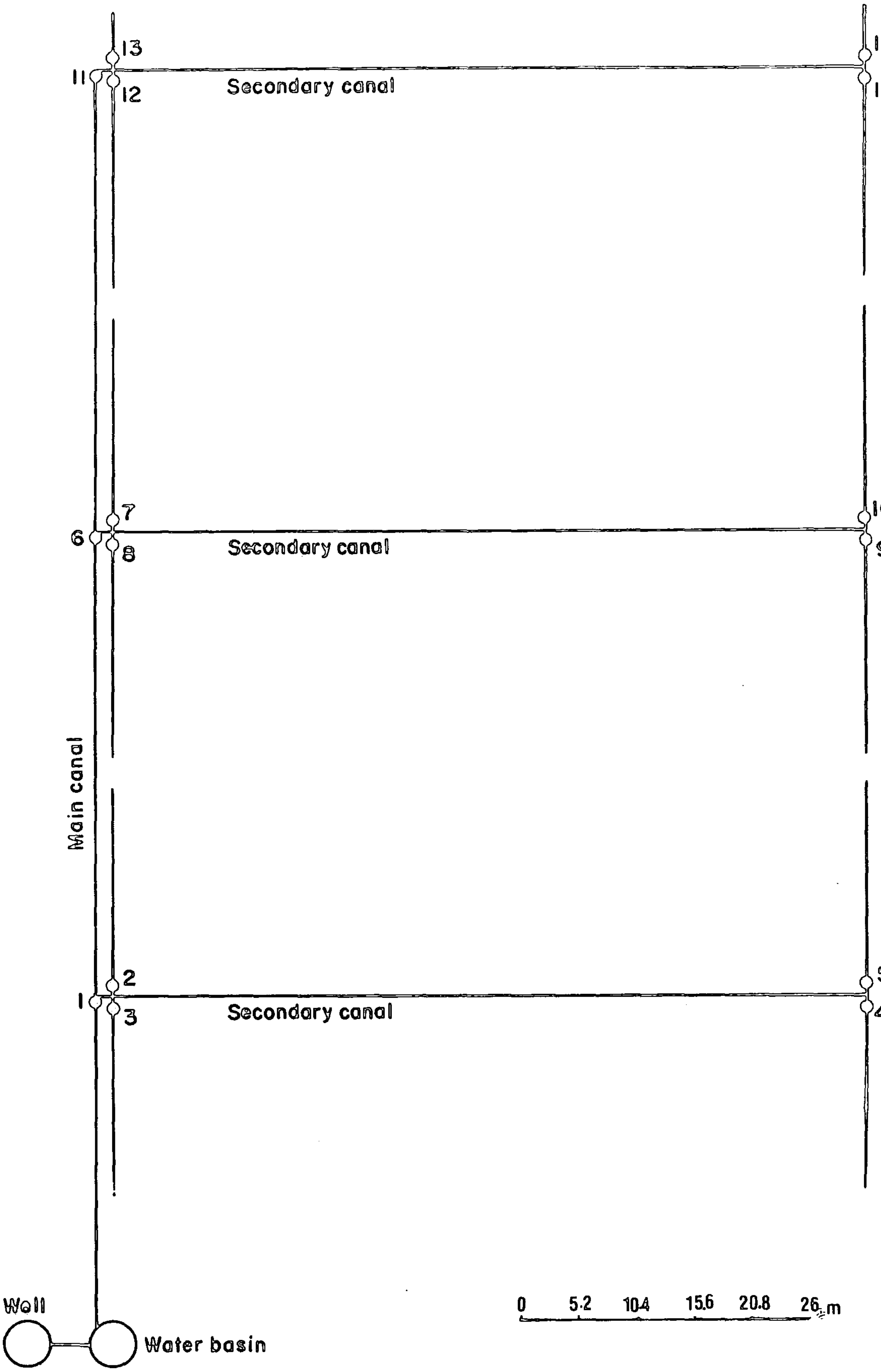
A measuring cylinder of 1000 cm^3 volume and can of 274,625 cm^3 (65 x 65 x 65 cm) capacity were used in the measurements. Both were used to measure the water discharge from the pump. Water was collected from the pump in the can for a specified period of time. The volume of water collected was measured using the measuring cylinder. This procedure was repeated several times. The water discharges in the canals was determined by : firstly, measuring the cross-sectional area, at a given point, in centimetres. Secondly, the cylinder was placed horizontally in the water, at the same points for a limited time. Then measurements were taken of the volume of water discharged at the given point calculated by :

$$\text{Volume of water} = \frac{\text{cross-section area}}{\text{periphery of the cylinder open}} \times \text{volume of water in the cylinder } cm^3/sec.$$

During this period the typical farm is irrigated on three successive occasions so as to avoid the soil drying out in the following way:

3.10.1.1 <u>First Irrigation</u> Table 3.8 and figure 3.11 shows that the water discharge at the first point was 0.92 m^3/min. To irrigate the first two furrows - points 2 and 3 - the points on the main canal after the first secondary canal and on this canal after the first two furrows are closed by earth blocks to divert the water into the first two furrows. Usually, the farmer leaves the water in the secondary canal to flow into the furrows freely. However, in order to carry out the water discharge measurements the first two and the last two furrows in each secondary canal were chosen to show the water losses along the canals. It was not possible to measure simultaneously the water discharge into more than two furrows. The water discharge at points 2 and 3 were 0.46 and 0.42 m^3/min. respectively. The difference between the water discharge at these points is due to variation in the areas of the head cross-section. It is worth while mentioning that the theoretical volume of water required to fill these two furrows to a level of 0.17 m is 1.02 m^3 in 2.2 and 2.4 min. respectively. But, actually, these furrows were only filled to the same level of 0.17 cm by a longer water application of 1.61 and 1.58 m^3 in 3.5 and 4.1 min respectively. This difference is due to the high infiltration rates, rapid permeability, deep percolation, seepage

Fig. 3·11 POINTS OF DISCHARGE MEASUREMENTS



and high evaporation rates in the canals.

The earth block in the secondary canal was then removed and another one was replaced before the last two furrows in this canal. After filling the furrows, which are located before the last two furrows, and closing them, the last furrows - points 4 and 5 - were filled with water. The water discharge at these points was 0.36 and 0.46 m^3/min respectively. These furrows have the same volume 1.2 m^3 but they required more water, 1.63 and 1.77 m^3 over a longer time, 4.5 and 3.9 min respectively, compared with the theoretical volume of 1.02 m^3 and time 2.8 and 2.2 min respectively, to attain a level of 0.17 m.

The other furrows in the farm were irrigated and the water discharge at the other points was measured in the same way as described above. The water discharge decreases with an increase in the distance from the water basin due to an increase in water losses. It reached 0.40 and 0.33 m^3/min at the last furrows in the farm - points 14 and 15. Whilst the average water applied to each furrow in the farm was 1.55 m^3 in 2.19 min, in fact pairs of furrows were filled simultaneously. So, the total water applied to fill the furrows was 311 m^3, the main canal held 20.6 m^3, the first secondary canal 7.77 m^3, the second canal 7.83 m^3, the third canal 7.9 m^3 and the water basin 1.4 m^3. Thus, the total water applied to irrigate the typical farm in the first irrigation is 356.49 m^3 in 8.20 hours and for the duration of the first two growth stages was 28162.71 m^3.

3.10.1.2 <u>Second Irrigation</u> Table 3.9 and figure 3.11 show that the applied quantity of water in this irrigation is generally lower than that in the first irrigation due to a decrease in the infiltration rate which results from filling a large number of the pore spaces of the soil with water and expansion of the soil colloids.

The furrows were irrigated and the water discharges measured in the same ways as in the first irrigation. The water discharge at the first point was 0.94 m^3/min and reaches 0.53 and 0.39 m^3/min at points 2 and 3. The first two furrows in the first secondary canal filled with a smaller quantity of water than in the first irrigation at 1.54 and 1.57 m^3 and in a shorter time at 2.9 and 4.0 min respectively, (see table 3.9). The other furrows were irrigated and the water discharges were measured in the same ways as in the first irrigation.

The average water applied to each furrow in the farm was 1.46 m^3. Thus the total applied water to fill the furrows 293.33 m^3, the main canal holding 18 m^3, the first, second and the third secondary canals are 6.3, 6.4 and 6.36 m^3 respectively. The total applied water to irrigate the typical farm in the second irrigation was 330.37 m^3 in 6.7 hours and in terms of the whole of the first two growth stages was 26100.8 m^3.

3.10.1.3 <u>Third Irrigation</u> : this irrigation was also carried out immediately after the second one and the water applied is generally less than in the second irrigation due to further decline in the infiltration rate.

The furrows were irrigated and the water discharges were measured in the same ways as in the first irrigation. Table 3.10 and figure 3.11 show that the water discharge at the first point was 0.96 m^3/min, it reached 0.55 and 0.39 m^3/min at points 2 and 3 on the first two furrows in the first secondary canal. These furrows were filled by less water at 1.49 and 1.35 m^3 in a shorter time at 2.7 and 3.7 min compared with those in the second irrigation, and thus with the other furrows.

Table 3.8 : Water discharge in the first irrigation during the first two growth stages

Point	Discharge $m^3/$	Discharge m^3/sec	Theoretical time to fill the furrow sec.	Actual water applied m^3	Actual time required sec.
1	0.920	-	-	-	-
2	0.46	0.0076	135	1.61	213
3	0.42	0.0070	146	1.58	226
4	0.36	0.0060	170	1.63	272
5	0.46	0.0076	135	1.77	234
6	0.86	-	-	-	-
7	0.42	0.0070	146	1.72	246
8	0.41	0.0068	150	1.78	263
9	0.43	0.0071	144	1.71	242
10	0.35	0.0058	176	1.63	282
11	0.82	-	-	-	-
12	0.41	0.0068	150	1.83	271
13	0.37	0.0061	168	1.69	278
14	0.40	0.0066	155	1.88	285
15	0.33	0.0050	204	1.73	346

Table 3.9 : Water discharge in the second irrigation during the first two growth stages

1	0.94	-	-	-	-
2	0.53	0.0088	116	1.54	176
3	0.39	0.0065	157	1.57	242
4	0.42	0.0070	146	1.59	228
5	0.47	0.0078	131	1.48	212
6	0.90	-	-	-	-
7	0.46	0.0076	135	1.58	208
8	0.40	0.0066	155	1.61	245
9	0.35	0.0058	176	1.48	256
10	0.45	0.0075	136	1.52	203
11	0.85	-	-	-	-
12	0.34	0.0056	182	1.46	262
13	0.48	0.008	128	1.50	188
14	0.41	0.0068	150	1.57	232
15	0.36	0.0060	170	1.41	236

Table 3.10 : Water discharge in the third irrigation during the first two growth stages

Point	Discharge m^3/min	Discharge m^3/sec	Theoretical time to fill the furrow sec.	Actual water applied m^3	Actual time required sec.
1	0.96	-	-	-	-
2	0.55	0.0091	112	1.49	164
3	0.39	0.0065	157	1.35	208
4	0.48	0.008	128	1.44	181
5	0.42	0.0070	146	1.45	208
6	0.93	-	-	-	-
7	0.47	0.0078	131	1.45	186
8	0.43	0.0071	144	1.37	194
9	0.41	0.0068	150	1.47	217
10	0.44	0.0073			
11	0.90	-	-	-	-
12	0.47	0.0078	140	1.49	192
13	0.40	0.0066	155	1.40	213
14	0.43	0.0071	144	1.47	208
15	0.37	0.0061	167	1.48	243

The average water applied to each furrow in the farm was 1.32 m^3 and the total water applied to fill the furrows 264.33 m^3, the main canal 17.1 m^3, the first, second and the third secondary canals 50, 5.2 and 5.71 m^3 respectively. Thus, the total water used to irrigate the typical farm in the third irrigation was 297.3 m^3 in 5.71 hours and in terms of the first two growth stages was 23486.7 m^3.

Consequently, the total water applied for irrigation of the typical farm is 984.08 m^3 in 20.6 hours per day and in terms of the whole first two growth stages is 77750.2 m^3.

It is worth while mentioning that the quantity of water applied to fill each furrow to a level of 0.17 m is drained and evaporated after an average period of about 1.50, 2.0, 2.50 hours respectively during the first, second and the third irrigation respectively. From this the infiltration rate can be calculated and classified using the Van Beers's 1974, ILRI-21 [(27)] scheme based on a 10 cm module:

Designation	Time required for 10 cm cumulated intake hours
Marginal (too slow)	40 - 20
Somewhat favourable (slow)	20 - 8
Favourable	8 - 15
Somewhat unfavourable (rapid)	1.5 - 1.0
Marginal (too rapid)	1.0 - 0.5

Each 10 cm of water disappears within 0.53, 1.17 and 1.4 hours during the first, second and the third irrigation respectively. According to the above criteria, these relative infiltration rates are considered as marginally too rapid in the first irrigation and somewhat unfavourably rapid in the second and third irrigations. Therefore, using successive irrigations during this period is the only means of providing sufficient moisture to the crops. However, these figures are probably rather pessimistic as not all the water infiltrates the soil, some is lost by evaporation.

3.10.2 Water supply in the mid-season stage

In this stage the typical farm is irrigated twice a day due to lower evaporation rates and to encourage flowering. The water supply in this stage is as follows:

3.10.2.1 Water supply in the first irrigation : Table 3.11 and figure 3.11 show that the water discharge at the first point was 0.95 m^3/min, reaching 0.48 and 0.46 m^3/min at points 2 and 3 on the first and second furrows in the first secondary canal. The water discharge decreased with increasing distance from the water basin and fell to 0.40 and 0.35 m^3/min at the last two furrows in the farm - points 14 and 15.

The average water applied to each furrow in the farm was 1.55 m^3 and the total water applied to fill the furrows was 311 m^3, the main canal 20.76 m^3, the first, second and the third secondary canals 7.74, 7.39 and 6.9 m^3 respectively, and the water required to fill the water basin 1.4 m^3. Thus, the total water applied to irrigate the farm in the first irrigation was 355.2 m^3 in 7.06 hours and in terms of the whole mid-season stage was 21667.2 m^3.

3.10.2.2 Water supply in the second irrigation : Table 3.12 and figure 3.11 show that the water applied in this irrigation is generally less than that in the first irrigation due to a decrease in the infiltration rate. The water discharge at the first point was 0.96 m^3/min reaching 0.49 and 0.44 m^3/min at points 2 and 3. This discharge decreased to 0.41 and 0.36 m^3/min at points 14 and 15.

The average water applied to each furrow in the farm was 1.46 m^3 and the water applied to fill the furrows 293 m^3, the main canal 18.5 m^3, the first, second and the third secondary canals 7.23, 7.22

Table 3.11 : Water discharge in the first irrigation during the mid-season stage

Point	Discharge m^3/min	Discharge m^3/sec	Theoretical time to fill the furrow sec.	Actual water applied m^3	Actual time required sec.
1	0.95	-	-	-	-
2	0.48	0.0080	128	1.53	192
3	0.46	0.0076	135	1.50	198
4	0.39	0.0065	158	1.52	234
5	0.48	0.0080	128	1.58	198
6	0.90	-	-	-	-
7	0.51	0.0085	120	1.56	184
8	0.36	0.0060	170	1.53	256
9	0.44	0.0073	140	1.59	218
10	0.39	0.0065	157	1.53	236
11	0.85	-	-	-	-
12	0.38	0.0063	162	1.61	256
13	0.44	0.0073	140	1.54	212
14	0.40	0.0066	155	1.60	243
15	0.35	0.0058	176	1.57	272

Table 3.12 : Water discharge in the second irrigation during the mid-season stage

1	0.96	-	-	-	-
2	0.49	0.0081	126	1.49	184
3	0.44	0.0073	140	1.51	208
4	0.52	0.0086	119	1.42	166
5	0.35	0.0058	176	1.43	248
6	0.92	-	-	-	-
7	0.48	0.0080	128	1.45	182
8	0.38	0.0063	162	1.42	226
9	0.35	0.0058	176	1.49	258
10	0.46	0.0076	135	1.47	194
11	0.87	-	-	-	-
12	0.36	0.0060	170	1.48	247
13	0.47	0.0078	140	1.51	194
14	0.41	0.0068	150	1.46	216
15	0.36	0.0060	170	1.47	246

and 6.9 m^3 respectively. Thus, the total water applied to irrigate the farm in the second irrigation was 332.8 m^3 in 6.64 hours and in terms of the whole of this stage 20303.8 m^3.

During this stage the quantity of water applied to fill each furrow to a depth of 0.17 m is drained and evaporated after an average period of about 2.10 to 2.70 hours. Each 10 cm of water disappears within 1.2 and 1.4 hours respectively. According to the above mentioned Van Beers's criteria in infiltration rate in both irrigations is considered as somewhat unfavourably rapid (assuming no loss by evaporation).

3.10.3 Water supply in the late stage

In this stage the typical farm is irrigated once a day which is appropriate for fruits to be formed and mature.

More water is used for irrigation in this late stage than during the previous stages. Table 3.13 and figure 3.11 shows that the water discharged at the first point was 0.93 m^3/min, reaching 0.48 and 0.43 m^3/min at points 2 and 3 respectively. The first two furrows should theoretically be filled to a level of 0.18 m by 1.08 m^3 of water in 2.2 and 2.5 min respectively, but in fact they required more water - 1.70 and 1.78 m^3 and over a longer time of 3.5 and 4.2 min respectively - compared with the theoretical needs and the previous irrigations. However, these furrows were also irrigated in the same way as in the other earlier irrigations. The water discharge also decreased with increasing distance from the water basin and fell to 0.38 and 0.36 m /min at points 14 and 15 respectively.

The average water applied to each furrow in the farm was 1.76 m^3 and the total water used to fill the furrows 352 m^3, the main canal 20.76 m^3, the first, second and the third secondary canals 7.93, 7.50 and 7.53 m^3 respectively and the water basin filled with 1.4 m^3

Table 3.13 : Water discharge during the late stage

Point	Discharge m^3/min	Discharge m^3/sec	Theoretical time to fill the furrow sec.	Actual water applied m^3	Actual time required sec.
1	0.93	-	-	-	-
2	0.48	0.008	135	1.70	213
3	0.43	0.0071	152	1.78	252
4	0.39	0.0065	166	1.71	264
5	0.47	0.0078	139	1.84	236
6	0.86	-	-	-	-
7	0.35	0.0058	186	1.72	298
8	0.49	0.0081	133	1.79	221
9	0.42	0.0070	154	1.73	248
10	0.34	0.0056	193	1.80	322
11	0.81	-	-	-	-
12	0.46	0.0076	142	1.79	236
13	0.32	0.0053	204	1.79	338
14	0.38	0.0063	172	1.72	274
15	0.36	0.0060	180	1.76	294

of water. Thus, the total water applied in the farm was 397.1 m^3 in 8.26 min and in terms of the whole of this stage 48,037 m^3.

The quantity of water used to fill each furrow to a level of 0.18 m is drained and evaporated after an average period of about 2.2 hours and each 10 cm of water disappears within 1.2 hours. According to the Van Beers criteria the relative infiltration rate is considered as somewhat unfavourably rapid.

The total water applied to irrigate the typical farm in the region during the growing season is 149,484.9 m^3 which is equivalent to 18 times the theoretical consumptive use of water for the crops, see figure 3.10 and about 6 times the theoretical irrigation and leaching requirements (see section 3.9) which is evidence of high water losses from the typical farm as explained below.

3.11 WATER LOSSES

These are vital factors in estimating the water efficiency of an irrigation system. In the typical farm in the region under discussion these losses vary from season to season and from one irrigation to another as follows:

Generally, these losses occur as the result of the high infiltration rate, rapid permeability, deep percolation, seepage, high evaporation rate and the run-off from the farm and on-farm they increase with distance from the water basin. In the first irrigations, during the first two growth stages they reach 0.05 m^3/min at the first point increasing to 0.24 m^3/min at the last furrows in the farm. The total water losses during this irrigation is 120.75 m^3 and in terms of the whole first two growth stages total 9,539.25 m^3 - see table 3.8.

In the second irrigation during the above stages these losses diminish due to a decrease in the infiltration rate resulting from filling of a large number of the pore spaces with water and the expansion of soil colloids. Thus, water losses reach 0.03 m^3/min at the first point and increases to 0.20 m^3/min at the last two furrows in the farm. The water losses in this irrigation total 59.55 m^3 and in terms of the first two growth stages amount to 4,704.45 m^3,(see table 3.9).

In the third irrigation during the first two growth stages the water losses at the first point decrease to 0.01 m^3/min and reach 0.17 m^3 at the last furrows in the farm. These losses total 35.12 m^3 in this irrigation and amount to 17,018.18 m^3 during the first two growth stages, (see table 3.10).

In the first irrigation during the mid-season stage these losses reach 0.02 m^3/min at the first point and increase to 0.22 m^3/min at the end of the last secondary canal. These losses total 55.7 m^3 in this irrigation and amount to 3397.7 m^3 for the whole mid-season stage, (see table 3.11).

In the second irrigation of the above growth stage, the water losses decrease to 0.01 m^3/min at the first point and increase to 0.20 m^3/min at the last furrows in the farm. These losses amount to 51.9 m^3 and in terms of the whole mid-season stage total 3,165.9 m^3, (see table 3.12).

At the late stage these losses reach 0.04 m^3/min at the first point increasing to 0.23 m^3/min at the last furrows in the farm. During this irrigation the total water losses are 83.73 m^3, which in terms of the whole of this final stage amount to 10,131.3 m^3.

Consequently the total water conveyance losses during the growing season in the typical farm amount to about 33,713 m^3,(see table 3.13).

The total field water losses which are lost from the furrows by deep percolation is equivalent to 42.5% of the total water applied (see section 3.2), and these losses total 49,135.4 m^3 during the growing season. Thus, the total water losses from the typical farm during the growing season is 82,848.4 m^3. This quantity is equivalent to 4.8 times the theoretical leaching requirement and represents 55.4% of the total water applied. This high quantity of water losses is due to the high infiltration rate, deep percolation, seepage, high evaporation and water leakage from the canals and furrows.

3.12 IRRIGATION WATER EFFICIENCY (IWE)

This is regarded as the most important factor used in the evaluation of an irrigation system and its measurement. It can be calculated by the following equation : $IWE = \frac{gw - wl}{gw} \times 100$

where gw is the gross water applied

wl is the total water losses

Calculation of the irrigation water efficiency of the system under discussion shows that the result is 44.5%. This percentage is considered low compared with the general theoretical estimation of the water efficiency of furrow irrigation suggested by the FAO (1972)[(28)] which ranges from 55 - 70%. This can be attributed to the low water holding capacity of the soil and poor management.

3.13 DRAINAGE

Irrigation practice, as previously mentioned, is influenced by the rapid movement of excess water through the soil and subsoil by gravity forces. Therefore, irrigation and drainage are complementary practices.

There is no surface drainage in the irrigated areas due to the fact that excess water drains naturally. This results from the coarse textured soil and consequently rapid permeability. In addition the depth to groundwater is not less than 10 m i.e. deep enough to allow subsurface drainage to occur successfully without causing waterlogging problems.

The excess irrigation water drains rapidly through the coarse soil and partially leaches this soil of the salts which are then carried by this water to the utilised aquifer causing its pollution. However, this excess water effectively does flush away part of soil salinity which was originally introduced to the root zone by the irrigation water itself.

Moreover, this rapid drainage process actually helps in soil ventilation i.e. it does cause the soil to dry out more quickly than can occur in clayey soils, although it also tends to leach the plant nutrient from the root zone.

3.14 CROP YIELD

This reflects the influence of the management as well as the efficiency of irrigation.

Tomatoes are the main crop in the region because they yield a high cash return, (see section 3.7). However, tomato production is subject to some risks and possible crop failure. The main risks involved are an increase in water salinity throughout the growing season, the possibility of frost occurring during a few nights in January and February, and a drop in available irrigation water. Therefore, many farmers cultivate secondary crops of onions and garlic to compensate for any losses incurred with tomato production.

At the beginning of December the fruit begins to ripen and they mature gradually through the following months until April. This enables the farmer to provide the markets with tomatoes during the period when prices are at the highest level.

Each tomato plant produces on average 2 kg of fruit and since the typical farm has some 16,000 plants, average farm production reaches about 32,000 kg. Each kilogram of tomatoes in this period fetches an average price of ID 0.250 (£0.46), so the total receipts from the tomato yield would be ID 8,000 (£13,913). The average total yield value from onions and garlic amounts to ID 1,000 (£1,739). Thus the total cash return from the crops is ID 9,000 (15,652),(see table 3.14).

Table 3.14 : The cost of establishing a new farm (ID)

Price	Details
4,000	well digging
400	turbine and engine and pipes
35	water basin
60	main canal
50	furrows and secondary canals
150	smoothing the furrows
120	chemical fertilizers
450	organic matter
300	windbreak
1,100	plastic sheets
50	seeds
1,500	worker wages
150	marketing
8,465	Total

The expected return is about 10,535 (£930) in the first growing season. This is low due to the cost of the construction of the well and purchase of the engine and turbine. However, net returns will increase in the successive seasons because capital costs will be paid off and current expenditure is fairly low. Consequently, if the same conditions, that is the quality of water and land, can be maintained over the following seasons annual profit can rise to about ID 5,853 (£10,179).

Because of these high profits, the number of farms in the region have been gradually increasing. In 1970, there were 300 farms which increased to 450 in 1975 and by 1981 the number of the farms reached 1,280 with about 140 unfulfilled requests to establish new farms.

3.15 LACK OF CONTINUITY

The local traditions of the farmers have a reverse effect on the lifespan of farms. After the first growing season the typical farm (farmed area) is usually abandoned because the farmer believes that the farmed area has been rendered unsuitable for agriculture and has to be fallowed for the next three years. Therefore, another farm (farm area) is established on the opposite side of the main canal, which itself can be again used for the conveyance of irrigation water to the new farm area, (see figure 3.12). This, in turn, requires the construction of new secondary canals, furrows, diversion boxes and windbreaks. This second farm area is cultivated as previously described, again being abandoned after one season. So long as the well is the only source of irrigation water, the farmed area is shifted around the well. Thus, the third farm is constructed beside the second abandoned one. This then requires a new main canal, secondary canals, furrows, division boxes and windbreak. This farm is again abandoned after one season and a fourth farm is established on the opposite side of the second main canal. Usually the groundwater quality and quantity has decreased by this time due to heavy pumping during the previous three years, and with adverse effects on production and profits. However, the suitability of water for irrigation determines the duration of cultivation around the well - see table 3.6. The farmers assess water quality by taste and the crop yield in the fourth season, when, if it is still suitable for irrigation, the first farmed area is re-cultivated. If the water from the central well continues to be suitable the second old farm area is later recultivated and so on until finally the irrigation water becomes unsuitable and the farmer, therefore, shifts to another spot to dig a new well and construct a new farm. The old well is left for 3-4 years to concentrate fresh water and is then cleaned and utilized again for agriculture.

In the past, the farmers used to cultivate tamarisk seedlings on both sides of the furrow before the farm area had been abandoned. Its irrigation would continue as long as the area around the well continued under cultivation. When the farm area was left, the tamarisk continued to grow as their roots had penetrated deeply enough to secure moisture. Today there are, therefore, large areas of the depressions covered with tamarisk trees which represent relics of formerly irrigated plots. The growth of tamarisk can further reduce soil suitability as the deep roots tap the saline ground water which is translocated to the above ground part of the tree. On decomposition of fallen leaves these salts are added to the soil surface.

3.16 CHANGING SOIL CONDITIONS

Soil samples were taken from the furrows of two types of farms, those which had been cultivated for one year, and others which had been cultivated for two years. The analyses of the former as shown in table 3.15 and soil samples 13 - 24 in appendix 2 to this chapter indicates that after a year of cultivation the average soil Ec had increased to 7.19 mmhos/cm. This must be attributed to the use of extremely saline water even though it is applied in quantities which greatly exceed the theoretical leaching requirement. Esp and SAR values also increased to 7.6 me/100 g and 10.2me/L respectively. The analysis further shows a slight increase of organic matter to 0.58%.

Soil analyses of the areas which had been cultivated for two years showed that in fact the average Ec value of the soil was no higher than that of the areas cultivated for one year. This is because furrows excavated after the first year are realigned to occupy the previously unused inter-furrow spaces,(see figure 3.12 and table 3.15).

However, this and other shifting operations are not deliberately designed to avoid increased soil salinity but result from the general faith of the farmers in annual bare fallowing as is clear from interviews in the field.

3.17 WATER SALINITY

As a result of the heavy pumping rates along with rapid drainage from the surface layers to the water table, the quality of the ground water becomes poorer and unsuitable for irrigation after 4-8 years from its first utilization for irrigation - see tables 3.3, 3.4 and 3.5. It was also noticeable that quality becomes poorer faster as the rate of extraction is increased. This is because saline water intrusion is speeded up and the rate of addition of water used for irrigation is

Fig. 3·12 THE SHIFTING OPERATION ROUND THE WELL

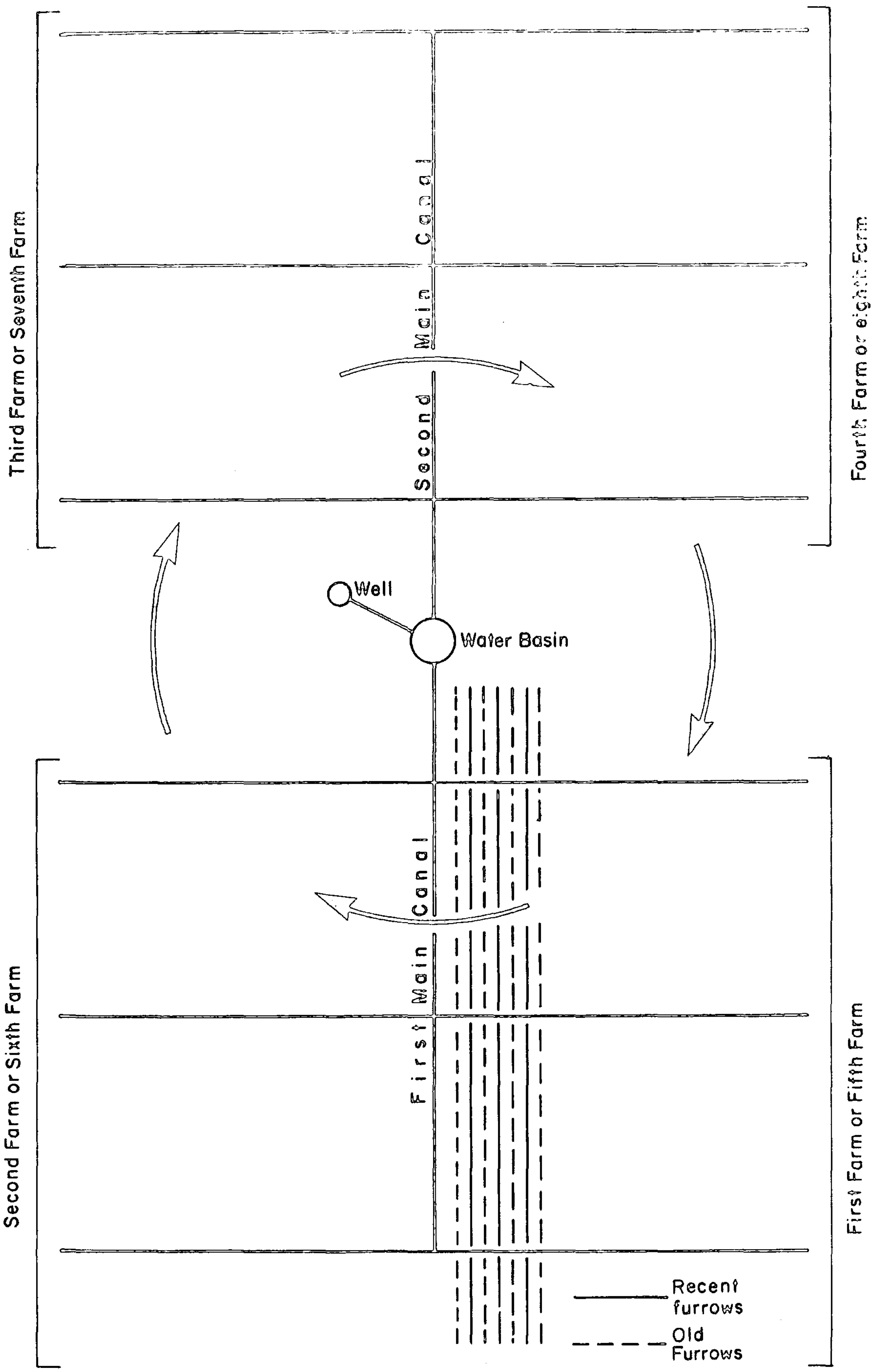


Table 3.15 : Average results of the soil analyses of cultivated areas

Cult-ivation years	pH	Ece mmhos/cm	Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C. me/100g	M.o %	Esp %	SAR me/L	Ca me/L	Mg me/L	Na me/L	k me/L	Cl me/L	So_4 me/L	HCo_3 me/L
one year	7.7	7.19	9.9	15.2	1.78	25.0	0.58	7.6	10.2	27	9.8	45.1	0.5	23.8	58	2.6
two years	7.8	6.91	4.4	15.2	1.26	25.0	0.35	4.9	9.9	23.5	11.8	43.7	0.7	29.8	58.7	2.9

For detailed results see samples 13-24 in Appendix 3.2.

increased. For example, in 1950 the average Ec values ranged between 2.5 and 4 mmhos/cm in the water of Al-Berjsiyah-Chwiba, 1.5 mmhos/cm in Al-Najmy waters and 0.7 mmhos/cm in Safwan waters. [29] These values indicate an annual increase of the Ec of approximately 0.2 mmhos/cm in Al-Berjsiyah-Chwiba and Al-Najmy waters, with an even higher increase of 4.1 mmhos/cm in Safwan water due to a heavier usage of the groundwater there than in the other two depressions. This fact in turn could mean that the farmers, particularly in Safwan, will face a serious problem of unsuitable water of extremely high salinity which will result in the abandonment of a large number of farms during the next few years if the water exploitation rate continues the same as at present.

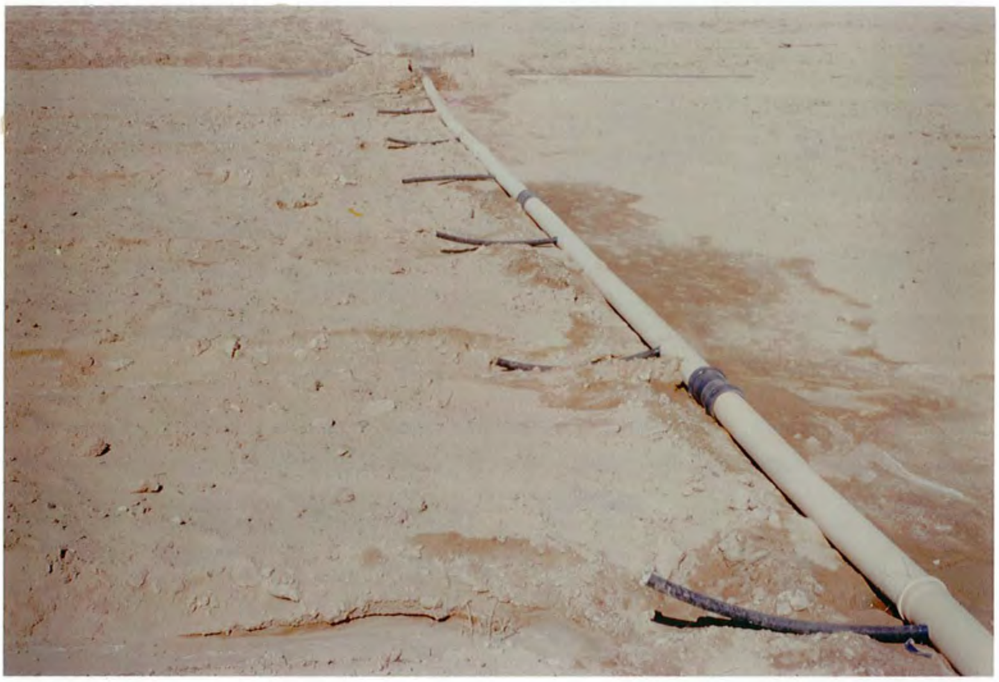
3.18 IRRIGATION EXPERIMENTS

These experiments were carried out in the Al-Berjsiyah-Chwibda depression to investigate alternative irrigation techniques generally suitable for the private farms which use the furrow irrigation system. The experimental station, located 16 km to the southwest of Al-Zubair city, is divided into four areas - 6,000 m^2 of the station area is used for drip irrigation, 3,000 m^2 used for sprinkler irrigation, 3,000 m^2 used for subsurface irrigation and the last 3,000 m^2 used for furrow irrigation. The results of these experiments can be summarised thus.

3.18.1 Furrow Irrigation

This method is practised in the same way as the traditional system in the region with the exception of the use of polyethylene pipes of 15 cm in diameter in place of the main canal, and three pipes - each one of 10 cm in diameter branching out from the main pipe at the diversion boxes, used in place of the secondary canals, (see figure 3.13).

FIGURE 3.13 : The secondary pipes used in experiment of furrow irrigation



The same frequency of irrigation and methods of cultivation are used as in the traditional system. The advantages of this method are : a decrease in the water conveyance losses through the main and secondary canals and diversion boxes. Therefore, these pipes fill the furrow in only 1.1 min at the head of the farm and about 2.5 min at the last furrows in the first irrigation, (see section 3.10). In the second irrigation, each furrow at the head of the farm is filled within 0.98 min and the last furrow in 2.1 min. In the third irrigation each of the first furrows is filled in 0.92 min and the last furrows in 1.94 min. Water use efficiency is certainly increased and the actual construction costs using these pipes is similar to the construction costs for the canals.

However, along with the advantages, there are certain disadvantages in the use of these pipes, for instance, coiled burlaps are used to divert the water from one canal to another and to prevent water flow from the secondary pipes to the furrows which have already been filled with water. However, this material is not completely impervious, so some water does pass through. In addition the speed of flow from the secondary pipes into the furrows causes erosion at the head of the furrow, particularly the head furrows of the farm, (see figure 3.13).

3.18.2 Subsurface irrigation

This type of irrigation is carried out in the experimental area by irrigating the root zone by a punctured plastic pipe of 10 cm in diameter. This pipe is buried at a depth of about 30 cm where the root zones of the tomatoes are located. There are many 5 mm diameter holes in this pipe to distribute the irrigation water to the root zones. The end of this pipe is exposed on the land surface and the intake is located near a tap which branches from the secondary 5 cm in diameter pipe line laid on the ground surface. This pipe joins with the 10 cm in diameter main irrigation pipe,(see figure 3.14). The length of each buried pipe is 10 m.

Tomato seedlings are cultivated in a line overlying the buried pipe, to take advantage of the added moisture. The average number of plants on each 10 m underground pipe is 30, there being an average distance of 2 m separating each of the pipes. The farm consists of three secondary pipes, each one providing irrigation water for 100 buried pipes, 50 pipes on each side. Thus the farm consists of 300 buried pipes and about 9,000 plants.

The discharge from each tap totals 0.0012 m^3/min. The plants are irrigated twice per day in the hotter months - July until November and once per day in the period from December until March or April. The amount of irrigation water provided for each plant is 0.006 m^3 per irrigation or in terms of growing season, each plant is supplied by 2.7 m^3 which is equivalent to 29% of the amount of irrigation water used for each plant in the traditional furrow irrigation system. However, this method has some disadvantages - the crop yield is less than that from the traditional furrow irrigation. This may be the result of blocking of the holes in the buried pipes by rootlets or sediment. In addition more mechanical spare parts must be available for this method - taps and pipes etc. and construction costs are higher than for those in furrow irrigation. Furthermore, as a result of the use of saline water which has an Ec value of 9.2 mmhos/cm accumulation of salts can occur, particularly near the root zones.

Analysis of soil samples, which were taken from this area, shows that the Ec value increases with depth, it is 1.99 mmhos/cm in the upper 15 cm, increasing to 9.97 mmhos/cm at 78 cm depth, see soil sample no.25, appendix 3.2

Thus, although this method offers greatly increased irrigation watter efficiency, it is expensive and gives a lower yield than the traditional furrow irrigation system.

3.18.3 Sprinkler irrigation

This method has also been tried at the experimental station but it failed after a few months because of the saline water used falling on the tomato leaves leaving salty spots after evaporation. This causes damage to the leaves and consequently affects plant growth. This experiment was, therefore, abandoned even though similar trials in other countries have proved successful.

3.18.4 Drip irrigation

This method provides the plants with water by a network of surface flexible plastic pipes.

Shallow furrows of 10 cm in depth and 50 m in length in which to lay the pipes are excavated by tractor. These furrows are of a V shape in order to concentrate any excess water which drops from the emitters around the plants. Excavations are dug in these furrows to an average of 30 cm depth and 20 cm width. These excavations are filled with a mixture of organic matter, chemical fertilizers and soil, the amount of organic matter used being only about 50% of the amount used for each excavation in the traditional furrow system. Spiral emitter pipes of 15 cm length and 2 mm in diameter drop the irrigation water on the seeds planted in the excavations. These pipes branch from flexible polyethylene pipes of 2 cm in diameter, at the locations of the excavations. These pipes in turn branch from secondary pipes of 3 cm in diameter. The secondary pipes join with the main irrigation pipe which finally connects with the automatic control board, filtration device and the pump.

FIGURE 3.14 : Structure of undersurface irrigation

FIGURE 3.15 : Drip irrigation lines

The farm consists of 80 lines of the first flexible piping. The length of each is 50 m and 100 plants are cultivated on each line. Thus, the farm is comprised of 24,000 plants,(see figure 3.15).

The average discharge water from each emitter is 0.00006 m /min. The tomatoes are irrigated for a period of 5 hours per day in the hotter months - July until November and 3 hours in colder months - December until March and April. So, each plant is irrigated by 0.019 m per day in the hotter months and 0.011 m per day in the colder months. In terms of the growing season, each plant is provided with 4.45 m of irrigation water which is equivalent to 47.8% of the amount used for each plant in the traditional furrow irrigation system. Therefore, drip irrigation can save about 52.2% of the total water applied in the traditional furrow irrigation. The saving of water by this method is due to the fact that there are no conveyance water losses along with the fact that less water is supplied than in the furrow system. Consequently, water losses by deep percolation are also very small. Furthermore, there is very little evaporation of irrigation water from the soil due to the small irrigated spots round the plants and there are no irrigated areas between the plants. Therefore, this method has a high water efficiency. It requires low pressure pumping of 1 bar to distribute the irrigation water to the plants, this due to the low flat topography. It also requires less labour, just one skilled worker to irrigate the farm. These advantages are associated with almost absolute control over the placement and amount of water applied which is slow but with high frequency. This maintains adequate moisture content in the root zones, minimizing soil moisture, stress due to which salinity is also held to its lowest possible level preventing concentration of salts in the root zone.

Because of the low moisture tension level maintained in the soil throughout the growing season, salts are concentrated on the soil surface and decrease with depth where the root zone is located. Analyses of soil samples (see sample 26 appendix 3·2) which were taken from this area show that the Ec value of the soil is 9.22 mmhos/cm at the upper 15 cm and decreases with depth to 4.9 mmhos/cm at a depth of 38 cm and to 2.99 mmhos/cm at a depth of 76 cm. Consequently, the SAR and Esp values decrease from 9.1 me/L and 6.4 % respectively at the upper 15 cm to 7.9 me/L and 4.3 % respectively at a depth of 76 cm, (see soil sample no.26).

However, this method does have some disadvantages such as, periodic blockage of the emitters which prevents water dropping on the soil and consequently affects the plant growth. This occurs due to the high evaporation along with the high salt content of the irrigation water, which causes accumulation of salts around the emitters and consequently blocks them. However, this problem can be overcome by using a filtration device for salts.

The production yield was about 1.50 kg, a little less than that obtained from traditional furrow irrigation which can be attributed to the blockage of some emitters which decreased the amount of irrigation water.

This method needs skilled workers and available spare parts to ensure maintenance of the pipe network. In addition the salt accumulation on the surface requires post harvest leaching or mechanical removal.

The total costs of this system are about ID 2500 (£4,347) and they are relatively similar to the costs of the traditional furrow system.

In view of the advantages above mentioned it can be recommended that this system be followed in this region, the one condition being that the farm workers are trained in the fairly simple but novel skills required.

3.19 CONCLUSION

It has already been pointed out that the hand dug wells are the only important sources of irrigation water. The quantity of water produced by the typical pump used determines that the average farm size is about 200 furrows or 3.66 donums. The water applied to irrigate the main crop - tomatoes - is about 40,900 m^3 per donum. Because of the low water holding capacity of the soil along with poor management, the water losses are high and equivalent to 55.4% of the water applied in the furrow system. Therefore, the irrigation water efficiency is low.

Because farmers believe that annual fallowing is necessary to maintain soil nutrients, along with the increasing salinity of the water extracted from well the farm is shifted round the well and the well and land unit from place to place.

It is recommended that plastic pipes are used to replace the traditional furrow system for conveying the irrigation water in order to decrease the conveyance water losses. However, experiments carried out in the region have shown that the trickle or drip irrigation systems are technically the most suitable systems which can be applied throughout the region because they require less than 50% of the water applied in the traditional furrow system and yield a similar production level of tomatoes at about the same cost. Such systems would slow down the general deterioration of water quality and soil salinization which is now taking place. Some improvement in irrigation farming would be worthwhile since this region supplies Iraqi markets with winter season tomatoes.

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CHAPTER 4

THE SOUTHERN TIGRIS REGION

4.1 INTRODUCTION

This region is located on both sides of the southern Tigris river upstream of its confluence with the Euphrates at Qurnah City. It extends from Qurnah City in the south to the Messan border in the north and from the Iraqi-Iranian border in the east to Thi-Qar border in the west. Thus, it occupies the northern part of Basrah province (see Fig. 4.1).

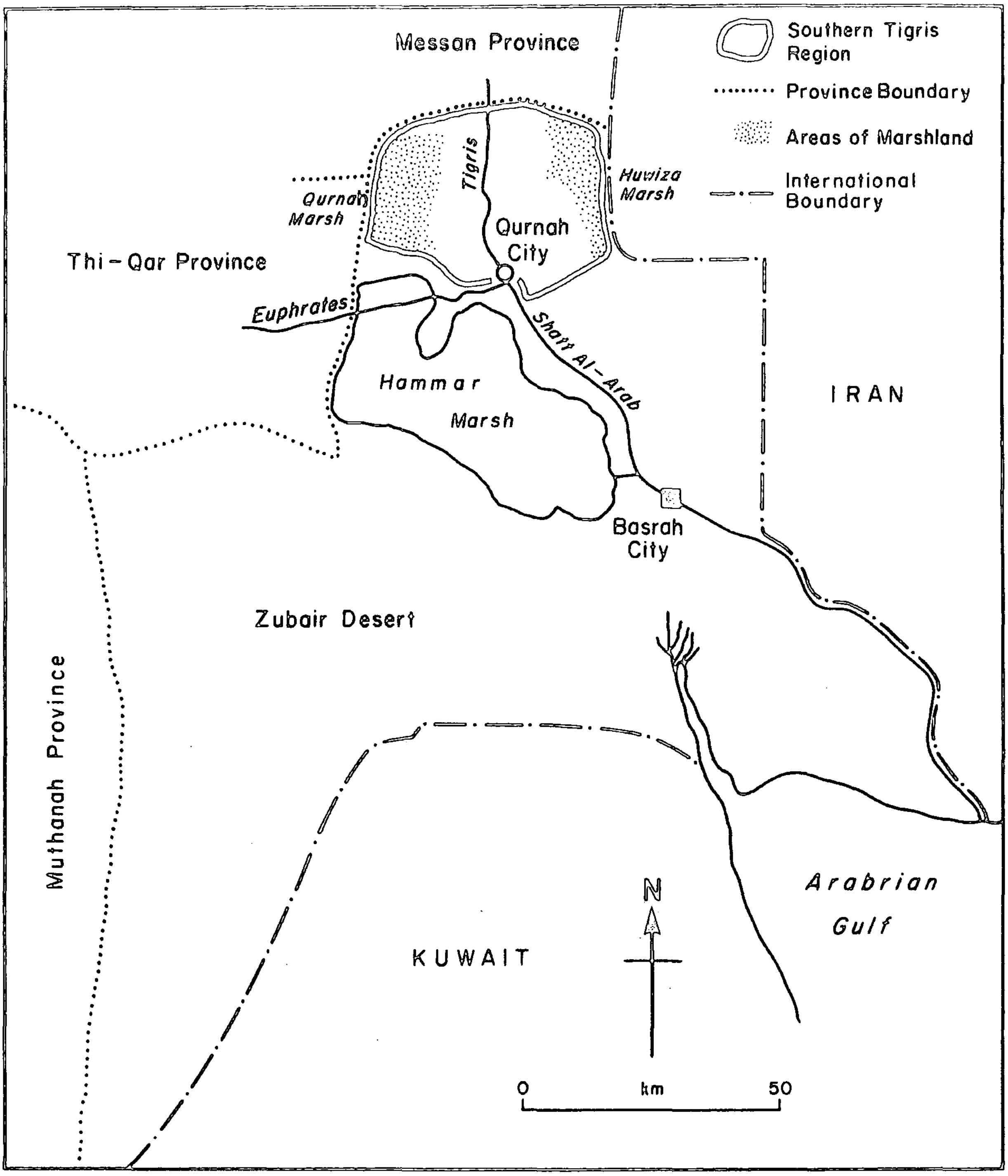
This region consists of flat areas sloping gently from the Tigris banks at 5 m G.T.S.,* to low lands lying at about 1 m G.T.S., which are covered by two marshes - Huwiza in the east and Qurnah in the west. The general average slope of the land is small, 25 cm/km.

There is no climatic station in the region, therefore the meteorological data from the Basrah station which is located some 80 km to the south, has to be used for calculating the consumptive use of water. The annual average rainfall is very low at 140 mm, which, given the high mean monthly temperature of 23°C, and high evaporation rates, (see sect. 1.4) is inadequate to maintain plant growth. Cultivation therefore depends on the use of water diverted from the Tigris river which flows through the region from north to south.

The soils are alluvial and have been subjected to over-irrigation without adequate drainage for a long time. Therefore, the majority of the area has been affected by salinity and much land consequently abandoned. Cultivation is now restricted to a narrow belt on both sides of the Tigris river. Salinisation

* Great Trigonometrical Survey Datum.

Fig 4·1 Location of the Southern Tigris Region



results from farmers' inability to give the water and soil resources sufficient conservation attention. This is mainly due to traditional low educational levels and, more recently, as other sources of cash have been created in other economic sectors which provide a higher income in shorter time, skills have been diverted away from agriculture.

Most parts of the region were covered in soil and water studies carried out by consultant companies. The T.A.M.S.Co. (1957) studied a small area of 12,170 donums in the south east of the region but on a general rather than an applied basis. In 1972, Nippon Koei Co.studied the region but since its results were regarded as unreliable therefore, they have been ignored. In 1978, Polservice Co. studied the region's soil and water characteristics with the exception of the state farm which will be considered later.

This chapter is divided into two sections : the first, section A dealing with the region as a whole, excluding the state farm which is considered in section B. Section A will focus on the availability and suitability of soils and water for irrigation purposes. Since it was not possible to study each farm separately, extensive investigations were carried out to select a typical case-study farm in which average conditions obtained and which illustrates clearly the irrigation and drainage system in the region. The study will show the effects of the soil, water, management, crops and the distribution system of water for the crops in the typical farm. Both the theoretical irrigation and leaching requirements and the actual water applied or the gross irrigation water are examined. This chapter will also show the results of practising this irrigation system as reflected in water losses and efficiency of use, crop yield and soil salinity.

Section B will discuss the state farm which is located in the south-eastern part of the region and is in some ways atypical in soils, irrigation, drainage and management conditions.

A. THE TRADITIONAL FARMING AREAS

4.2 WATER RESOURCES

Both surface and groundwater are essential for irrigated agriculture because the effectiveness of the low average annual rainfall, 140mm, is nullified by the high evaporation rate. Both these resources will be discussed separately to show their availability and suitability for irrigation purposes.

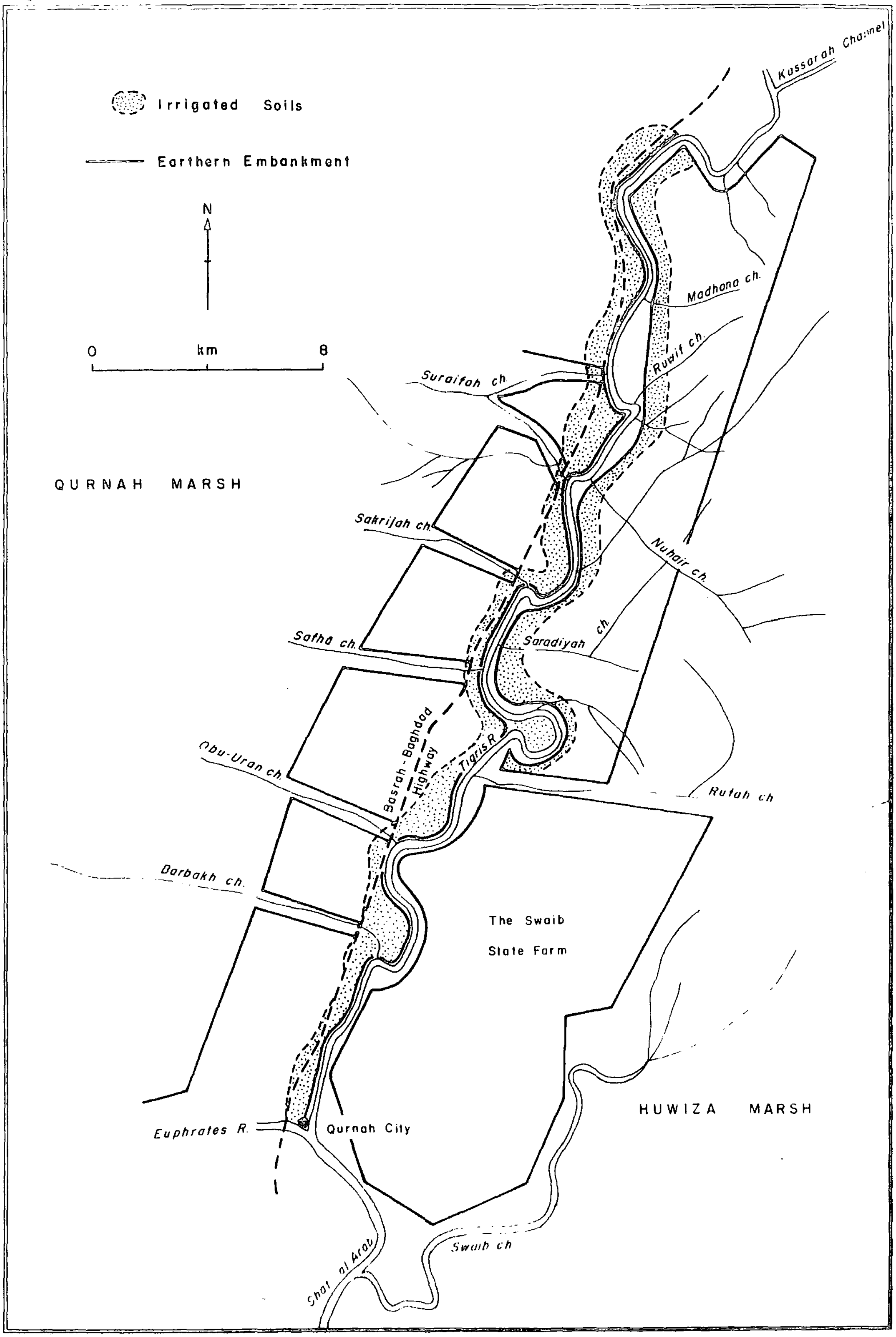
4.2.1 Surface Water

Surface water is available from three sources, the Tigris and the Qurnah and Huwiza marshes.

4.2.1.1 The Tigris flows through the centre of the region in a north-south direction, from the northern border of the province, down to its confluence with the Euphrates at Qurnah City (see Fig. 4.2). Its total length in this region of about 47 km represents the last section of the Tigris river. It has a very low mean gradient of about 2 cm/km, which gives it a meandering character. The Tigris river at the northern border of the region has a narrow width of 40 m and a depth of 1 m which increases near Qurnah City to 160 m in width and 7 m in depth.

In the Amarah area, the Tigris river loses about 97% of its total discharge at Baghdad through many branches which terminate in the Qurnah and Huwiza marshes (see sect.2.2.1.2.1).Most of these waters which accumulate in the marshes are again discharged through numerous channels into the Tigris downstream of the Amarah area. Five major left bank outlets join the Tigris in the region all of which come from the Huwiza marshes - Madhona, Ruwif, Nuhair, Saradiyah and Rotah. In the extreme south of the region the

Fig. 4.2 The Lower Tigris Region. Surface Water Resources



Source : Ministry of Irrigation, General Directorate of Dams and Reservoir, Map of the Shat al Arab Location, Map no. 1631, Baghdad, March 1975, Scale 1:100,000

Swaib Channel flows from the eastern part of the region and joins the left bank of the Shat Al-Arab. In addition, eight rightside outlets join the Tigris from the Qurnah marshes - Jery, Heddama, Suraifah, Sakrijah, Safha, Abu-uran and Barbakh (see Fig.4.2). These inflows supply the lower Tigris with water particularly in the flood seasons, most of which originated in the Tigris further upstream.

Although river regime data is available for the Tigris from six gauges in the region, unfortunately the records cover differing periods, the only common year being 1978. Thus, for comparative purposes only the data for discharge and quality in this year will be used.

4.2.1.1.1 Water discharge : Table 4.1 shows that the mean monthly water discharge of the Tigris at the gauge upstream of the Kassarah channel, located some 6 km upstream of the north border of the region, is 24 cumecs. This increases to 207 cumecs at the Qurnah gauge before the confluence with the Euphrates. This means that the discharge at the second gauge is equivalent to 8 times that at u/s Kassarah channel. This results from a large amount of inflow from the Huwiza and Qurnah marshes through the outlets previously mentioned. For example, the annual discharge of the largest channels - Kassarah and Rotah, bring to the Tigris 97 and 25 cumecs respectively.

Water discharges from the Tigris varies both seasonally and yearly (see sect.2.2.1.2.2). In this region the water discharge u/s Kassarah starts to increase from January and the flood peak takes place in March, April and May with discharges of 37, 43 and 38 cumecs respectively. These discharges equal about 41% of the

Table 4.1 : Mean Monthly water discharge (cumecs) in 1977-1978

Locations	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Ave-rage
The Tigris u/s Kassarah	8	9	14	22	28	37	43	38	33	22	18	14	24
Kassarah channel	23	32	57	108	126	139	150	145	143	114	88	51	97
The Tigris d/s Kassarah	30	42	74	137	158	175	187	182	169	143	108	65	122
Rotah channel	4	4	6	18	25	34	47	52	49	38	17	8	25
The Tigris at Qurnah	71	75	106	158	200	241	297	342	362	315	190	126	207

Source : Polservice Co. Shat Al-Arab Project, Surface Water Study, part A, Vol.VII, Basrah, 1979, p.49.

annual water discharge at this gauge. From May water discharge falls to reach a low in October of 8 cumecs, (see Fig. 4.3). At Qurnah, the water discharges also begin to increase from January but the flood peak occurs later - May, June and July, the water discharges being 342, 362 and 315 cumecs respectively. These too represent 41% of the annual water discharge of the Qurnah gauge, (see Fig. 4.4). The reason for the delayed flood peak which occurs at Qurnah compared to that at u/s Kassarah is because of the high discharges of water entering the marshes from the Tigris in the Amarah area. This flood water is distributed through the marshes which act as a reservoir, thus delaying the flood peak until the reservoir capacity is reached and discharge increases from the marsh outlets. Therefore the flood peak does not reach the Tigris at Qurnah until the beginning of May (see Fig. 4.5.1). In the dry seasons the water discharged from the Tigris into the marshes is low, consequently the water discharged from the marshes into the Tigris in the region is low as well, (see Fig. 4.5.2 and Table 4.1).

4.2.1.1.2 Water level : The mean water levels of the Tigris keep pace with the discharges above mentioned. Table 4.2 shows that the monthly water level at Qurnah is 1.30 m G.T.S. while at u/s Kassarah it reaches 2.60 m. G.T.S. This unexpected difference can be attributed to the variation of the Tigris course itself at both the above gauges; the Tigris course u/s Kassarah is shallower and narrower than at Qurnah area. The monthly water level changes according to the fluctuations of the water discharges (see table 4.3). The mean annual water level at Qurnah reached 1.89m G.T.S. in the wet year 1969 and dropped to 0.73 m G.T.S. in the dry year 1971. The mean high water level at the same gauge is 2.09 m G.T.S. and the mean low water level is 0.22 m G.T.S.

Table 4.2 : The water levels of Tigris m G.T.S. as recorded periodically in 1977-1978 (1)

Date	Location u/s Kassarah	Date	Location Qurnah
26 Oct. 1977	1.55	6 Nov. 1977	0.46
3 Dec. 77	1.62	4 Dec. 77	0.86
2 Jan. 1978	2.98	3 Jan. 1978	0.96
3 May 78	3.52	5 Feb. 78	1.3
1 June 78	3.39	5 Mar. 78	1.4
2 Jul. 78	3.16	3 Apr. 78	1.6
2 Aug. 78	2.82	7 May 78	1.92
3 Sep. 78	2.26	7 Jun. 78	1.97
18 Nov. 78	2.14	9 Jul. 78	1.92
4 Dec. 78	2.07	6 Aug. 78	1.46
		5 Sept. 78	1.05
		2 Oct. 78	0.53

(1) Polservice, Shat Al-Arab Project, Studies of Salinity problems, part A, Vol.VIII, pp.170-171.

Table 4.3 : Mean Annual water level at Qurnah m G.T.S. (1)

Year	HWL	LWL	MWL	Year	HWL	LWL	MWL
1963	2.46	0.20	1.23	1971	1.92	0.20	0.78
1964	1.84	0.34	1.07	1972	2.72	0.32	1.28
1965	1.88	0.10	0.98	1973	1.16	0.24	0.76
1966	1.94	0.30	1.18	1974	2.42	0.0	1.02
1967	2.12	0.24	1.04	1975	1.42	0.0	0.82
1968	2.58	0.40	1.15	1976	2.80	0.0	1.19
1969	3.06	0.48	1.89	1977	1.81	0.2	1.17
1970	1.78	0.24	1.19	1978	2.04	0.2	1.80
				mean	2.09	0.22	1.14

(1) Polservice, op.cit., Study of surface water, p.40.

Fig 4·3 Monthly Water Discharge and Ec Value of the Tigris upstream of Kassarah

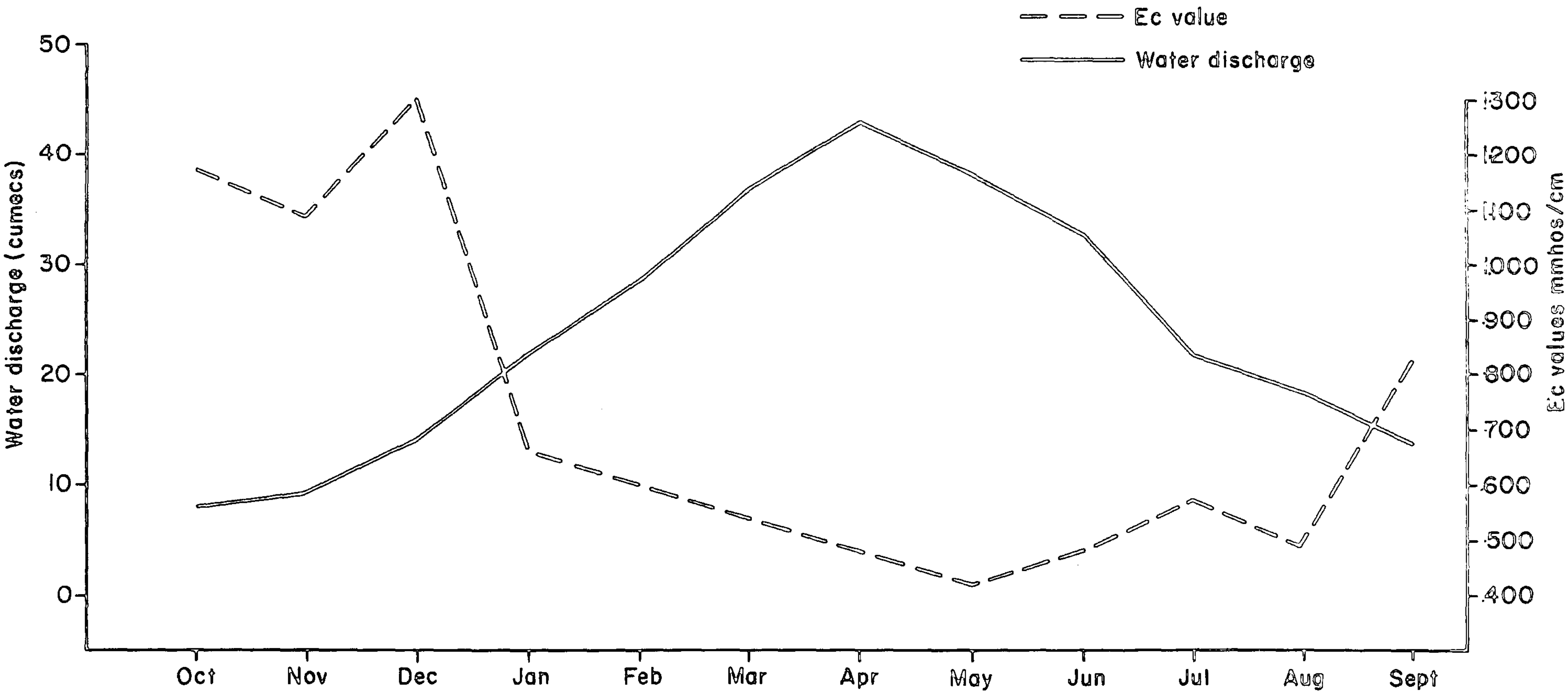


Fig 4·4 Monthly Water Discharge and Ec value of the Tigris River at Qurnah

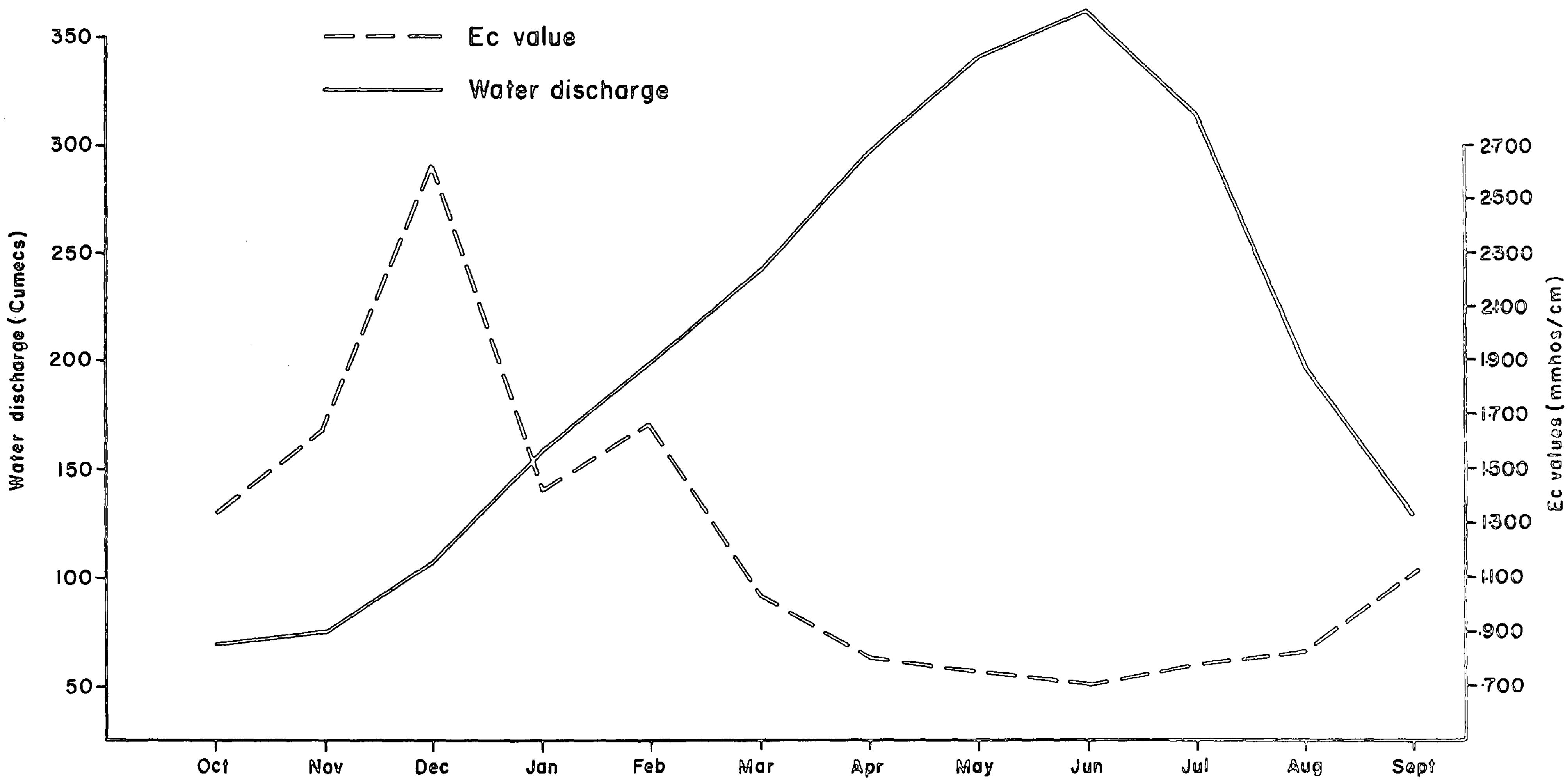


Fig. 4.5.1 Water Balance in the Flood Season

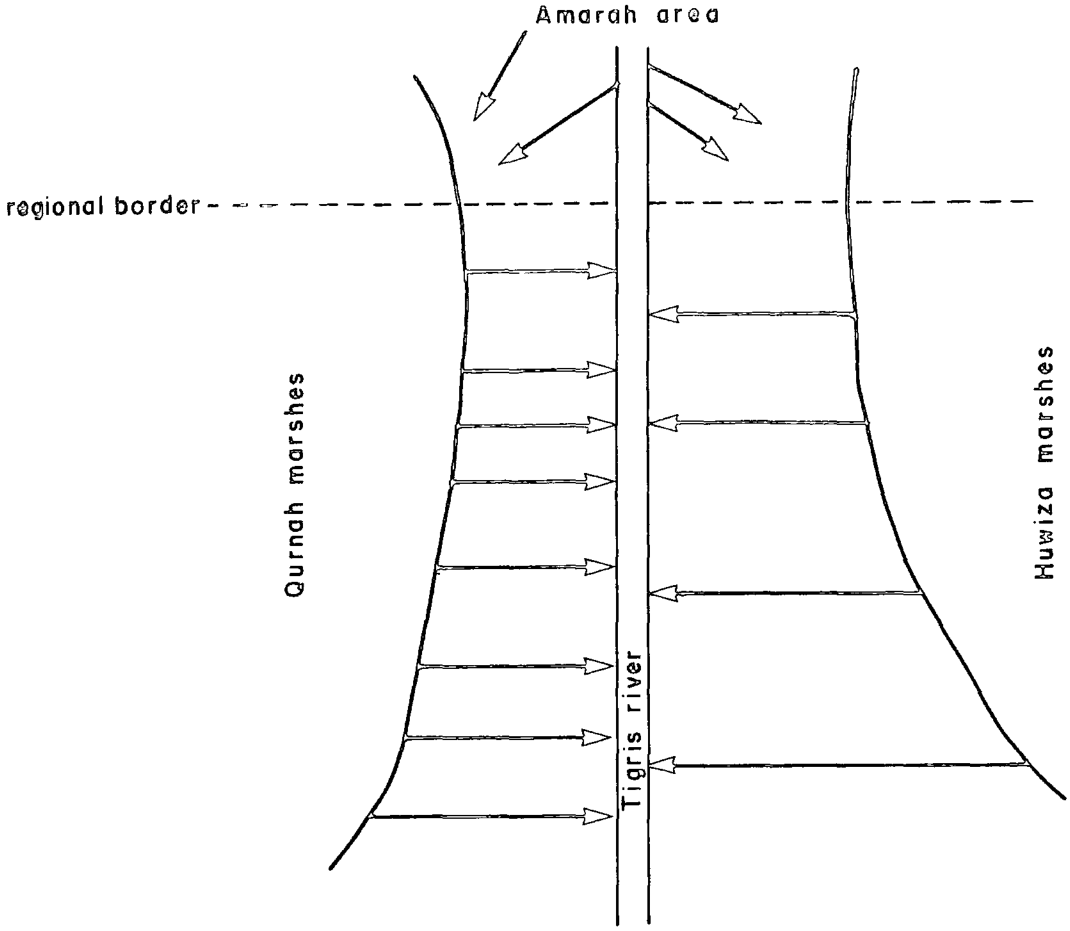
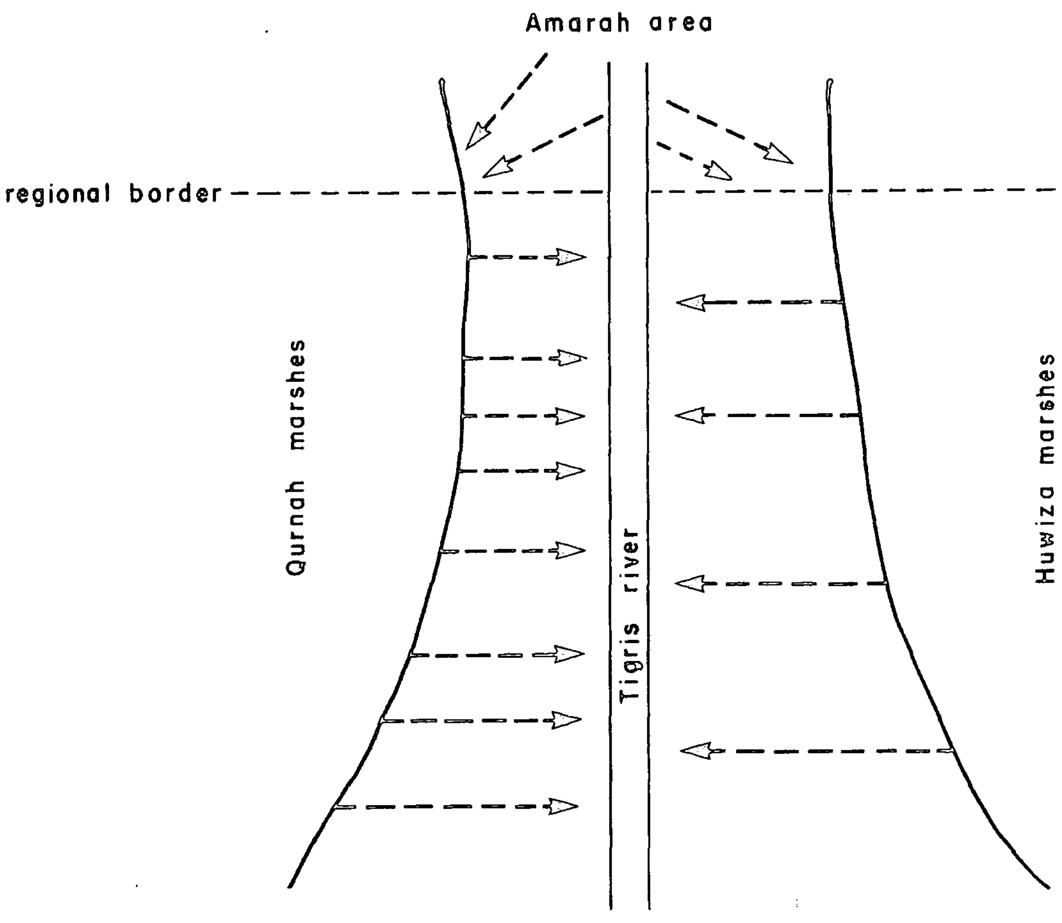


Fig. 4.5.2 Water Balance in the Dry Season



Additionally, it should be noted that the monthly mean water level varies from month to month according to the water discharges. Upstream of Kassurah, the highest water levels occur in the flood peak period. For example, in May 1978 the water level reached 3.52 m G.T.S. However, at Qurnah the highest mean water levels are 1.92, 1.97 and 1.92 m G.T.S. in May, June and July respectively. At both gauges the lowest water levels occur during October and November as a result of low water discharges.

The Tigris water levels are lower than the ground surface levels in the region which are more than 3 m G.T.S. However, in the high flood peak such as in 1954 and 1969 the Tigris water submerged the adjacent lowlying lands. Therefore, the Tigris was leveed recently with dykes to a height of 5 m G.T.S. height. As a result the cultivated lands have been protected from the high flood waters which occur in some years (see Fig. 4.2). The distance between the dykes and the river banks vary from 20 to 300 m.

The water level in the Shat Al-Arab river is influenced by the tidal movements which occur in the Gulf. This influence extends upstream through the Tigris river as far as the Kassarah channel and causes slight differences in water levels in the Tigris river in the region. However, these differences range only between 20cm in the flood seasons to 50 cm in the dry seasons and these currents are not sufficient to provide irrigation water distribution by gravity as in the Shat Al-Arab region (see Chap. 6).

It is significant that the water discharges and levels of the Tigris have an effect on irrigation methods used and the surface and groundwater quality and quantity. As a result of the low water levels in the Tigris compared with the ground surface level mentioned above, gravity irrigation directly from the river cannot be practised. The irrigation water has to be lifted from the river to irrigate the land. This operation requires an excavation of canals and water basins on the low flat river banks to supply pumps or other lifting devices with sufficient water, particularly during the low water level periods.

4.2.1.1.3 Suspended sediments The Tigris river carries large amounts of suspended sediments some of which are deposited on the land surface by irrigation operations. However, the total sediment load of the Tigris is generally lower than that in the northern and middle sections, because large amounts of sediment are deposited in the marshes before they arrive at the Tigris section in the region. The quantities of these sediments vary according to the differences in the water discharges. Thus, the largest amounts are carried during the flood peak period averaging 2200 ppm, falling to an average of 200 ppm in the remaining months. (1)

4.2.1.1.4 Water quality Table 4.4 shows that the average Ec value of the Tigris u/s Kassarah is 0.825 mmhos/cm, increasing to 1.152 mmhos/cm at Qurnah (see Table 4.5) due to the discharge of waters of greater salinity from the marshes into the Tigris section between these gauges. For example, it receives water from Kassarah channel which has an average Ec value of 0.949 mmhos/cm and from Rotah channel with an average Ec value of 1.756 mmhos/cm. According to U.S.D.A. (1954) classification of irrigation water, as mentioned in section 2.2.1.1.5 from the viewpoint of salinity, the Tigris water is considered as medium or class 3. This class of water can be widely used on soils of moderate to good permeability. Under good management - leaching and drainage - a satisfactory growth

Table 4.4 : Water quality of the Tigris at u/s Kassarah[(1)] 1977-1978

Date	Ec mmhos/ cm	pH	Na me/L	Ca me/L	Mg me/L	Cl me/L	HCO me/L	CO me/L	SO 4 me/L
26 Oct. 1977	1.170	7.9	6.0	2.3	3.8	5.5	2	0.3	7.7
3 Dec. 77	1.296	8	5.2	2.5	4.8	4.8	3.1	0.2	9.3
2 Jan. 1978	0.660	7.8	2.2	3.0	0.3	2.0	3.0	-	7.9
3 May 78	0.420	8.5	1.3	2.1	2.6	1.2	2.5	0.2	5.2
1 June 78	0.482	8.4	1.6	0.7	1.8	1.4	2.8	0.1	4.8
2 July 78	0.573	8.1	0.9	2.8	1.9	1.6	3.1	0.1	1.8
2 Aug. 78	0.491	7.7	1.7	4.7	1.6	1.6	3.0	0.1	5.4
3 Sept. 78	0.819	8.4	2.9	3.6	3.3	2.8	2.7	0.2	3.6
18 Nov. 78	1.092	7.8	3.7	7.5	5.7	3.9	2.7	0.3	7.9

Table 4.5 : Water quality of the Tigris at Qurnah 1977-78 [(2)]

6 Nov. 1977	1.688	8	8.4	2.9	4.9	8.3	2.4	1.1	7.6
4 Dec. 77	2.623	7.8	10.6	5.4	8.7	12.4	3.7	0.3	13.1
3 Jan. 1978	1.458	7.7	5.3	6.7	1.0	6.1	3.5	0.3	8.0
5 Feb. 78	1.683	7.7	5.1	4.6	1.6	7.5	3.7	0.2	8.2
5 Mar. 78	1.077	7.8	5.4	4.0	0.6	4.2	3.6	0.1	7.8
3 Apr. 78	0.800	8.5	2.4	3.1	2.1	2.7	3.6	0.2	9.3
7 May 78	0.755	8.3	2.8	3.1	6.0	3.1	3.6	0.1	5.3
7 June 78	0.703	8.4	1.9	0.8	2.3	2.3	3.6	0.1	5.6
9 Jul. 78	0.797	8.3	2.5	2.6	2.2	2.8	3.4	0.1	3.1
6 Aug. 78	0.818	7.6	3.0	4.3	2.3	3.5	3.8	0.2	6.0
5 Sep. 78	1.105	8.4	4.2	1.6	5.1	3.7	3.7	0.2	4.3
2 Oct. 78	1,357	8.4	7.9	11.4	1.4	5.1	3.4	0.3	7.1

(1) Polservice, Hydrological investigation of surface water, part B, Vol.11, p.165.

(2) Ibid, p.171.

of moderate to good salt tolerant plants is obtained. Otherwise the salt concentration in the soil will build up and yields will decline. Numerous studies have shown that the salt content of soil solution varies somewhat directly to the salt content of irrigation water and inversely with soil permeability.[2] However, the irrigation practices greatly modify the actual relationship.

The Ec value of the Tigris is affected seasonally by the water discharge i.e. its proportion varies inversely with the water discharges - the higher water discharge, the lower the Ec value and vice versa. Tables 4.4 and 4.5 and Figures 4.3 and 4.4 show that the Ec value of the Tigris water decreases in the flood season to 0.593 and 1.011 mmhos/cm at u/s Kassarah and Qurnah respectively. In the dry season, the values increase to 1.114 and 1.674 mmhos/cm respectively at the same gauges. This is because the river receives more fresh water during the flood season than in the dry season.

Sodium percentage in the Tigris water u/s Kassarah is 27.3%, increasing to 31.3% at Qurnah due to inflow from the marshes with higher percentages at 32% and 35% in the waters of Kassarah and Rotah channels respectively. According to the sodium content classification suggested by Wilcox (1955) as mentioned in section 3.3.5, the Tigris water is considered good from this standpoint. However, the sodium hazard is determined by the absolute and relative concentrations of the cations- Its tendency to be adsorbed from irrigation water can be evaluated through the sodium adsorption ratio (SAR). The SAR values are 1.4 and 2.0 me/L at u/s Kassarah and Qurnah respectively. Although the SAR value varies seasonally at both gauges, it is still less than 10. According to the U.S. Salinity Lab. Staff (1954) classification of water quality from the viewpoint of SAR and Ec values - see sect. 2.2.1.1.5 the Tigris water is classified as low sodium hazard (S1). This class is considered good for irrigation on almost all soils with little danger of accumulation of harmful amounts of exchangeable sodium if adequate drainage takes place.

The RSC value of the Tigris water is considered safe for irrigation purposes according to Eaton's (1950) criteria noted in sect. 3.3.5.

Calcium content of Tigris water is about 3.2 and 4.2 me/L at u/s Kassarah and Qurnah respectively. Magnesium content is 2.8 and 3.1 me/L at both gauges respectively. Chloride content is 2.8 me/L at u/s Kassarah, increasing to 4.4 me/L at Qurnah. Sulphate is the dominant anion, reaching 5.5 and 6.2 me/L at u/s Kassarah and Qurnah respectively. The concentration of the cations and anions increases in the dry seasons and decreases in the flood seasons (see tables 4.4 and 4.5).

Boron is essential to plant growth but only in micro-concentration; a previous study on the Tigris water in the region showed that boron is considered to be sufficiently low to permit cultivation of all tolerant and nearly all boron sensitive plants throughout the year.(3)

4.2.1.2 The Huwiza marshes. These marshes, wet lowlands locally called Hors, extend along the eastern side of the Tigris from Musharah district (Nahia) in Messan province in the north, to the Qurnah area in the south and from the Iraqi-Iranian border in the east to the central areas of the eastern part of the region in the west. The average length of these marshes is about 72 km and the average width is 29 km. Thus, the total area of these marshes is about 2100 km^2, increasing in the flood seasons to 3590 km^2 and shrinking in the dry seasons to about 948 km^2.

Generally these marshes can be divided into two relatively separate parts - eastern and western, particularly in the dry season. Most areas of the eastern part of the region used to be submerged periodically by flood water from the western marshes. This water covered the arable and cultivated lands and left the salts on the surface after evaporation. As a result large areas have been abandoned. In order to prevent further abandonment, earthen embankments have been built in the 1970's around the western borders of these marshes.

However, Huwiza marshes play an important role in the periodic retention of river water. The normal storage during the flood season has been estimated to be more than 3 milliard cubic metres, from which the Tigris river in the region receives the greatest part of its supply. In addition, the maximum anticipated flood peak of the Iranian streams terminating in the eastern part of these marshes is in the range of 2500, 1000 and 1000 cumecs from Karkhah, Duwairij and Teab streams. Consequently, the retaining function of the Huwiza marshes in controlling the flood water discharges, is of a great importance as regards the water inflow both from Iranian streams and from the Tigris river.

The average water levels of the Huwiza marshes range between 0.50 and 3 m G.T.S. in the flood seasons and from 0.30 to 2 m G.T.S. in the dry seasons.

There is no direct data available for the water quality of these marshes. However, their water quality can be deduced from the limited data from the Kassarah, Rotah and Swaib channels which discharge from these marshes. Tables 4.6, 4.7 and 4.8 show that in 1977-78 the average of Ec values are 0.949, 1.765 and 2.582 mmhos/cm in these channels respectively. The first two values are lower than the third because the Kassarah and Rotah drain the western part of the Huwiza marshes, which are supplied with water mainly from the Tigris which has an Ec value of 0.992 mmhos/cm in the Amarah area. The Swaib channel on the other hand drains the eastern part of the marshes which are affected by the saline water carried from the Iranian side by Karkhah, Duwairij and Teab which have Ec values of 1.687, 5.781 and 5.781 mmhos/cm. In addition, this channel drains the drainage water of the state farm.

The sodium percentages of these waters are 32%, 35% and 46% in the Kassarah, Rotah and Swaib respectively. According to the Wilcox (1955) classification the first two are considered good and the third is permissable for irrigation purposes. The SAR values of these waters are 1.6, 2.7 and 4.3 me/L in the same three channels, and although these values vary from season to season, they are still under 10 me/L (see Tables 4.6, 4.7 and 4.8). According to the U.S.D.A. (1954) SAR classification, these waters are regarded as low-class (S1). The RSC values of these waters throughout the year are considered safe for irrigation purposes.

The predominate ions in these waters are chloride and sulphate. The chloride concentration is 3.5, 7.2 and 13.8 me/L in Kassarah, Rotah and Swaib waters and the sulphate contents are 6.7, 8.7 and 11.2 me/L. The bicarbonate contents are 3.4, 3.5 and 3.7 me/L respectively.

Table 4.6 : Water quality of Rotah Channel

Dates	Ec mmhos/cm	pH	Na me/L	Ca me/L	Mg me/L	Cl me/L	HCo3 me/L	S04 me/L	C03 me/L
29 Oct. 1977	1517	7.9	8.0	2.7	5.2	7.0	2.9	8.5	0.4
12 Dec. 1977	2594	7.8	9.8	5.0	5.5	13.7	3.5	12.4	0.2
2 Mar. 1978	2153	8	8.0	6.1	3.9	10.3	3.5	10.4	0.6
2 Apr. 1978	1740	8.9	5.4	5.4	4.4	7.8	3.9	13.2	0.0
3 June 1978	1050	8.4	3.9	1.2	3.0	3.5	3.8	7.4	0.1
3 July 1978	1063	8.3	2.3	3.2	4.0	4.0	4.1	4.6	0.1
28 Sep. 1978	1463	7.6	5.3	5.2	4.1	5.8	2.1	7.9	0.3
19 Nov. 1978	1508	7.8	5.6	7.5	8.0	6.0	4.0	6.2	0.0
4 Dec. 1978	1768	7.4	6.6	11.5	5.3	6.9	4.0	7.2	0.1

Source : Polservice, op.cit. Part B, Vol.11, p.11B-2-196.

Table 4.7 : Water quality of Kassarah Channel

Dates	Ec mmhos/cm	pH	Na me/L	Ca me/L	Mg me/L	Cl me/L	HCo3 me/L	S04 me/L	C03 me/L
27 Oct. 1977	1312	8	6.6	2.6	4.3	5.6	2.9	8.5	0.4
7 Dec. 1977	1945	7.8	5.5	4.7	2.7	9.6	3.7	10.5	0.2
16 Jan. 1978	1300	7.5	3.4	3.7	2.0	5.1	3.4	9.5	0.1
11 Feb. 1978	1063	7.7	2.6	3.8	0.5	3.4	4.5	6.3	-
2 Mar. 1978	856	7.5	2.7	3.5	1.7	3.5	3.1	7.5	0.3
2 Apr. 1978	786	8.5	2.0	3.2	1.8	2.1	3.3	7.5	0.4
3 May 1978	480	8.5	1.6	2.3	3.0	1.5	2.9	4.9	-
1 June 1978	483	8.5	1.6	1.8	0.6	1.2	5.0	4.9	0.2
2 July 1978	573	8.3	1.0	3.2	1.8	1.5	3.2	-	0.1
2 Aug. 1978	654	7.7	2.4	3.0	3.2	2.6	3.5	4.6	0.2
24 Sept.1978	989	7.7	3.1	3.7	5.0	3.3	2.6	2.8	0.3

Source : Polservice op.cit. Part B, Vol.11, p.11B-2-196.

Table 4.8 : Water quality of Swaib Channel

Dates sampled	Ec mmhos/cm	pH	Na me/l	Ca me/L	Mg me/L	Cl me/L	HCo3 me/L	S04 me/L	C03 me/L
12 Nov. 1977	2622	7.7	19.4	5.4	11.2	20.1	3.3	0.4	13.8
10 Dec. 1977	4306	7.7	10.1	5.6	8.1	18.3	4.1	0.1	13.1
1 Feb. 1978	3308	7.7	14.0	7.3	4.7	21.8	4.7	0.0	11.2
7 Mar. 1978	2790	7.6	15.6	8.0	8.5	17.6	3.7	0.0	9.4
5 Apr. 1978	2230	8.0	9.0	7.5	3.6	13.7	4.2	0.3	12.1
7 Jun. 1978	1714	8.2	9.1	6.2	6.6	9.3	3.8	0.1	19.5
11 July.1978	1840	8.0	8.1	4.4	5.3	11.0	3.2	0.2	6.9
8 Aug. 1978	2794	7.6	10.1	6.0	4.6	12.2	4.8	0.1	13.3
7 Sep. 1978	2030	7.8	5.4	2.4	7.2	6.4	4.5	0.2	6.2
4 Oct. 1978	2100	8.4	7.7	4.9	8.7	7.9	1.6	0.3	6.6

Source : Polservice, op.cit., part B, Vol.11, p.11B-165.

4.2.1.3 The Qurnah marshes These marshes consist of a series of shallow wet lowlands in the western part of the region (see Fig.4.2). They spread from the Messan province in the north down to the Euphrates river in the south, and from Thi-Qar province in the west to the central western areas of the region in the east. The total area of these marshes is about 4000 km^2 which increases in the flood seasons to about 6375 km^2 and shrinks in the dry seasons to about 1919 km^2. These marshes are supplied with water by the lower Tigris branches - Musandaq escape, Butairah and Al-Majar - which leave the Tigris in Messan province (see sec.2.2.1.2). The water depth of the marshes range from 0.20 to 3.0 m. Their waters are drained either into the Tigris river by the outlets mentioned earlier and or via 46 culverts into the Euphrates river (see sect.5.2.1).

The mean water level ranges between 0.50 and 2.5 m G.T.S., increasing in the flood season to 3.5 m G.T.S. and decreasing in the dry seasons to less than 0.50 m G.T.S. In the past, large areas of the western part of the region were inundated by the waters of these marshes during the flood seasons causing damage to the cultivated areas by leaving the salts on the surface after evaporation. Therefore, earthen embankments were constructed in the 1970's to protect these areas from flooding.

Apart from the Ec there is no other data available about the water quality of these marshes. The Ec value is about 1.500 mmhos/cm, water with this Ec value is considered as medium of class C.3.

4.2.2 The groundwater

Generally the groundwater in the region is abundant and shallow, this is principally a function of:

a) The groundwater in the Mesopotamian plain flows southward,following the general dip of the land surface (see sect. 2.2.4.) and concentrates in the southern lowlands which include the region under discussion.

b) In addition, the groundwater in the region is sustained by huge amounts of water seeping from the Tigris river and its branches, as well as from the marshes.

Thus, the depth to the groundwater ranges from 1.0 to 3.0 m. Since this water is fed by the surface water, its level fluctuates according to the variations in surface water discharge. Therefore, the groundwater table tends to rise in the flood seasons and fall in the dry seasons, by between 0.4 and 1.0 m.

Generally, the groundwater quality is poor and characterised by high soluble salt concentration. The Ec value varies locally and seasonally according to the variations of the locations of the fresh water sources and their discharges. The Ec value ranges from 3.425 mmhos/cm near the Tigris river to 4.687 mmhos/cm in the surrounding lowland areas.(4) According to the U.S.D.A. (1954) classification, the salinity of the groundwater in the region ranges from high (C4) to very high (C5). The 4th class water can be used for irrigation only on soils of good permeability and where special leaching is provided to remove excess salt. The 5th class water is generally undesirable for irrigation and should be used only on highly permeable soils, with frequent leaching and with plants of high salt tolerance.

From the foregoing it is apparent that the Tigris water is both more accessible and suitable for irrigation purposes than the other surface and groundwater sources in the region.

4.3 THE SOILS

The soils of the region form part of the southern Mesopotamian Plain which have the general characteristics as noted in section

The cultivated lands have retreated toward the Tigris levees which occupy about 4% of the total area of the region. This is largely because these levees are relatively higher than the surrounding areas and provide somewhat better drainage. About 56% of the total area of the region has been subjected in the past to irrigation practices without an adequate drainage which led to increased salt concentration and finally abandonment. The remaining 40% of the region is covered by the marsh waters.

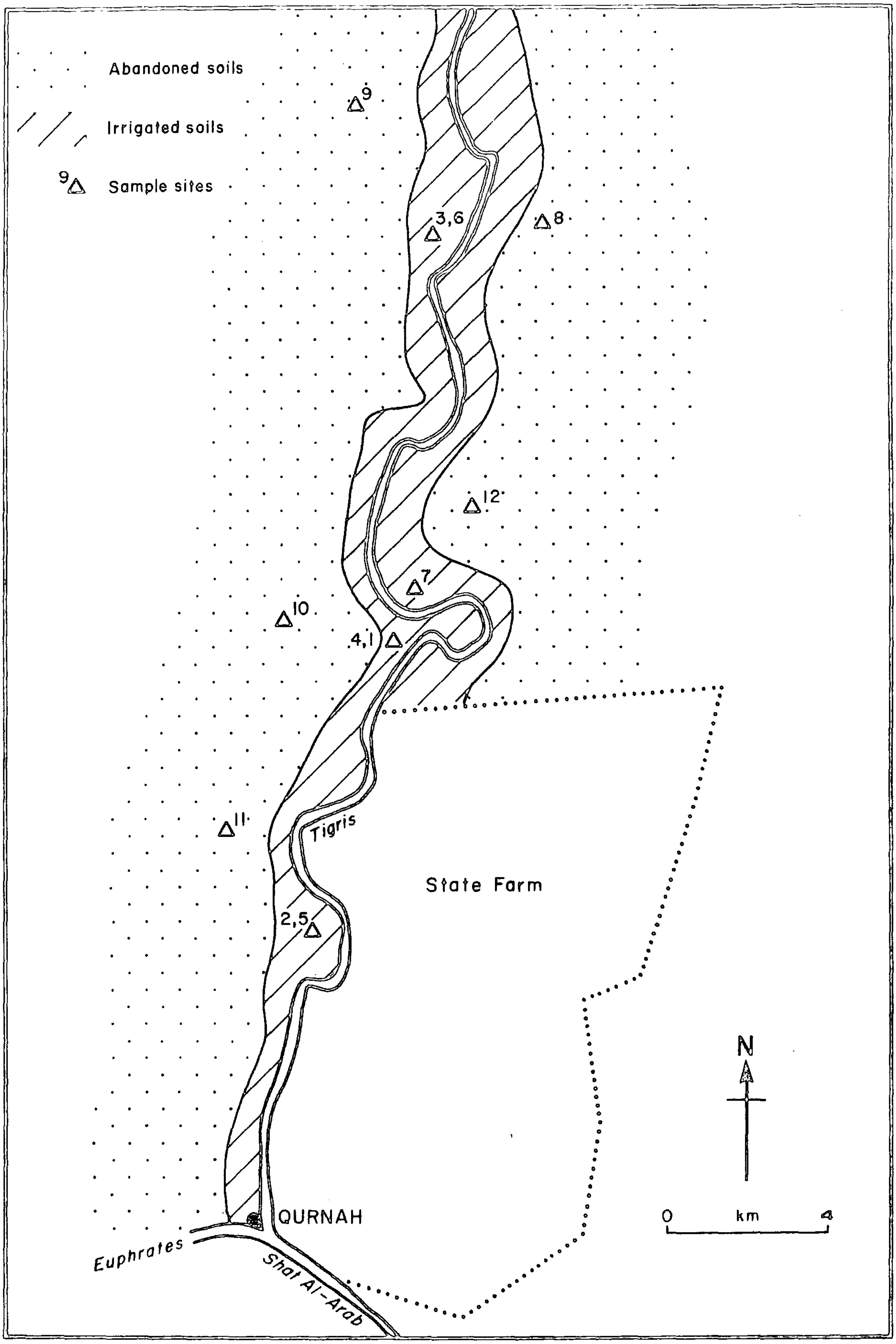
It is convenient to discuss first the characteristics of the present irrigated soils, and then the previously used but now unirrigated land soils affected by inadequate irrigation and drainage practices.

4.3.1 Irrigated Soils

In order to assess the properties of irrigated soils, three sites - soil samples Nos. 1, 2 and 3 were selected, see Figure 4.6 for location and Appendix 4.1 for analytical data. These sites were located near the soil sample sites which were chosen by Polservice Co. (see samples 4-7 in Appendix 4.1) to show the effects of the irrigation on these soils (see Fig. 4.6).

4.3.1.1 Physical Analysis : analysis of the above samples, see Table 4.9 and Appendix 4.1 show that the average silt content is high, 60% increasing in the top horizon to 68% due to the irrigation practices using the Tigris water which leaves a deposit of silt on the soil surface. Clay content is about 32% with only

Fig 4·6 Location of the Soil Samples



8% sand. These soils can thus be classified as silty-clay loams.

Since soil water movement and aeration are closely related to soil texture, the presence of a high silt and clay content generally imparts to these soils both slow water and air movement. That in turn means the intake rate of water, after watering, is slow.

These soils usually become relatively sticky and swell when wet and tend to be cloddy and shrink when dry. The shrinkage results in a number of cracks of various width from 0.1 to 7.0 cm and depths from 2 to 20 cm. Thus, when dry, these soils have an initially high infiltration rate that slows down rapidly as the soils become wet and expand, filling up the cracks.

The volume weight or bulk density in the upper metre of these soils is generally high 1.68 g/cm^3 and the percentage of the pore space or the porosity is 39 with a void ratio of 0.61. This percentage shows that the water holding capacity of these soils is generally high and the infiltration rate is relatively slow since the pore spaces are very fine.

The infiltration rates of these soils, as measured by double ring infiltrometers, range between 0.21 and 2.6 cm/hr. which, according to F.A.O. criteria (1971),[5] the infiltration rate of these soils range between slow and moderate. However, soils which have low infiltration rates have to be irrigated either by a method permitting the water to remain on the soil surface for a long period without waste from runoff or by little water with frequent irrigations. The first method, however, in a hot, arid environment such as in this region leads to evaporation of the irrigation water and consequently increasing salt concentration within the soil.

The permeability in the upper two metres of these soils ranges between 0.09 to 1.5 m/day. According to Soil Survey Manual criteria (1951)[6] the permeability of these soils can be classified between slow to moderate. Again this is a result of presence of a high amount of silt and clay.

With most soils reaching field capacity at a tension of $\frac{1}{3}$ atm. and wilting point at 15 atm,[7] in the light of this fact the moisture content at field capacity of these soils is 30.6% and at permanent wilting point it is 16.2%. Generally these soils reach field capacity in 2 to 3 days after irrigation. In addition, each cubic metre of these types of soil at field capacity hold about 0.27 cubic metre of water.[8] Thus, the available moisture content of these soils is relatively high, 14.4% due to their high field capacity mentioned above.

Generally, these soils tend to be hard, baked, cracked and difficult to break down soon after the moisture content falls below field capacity.[9] However, the available moisture content decreases with depth as a result of decreased porosity and increasing compactness with depth. The available moisture determination is very important since it indicates the amount of water that can theoretically be used or removed from the soil to support higher plants.

4.3.1.2 Chemical Analysis : Table 4.9 and soil samples nos. 1 - 3 in Appendix 4.1 show that the average organic matter content is generally low, at 1.46% in the upper 20 cm and decreasing with depth to 0.58% at about 1.0 m. Since the organic matter serves as a granulating agent in the soils, they have low granulation properties and exhibit poor aggregation when tilled. These soils require addition of organic matter when cultivated.

These soils contain a high lime (CaCo3) content with a mean

Table 4.9 : Average results of soil sample analysis

Soil Sample No.	Sand %	Silt %	Clay %	Gyp-sum %	Lime %	O.M. %	pH	Ec mmhos/cm	Ex. Na me/100g	CEC me/100g	Esp %	SAR me/L	Ca me/L	Mg me/L	Na me/L	K me/L	HCo3 me/L	Cl me/L	SO4 me/L	CO3 me/L
1	4.6	56.6	39	1.4	30.1	1.16	6.6	17.6	1.17	23.5	4.9	12.1	38.6	126	110	0.98	0.93	115	163.6	0.46
2	15	56	32.3	2.0	38.6	1.18	6.8	27.9	2.49	21.1	11.8	23.0	37.3	68	167	0.80	0.93	145	127.6	0.23
3	4.3	66.6	29.3	2.2	29.9	0.7	6.9	10.52	1.61	26.0	6.19	8.6	46.6	38.6	56.6	0.66	0.80	65.8	67.3	0.36
Aver-age	7.9	59.7	33.5	1.8	32.8	1.01	6.7	18.6	1.60	23.5	7.6	14.5	40.8	77.5	111.2	0.81	0.88	108.6	119.5	0.23

of 32.9% while their gypsum (CaSo4) content is generally low at a mean of 1.86%.

The Ec of the saturation extract of these soils averages 18.6 mmhos/cm at 25°C, which according to the U.S.D.A. classification (1954) means that these soils can be primarily considered as of high salinity but in the lower range. However, the average Ec value increases in the top 20 cm to 23.4 mmhos/cm which is regarded as strongly saline. This increase in salinity towards the surface is a result of prolonged use of irrigation water in this area which has an average Ec of 0.988 mmhos/cm. Soil solution data has found that the Ec value of the soil solution varies from 2 to 100 times that of applied irrigation water.[10] In these soils the Ec value equals about 18 times the Ec value of the Tigris water which is applied for irrigation in this region. Soil solutions containing high concentrations of soluble salts necessitate heavier water application than would be the case for soils with a low Ec value. This is in order to keep a low salt balance in the root zone or, in other words, to reduce the osmotic pressure of the soil solution. Since the osmotic pressure was found to be 36% of the Ec value of the soil solution, the osmotic pressure of these soils is about 6.6 atm, increasing in the upper 20 cm to 7.4 atm. Increasing the osmotic pressure leads to decreasing availability of water which can be absorbed by plants.

The average pH value is 7.6. The exchangeable sodium in these soils is generally low at 1.75 me/100g. Since high amounts of exchangeable sodium lead to the destruction of the soil structure causing impermeability, these soils are considered to be primarily safe from such adverse effects.

The total cation exchange capacity, C.E.C. indicates generally the most important source of available plant nutrients. The average C.E.C. value of these soils is 23.5 me/100g. According to ILACO (1981) criteria noted in section 3.2.1.2, the C.E.C. of these soils is considered medium. The average SAR is 14.5 me/L and Esp averages 7.6%. Soils with Esp less than 15% are regarded as free from alkalinity.

From what has been said it is evident that these soils are saline and free from alkalinity, this reflecting the U.S.D.A. (1954) definition of saline soils.[11]

Soluble calcium level in these soils averages 40.8 me/L, but the magnesium content is higher 77.5 me/L. The predominate cation is sodium, 111.2 me/L. Potassium exists in very small amounts, less than 1 me/L. As potassium is necessary for utilising saline soils, a good supply of it is essential but high contentrations of potassium may contribute to increasing the osmotic pressure.[12]

The soils under discussion have a low amount of bicarbonate 0.88 me/L but they have a high concentration of chloride ions 108.6 me/L. Sulphate is present in higher amounts of 120.0 me/L and dominate the soluble anions. This ion is considered less toxic to the plants than chloride.[13] The soluble carbonate is very low, less than 1.0 me/L. Thus, these soils are considered as sulphate-sodium type saline soils.

According to the U.S.D.A. Interior Bureau of Reclamation's determination of the suitability ranges of land for profitable, sustained irrigated agriculture (see sect. 3 .2.1.2), these soils are regarded relatively profitable.

The U.S. Bureau of Reclamation classification of land for irrigation is based not only on the general soil properties but also on the socio-economic conditions on the given land. However, it is not possible here to make firm assumptions of socio-economic capabilities or background for purposes of classification of land for irrigation suitability (see sec. 4.4) . Therefore, Polservice Co. (1978)(14) appraised these soils only on the base of the soil characteristics and considered them as class 3 soils. This is because the deficiencies of these soils are indicated by high Ec value and low infiltration and permeability rates. This class is considered suitable for irrigation development but is approaching marginality for irrigation and it is most suitable for dates and cereals cultivation.

4.4 MANAGEMENT

In relation to irrigation and drainage, management characteristics can be summarised on the base of extensive personal investigations of the socio-economic status and the educational level of the traditional farmers in the region, as follows.

4.4.1 Socio-economic status

At present the farmer still tries to have a large family because in a village life a large family imparts considerable socio-economic advantages. These advantages are measured largely on the availability of a large labour force which can obtain income either from cultivation and/or from other economic sectors. However, the importance of nonagricultural sectors has increased in the last decade due to general improvements in the Iraqi economy, which has seen a marked increase in non-farming employment opportunities. Due, however, to increasing demand for crops in the Iraqi markets, together with new employment opportunities, the government has been providing many facilities for the farmers to cultivate their lands effectively.

These facilities include the provision of better seeds, fertilizers, low rents on lands, agricultural machines, etc. Despite all these facilities, the majority of the young people in the agricultural villages tend to leave the farm to work in unskilled jobs which are available in the nearby cities - Basrah, Qurnah and Uzair, and which give more cash in a shorter period of time compared with agriculture. Investigations in the region showed that only the old people, women and children now practise cultivation in the farms. With the exception of school children, the majority of these people are illiterate and not suited for ecologically or commercially sound agriculture. Moreover, the children's part in cultivation operation is only during vacations and the women's contribution only when they have time. That in turn means that the regular availability of competent labour for cultivation purposes is small and as a result farming now provides only a small proportion of the farming family income.

Current agricultural activities concentrate on the cultivation of crops which provide the highest cash return - vegetables, and those needed by the farmer such as grain and fodder.

There is no immediately available data about the number of farms and type of ownership. From personal field work it is estimated that there are about 700 farms in the region, some owned by the farmers themselves and others rented from the government for a low rent. The size of these holdings ranges from 5 to 30 donums with an average farm area of 10 donums. As a result of restriction of cultivated lands at present on both sides of the Tigris river, the farms tend to be less in width than in length near the river banks. Therefore, most of the farms are long and narrow and/or rectangular in shape (see Fig. 4.7). Since all the farms are individually irrigated from the Tigris by separate canals, problems about the distribution of irrigation water quantities between farmers are avoided.

4.4.2 Educational status

Although most members of the family are able to read and write, it is those best educated who are attracted to non-agricultural sectors. Consequently most agriculture is carried out by the residue of illiterate farmers who rely on their own and inherited experiences. Thus, they are unable to use advice put out in the newspapers and other publications. To overcome this problem radio and T.V. carry farming programmes in the local language covering explanations and recommendations about better methods of tillage, time of sowing, irrigation, nursing, fertilizers etc. Even so the response by farmers is minimal. The overall result is that most of the farmers do not realize the importance of the land and the water they use. This fact results from the following factors:

a) The main income of the farmer's family comes from non-agricultural jobs.

b) The land and the water can be obtained at very little cost as mentioned earlier.

c) The scarcity of hired agricultural labour which requires high wages.

d) The low educational and technical abilities of the farmers.

Consequently, the farmer does not put land and water resources to their best possible use; for example, fallowing is still widely practised despite the widespread availability of fertilizers. This again reflects the shortage of labour to put all the land under crops and also the fact that there is no pressure to maximise income from the farm whilst most of the family's income is derived from non-agricultural sectors. However the fallow system usually leads to salt accumulation on the soil surface brought by capillary action from saline groundwater and seepage from neighbouring irrigated farms.

From many discussions with the local farmers, it is obvious that the majority do not know the fundamental agricultural principles of the system which they are using. For example, the farmer does not know the importance of drainage in the cultivated lands, the factors which lead to increased soil salinity and he also believes that using more water to irrigate the land gives a higher yield.

From the foregoing it is evident that the nature of the farming community i.e. reliance on non-agriculture income, shortage of labour and low educational level of those carrying out the farming, is such that there is a danger of the system collapsing. The characteristics mentioned above are certainly reflected on the utilization of the water and soil resources in the irrigated belt, through tillage, distribution system of water, water losses and efficiency, soil salinity and the crop yield.

4.5 LAND PREPARATION AND TILLAGE

Generally, the lands of the irrigated belt immediately on the sides of the Tigris river are almost flat, sloping very gently away from the river banks. Levelling of the land is therefore not considered necessary. However, there are many very shallow and small depressions hardly noticeable by the eye, which may lead to great difficulties in getting a uniform distribution of irrigation water. These depressions can only be noticed when the first irrigation in the farm is practised, through water accumulation in some parts of the farm. However, the farmer can overcome this problem by moving earth from the higher parts to the lower parts in the furrows, canals or basins.

Before the land is tilled, it is usually leached to reduce the salt concentration built up by capillary rise during the fallow period. Leaching is carried out by the addition of large quantities of water for 1 to 3 days. Following leaching the land is ploughed. Timeliness of cultivation is vital. If ploughed when the soil is too dry, then large irregular clods are produced at the surface which interferes with the even distribution of irrigation water. These clods are either left to collapse on webbing or are broken down by hand.

The vegetation which is usually found in the fallow lands is of salt tolerant species, such as Shok (Lagonyehium spp.) and Agol (Alhagi maurorum) which are killed by ploughing.

The tillage of the farm is achieved by tractor ploughing which is worked in parallel lines of more than 30 cm depth and 5 to 15 cm apart. The alignment of the irrigation water canals within the farm takes place at the same time as tillage. These operations cost about ID 20 (£36)* for a typical farm with an area of 10 donums or 25000 m^2.

4.5.1 The Water Distribution System

The distribution system of the typical farm consists of a feeder canal, a water storage basin houdh, pump, pipes, a spill water basin Berchah, buried pipes which are permanent, and canals and furrows which are temporary (see Fig. 4.7). These are used for conveying the irrigation water from the Tigris river to the plants.

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* The sterling prices in this chapter are converted by the price of pound in 1982 which was equal to ID 0.555.

As the level of the Tigris is below the surrounding land, irrigation water has to be pumped from the river into the main canal.

The distribution system varies from winter to summer according to the types of the crop grown.

4.5.1.1 The distribution system of water for summer crops : Summer crops consist of vegetables (see sect. 4. 6). Figure 4.7 shows that this system comprises, first, the feeder canal which is excavated in the Tigris banks to connect the Tigris water and the water storage basin. As a result of the variations in the width of the banks, the length of the feeder canal varies from 10 to 300 m and its width ranges from 50 to 70 cm. This canal must be excavated about 30 cm deeper than the lowest water level in the Tigris so as to secure water flow from the river to the store water basin. It also has to be deepened over the irrigation period as the level of the Tigris falls and any sediment accumulating removed. Its depth varies between 50 to 120 cm depending on the state of the river, (see sect. 4.2.1.1.2). This earthen land-dug open canal costs about ID24 (£43)for each 10 m length, wages for two digging workers.

The water storage basin houdh is dug by hand at the end of the feeder canal. The unlined basin measures 2 m in diameter and 2 to 3 m in depth. Thus, its volume is about 7.8 m^3 and its base has to be 1.0 m below the feeder canal in order to store sufficient water for efficient operation of the pump. This basin periodically also has to be cleaned of the deposits that accumulated during the flood season. This basin costs about ID 30 (£54). The waste earth produced from the basin is stacked on the adjacent ground surface to build a mound on which the pump will be installed, thus protecting it from any unusually high water level in the river. Two pipes are joined to the pump, each one 10 cm in diameter. One of 3 m length is used to withdraw the water from the houdh, the other which has a length ranging from 2 to 3 m is used to discharge the water into the spill water basin, berchah. The pump most commonly used in the majority of the farms, has a capacity of 5 h.p. with a maximum pumping capacity of 5 m^3/min. Its use is governed by its low price and availability of the spare parts. The cost of the pump, pipes and their installation is about ID 400 (£720).

The spill basin is excavated manually some 1.5 to 2.5 m from the pump. The depth of this unlined berchah ranges from 70 to 150 cm and is 150 cm in diameter. This basin receives water from the second pipe of the pump and discharges it into a buried pipe. The cost of its excavation is about ID 20 (£36). The above constructions are located between the protecting dyke and the river, while the following with the exception of the buried pipe are located on the other side of the dyke (see Fig. 4.7).

A concrete pipe of 25 cm in diameter and 15 to 20 m in length carries the water from the berchah underneath the protecting dyke to the main canal, flow in this pipe being by gravity. The government makes these pipes available to the farmers free of charge, when constructing the dyke to facilitate conveyance of water to farms.

The main irrigation canal is earthen and hand dug in the first 30 m and the other section is excavated by tractor and is used to convey irrigation water from the buried pipe to the secondary canals. it slopes away from the river slightly with the general gradient of the ground surface. However, it is essential to ensure that this canal slopes gently so as to avoid either too fast or very slow flow in order to avoid either erosion or deposition. The workers achieve the necessary grade simply by spilling water

Fig. 4.7 The Distribution System of the Typical Farm

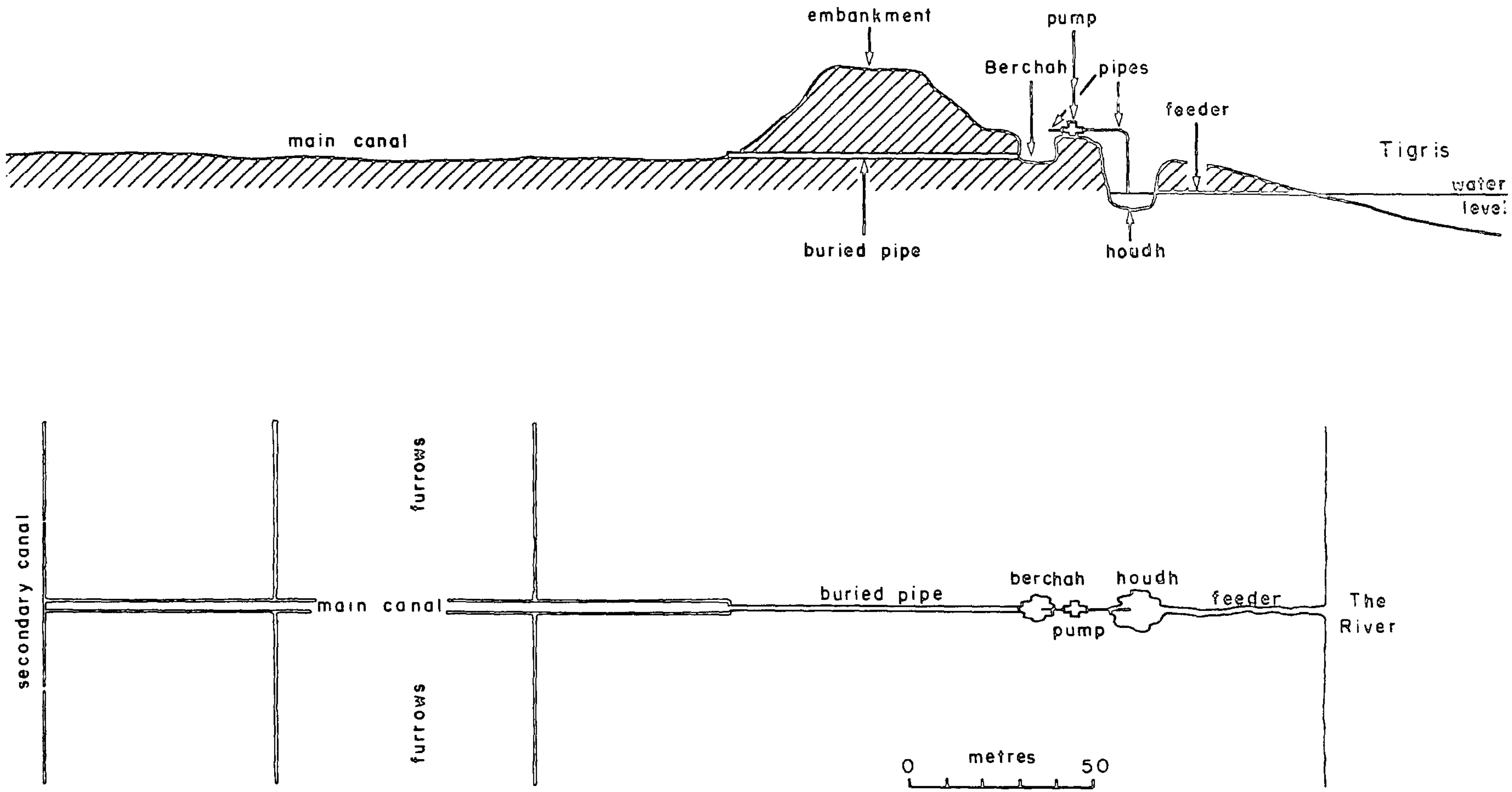
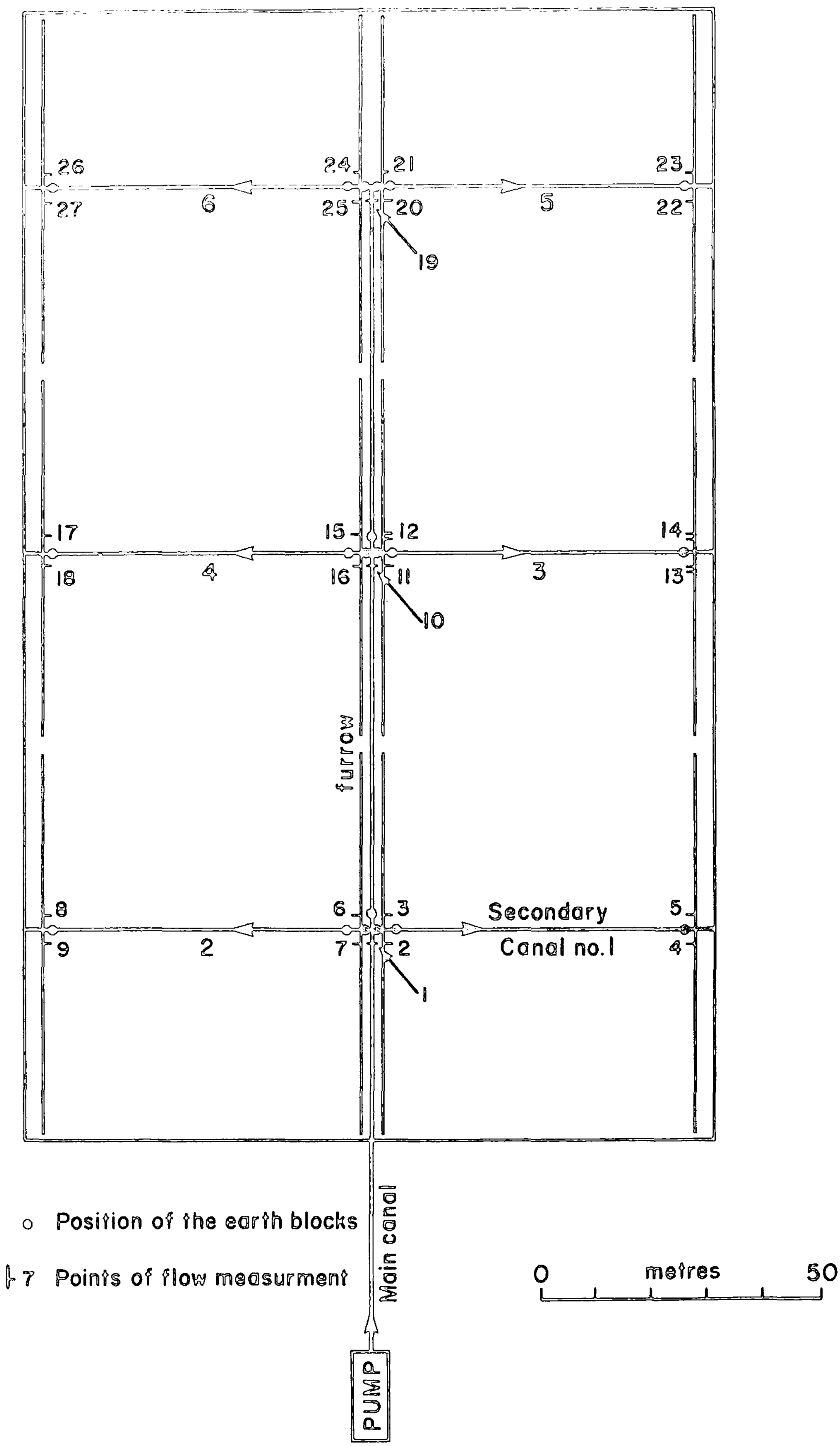


Fig 4·8 Water Distribution System in the Summer

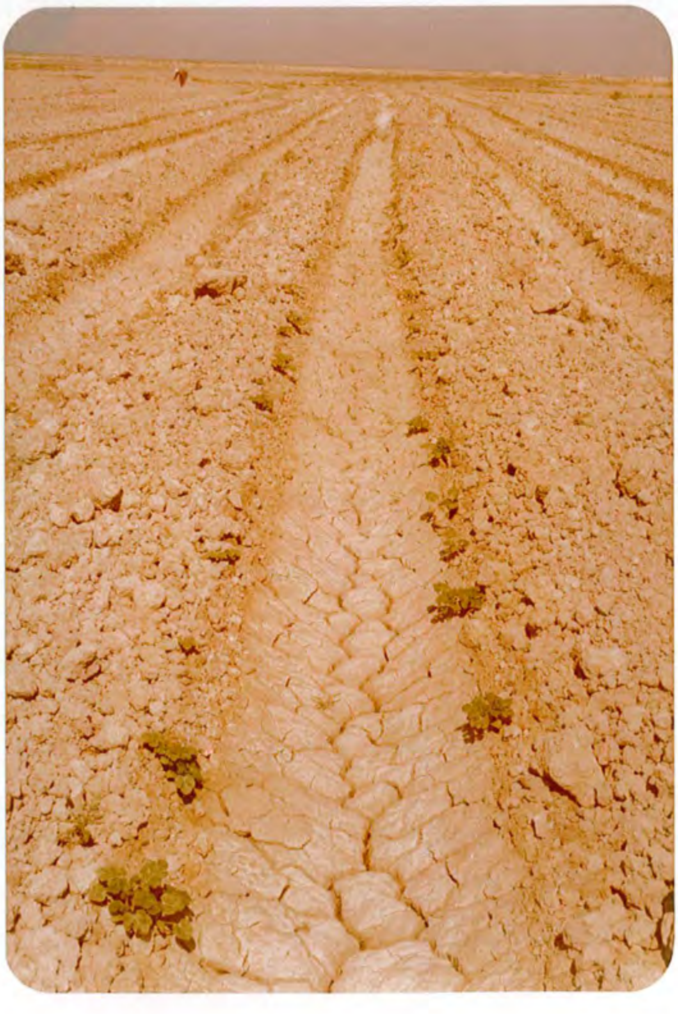


into the canal and watching for any slow or rapid flow, then by moving soil from higher parts to the lower ones the workers produce a uniform satisfactory flow. This canal measures 50 to 80 cm in depth, 70 to 100 cm surface width and 50 to 70 cm at the base. Its length varies from 180 to 500 m, according to the length of the cultivated area in the farm and the location of the farm relative to the river. This canal is always excavated through the central parts of the farm in order to divert irrigation water into secondary canals which are located on both sides of the canal. The permanent canals are cleared of sediment every season. The banks of the canals are about 20 cm higher than the adjacent land, but are often poorly constructed, consisting of clods of varying size arranged in such a way that the water leaks through the banks (see Fig. 4.9). This reflects the low management skills when the land is laid out and tilled. These characteristics together with the uncovered surface and unlined floor and sides of the canal contribute to high water losses. The first hand-dug section of 30 m costs about ID 50 (£90). The other sections' cost is included in the general tillage costs.

The typical farm in the region contains 6 secondary canals, about 65 m apart and excavated by tractor at right angles from the main canal (see Fig. 4.7). These secondary canals are about 62 m long, 70 to 80 cm wide at the surface, 40 to 60 cm at the base and 40 to 55 cm deep. Thus, the volume of each totals about 18 m^3. These open unlined canals are excavated by tractor, as linear excavations, being later graded by hand shovel in the same way as in the main canal. Grading of these canals and the second section of the main canal cost about ID 50 (£90). The banks of these canals are higher than the adjacent land by an average of 15 cm, and again tend to be constructed of different size of clods. These canals divert the

FIGURE 4.9 : Uneven clod sizes and water leakage through the banks

FIGURE 4.10 : The furrows



irrigation water from the main canal into the furrows, lebbabi.

The furrows are excavated by tractor as linear excavations at right angles from the secondary canals (see Fig. 4.10). They are smoothed by hand shovel in the same way as the main canal. The typical farm in the region contains about 480 furrows, each 80 furrows served by a secondary canal, with regular spacing at about 1.0 m. The dimensions of the furrow are about 32 m long, 50 to 70 cm wide at the top grading to 20 to 30 cm at the base, and about 40 cm depth. The average volume of each furrow is 5.44 m^3. These open unlined furrows convey irrigation water from the secondary canals to the crops which are planted on both sides of the furrows. Again their banks contain different sizes of clods. Grading of each furrow costs about ID 0.150 (£0.27).

The joins between the main secondary canals and furrows are closed by earth blocks dug from the adjacent soil. They are opened by digging out the block to divert irrigation water where it is needed. However, if the earth is cloddy these earth blocks are prone to continuous leakage (see Fig. 4.11).

With the low management levels that predominate in the region, the system is prone to considerable water losses and inaccurate applications. This is due in large part to the poorly constructed "cloddy" banks and earth blocks. The low initial costs, together with the ease of construction and maintenance are one of the major advantages of this type of the canals. With the exception of the main canal the other secondary canals and the furrows are temporary and are abandoned after the summer growing season.

FIGURE 4.11 : Water leak through earth block

4.5.1.2 The distribution system of water for the winter crops

Winter crops consist of vegetables and grain (see sect. 4.6). The land which has been dry fallowed during summer is cultivated in winter according to the fallow system.

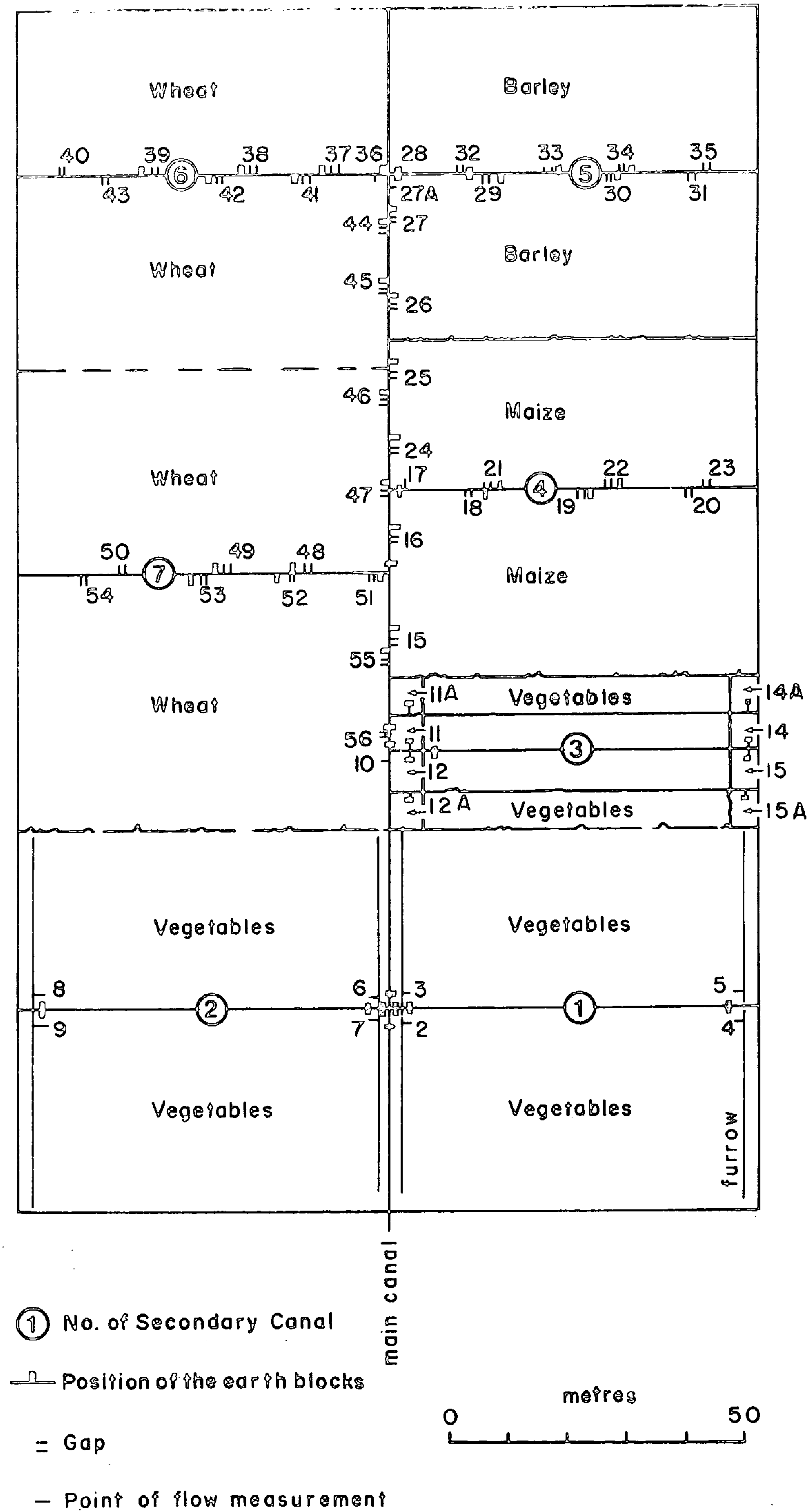
The distribution system in winter is also affected by crop choice i.e. the farm is usually divided into two fields, the smaller being devoted to vegetable cultivation and the larger allocated for grain. This split in land use with the greater area down to grain is mainly a function of labour shortage in this season, grain requiring lower labour inputs. The majority of winter vegetables are cultivated on furrow sides - tomates, legumes, onions, garlic etc. and the minority are cultivated in small basins - carrots, celery, radish, spinach etc. The grain is planted in larger basins (see Fig. 4.12).

The total area of the vegetables which are cultivated on the furrows in the typical farm is about 9238 m^2. This area contains the first 64 m of the main canal, two secondary canals and 160 furrows. Their measurements and characteristics are the same as those in the distribution system of the summer crops with the exception of the furrow lengths which decrease to about 29 to 31 m due to design requirement of the distribution system. Thus, the volume of each furrow averages about 5.1 m^3.

The total area of vegetable basins is about 1550 m^2, this being divided into 48 basins, the area of each totalling 30 m^2.

A typical grain field covers 15562 m^2 and contains the second section of the main canal and four secondary canal from which the irrigation water is diverted directly through small gaps excavated on their banks into the basins. The average areas for grain are 3410, 3596 and 8556 m^2 for maize, barley and wheat respectively.

Fig 4·12 THE DISTRIBUTION SYSTEM IN WINTER



4.6 THE CROPS

The main crops planted in the typical farm are vegetables because they yield high cash return, and grain which is needed by the farmer to feed his family and livestock.

4.6.1 The summer crops

These are tomatoes, aubergines, okra, melons, water melons and green beans which are planted on the furrow sides. Cultivation of vegetables requires considerable labour particularly during harvest time. Therefore, one of the main reasons for cultivating vegetables in this season is related to the availability of labour for harvesting which is represented by school children during the summer holidays of 100 days.

According to the FAO classification (1971) of crop growth stages (see sect. 3.7), the average periodicity of these stages in the typical farm is as follows:

4.6.1.1 The initial stage : after smoothing and grading the furrows, small excavations of 10 cm depth and 5 cm width and about 50 cm apart are dug by hand sickle on both sides of the furrows. An average of 5 to 10 seeds are put into each excavation, a number being planted to avoid complete failure. The seeds are then irrigated twice a week until the seeds germinate and the seedlings reach a height of 10 to 15 cm at the end of this stage. At this point the seedlings are thinned so as to leave only the most healthy to grow free from competition. This stage takes about 30 days starting from the 5th March until the 13th August.

4.6.1.2 The developing stage : in this stage the crops are again irrigated twice a week as they are still sensitive and not tolerant to drought. Growth throughout this stage is vegetative and lasts for about 40 days, from the 14th April until the 23rd May.

4.6.1.3 The mid-season stage : irrigation is reduced to once a week and the farm becomes green. Some of the lower plant leaves tend to be yellowish and the fruit flowering takes place. The fruits begin to form at the end of this stage which lasts about 45 days from the 24th May to the 6th July.

4.6.1.4 The late stage : in this stage the crops are also irrigated once a week and the fruits mature gradually. This stage takes about 45 days, from the 7th July to the 7th September.

Thus, the total growing season for the summer crops is about 160 days, from the 15th March until the 7th September.

4.6.2 The winter crops

Some of the winter vegetables are planted on the furrow sides in the same way as the summer crops, whilst others and the grain is sown in the basins. The average time of the winter crop growth stages vary according to the crop species as follows:

4.6.2.1 The initial stage : in this stage the vegetables which are planted on both basins and furrows have the same characteristics as those of the summer crops with the exception that the vegetables in the basins are not thinned as those on the furrows. This stage lasts about 30 days, from the 10th October until the 8th November, during which the crops are irrigated once a week.

4.6.2.2 The developing stage : this is a period of vegetative growth and it lasts about 48 days from the 9th November to the 26th December. The crops are irrigated also once a week.

4.6.2.3 The mid-season stage : as with earlier stages, this stage in winter takes longer than in summer lasting for some 55 days from the 27th December to the 19th February. The crops are again irrigated once a week.

4.6.2.4 The late stage : it takes about 50 days, longer in winter than in summer, starting from the 20th February to about the 11th April, in which the crops are irrigated once a week until the crops are harvested.

4.6.3 The grain growth stages

4.6.3.1 The initial stage : in this stage the grain germinates and seedlings reach a height of between 10 to 20 cm. This stage takes about 20 days, from the 20th October to the 8th November, during which the crops are irrigated once a week.

4.6.3.2 The developing stage : this vegetative growth stage lasts some 30 days, a shorter period than for vegetables, reflecting the physiological differences in the crops. Irrigation water is applied weekly, and the stage lasts from the 8th November to the 8th December.

4.6.3.3 The mid-season stage : this flowering and fruiting stage takes about 55 days, from the 9th December to the 1st February. As with previous stages irrigation is carried out weekly.

4.6.3.4 The late stage : In this stage the grain is irrigated once every two weeks. This reduction in irrigation frequency is to reduce the moisture content of the crop seeds. This stage lasts about 45 days, from the 2nd February to the 18th March.

Thus the growing season of the winter vegetables takes about 183 days from the 10th October to the 11th April. The growing season of the grain lasts about 150 days from the 20th October to the 18th March. It is obvious that the winter cropping cycle overlaps the beginning of the summer cycle. Even the gap between the end of the summer cycle and beginning of the winter one is relatively short and any delay in the summer cycle would have serious effects on the planting dates of the winter crops and partly because of this some farmers believe that part of the farm area must be left fallow in each season. Further complications are added to the start of cultivation according to the variations in the availability of labour and other agricultural inputs e.g. tractor, fertilizers etc. In addition, the crop types and areas vary relatively from farm to farm according to the selection of crops made by individual farmers.

4.7 CONSUMPTIVE USE OF WATER

Consumptive use requirements calculated in Section 1.4 will be used for this region. Located only some 80 km to the north of the Basrah climatic station, there are no specific factors which produce any differences in climate between the two locations.

Table 4.10 and Figure 4.13 show that the consumptive use of water for the crops in the typical farm varies throughout the months of the growing seasons. Generally, the values decrease in the colder months and increase in the hotter ones due to the variations of temperatures, wind velocities, sunshine hours and the relative humidity percentages, and also due to differences of the crop areas and physologies.

In order to show the consumptive use of water for the crops, mentioned earlier, according to their areas and lengths of their growth stages in the typical farm, the crop coefficients (kc) have been selected from F.A.O. data (1971).[15] The total theoretical consumptive use of water for the summer crops in the typical farm is 26798 m^3 during their growing season, while for winter crops it is 10003 m^3 of which 4943 m^3 is for grain and 5060 m^3 for vegetables. Vegetables are planted both in furrows and basins,

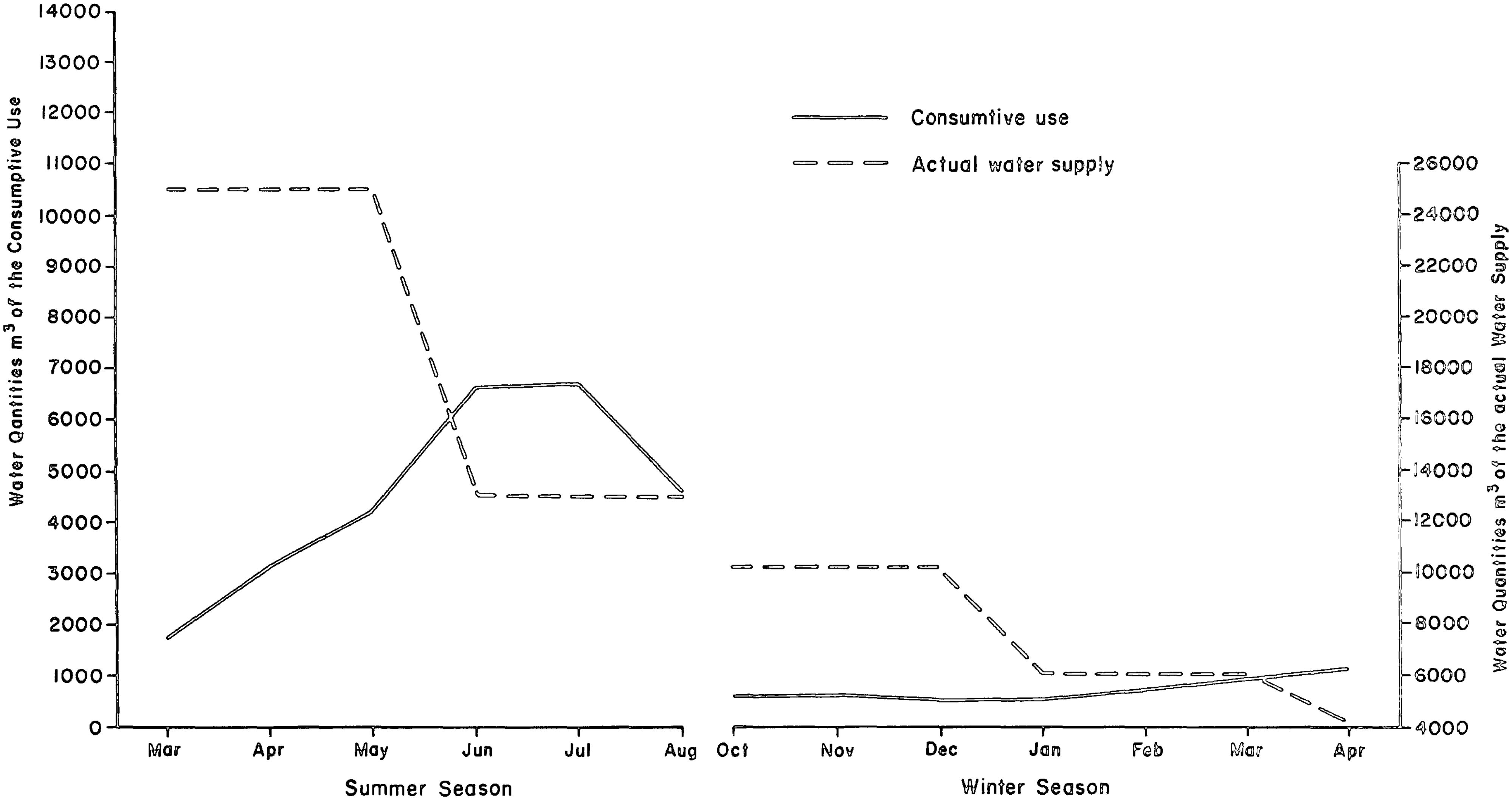
Table 4.10 : Consumptive use for the typical farm

Month	Et mm/month	Area of summer crops m^2	Area of winter crops m^2	Area of grain basins m^2	Area of winter vegetables m^2	Area of veget-ables in basins m^2	Area of veget-ables on furr-ows in winter m^2	Et of veget-ables in summer (*) kc = 0.76	Et of grain kc = 69 mm	Et of veget-ables in winter kc = 0.76	Et of summer vegetables area m^3 (**)	Et of winter Vegetables area m^3	Et of the basin vegetables m^3	Et of veget-ables on furr-ow in winter m^3	Et of the grain area m^3
Jan.	52.6		25000	15562	9300	1550	7750		60.49	54.17		503.7	83.9	419.8	941.3
Feb.	78.4		25000	15562	9300	1550	7750		21.95	80.75		750.9	125.1	625.8	341.5
Mar.	128.5	25000	25000	15562	9300	1550	7750	62.96	35.98	97.66	1574	908.2	151.4	756.8	559.9
Apr.	164.7	25000	25000					125.17		125.17	3129.2	1164.0	194	970	
May	221.4	25000						186.26			4206.5				
June	256.5	25000						264.19			6604.7				
Jul	259.5	25000						267.28			6682				
Aug.	242.2	25000						184.07			4601.7				
Sept.	193.4	25000													
Oct.	137.2		25000	15562	9300	1550	7750		68.60	67.22		625.1	104.2	520.9	1067.5
Nov.	84.3		2500	15562	9300	1550	7750		69.12	64.06		595.7	99.3	496.4	1075.6
Dec.	53.5		2500	15562	9300	1550	7750		61.52	55.10		512.4	85.4	427	957.3
Total	1872.2										26798	5060	843.3	4216.7	4943

(*) Et x kc

(**) Crop area x(*) 1000

Fig 4·13 Theoretical Consumptive use and actual Water Supply m^3



the consumptive use value for those in furrows being 4216.7 m^3 and for vegetables in basins 843.3 m^3.

4.8 LEACHING REQUIREMENTS

According to Thorne and Peterson's equation (1954) (see sect. 3.9), the leaching requirement is for 5.3% more water to be used than that actually required to bring the soil to field capacity and to maintain the soil Ec value at 18.6 mmhos/cm, (see sect. 4.12.1.2). To reduce the Ec value of the soil solution from 18.6 to 8 mmhos/cm the leaching requirement would be 12.35% and it should be 24.7% if the permissible Ec value of the soil is 4 mmhos/cm.

However, adequate leaching is not taking place in these soils as shown by the increase in an Ec value with time. Soil samples nos. 4 - 7 in Appendix 4.1 were taken and analysed in 1978 by Polservice Co. (see Fig. 4.6) and showed that these soils have an Ec value of 11 mmhos/cm (see Table 4.18). However, soil samples nos. 1, 2, and 3 taken from the same locations and analysed in 1982 showed that the Ec value of these soils has increased to 18.6 mmhos/cm. This in turn means that the Ec value of these irrigated soils has increased at an average rate of 1.9 mmhos/cm per year. Thus if this value is added to the average value of Ec in 1982, the Ec value of these soils would be 20.5 mmhos/cm at the end of that year. Depending on this Ec value the leaching requirement is for 4.72% more water to be used than is actually required to bring the soil to field capacity. The total leaching requirements, depending on the consumptive use value, are 1264.8 and 472 m^3 for the summer and winter seasons respectively.

Thus, the theoretical water demand required for irrigating and leaching the typical farm is 28062.8 and 10475 m^3 for summer and winter respectively.

4.9 THE WATER SUPPLY

The gross irrigation water applied in the typical farm can be realized in the light of real measurements to the water discharges at key points in the farm (see Figs. 4.8 and 4.12), to show water losses and efficiency.

The water supply varies from season to season due to differences between crops, their growth stages, consumptive use and the distribution systems.

4.9.1 Water supply for summer crops

These crops are irrigated twice a week for 10 weeks in the initial and developing stages. In the region under discussion the farmers irrigate farms according to their experience of the plants' visual appearance - colour, curling and wilting of the leaves - and on the size and density of the cracks in the soil surface. They suggested also that the irrigation frequency and the amounts depend on the growing stage i.e. in the earlier stages the crops are irrigated by more water in order to avoid probable wilting. In other stages the crops are irrigated by less frequency but with slightly larger water doses to help the fruit to mature quickly. Thus, the water supply in summer season varies according to the growth stages of the crops as follows : see Fig. 4.8.

4.9.1.1 The water supply in the first two growth stages : in these stages the crops are irrigated twice a week, each irrigation taking about 20 to 21 hours. It is achieved in two days as shown below. It is worth while mentioning that the pump used in the typical farm has a 5 h.p. capacity with a maximum yield of about 7.5 m^3/min. However, if the maximum power of this pump is used, the farm may be irrigated in a shorter time, 10 to 11 hours, and irrigation can be achieved in just one day. But discussions with the local farmers showed that they believe if the maximum power of the pump is used under the hot, arid conditions, the pump's working life may be reduced. However, when they were asked why they did not use pumps at a higher capacity in order to irrigate their farms in only one day, they suggested that the first pump is cheap and the spare parts are available. In addition, the maximum water discharge may cause erosion of the canals.

On the first day the irrigation operation continues for 12 hours from 6 a.m. until 6 p.m. The water pump discharges were measured at key points, (see Fig. 4.8 and Table 4.11). Measurements of water discharges in the earthen canals, where their volumes are affected by deposition of sediments and erosion to some extent, was not easy because it was not possible to use the common water scales - weir or partial flume, the findings, therefore may be considered less precise than those carried out in lined canals.

The measurements were carried out on three farms to reach an average reading of the water discharges. The same equipment and method was used as noted in section 3.10.1.

Looking at Table 4.11 and Figure 4.8, it can be seen that the water discharge from the pump averages 2.36 m^3/min. This water is delivered from the spill water basin into the buried pipe and then to the main canal by gravity. The amounts of irrigation water applied to fill the basin, buried pipe and the main canal section before point 1 are 1, 1 and 21.75 m^3 respectively.

The water discharge at the first point averages 2.34 m^3/min. To irrigate the furrows which joint the first secondary canal, the second secondary canal and the next section of the main canal are

Table 4.11 : Water discharges during the first growth stages in summer

	Point	Discharge m^3/min.	Discharge m^3/sec.	Theoretical time required to fill the furrow sec.	Actual water applied m^3	Actual time required (seconds)
First day	1	2.34				
	2	1.25	0.0208	229	5.26	253
	3	1.08	0.018	264	5.11	284
	4	1.02	0.017	280	4.81	283
	5	0.98	0.0163	292	5.28	324
	6	1.06	0.0176	271	5.13	292
	7	1.24	0.0206	231	5.21	253
	8	0.94	0.0156		5.22	335
	9	1.08	0.0180		5.25	292
	10	2.30	0.0195			
	11	1.17	0.0185		5.38	276
	12	1.11	0.0146		5.03	272
	13	0.88	0.0195		4.93	338
	14	1.17	0.0191		5.22	268
	15	1.15	0.0186		5.19	272
	16	1.12	0.0176		5.24	282
	17	1.06	0.0156		5.19	295
	18	0.94			5.05	324
Second day	1	2.35				
	10	2.33				
	19	2.32				
	20	1.22	0.0203		4.85	239
	21	1.09	0.0181		5.70	315
	22	0.92	0.0153		4.94	323
	23	1.11	0.0185		5.21	282
	24	1.05	0.0175	272	5.14	294
	25	1.26	0.021	227	5.27	251
	26	0.87	0.0145	259	4.90	338
	27	1.13	0.0188	253	5.03	268
						6,953

closed by earth blocks. Thus, the water is diverted into the first secondary canal. Usually the farmer leaves the water in this canal to flow freely into the furrows. However, in order to carry out measurements of the water discharges into the furrows, the first two and the last two furrows were chosen in each secondary canal to show the water losses. It was not possible to measure the water discharges into all the furrows at the same time. Therefore, an earth block was put in the first secondary canal immediately after the first two furrows in order to divert the water into them - points 2 and 3 in Figure 4.8. The water discharges at these points are 1.25 and 1.08 m^3/min respectively. This difference of the water discharge in these points is due to the variations of the cross-sectional area at the head of these furrows. It is worth while mentioning that the theoretical water volume required to fill these furrows to a level of 35 cm is 4.76 m^3 for each in 3.81 and 4.4 min respectively. But, indeed these furrows in order to be filled to the same level took more water, 5.26 and 5.11 m^3 in 4.21 and 4.73 min respectively. This is due to the existence of cracks in the furrow floors, see Figure 4.10, leaking of water through and over the furrow banks and earth blocks, see Figures 4.9 and 4.11, as well as through the influence of the infiltration rates and high evaporation.

Then, the earth block in this secondary canal was removed and another one was placed before the last two furrows - points 4 and 5 (see Fig. 4.8). Consequently, the water entered into the other furrows and just after filling them, this block was removed and the measurements at these points were carried out. The water discharge at these points are 1.02 and 0.98 m^3/min respectively. The first furrow - point 4 - was filled by more water 4.81 m^3 in a longer time 4.71 min compared with the theoretical volume of 4.76 m^3 and time of 4.66 min. The second one - point 5 - theoretically required the same above volume and time but it was filled to the same level 35 cm by more water 5.28 m^3 in 5.40 min. In the first day the above operations and measurements were carried out in other canals and furrows until about 6 p.m. then the pump was stopped. On this day the first 320 furrows which join the first four secondary canals were irrigated (see Table 4.11 and Figure 4.8). These measurements are assumed to be representative of averages throughout the growing season. Some variations however may occur as the water stream causes erosion at the heads of the furrows and sedimentation in the last sections which may affect the size or the volume of water applied to fill the furrows over the season. However, investigation in the region showed that the farmer always tried to grade the furrows by hand shovel moving the earth from higher places to lower ones. Additionally, the measurements were repeated twice throughout the growing season and showed very close similarity to those which were carried out on the first occasion.

On the second day the water discharge from the pump was similar to that in the first day at 2.36 m^3/min. The water discharges at points 1 and 10 were higher, at 2.35 and 2.33 m^3/min, than those in the first day due to the saturation of the soil which reduces the infiltration rate.

The same measurements carried out on the first day were repeated. The water discharge at point 19 was 2.32 m^3/min. The water was diverted into the sixth secondary canal and then into the first two furrows in the same way as previously mentioned. The water discharge at points 24 and 25 were 1.05 and 1.26 m^3/min. These furrows should theoretically be filled to the same level 35 cm in 4.53 and 3.78 min respectively but actually they were filled by 5.14 and 5.27 m^3 in

4.90 and 4.18 min respectively. The water discharges in the last two furrows in this secondary canal were measured at points 26 and 27 and were found to be 0.87 and 1.13 m^3/min. The theoretical volume and time to fill these furrows are 4.76 m^3 in 4.31 min and 4.76 m^3 in 4.21 min respectively but these furrows were filled by more water over a longer time at 4.90 m^3 in 5.63 min and 5.03 m^3 in 4.46 min respectively, (see Table 4.11 and Fig. 4.8).

Calculating the average actual water applied in each irrigation achieved within two days, utilising the measurements shown in Table 4.11 gives the following results:

a) The average water discharge into each furrow is 1.079 m^3/min.

b) The average water discharge into each of the first four secondary canals is 2.29 m^3/min and into each of the last two secondary canals is 2.31 m^3/min.

c) The average water discharge in the main canal in the first day is 2.32 m^3/min and in the second day is 2.33 m^3/min.

d) The average water and time necessary to fill each furrow are 5.2 m^3 in 4.828 min. It should be noted that each pair of furrows is filled in the same time according to the method of measurements noted above.

e) The average water and time applied to fill each secondary canal is 17.2 m^3 in 8 min.

f) The average water and time applied to fill the main canal in the first day are 51 m^3 in 22 min and in the second day 67.3 m^3 in 28.9 min.

g) Added to the above measurements is the water and time applied to fill the water basin and the buried pipe at 1 m^3 in 26 sec.

and 1.1 m^3 in 28 sec. respectively. Thus, the gross irrigation water applied in each irrigation - in two days, totals 2969.68 m^3 in 20.94 hours and in terms of the first two growth stages - 10 weeks - the gross water applied totals 59353.6 m^3.

It is worthwhile mentioning that the irrigation water in the furrows moves downward and laterally to moisten the plant root zones. Additionally, it was noticed that the water front in the furrows and canals has abrupt characteristics, i.e. it moves slowly when the cracks are empty and accelerates after the cracks are filled.

4.9.1.2 The water supply in the second growth stages : in these stages the crops are irrigated once a week, each irrigation takes about 22 to 23 hours and it is achieved within two days.

On the first day the irrigation operation continues for about 12 hours from 6 a.m. to 6 p.m. Measurements were carried out as described in the preceding section, using the same points (see Fig.4.8).

Table 4.12 and Figure 4.8 show that the water discharge from the pump is similar to that in the first two stages. The water discharge at the first point is 2.33 m^3/min and at points 2 and 3 are 1.12 and 1.20 m^3/min respectively. The first two furrows should theoretically be filled to level 37 cm by 5.03 m^3 for each in 4.51 and 4.2 min respectively but actually they were filled to the same level 37 cm by more water 5.72 and 5.88 m^3 in 5.13 and 4.9 min respectively. This is due to the factors previously mentioned. The water discharge decreases proportionally by increasing the distance from the pump; it amounts to 2.30 m^3/min at point 10, and totals 0.96 and 1.02 m^3/min at points 13 and 14 respectively. The first two furrow-points 13 and 14 - were filled to the same level

Table 4.12 : Water discharges during the second growth stages in summer

Point		Discharge m^3/min.	Discharge m^3/sec.	Theoretical time required to fill the furrow sec.	Actual water applied m^3	Actual time required (seconds)
First day	1	2.33				
	2	1.12	0.0186	271	5.72	368
	3	1.20	0.020	252	5.88	294
	4	1.07	0.0178	283	5.82	327
	5	0.93	0.0155	325	5.67	366
	6	1.18	0.0196		5.97	305
	7	1.13	0.0188		5.86	312
	8	1.10	0.0183		5.45	298
	9	0.90	0.0158		5.40	342
	10	2.30				
	11	1.14	0.019		5.83	307
	12	1.14	0.019		5.62	296
	13	0.96	0.016		5.36	335
	14	1.02	0.017		5.50	324
Second day	1	2.35				
	10	2.34				
	15	1.17	0.0195	258	5.88	302
	16	1.15	0.0191	262	5.76	302
	17	1.02	0.0170		5.13	302
	18	1.06	0.0176		5.42	308
	19	2.32				
	20	1.22	0.0203		5.68	280
	21	1.08	0.018		5.76	320
	22	1.06	0.0176		5.13	292
	23	0.94	0.0156		5.47	351
	24	1.02	0.0170	296	5.28	311
	25	1.26	0.021	240	5.92	282
	26	0.99	0.0165	305	5.41	328
	27	0.97	0.0161	313	5.50	342
						7,534

37 cm by 5.36 and 5.50 m³ in 5.58 and 5.4 min respectively. The water quantity and time of filling is greater and longer than the theoretical ones (see Table 4.12).

On this day the irrigation operation goes on until 6 p.m. then the pump is stopped. Only 50% of the total furrows are irrigated i.e. the furrows belonging to the first three secondary canals, because the irrigation of each furrow in this stage takes longer compared with that in the first two stages. This is due to the fact that each furrow is filled to level 37 cm instead of 35 cm.

On the secondday, the water discharge from the pump is similar to that in the first day at 2.36 m^3/min. The water discharge at points 1 and 10 are higher at 2.35 and 2.34 m^3/min than those on the first day due mainly to repairs of the canal banks where the water leak occurred on the first day and also because the infiltration rate is lower as a result of the soil being saturated by the irrigation of the first day. The water discharge at points 15 and 16 are 1.17 and 1.15 m^3/min respectively. These furrows should theoretically be filled to the same level 37 cm by 5.03 for each in 4.30 and 4.38 m^3 respectively. However, they were filled to the same level by more water at 5.88 and 5.76 m^3 in a longer time of 5.03 min. The water discharge of the last two furrows - points 26 and 27 - of the sixth secondary canal are 0.99 and 0.97 m^3/min respectively. These furrows were filled by 5.41 and 5.50 m^3 in 5.46 and 5.70 min respectively.

Consequently, the average water discharge into each furrow is 1.076 m^3/min and into each of the secondary canals is 2.30 m^3/min and into the main canal in the first and second day is 2.31 and 2.33 m^3/min respectively. The average water applied to fill each furrow is 5.58 m^3 in 5.23 min, each pair of furrows are filled simultaneously according to the measurement operation earlier mentioned. The water and time applied to fill each secondary canal are 17.15 m^3 in 8.05 min and to fill the main canal on the first and second day are 44.58 and 74.5 m^3 in 19.3 and 32 min respectively. Besides, the water and time applied to fill the water basin and the buried pipe should also be added. Thus, the gross irrigation water applied in each irrigation - in two days - totals 3197.8 m^3 in 22.59 hours and in terms of the total for the second two growth stages is about 41091.73 m^3. However, in terms of the growing season of the summer crops, the gross water applied is about 100445.33 m^3, (see Fig.4.13).

The depth of water in the furrows in the first two stages and second two stages are 35 and 37 cm respectively. Each 10 cm of water drained and evaporated within 2.86 and 2.70 hours from the furrows in the first two and second two stages respectively. According to Van Beers' criteria (1974) noted in section 3.10.1.3, these relative infiltration rates are considered favourable. However, using irrigation water which has an average Ec value of 0.988 mmhos/cm under the prevailing hot, arid conditions will certainly lead to an increase in the soil salinity (see sect. 4.14).

4.9.2 Water supply for the winter crops

The quantity of water applied to irrigate these crops varies according to the variation of crop type and the distribution systems. These crops, vegetables and grain are irrigated once a week in the first two growth stages and in the second two growth stages the vegetables are also irrigated once a week while the grain is irrigated once per two weeks by different quantities of water. Each irrigation is spread over two days, in the first day from 6.30 a.m. to 5.30 p.m. in which the vegetables and the maize basins can be irrigated as follows:

4.9.2.1 <u>Water supply for the vegetables on the furrows</u> : Measurements of water discharges and irrigation operation were carried out as described in section 4.9.1.). Table 4.13 and figure 4.12 show that the water discharge from the pump is still constant at 2.36 m^3/min. The farmers suggested that the pump worked best at this power. The water discharge at the first point is 2.34 m^3/min and at points 2 and 3 being 1.08 and 1.25 m^3/min respectively. The first two furrows should theoretically be filled to level 35 cm by 4.46 m^3 for each in 4.13 and 3.56 min respectively but they were filled to the same level by 5.14 and 5.47 m^3 in 4.76 and 4.38 min respectively. The water discharge decreases with increasing distance from the pump. It amounts to 1.03 and 0.97 m^3/min at points 8 and 9. The water discharged into each furrow is 1.08 m^3/min and into each of the first two secondary canals is 2.32 m^3/min and in the first section of the main canal is 2.33 m^3/min. The water and time applied to fill each furrow is 5.31 m^3 in 4.91 min and the first two secondary canals is 17.2 m^3 in 8 min and the first section of the main canal is 18.64 m^3 in 8.72 min. The water required to fill the water basin and the buried pipe has to be added to the above figures. Thus, the gross irrigation water applied in each irrigation totals 985.16 m^3 in 6.98 hours and in terms of the growing season amounts to 25752 m^3.

4.9.2.2 <u>Water supply for the vegetables in the basins</u> : These 48 basins are irrigated immediately after the furrow irrigation. The water is diverted from the main canal into the third secondary canal by placing earth blocks in the heads of the first two secondary canals and the other section of the main canal. Additionally another is placed immediately after the gaps of the first two basins so as to close the other section of the third secondary canal (see Fig.4.12). This is done to measure water discharge into these basins - points 11

Table 4.13 : Water discharges in winter

Vegetables in the furrows

Point	Discharge m^3/min.	Discharge m^3/sec.	Theoretical time req. sec.	Actual water req. m^3	Actual time req. sec.
First day					
1	2.34				
2	1.08	0.018	248	5.14	286
3	1.25	0.0208	214	5.47	263
4	1.12	0.0186		5.52	297
5	0.90	0.0158		5.02	318
6	0.96	0.016		5.15	322
7	1.36	0.0226		5.74	254
8	1.03	0.01716	260	5.07	296
9	0.97	0.0161	277	5.13	321
					2357

Vegetables in the basins

10	2.33				
11	2.31	0.0385	46.8	3.15	82
11A	2.30	0.0383	47	2.72	71
12	2.30	0.0383		3.33	87
12A	2.27	0.0378		2.53	67
13	1.98	0.0330		3.23	98
13A	1.96	0.0326		2.28	70
14	1.99	0.0331	54.4	3.17	96
14A	1.95	0.0325	55.4	2.30	71
					642

and 12, and the other two basins - points 11A and 12A, which join them. Two gaps are excavated on the banks of this secondary canal to divert the water into these basins. The water measurements were carried out using the method described earlier. Table 4.13 and figure 4.12 show that the water discharged at point 10 is 2.32 m^3/min and at point 11, which is the first basin, is 2.13 m^3/min. The theoretical water volume and time required to fill this basin to level 6 cm is 1.8 m^3 in 0.78 min. However, this basin was filled to the same level by 3.15 m^3 in 1.36 min. This is due to the effects of the infiltration rate, cracks, water leaking through and over the banks as well as the evaporation rates. A small gap is excavated by hand shovel, immediately after irrigating the first basin, on the back bank which is located between this basin and the adjacent one - point 11A. This is to divert the irrigation water from the first basin into the second one which theoretically should be filled to the same level 6 cm by 1.8 m^3 in 0.78 min. But it was filled to the same level by 2.72 m^3 in 1.18 min. The differences in the amount of water and time taken to fill both basins is related to the differences in discharge rates from the canal to the first basin and from this basin to the second one - point 11A. The water discharge from the first basin to the second basin is greater than that from the canal to the first basin as this basin provides a greater head of water.

Then, the first gap - point 11 is closed and a small gap is excavated on the opposite bank of this secondary canal - point 12, to divert the water into the third basin. The water discharge at this point is 2.30 m^3/min, filling the basin to a depth of 6 cm with 3.33 m^3 in 1.50 min. Filling of the fourth basin again took less time and required less water (see table 4.13 and figure 4.12).

The water discharged into each basin is 2.132 m^3/min, the secondary canal being 2.3 m^3/min and the main canal being 2.32 m^3/min. The average quantity of water and time applied to fill each basin is 2.83 m^3 in 1.33 min, the secondary canal 17.3 m^3 in 7.3 min and the main canal 11.65 m^3 in 5 min. Consequently, the total water and time applied to irrigate these basins is 178.32 m^3 in 1.27 hour and in terms of the growing season the water applied totals 4661.3 m^3.

Thus, the total water applied to irrigate the vegetables throughout the growing season is 30413.3 m^3 which includes the water losses as well.

4.9.2.3 Water supply for the maize basins : these basins have different sizes and are irrigated from both the main and the fourth secondary canals as follows:

The first basin, with a total area of 1860 m^3, is irrigated immediately after completion of the irrigation of the vegetable basins. The block in the main canal is removed and replaced another one after the branching of the fourth secondary canal and the first three secondary canals are also closed. Then, a small gap - point 15 - is excavated in the bank of the main canal to divert the water into the first maize basin. The water discharged at this point is 2.32 m^3/min, this gap is closed after 14.4 min and then another gap - point 16 - is excavated on the same bank of the main canal. This is allowed to flow for 12.55 min before it is closed. The secondary canal no.4 is then linked to the main canal and blocks placed successively to divert water through gaps excavated at points18, 19 and 20. The water applied and times are 2.29, 2.26 and 2.21 m^3/min respectively, (see Table 4.14 and Fig. 4.12). This basin requires 93 m^3 of water to fill to depth of 5 cm in 40.79 min by five gaps. The local farmers were asked why they did not excavate these gaps at the same time and they suggested that it required more labour than was available to observe and operate all the gaps simultaneously. Consequently, they were asked why they did not excavate only one or two gaps instead of five and they explained that this would cause an uneven distribution of water, such that the water would concentrate in some parts and be shallow in other parts. This results from uneven levelling of the land. However, the average water discharge from each gap is 2.28 m^3/min and the secondary canal being 2.30 m^3/min and the main canal is 2.32 m^3/min. Thus, the total water applied to fill this basin in each irrigation to level 5 cm is 213.14 m^3 in 90.3 min. The same quantity is applied during the first and second growth stages but at weekly intervals during the first stages and fortnightly in the second stages. Consequently, the total water applied throughout the growing season for this basin is 3043.64 m^3. It should be noted that the sediment deposition is not taken into consideration when calculating the gross water volume applied because the level 5 cm thickness of water applied was measured over the ground surface of the basins.

The second basin with an area of 1550 m^3 is irrigated in the same manner as for the first basin and it is the last part of the farm to be irrigated on the first day of the irrigation cycle. The average water discharge from each gap is 2.26 m^3/min. The theoretical water and time applied to fill this basin to level 5 cm is 77.5 m^3 in 34.2 min, in practice the basin 146.36 m^3 of water to fill in 62.21 min. This quantity in terms of the growing season totals 2090 m^3. Thus, the total water applied to irrigate the maize basins during the growing season is 5.33.64 m^3.

On the second day the remaining grain basins are irrigated as follows:

4.9.2.4 Water supply for the barley basins : these basins are of different sizes and require different amounts of water.

The first basin is irrigated, see figure 4.12 and table 4.14, by five gaps, two of which are from the main canal and the others from the fifth secondary canal. The total area of this basin is 1736 m^3 and the average water discharged from each gap is 2.29 m^3/min. This basin should theoretically be filled to level 6 cm by 104.16 m^3 in 45.38 min but it was filled to the same level by 155.74 m^3 in 67.9 min. To which has to be added the water required to fill the main canal to point 27 and the buried pipe which amounts to 79.22 m^3 in 34 min, plus the water applied to fill the fifth secondary canal 17.2 m^3 in 7.5 min. The gross water and time applied to fill this basin is 259.97 m^3 in 125.2 min and in terms of the growing season totals 3712.37 m^3.

The second basin with an area of 1860 m^3 is irrigated by four gaps from the fifth secondary canal at which the main canal terminates. The theoretical water and time required to irrigate this basin is 212.49 m^3 in 90.13 min. The total water applied to irrigate this basin during the growing season is 3034.35 m^3 and the gross water applied to irrigate barley basins throughout the growing season is 6746.72 m^3.

4.9.2.5 Water supply for the wheat basins : there are four wheat basins, their areas being 1984, 2046, 2108 and 2418 m^2 respectively. They are irrigated in the same way as the other basins. The volumes of each basin to level 6 cm are 119, 122.76, 126.48 and 145 m^3 respectively and the volume of each secondary canal is 15 m^3. The water discharged from each gap is 2.247 m^3/min. The water applied to fill each secondary canal is about 17.3 m^3 and the gross water and time applied to fill these basins from the first to the fourth is 232.05 m^3 in 98.33 min, 248.05 m^3 in 105.11 min, 262.17 m^3 in 112.48 min

Table 4.14 : Water supply for the grain

The first basin of maize

Point	Discharge m^3/min.	Discharge m^3/min.	Theoretical filling	Actual water req. m^3	Actual time req. sec.
15	2.32	0.0386	482	33.3	864
16	2.32	0.0386	482	29.06	753
17	2.30				
18	2.29	0.0381	458	25.60	672
19	2.26	0.0376	495	40.87	1087
20	2.21	0.0368	505	43.16	1173
					4549
The second basin of maize					
21	2.28	0.038	408	24.51	645
22	2.26	0.0376	412	30.90	822
23	2.20	0.0366	424	32.72	894
24	2.29	0.0381	407	23.12	607
25	2.29	0.0381	407	29.14	765
					3733
The first basin of barley					
Second day 1	2.35				
10	2.34				
25	2.33				
26	2.33	0.0388	537	32.78	845
27	2.32	0.0386	540	27.94	724
27A	2.32				
28	2.30				
29	2.30	0.0383	544	26.54	693
30	2.28	0.0380	548	34.08	897
31	2.26	0.0376	554	34.40	915
					4074

Table 4.14 (Cont)'

The second basin of barley

32	2.30	0.0383	729	49.56	1294
33	2.28	0.0380	734	51.87	1365
34	2.25	0.0375	744	48.26	1287
35	2.23	0.0371	752	54.24	1462
					8408

The first wheat basin

36	2.30				
37	2.30	0.0383	777	50.63	1322
38	2.28	0.0380	783	51.14	1346
39	2.27	0.0378	788	52.46	1388
40	2.25	0.0375	794	52.27	1394
					5450

The second wheat basin

41	2.29	0.0381	644	42.82	1124
42	2.27	0.0378	650	52.23	1382
43	2.26	0.0376		51.21	1362
44	2.32	0.0387		43.15	1115
45	2.32	0.0387		50.04	1324
					6307

The third wheat basin

46	2.33	0.0388		52.22	1346
47	2.33	0.0388		43.61	1124
48	2.32	0.0387		42.87	1108
49	2.30	0.0383		51.47	1344
50	2.29	0.0381		52.46	1377
					6299

The fourth wheat basin

51	2.32				
52	2.31	0.0385		43.19	1122
53	2.29	0.0381		51.54	1353
54	2.26	0.0376		51.21	1362
55	2.34	0.0390		42.35	1086
56	2.34	0.0390		50.62	1298
					6221

and 244.72 m^3 in 103.7 min respectively, (see Table 4.14). Thus, the total water and time applied for the wheat basins in each irrigation is 986.99 m^3 in 6.99 hours and in terms of the growing season the total water applied is 14094.21 m^3.

The total water applied to irrigate the winter crops is 56387.87 m^3 an almost 50% reduction in water supply in winter over summer. Although 63% of the total area of the farm in winter is under basin irrigation to which the water required should be logically more than that required for the furrows due to the largerexposed surface area of water than that of the furrow, the actual water supply as has been shown is less. This can be attributed to the lower evaporation rates from smaller wetted surfaces and consequently lower water losses, (see Fig. 4.13).

The rate of infiltration of the applied water was measured on a number of occasions during the growing season. The water applied is drained and evaporated entirely after 9 to 13 hours in the vegetable furrows, 1 to 2 hours in the grain basins during the first two growth stages, decreases to 1 to 1.6 hours during the last two growth stages, the vegetable basins at a rate of 1 to 2 hours throughout the growing season. Each 10 cm of the water applied is drained and evaporated in the furrows within 2.976 hours, in the basins 2.5 hours in the first two growth stages whilst it takes about 2.16 hours during the second two growth stages. According to Van Beers criteria (1974) which was mentioned in section 3.10.1.3, the relative infiltration of the farm soil is classified as favourable. However, there are noticeable variations of the time required to exhaust 10 cm of water between the summer and winter season, the furrow and basin methods and between the growth stages. The differences can be attributed to variations in evaporation rates and density of the cracks as well as the variations in the area of water surface exposed and the depth of the applied water.

4.10 WATER LOSSES

These losses can be divided into two types on the basis of their location within the system as follows:

4.10.1 Water conveyance losses

These consist of the water which is lost throughout the main and secondary canals due to seepage, leakage of water, deep percolation and evaporation. These losses vary between summer and winter seasons due to the variations in the evaporation rates, distribution system, the irrigation times and the quantities of water applied.

Within the summer cropping cycle the losses also vary according to whether it is the first or second day of irrigation, and whether the irrigation is during the first or second growth stages. The variations in losses between days results from differences in soil moisture content.

On the first day, Table 4.11 shows that the water discharge decreases with distance from the pump due to increasing the water conveyance losses through the main and secondary canals. This increase is a result of increment of cracks, water leakage, evaporation, deep percolation and seepage with increasing distance. In the main canal these losses amount to 0.02 m^3/min at the first point and increases to 0.06 m^3/min at the second point, (see Fig. 4.8). At the head of the first secondary canal, these losses total 0.03 m^3/min and increase to 0.36 m^3/min at the last section due to the above effects. These losses at the head and last section of the second, third and fourth secondary canals are 0.06 and 0.34, 0.08 and 0.31, 0.09 and 0.36 m^3/min respectively.

On the second day these losses in the main canal are lower than those on the first day due to the saturation of the soil of the main canal base which means that the initial cracks in the surface have been filled by soil expansion and the infiltration rate is greatly reduced. At the first point they are about 0.01 m^3/min and in the second point are 0.03 m^3/min but they increase in the last section to which the irrigation water on the first day has not arrived, and they reach 0.04 m^3/min at point 19. These losses in the heads and last sections of the fifth and sixth canal are 0.05 and 0.33, 0.05 and 0.36 m^3/min respectively, (see Table 4.12). These losses in each irrigation in the first and the second two growth stages amount to 282.13 and 315.13 m^3 respectively and in terms of the first and second two stages, theytotal 4049.3 and 5643 m^3 respectively. Thus, the total losses for the summer season from the main and secondary canals amounts to 9692 m^3 which is equal to 9.64% of the total water applied in this season. This high percentage can be attributed to the low management efficiency as mentioned earlier.

In winter these losses also vary during the first to second irrigation day and from the first two growth stages to the second two stages according to 14 variations of the quantities of the water applied.

On the first day, Table 4.13 and Figure 4.12 show that these losses in the main canal at the first point are 0.02 m^3/min increase to 0.03 m^3/min at point 10 and to 0.06 at point 17. At the heads and last sections of the first, second, third and fourth secondary canalsthese losses reach 0.03 and 0.34, 0.04 and 0.36, 0.06 and 0.37, 0.06 and 0.16 m^3/min respectively giving a total of about 137.88 m^3.

On the second day the losses are generally lower than those on the first day because the soil was saturated in the first day. In addition, the number of the gaps in the remaining three secondary canals are less than those of the first day in the first five secondary canals are less than those of the first day in the first five secondary canals. Thus, water conveyance losses on the second day amount to 65.38 m^3, giving a total over two days of 203.26 m^3 and in terms of the growing season these amount to 3871.72 m^3 of which 960.53 m^3 comes from the grain basins and 2911.2 m^3 from the vegetable field. This variation can be attributed to the differences of the growth stages, distribution system, irrigation times and quantities of water applied. However, these losses equal 6.86% of the total water applied. This can be attributed to the low water conveyance losses from the canals irrigating the grain basins which occupy about 63% of the total area of the farm. However, it should be noted that with the exception of water lost by evaporation the other water losses by seepage, leaking and infiltration contribute to some extent to irrigation of the crops.

4.10.2 The field water losses

These losses take place in the furrows and basins themselves by seepage, water leak through and over their banks, infiltration, deep percolation and evaporation. Since it was not easy to measure these losses directly, they can, therefore, be calculated by adding the conveyance losses to the consumptive use plus the leaching requirements and the result is subtracted from the gross water applied. Calculating the field water losses from the above operation, the results are 62380.5 and 41941.5 m^3 in winter and summer seasons respectively. These amounts equal 62.1% and 74.3% of the gross water applied in summer and winter respectively. The percentage of these losses in winter is higher in summer due to the differences of the distribution system i.e. about 63% of the farm area is irrigated by basin method in which the water surface is exposed.

The total water losses in summer is 72072.5 m^3 and in winter is 45813.2 m^3 which equals 71.7% and 81.2% of the gross water applied respectively. These high percentages are due to the seepage, deep percolation, evaporation and leaking of the water from the banks of the basins, furrows and canals.

It is appreciated that the data laboriously compiled and analysed in the preceding sections and the totalling of water applications and wastages for different purposes and different seasons, have margins of error and are place and time specific. However, since no other detailed studies of actual water application rates have ever been carried out in this region, for all their deficiencies these data provide the only basis for overall measurement of water inputs. Since, also, the order of the difference between the actual and theoretical figures is large it is felt that an extrapolation of these sample measurements to a larger scale is reasonably justified.

4.11 IRRIGATION WATER EFFICIENCY (IWE)

This is considered to be the most important factor used in the evaluation of an irrigation system and its management. Using the data collected and applying the efficiency equation noted in Section 3.12, the irrigation water efficiency of the irrigation system under discussion is 28% during the summer season and 24% and 20% for the furrows and basins respectively in winter. These percentages are very low compared with the general theoretical estimation of F.A.O.(1972)

of the water efficiency of the furrow and basin irrigation which range from 55 to 70% and 60 to 80% respectively. It is probable that many irrigation systems would appear to be equally inefficient if detailed measurements of the type noted above were made.

4.12 DRAINAGE

The addition of irrigation water surplus to plant consumptive use is essential so as to prevent a build up of soluble salts. However, if there is too much water which exceeds the rate of drainage to the point where shallow water remains at the surface for prolonged periods this will conversely cause salinity problems. Good drainage is therefore essential to any irrigation system so as to remove rapidly any surplus water from the soil.

In this region natural drainage is inadequate to drain the cultivated lands given the water applications and has led to increasing the salinity of the irrigated soils. Therefore, about 56% of the cultivable lands in the region have been abandoned. Another 40% is occupied by marshes and only about 4% represents the cultivated lands. These areas remain in use generally because they are higher than the surrounding lowlying lands and in which the ground water table is deeper. This lessens the probability of raising the groundwater table to the soil by capillary action caused by over-irrigation compared with the lowlying adjacent areas. Therefore, these lands are still under cultivation, but because of the absence of sound management, the soil salinity has been increasing even here as a result largely of poor or inadequate drainage. However, as already explained, about 71.7% and 81.2% of the total applied water in summer and winter are lost into the soil and by evaporation. These quantities are high enough to reduce the soil salinity to the lower limit if improved drainage is installed.

An experiment was carried out by WAPSOC Co. (1980) at Qalat-Saleh in Messan province. This area represents the northern extension of the irrigated soils in the region under discussion, and the soil and water conditions are very much similar to those in this region. This company constructed a network of open drains and used one particular leaching-irrigation equation which determines the leaching requirements throughout the irrigation, the Volobuevi equation:[17]

$$NL = kh \log \left(\frac{s}{s_1}\right)\alpha$$

where NL = net leaching requirement expressed in m^3/donum

k = total given area expressed by donum

h = soil depth which is required to be leached

s = initial soil salinity expressed by Ec

s_1 = permissible soil salinity expressed by Ec

α = parameter depths on the soil characteristics

The experiment showed that the leaching requirements to reduce the Ec value of the soil from 10 to 4 mmhos/cm, in the upper metre was 1262 m^3/donum in 45 days and from 30 to 4 mmhos/cm being 2778 m^3/donum in 62 days.[18] Consequently, if there are any adequate drains in the irrigated belt along with the necessary excess quantities of water, the soil salinity could be decreased to the lowest values in a short time.

Depending on these considerations, the Ec value of the irrigated soils can be reduced from its level at 18.6 mmhos/cm to 4 mmhos/cm in the upper metre by using 2117.49 m^3 of water per donum, more than that required to the consumptive use, in 52 days if adequate drainage takes place. The excess water applied per donum in the typical farm is 7364 and 4638 m^3 in summer and winter respectively and the growing season of summer and winter crops is 160 and 166 days respectively. The excess water applied and the length of the growing seasons are high enough to satisfy the above requirements if adequate drainage is constructed or, in other words, there is enough water and time to leach the excess soluble salts from the irrigated soils if an adequate drainage takes place. However, the absence of an adequate drainage, together with high evaporation and over-irrigation practice lead to increasing the soil salinity which then reduces the crop yields.

4.13 THE CROP YIELDS

These reflect the influences of management both directly in terms of cultivation methods and also in terms of the irrigation, leaching and drainage efficiencies previously discussed.

The most common summer crops are tomatoes, melon, water melon, okra, aubergines, cucumbers and green beans. In winter, the main crops are onions, garlic, cabbages, legumes, spinach, carrots, celery, radish as well as wheat, maize and barley. Vegetables yield a greater cash return but require more labour then grain, as noted earlier. In winter about 63% of the farm is down to grain and the remainder to vegetables, this is partly due to the scarcity of labour and the grain itself is needed by the farmer for domestic purposes although any surplus is sold.

Table 4.15 shows the crop yields from the typical farm according to the local farmers' estimations and current prices in 1982. The cash return in summer is more than in winter because of the vegetable area in summer is greater than in winter.

The vegetable crops are sold either along the Basrah-Amarah highway, a marketing method used particularly for low value vegetables,

Table 4.15 : Crop production on the sample (typical) farm

Crop	(kg)	Price in ID 1982
Tomato	650	220
Melon	2180	436
Water melon	2830	340
Okra	425	258
Aubergine	1680	168
Cucumber	2200	440
Green beans	640	160
Onion	410	68
Garlic	98	76
Cabbage	225	87
Legume	186	96
Spinach	45	37
Carrot	94	32
Celery	23	14
Radish	48	28
Lettuce	95	72
Wheat	720	185
Maize	308	68
Barley	324	62

whilst those of high value are sent to markets in Basrah, Qurnah and Uzair.

The total cash return from summer and winter crops is approximately ID 2022 (£3,643) and ID 825 (£1,486) per farm respectively. The gross expenses for the summer and winter crops, see Table 4.16, are ID 1282 (£2,309) and ID 701 (£1,263) respectively. It should be noted that most of the labour input is not paid for in cash because the farmer himself and a number of his family help to do most of the irrigation and cultivation operations. The total monetary wages is then ID 342 (£616) and ID 251 (£452) in summer and winter respectively. Thus, the farmer regards himself as making ID 940 (£1,693) and ID 450 (£810) in summer and winter respectively (this includes in fact family wages).

However not all farms grow the full range of crops shown in Table 4.15 in either summer or winter. This is a reflection of individual farmer variations in perception of the balance between cash crops and those needed on farm and domestically. Thus, the majority of these farms carry melons, okra, tomatoes and cucumber in summer, whilst in winter they are down to legumes, lettuces, onions, garlic and maize. A breakdown of the estimated total cultivated area by individual crop is further complicated by the practice of intercropping, particularly in summer. Accepting this, it was decided that the best approximation would be obtained by using the averages of crop yields, kg/donum, as calculated for the "sample" farm studied in detail. Table 4.17 shows the extrapolated averages of selected crop yields in the region under discussion, grain being calculated separately. Comparative data for the region is almost impossible to come by except wheat, maize and barley yields on the

Table 4.16 : Crop production expenditure on the sample farm

Materials	ID in summer	ID in winter
Seeds	30	22
Fertilizers	25	20
Wages (hired)	1157	594
Tractor	20	20
Marketing	50	45
	1282	701

Table 4.17 : Average crop yields in the region and the province

Crop	In the region kg/donum	In the province kg/donum
Wheat	190	176
Maize	250	290
Barley	195	242
Legume	866	1333
Tomato	1600	1700
Onion	1400	2275
Garlic	800	700

Source: General Directorate of the Agriculture in the Basrah Province, The Crops, (unpublished data).

typical farm for some grains are 210, 226 and 225 kg/donum respectively, these amounts being similar to regional averages of 190, 250, 195 kg/donum. In general, however, the averages of the crop yields in this region tend to be higher than those for Basrah province as a whole at 176, 290, 242 kg/donum respectively. This can be attributed to the higher salinity in the other regions.

4.14 SOIL SALINITY

In the light of the low management reflected in over-irrigation together with the high water losses, inadequate drainage and shallow groundwater levels, it is to be expected that the irrigation system practices, already discussed, would have led to an increase in soil salinity and consequently a decrease in crop yields.

Soil samples nos. 4, 5, 6 and 7 in Appendix 4.1 which were taken and analysed in 1977 by Polservice Co. from the irrigated belt show that the Ec value of these soils averaged 11 mmhos/cm, (see Table 4.18). However, soil samples nos. 1, 2 and 3 taken during this field research from the same sites in 1982, show that the average Ec value of these soils had increased during 5 years to 18.5 mmhos/cm with the same irrigation and drainage conditions prevailing at each occasion. This change is too great to be dismissed as accidental and must, at least in part be due to the practice of over-irrigation along with inadequate drainage with respect to water quality. Additionally, the Ec values at the top horizon increased to 23.4 mmhos/cm due to evaporation under the hot arid conditions of standing irrigation water with an average Ec value of 0.988 mmhos/cm. Moreover, the average SAR

Table 4.18 : Analytical results of the soil samples - average of all depths

Soil sample No.	Gypsum %	Lime %	O.M %	pH	Ec mmhos/cm	Ex.Na me/100g	C.E.C. me/100g	Esp %	SAR me/L	Ca me/L	Mg me/L	Na me/L	K me/L	HCO_3 me/L	Cl me/L	SO_4 me/L	CO_3 me/L
4	0.56	28.2	1.59	7.53	9.51	5.76	69.5	8.2	7.6	26.3	28.1	40	n.d	8.8	49	39	n.d
5	0.10	25.4	1.50	7.7	9.1	3.1	34.0	9.1	7.9	34.6	67.3	56.6	n.d	6	69.3	46.3	
6	0.13	28.6	1.80	7.7	5.96	1.6	20.9	7.6	5.38	29.3	30.0	29.3	n.d	10.9	30.3	39.6	
7	0.6	29.1	1.48	7.6	19.4	3.8	28.4	13.3	11.7	50.6	78.3	93.6	n.d	5.0	152	87.6	
Average	0.34	27.8	1.59	7.63	11.0	3.5	38.2	9.1	7.9	35.2	60	54.8	-	7.6	75.1	53.1	

value increased from 7.9 me/L to 14.4 me/L, and the soluble calcium and magnesium and sodium cations increased from 35, 60 and 54 me/L to 77.7, 40.8 and 111.2 me/L respectively as these became concentrated over time in the soils. In addition, the samples further show that the sulphate and chloride ions also increased from 53 and 75 me/L to 108 and 120 me/L respectively.

Because of the continuous use of the irrigation system, discussed above, previously irrigated soils located adjacent to the present irrigated zones, a large area of land has been abandoned in the past because of the same deteriorating changes which are still going on (see Fig. 4.2). Because of the soil salinity in the irrigated belt itself the cultivated area declined from 15200 donums in 1971 to 1981 when it totalled 7582 donums.

4.15 THE ABANDONED SOILS

Investigations in the region showed that the potentially cultivable land of the region is 222,480 donums of which 214,898 donums have been abandoned due to the processes described in section 4.14 associated with the poor irrigation methods described above.

Soil samples nos. 8, 9, 10, 11 and 12 in appendix 4.1 and Table 4.19 and Figure 4.6 show that the Ec value of these abandoned soils averaged 31.2 mmhos/cm and the highest Ec value can be noticed in the top layer which averages 54.8 mmhos/cm. According to U.S.D.A., Agricultural Handbook no. (60)(1954), these soils are considered as strongly saline in the highest limit of this class and their upper layer is extremely saline. The pH value averages 7.0.

The average lime content of these soils is 32% and the gypsum is 2.8%. The exchangeable sodium of these soils at 3 me/100g equals about twice that of the irrigated soils which is at 1.6 me/100g. The

Table 4.19 : Analyses of soil samples - average of all depths

Soil sample No.	Gypsum %	Lime %	O.M %	pH	Ec mmhos/cm	Ex.Na me/100g	C.E.C. me/100g	Esp %	SAR me/L	Ca me/L	Mg me/L	Na me/L	K me/L	HCO_3 me/L	Cl me/L	SO_4 me/L	CO_3 me/L
8	6.7	27.0	0.83	6.4	41.1	3.1	27.5	11.2	32	65.3	178.6	353	1.5	0.93	370	226.3	0.6
9	3.1	37.6	1.23	6.5	20.3	3.4	24.2	14	14.5	54.6	94.5	125.3	0.5	0.93	181.6	93.0	0.6
10	3.4	34.6	1.13	6.8	25.7	0.98	21	4.6	21.3	45.3	134.6	202	1.6	1.0	218.3	154.6	0.6
11	0.6	33.4	1.19	7.7	38.0	5.0	23.7	22	35	53	114.3	319.6	n.d	5.0	321.6	133	n.d
12	0.4	27	0.95	7.8	31.0	4.3	25.5	16	14	25.6	26.0	70.0	n.d	4.6	70.0	43	n.d
Average	2.8	32	1.1	7.0	31.2	3.3	24.1	13	24	48.6	109.6	213.9	1.2	2.5	232.3	130	0.6

average SAR is 24.0 me/L again higher than that in the irrigated soils at 14.4 me/L. The average Esp value is 13.0% this in turn means that these soils are also free from alkalinity. The average sodium content is 214 me/L and the chloride level is 232 me/L which is dominant in these soils. The other cations - magnesium and calcium and the other anions - sulphate, bicarbonate and carbonate are present in lower amounts, see Table 4.19.

4.16 CONCLUSION

As stated, the Tigris river is the most suitable source for irrigation water. The quantity of water applied in the region to irrigate the summer and winter crops by furrow and basin methods is estimated at 10044.5 and 56387.8 m^3 respectively. However, due to inadequate drainage, together with poor management and high evaporation, water losses are high at 71.7% and 81.2% of the total water applied in summer and winter respectively. Consequently, the irrigation water efficiency is very low at 28% for summer season and 22% for winter seasons. Because of use the over-irrigation under hot, arid conditions along with the absence of an adequate drainage, the soil salinity has increased and caused abandonment of 56% of the region area. The cultivated area is, therefore, only 4% and is restricted to the Tigris levees. Thus, it is recommended, first, the need to construct a drainage system similar to that in the state farm, see section 4.2 2, in order to extend the irrigated lands. Secondly, the crop prices should be raised so that agricultural employment is more attractive and the labour force increased. Moreover, the farmers have to be taught adequate agricultural principles such as the appropriate application of water for all purposes and the need to raise water use efficiency.

B. THE STATE FARM

4.17 LOCATION AND HISTORY

This farm is located at Swaib in the south eastern part of the region (see Fig. 4.2). It extends from the Tigris river in the west to the Swaib channel in the east and from the Rotah channel in the north to the Shat Al-Arab river in the south. The farm occupies an area of 23417 donums of land submerged annually by Huwiza flood water until a few years ago when protective dykes were built. As a result of annual flooding the soils were affected by salinity.

This area was chosen as the state farm for the following considerations:

a) Existence of the necessary agricultural labour in the Muzairah village which is located adjacent to the farm.

b) The need to provide the southern markets of Iraq and the Arabian Gulf States with vegetables.

c) The farm is located near the Basrah-Baghdad high-way and the Tigris river and in the vicinity of Qurnah and Basrah at 5 and 80 km respectively.

d) A large part of the farm area already belonged to the government and the remaining small private area could be taken over on payment of compensation.

Because of high salinity, the farm area as a whole was relatively unsuitable for agricultural purposes and reclamation operations had to be carried out. These operations were divided into two stages : the first affecting the large part of the farm, the second is the smaller.

The reclamation and cultivation operations faced many problems because of mis-management which of course affected the farm productivity. Therefore, it has not been easy to obtain the precise information, particularly that which is concerned with the contract achievement between the contractors and the state administration. Additionally, the full details about the farm were not easy to obtain because of its location near the Iraqi-Iranian borders where the present war is being waged.

The farm was studied by a team from the University of Basrah in 1979 from the economic and administrative viewpoint with a brief and general reference to the irrigation and drainage networks.

In this section the soil and water conditions will be discussed, then the reclamation operation, irrigation and drainage systems and finally the crop yields.

4.18 WATER RESOURCES

The only suitable and available water resource for the farm is the Tigris river, as both the Rotah and Swaib channels have more saline waters, (see sect. 4.2.1.1.4). In addition, the groundwater in the state farm is shallow, with depth ranging from 1.3 to 3.0 m and it has a salinity ranging from 49 to 189 mmhos/cm. (19)

The quality of irrigation water used in the state farm is indicated by the quality of the Tigris river at Qurnah gauge, (see sect. 4.2.1.1.4.).

4.19 THE SOILS

The soils of the state farm are only slightly different from the irrigated soils in the region, (see sect. 4.3). The farm area incorporates the marginal lands of the Huwiza marshes, which particularly in the eastern sector were earlier subjected to annual submergence by seasonal floods.

4.19.1 Physical analysis

Soil investigations carried out by the State Organization for Soils and Lands Reclamation (1970)[20] showed that these soils are alluvial and the majority of them have fine textured clay-silt-loam and the minority have coarse textured, loamy sand. These soils become very compact and deeply cracked during the dry season. The State Organization classified these soils into four types according to the variations in the texture and permeability as follows:

CLASS ONE : these soils are located in the northern and eastern parts. Their texture ranges from fine to moderate and their permeability is slow at 0.5 m/day.

CLASS TWO : they have a coarse texture in the upper metre and then fine to moderate in the deeper layers. Their permability is also slow at 0.5 m/day. They occupy a large area in the northern and eastern parts.

CLASS THREE : these soils are also fine to moderate in texture in the upper metre and coarse through the second and third metres. Their permeability is moderately rapid at 1.7 m/day. They are located in the western parts.

CLASS FOUR : they occupy a large area in the southern and central parts, their texture ranges from fine to coarse, consequently their permeability is rapid at 3 to 4 m/day but at the lower limit, (see sect. 3.2.1.1.).

The infiltration rates of these soils are generally moderately slow ranging between 1.0 to 2.1 cm/h. [21] The permeability and infiltration rates show that these soils can be drained by open or pipe drains.

4.19.2 Chemical analysis

The average Ec value of these soils was higher than those in the irrigated soils in the region due to the earlier practising of over-irrigation without adequate drainage. The Ec values of these soils averaged 45 mmhos/cm increasing in the upper layer from 28.6 to 84.5 mmhos/cm. According to the U.S.D.A. criteria (1954), these soils are considered as extremely saline. the pH value ranges from 7.6 to 8.5.

The Esp averages 5.9 %, [22] thus, these soils are saline but free from alkalinity, (see Table 4.20). Their lime and gypsum contents are 32.7% and 13.2% respectively. As for the other soil characteristics they are virtually the same as those of the irrigated soils in the region.

With such high salinity and proximity of the ground water to the surface, capillary rise occurs, which together with high evaporation of flood water leaves a white salt deposit on the soil surface. Thus, these soils were not suitable for agriculture without major reclamation.

4.20 THE MANAGEMENT

The staff of the state farm consist of 193 persons, of which 20 are technicians and administrative officers, 76 skilled agricultural workers and 97 unskilled workers. The farm was provided with agricultural equipment - 6 drawing machines, 2 levelling machines, a smoothing machine, 3 digging machines, a shovel, 14 lorries and 16 moveable pumps. Additionally, the farm is supplied with fertilizers and seeds when needed. Theoretically, the state farm receives adequate support.

Generally, it was noticed that there were many negative aspects in the state farm, see section 4.23 , mainly concerned with the low

Table 4.20 Soil quality to depth 30 cm

Canal Zone	pH	Ec mmhos/cm	Lime %	Gyp-sum %	Na me/100g	Ca me/L	Mg me/L	Na me/L	HCO3 me/L	Cl me/L	SO4 me/L	Co3 me/L
1	7.7	42	29	8.7	5	96	198	670	1.2	792	192	0
2	7.6	35	30	9.4	5.5	62	66	430	1.1	438	132	0
3	7.8	68	28	8	5.5	82	140	1000	2.2	1140	132	0
4	7.6	40	35	8	3.8	96	176	660	1.2	790	190	0
5	7.7	40	32	13	5	94	170	640	1.2	782	190	0
6	7.9	36	32	9.5	4	48	90	420	1.1	4000	1066	0
7	7.3	48	27	21.5	6.2	60	110	840	1.6	768	278	0
8	8.2	48	35	13.0	3.7	92	112	580	1.4	530	270	0
9	8.5	40.5	34	18	3.9	59	98	440	0.4	400	210	0
10	8.2	46.5	39	13.4	3.7	64	104	430	1.1	540	86	0
11	7.9	51.4	17.8	6.9	4.2	65	91	508	1.5	561	139	0
12	8.0	45.6	33	4.2	4.2	66	110	563	1.4	645	80	0

Source: Establishment of Cultivation, the primary report of the Swaib State Farm, Baghdad, 1982, p.34 (under printing) management efficiency. Discussions carried out with the staff revealed the following:

a) The management committee is subordinate to the higher administrative agricultural officers. Therefore, this committee has to inform these officers about every serious problem which takes place in the farm and about their immediate requirements. These procedures often take a long time because of routine communication problems. However, some problems which occur on the farm need immediate measures or authorisation to proceed with regular maintenance, such as seepage from the irrigation canals, collapse of the canal and drain sides, lining of the irrigation canals, accumulation of the earth on the canal and drain floors, etc. What should be regular activities each have to be officially approved and routine official letters between the farm committee and other agricultural offices delay action. Consequently, these have adverse influence on crop yields. For example, the committee did not take over the irrigation and drainage networks of the first stage until a year after their construction. This caused accumulation of the earth on their floors by wind deposition, animals and collapse. In addition, a decision to line the canals was taken after two years of discovering there was a high seepage from the canals.

b) Sometimes hurried decisions are taken about maintenance of the canals and drains and determination of the crop types and areas which need to be cultivated, without taking the soil and water conditions into account. For example, a decision was taken in 1978 to stop the leaching operations in order to line the canals, but after a few months the decision was reversed and the leaching was continued together with the lining operations. However, the need for water for making the concrete linings, reduced the amount of water available for leaching. In addition, a decision was taken in 1973 and 1974 to cultivate the soil which had an Ec value of more than 8 mmhos/cm. This led to very low yields, (see sect. 4.23). Barley seeds did not germinate after they were sown in 1977 because of the high salinity.

c) The most serious factor which affects the crop yield is the lack of workers' motivation. It was noticed that the workers did not work in the farm as hard or as long as they could, because they receive their salaries regularly whether they work hard or not. This, together with poor supervision and control, also leads to poor results.

4.21 THE RECLAMATION OPERATIONS

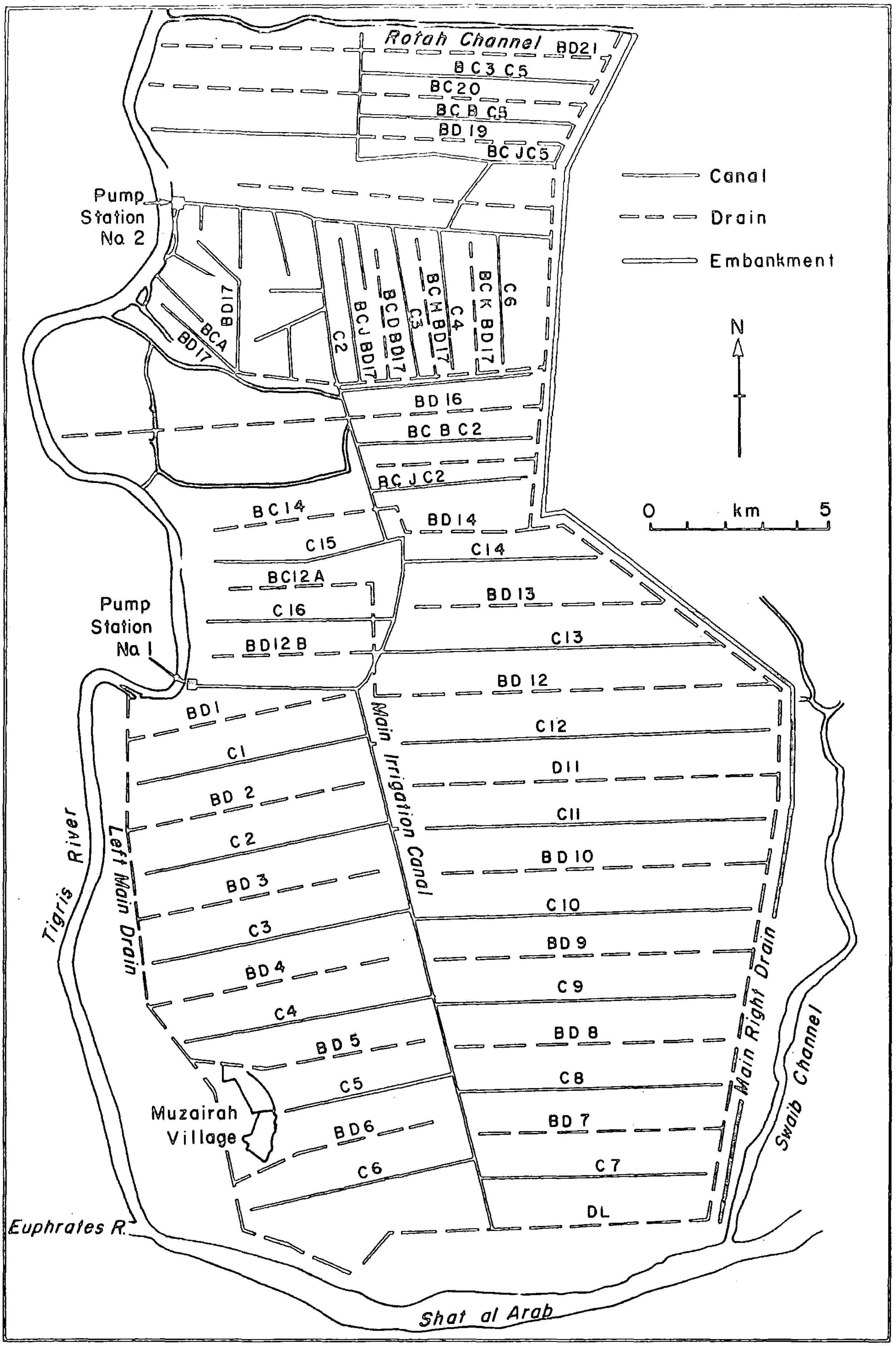
As a result of routine procedures about transferring the small private area to the government, the farm area was divided into two stages from the point of reclamation. The first stage was carried out in 18,000 donums belonging to the government, in the southern and central parts and the second stage was carried out in the 5,000 donums in the northern part which was later transferred to the government.

4.21.1 Irrigation system in the first stage

First the farm had to be protected against the Huwiza flood waters, an earth embankment of 41 km length was, therefore, constructed in 1968 along the left side of the Swaib channel, (see Fig.4.14). Then, soil and hydrological investigations were carried out as previously mentioned.

An irrigation network was planned and built and a pump station was installed on the right bank of the Tigris river. This consists of three pumps, one spare, each having a capacity of 89.38 m /min. The irrigation canals network of this stage, see Figure 4.15, consists of : the main canal which was unlined and open, measuring 95 km in

Fig. 4.14 Irrigation and Drainage System of the Swaib Project



Source : University of Basrah, Op. Cit. P.38

FIGURE 4.15 : The main canal and the weed growth depending on irrigation and seepage water

FIGURE 4.16 The weed growth and sediment accumulation in a secondary canal

length, 8 m surface width and 1.5 m the base width and 1.85 m in depth. 16 secondary canals which join the main canal, with a total length of 47 km. These earth open canals are 1 km apart, 1 m in depth, 4 to 5 m surface width and 0.75 m base width. The designed average discharge of each canal is 12.81 m /min. However, due to the increased requirement of water for leaching and cultivation operations the water discharge is over the designed capacity and averages 19.86 m^3/min, (see Table 4.21). The field canals join the secondary canals at right angles, the length of each is from 400 to 500 m, 0.50 to 0.70 m in depth, the surface width is 3 m and the base width average 0.50 m. These unlined open canals are undesirable particularly in soils containing a high percentage of gypsum because it leads to high seepage. In addition, the sides of these canals have been subjected to erosion both by rain and excessive water discharges and to collapse caused by burrowing animals. Moreover, this type of canal offers an ideal environment for weeds to grow both along the canals and their banks, (see Figs. 4.15 and 4.16). These factors cause accumulation of soil and the suspended sediments on the floor of these canals and increase the water losses, (see Fig.4.16). Consequently, the water discharge capacity decreases with time and with increasing the distance from the pump. Additionally, the joints between these canals which are made of concrete and metal sluice gates are not maintained, causing further water losses, (see Fig.4.17).

Because of high water conveyance losses, a decision was taken in 1978 to line the main and the secondary canals. However, the lining operation was carried out very slowly and by 1982 only about 20% of the total canal length had been lined. It was estimated that the lining operation would reduce the water losses to 34% and 38%

Table 4.21 : The secondary canals of the first stage

Canal	Length km	The area to be irrigated (donum)	Designed discharge m^3/min	Actual discharge m^3/min
1	2.600	1052	10.2	17.4
2	2.7500	1021	11.1	19.2
3	2.916	1093	11.4	16.8
4	2.847	948	10.8	12.6
5	1.750	450	7.2	12.6
6	2.528	1023	12	11.7
7	2.630	1068	11.4	13.8
8	3.050	1029	15	15
9	3.545	1206	15	25.2
10	3.900	1344	18	42
11	4.175	1625	18	24
12	4.425	1662	21	39
13	3.700	1272	16.2	28.5
14	2.200	1010	9.8	14.4
15	2.200	997	9.6	15.2
16	2.100	985	8.2	10.4

Source: Establishment of cultivation, op.cit., p.25.

in winter and summer respectively.(23) Consequently, the water efficiency should be at 66% and 62%,(24) higher than that in the typical farm in the region discussed earlier.

4.21.2 Drainage network

Because of the high groundwater levels and the high soil salinity, irrigation operation cannot be successful without an adequate drainage system. The drainage system was designed and constructed to take account of the following considerations:(25)

a) The flat topography with an average general slope of 2 cm to 1.0 km.

b) The soil layers are virtually homogeneous.

c) The soil texture ranges from fine to coarse.

d) An impermeable stratum was found at a depth of 35m under the ground surface.

e) The soil permeability is moderately slow to rapid.

f) The infiltration rate is moderately slow.

g) The high salinity of both soil and groundwater.

h) The high groundwater table.

i) The hydraulic head was assumed to be 0.6 m.

j) The drainage coefficient was assumed to be 0.0035 m/day.

Hooghoudts equation was used to determine the radial flow and drain spacing as follows: $S^2 = \frac{4k_1H_2}{q} + \frac{8k_2dH}{q}$

where S = drain spacing by metre

k_1 = the soil permeability above the drain

k_2 = the soil permeability below the drain

H = Hydraulic head above the drain

d = equivalent depth of the impermeable layer below the drain, this was obtained from Hoodghoudt's graph.

q = drainage coefficient.

FIGURE 4.17 : One of the neglected joints and canals

FIGURE 4.18 : One of the neglected secondary drains

According to these considerations, the drainage system of the first stage consists of the main open drain, (see Fig.4.14). This comprises the left drain which is of 19 km in length, 5.5 m deep, 18 m wide at the surface and 2 m at the base. The right drain is 7.3 km long, 4.5 m deep, 15 m wide at the surface and 1.5 m wide at the base. These collector drains discharge their water into the Swaib channels via a pump station which has a discharge capacity of 129 to 170 m^3/min.

There are 13 secondary drains joining the main drain, (see Figure 4.14 and Table 4.22). The depth of each is 2.5m, the surface width averages 8 m and the base width is 1 m. These drains are parallel to the secondary canals. They joint the open field drain which has the same lengths as the field canals. A surface width of each is 7 m and base width is 0.75 m and the depth is 2.25 m. These drains were constructed in areas of higher permeability, whilst in the areas which have lower permeability, see section 4.2.2, buried drains are installed, see Table 4.23. The buried drains are constructed of pottery pipes of 10 cm in diameter at a depth of 2 m. These are enveloped by graduated sizes of gravel and sand as a filter. The spacing ranges from 50 to 250 m according to the soil texture, i.e. the small spaces are indicated in the fine texture soils and the large spaces are in the coarse texture soils. However, only 20% of these drains were constructed due to delays in the routine procedures between the farm committee and other agricultural officers and the contractors.

With the exception of the buried drains,the others have been subjected to sediment accumulation on their floor from rain erosion, burrowing animals and wind deposition,(see Figure 4.18). This sedimentation reduced their discharge capacity.

Table 4.22 : Drains network

Drain No.	Length km
1	2.500
2	2.700
3	2.800
4	2.900
5	2.600
6	2.400
7	2.700
8	3.200
9	3.600
10	4.000
11	4.200
12	3.800
13	2.200

Source : Establishment of Cultivation, op.cit., p.32.

Table 4.23 : The buried drains

Soil class	Total length m	Number of drains	Average distance between each two (m)
A1	125000	280	50
A2	103500	230	50
A3	181000	400	150
A4	421000	90	250

Source : Establishment of Cultivation, op.cit., p.34.

4.21.3 Irrigation system, second stage

This sytem is affected by the small area of this stage, therefore, the canals network has smaller dimensions than those of the first stage.

A pump station on the Tigris river was installed consisting of three pumps, one spare, the capacity of each being 45 m^3/min. The length of the main canal totals 4.258 km, 1.6 m deep, 6 m wide at the surface tapering to 1 m. There are 28 secondary canals joining the main canal, see Figure 4.14 and Table 4.24, the average spacing between them is 500 m and the depth is 0.90 m, 3 to 4 wide at the surface and 0.6 m wide at the base. The average designed discharge capacity is 5.09 m^3/min. The field canals join the secondary ones at right angles. The average length of each is 200 to 300 m, 0.40 to 0.50 m deep, 2 m wide at the surface tapering to 0.30 to 0.40 m at the base.

4.21.4 Drainage network

The drainage system of this stage is similar to that of the first stage, having the same soil and water properties to deal with. The drain lengths are shorter owing to the smaller area covered and the main collector drain discharges into the northern extension of the right main drain of the first stage, (see Fig. 4.14).

4.22 LEACHING OPERATIONS

As a result of high soil salinity, the soil could not be cultivated without reducing their Ec values to desirable levels less than 8 mmhos/cm. Therefore, leaching operations have been carried out in the farm area since 1976. There were carried out only during winters to avoid the high evaporation rates of summer months and also to reduce the volume of water needed.

Table 4.24 The secondary canals of the second stage

Canal No.	Length km	The area to be irrigated (donum)	Designed discharge m^3/min
C1	2.395	173	7.26
C1-1	1.000	81	2.4
C1-2	1.100	136	3
C-A	0.741	85	1.8
C-B	0.950	177	3
C-C	0.944	183	4.2
C-2	1.920	-	27.4
C-2-1	0.950	157	1.8
C-2-2	1.000	170	2.7
C-2-3	0.576	112	2.1
C-2-1L	1.503	186	3
C-2-2L	0.576	84	1.8
C-C1	0.700	65	1.8
C-E	0.700	62	1.8
C-D	0.617	141	1.8
C-3	1.789	195	4.5
C-3R	0.810	48	1.8
C-3RL	0.125	49	1.8
C-4	1.520	333	1.8
C-6	1.420	214	4.9
C-61	0.562	52	7.9
C-62	0.479	102	1.8
C-63	0.399	91	1.8
C-5	1.993	-	23.2
C-5A	2.469	513	9
C-5-B	2.469	388	7.5
C-5-C	2.097	369	6.6
C-5-D	1.978	245	4.2

Source :Establishment of Cultivation, op.cit., p.37.

After determining the Ec values of the canal areas, see Table 4.25, these areas were divided into many basins by earth embankments of 40 to 60 cm in height. These basins were designed to be confined between the canals on one side and the drains from the other side so that any excess water would enter the drains. The water was allowed to submerge each basin to a height of 25 cm for an average of two months. However, the quantity of water applied and the period of submersion varied according to the soil salinity i.e. a larger quantity of water was used for a longer time where the soil salinity was high. The average quantity and time required for each basin was 1500 m^3 per donum in two months. It should be noted that the successful leaching operation for saline soils often need the addition of gypsum to replace any exchangeable sodium. However, no gypsum was used when these soils were leached because they naturally contained high amounts of gypsum and relatively low amounts of sodium.

Table 4.26 shows that the soils which have a high salinity occupy about 82% of the farm's total area.

Leaching operation faced some difficulties which led to lowering its efficiency and consequently decreasing the crop yield, see section 4.24. These are as follows:

a) Inadequate quantities of water were applied to achieve the largest reduction in soil salinity. This was a direct result of

(i) Accumulation of the earth on the floors of the canals due to the collapse, wind deposition, animals activity and rain erosion. This led to a reduction in the flow of water in the canals.

(ii) An increase of the water losses by seepage, leaks along the joining gates, evaporation and deep percolation caused a decrease in water discharge in the canals.

Table 4.25 : Distribution of soil salinity before leaching

Canal No.	Area belongs to canal (donum)	Area of non-saline less than 4mmhos/cm (donum)	Area of low salinity soils 4-8mmhos/cm (donum)	Area of moderate salinity 8-16 mmhos/cm (donum)	Area of high salinity more than 16 mmhos/cm (donum)
1	1052	nil	4	100	948
2	1021	"	nil	100	921
3	1093	"	"	75	1018
4	948	"	"	nil	948
5	450	"	"	"	450
6	1023	"	"	175	848
7	1068	"	"	50	1018
8	1029	"	25	nil	1043
9	1206	"	25	"	1181
10	1344	"	nil	25	1319
11	1625	"	"	50	1575
12	1662	"	"	25	1637
C1	301	18	60	93	130
C2	657	nil	12	15	630
C3	341	"	35	38	268
C4	300	"	12	15	273
C5	415	50	nil	45	320
CA	85	nil	6	15	64
C6	1024	600	50	54	320
CB	197	nil	26	48	123
CC	183	22	40	nil	121
CD	161	nil	nil	40	121
CE	71	"	21	14	36
CF	65	"	nil	8	57

Source : Establishment of cultivation, op.cit., p.28.

Table 4.26 : Distribution of soil salinity after leaching

Canal No.	Area belongs to canal (donum)	Area of non-saline less than 4mmhos/cm (donum)	Area of low salinity soils 4-8mmhos/cm (donum)	Area of moderate salinity 8-16 mmhos/cm (donum)	Area of high salinity more then 16 mmhos/cm (donum)
1	1052	50	450	350	202
2	1021	100	450	221	250
3	1093	150	700	150	93
4	948	200	250	150	348
5	450	100	250	100	nil
6	1023	nil	823	200	nil
7	1068	643	235	66	124
8	1029	344	215	220	250
9	1206	476	220	255	255
10	1344	446	664	100	134
11	1625	836	608	162	20
12	1662	613	836	94	119
C1	420	244	105	14	57
C2	703	72	400	103	128
C3	292	132	75	10	75
C4	333	128	85	35	85
C5	1515	592	620	93	210
CA	85	18	46	4	17
C6	464	194	101	48	121
CB	177	30	117	nil	30
CC	183	93	28	12	50
CD	62	15	7	nil	40
CE	141	68	40	8	25
CF	65	44	15	nil	6

Source : Establishment of cultivation, op.cit., p.47.

(iii) The design of the irrigation network was not adequate. The bottom levels of the canals were not smoothly graded to allow ease of flow from the main canal to the field canals. It was noticed that when the water level in the main canal falls to certain limits the water does not flow into many field canals.

(iv) Use of moveable pumps to divert the required water for leaching from the canals which have sufficient water discharge into those which have a low water discharge. This operation together with periodic breakdowns of these pumps sometimes causes insufficiency of the water required for leaching.

b) The surface of the farm area was not completely levelled before the leaching operation took place. Therefore, the leaching water accumulated on the lower parts, and some parts were uncovered.

c) Additionally, it was noticed that the drainage water level in the main drains was equal to that in the secondary drain outlets due to the accumulation of the earth on the floor of the main drains. Consequently, this impaired the flow of drainage water.

Because of these reasons the leaching operation was stopped in May 1978 for the maintenance of the irrigation and drainage networks and the lining of the canals carried out for a few months, then the leaching operation began again along with the lining. Consequently, the leaching was achieved in some areas by interrupted flooding at irregular intervals and this caused major variations in leaching efficiency. This can be attributed to the poor management.

Table 4.26 shows the effectiveness of leaching operations, the areas which have an Ec value of more than 8 mmhos/cm range between 9 and 64% of the leached sections. The leaching effectiveness was a variable, e.g. the Ec value of the areas belonging to canal 11 and

12 were 51.4 and 45.9 mmhos/cm respectively before the leaching, and decreased after leaching to 6.9 and 5.4 mmhos/cm respectively. However, other areas such as those belonging to the canal nos. 1, 4 and CD were leached insufficiently, therefore, their areas which have Ec values of more than 8 mmhos/cm after leaching were 52, 52 and 64% respectively. Thus, such areas had to be leached again to reduce their Ec values to less than 8 mmhos/cm.

However, the leached areas were fertilized to improve their productivity by planting barley, maize and legumes ploughed green into the soil. These crops are especially suitable for cultivation during the reduction of the soil salinity and to improve the biological and organic properties of these soils. Additionally, chemical fertilizers - Urea 25 kg/donum and phosphate 25 kg/donum - were added because the leaching operation caused leaching of these nutrients from the soils. Table 4.27 shows that the soil salinity further decreased after the fertilization operation. The areas which have an Ec value of more than 8mmhos/cm were reduced, ranging from 0.0% to 26%. These form 12% of the total area of the farm. This means that about 50% of the leached soils were converted to low saline soils.

4.23 CROP YIELDS

Despite the fact that the main reason for establishing the state farm was vegetable production, grain and fodder crops have also been cultivated due to their ability to grow in saline soils. These crops are planted in the same way as currently done on local farms in the region.

However, the crop types, yields and areas have varied from year to year with the yield being generally low due to the following factors:

Table 4.27 : Distribution of soil salinity after fertilization[1]

Canal No	Area of non saline donum	Area of low salinity donum	Area of moderate salinity donum	Area of high salinity donum
1	300	650	0	102
2	350	550	50	71
3	250	550	0	293
4	250	450	150	98
5	200	250	50	0
6	0	923	100	0
7	650	220	66	132
8	408	378	126	117
9	639	459	96	18
10	453	608	167	116
11	843	535	171	76
12	659	947	24	32
C1	253	100	15	22
C2	189	342	78	94
C3	177	100	5	10
C4	150	100	40	43
C5	640	775	72	28
CA	18	60	4	4
C6	194	215	30	25
CB	60	41	6	10
CC	106	34	38	5
CD	74	50	10	7
CE	12	15	0	0
CF	59	6	0	0

(1) Establishment of cultivation, op.cit., p.48.

a) There is no constant agricultural scheme for determining the crop areas and types. Table 4.28 shows that the cultivated areas in 1971 were 1,385 donums which equals 34% of the total arable lands in that year. Then, the cultivated lands were increased, before the leaching operation, in 1973 and 1974 to 6,464 and 6,830 donums respectively.This means the crops were planted in saline soils - non arable lands as well as in the arable areas. Because of consequent low productivity, the area cultivated was decreased in 1975 and 1976 to 4,170 and 4,615 donums respectively. This area was reduced again in 1978 and 1979 to 2,770 and 940 donums respectively because of the commencement of leaching and maintenance operations for the canals and drains. Following these operations, the cultivated areas were increased to 9,990 donums in 1980. However, even today the area cultivated still amounts to only 55% of the total area of the farm. This is a result of the poor management which has resulted in :

i) Low leaching efficiency overall with variability from one area to another.

ii) Using low amounts of fertilizers which led to low yield. The amounts of fertilizers used were urea and phosphate at 25 kg/donum of each. An experiment carried out in the farm showed that the amounts between 50 to 75 kg/donum of these fertilizers were required to increase the soil productivity.

b) The cultivated areas did not receive the required water quantities due to a part of the irrigation water being used for leaching operations.

Table 4.29 shows that wheat, barley and maize yields are 53,107 and 93.9 kg/donum respectively. These yields are lower than those produced in the typical farm, the region and the province. The

Table 4.28 : Swaib farm cultivated area (donum)

Year	Total cultivated area (donum)	Cultivated area in winter	Cultivated area in summer
1971	1,385	980	405
1972	2,793	2,378	415
1973	6,464	6,115	349
1974	6,830	6,830	nil
1975	4,170	4,170	nil
1976	4,615	4,615	nil
1977	3,030	1,880	1,150
1978	2,770	2,220	550
1979	940	940	nil
1980	9,990	9,990	nil

Source: The registers of the Administrative Committee of the Swaib farm, 1971-1980 (unpublished).

Table 4.29 : Swaib farm crop yields and areas

Crop	Year	Yield kg/donum	Crop	Year	Yield kg/donum
Wheat	1972-73	53	Aubergine	1971,1973	1134
Barley	1973-78	107	Okra	1972-1973, 1978	36.99
Rice	1974,1976	26.9			
Maize	1972, 1974-76, 1978	93.9	Melon	1972-73, 1977-78	301.3
Onion	1971-78	402.9	Water Melon	1973, 1977-78	128.7
Garlic	1978	418.7			
Legume	1971-73	48.4			
Tomato	1971-73	40.02			
Squash	1972	22.2			
Cucumber	1972, 1977	197.9			

Source: The registers of the Administrative Committee of the Swaib farm, 1971-1980 (Unpublished).

Table 4.30 : The incomes and payments of the state farm

(ID)

Year	Payments	Incomes
1971-72	29,646	nil
1972-73	46,782	5,940
1973-74	43,534	13,281
1974-75	147,787	16,538
1975	88,598	28,998
1976	99,685	8,820
1977	111,151	18,822

Source: The University of Basrah, Economic and Scientific study of the state farm in the Swaib, Basrah, 1979, p.62.

low crop yields may indicate two facts:

a) The magnitude of the difficulties which faced cultivation of these lands and caused mainly by poor management.

b) An increase in the financial losses of the investments in the state farm. Table 4.30 shows that the total incomes equal only 16% of the total payments. That means the annual average financial losses between 1971 and 1977 was ID 90,749.28 (£163,512).

4.24 CONCLUSION

It has already been pointed out that the poor management of the state farm is mainly responsible for the reclamation of the farm and consequently for the soil salinity and the low crop yield. In addition, crops from the farm cannot adequately supply the southern Iraqi markets and the Arabian Gulf states with vegetables because production is still limited. Therefore, to satisfy this aim it is recommended that the following procedures are adopted:

a) An adequate agricultural scheme for the crop types and areas should be drawn up.

b) Urgent decisions have to be taken as quickly as possible.

c) The programme of canal lining and maintenance must be continued.

d) Cleaning the canals and the drains should be carried out regularly.

e) Stopping the collapse of the drain sides by fixing a metallic net on them.

f), The workers must be educated and supervised.

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CHAPTER 5

THE MARSHES REGION

5.1 INTRODUCTION

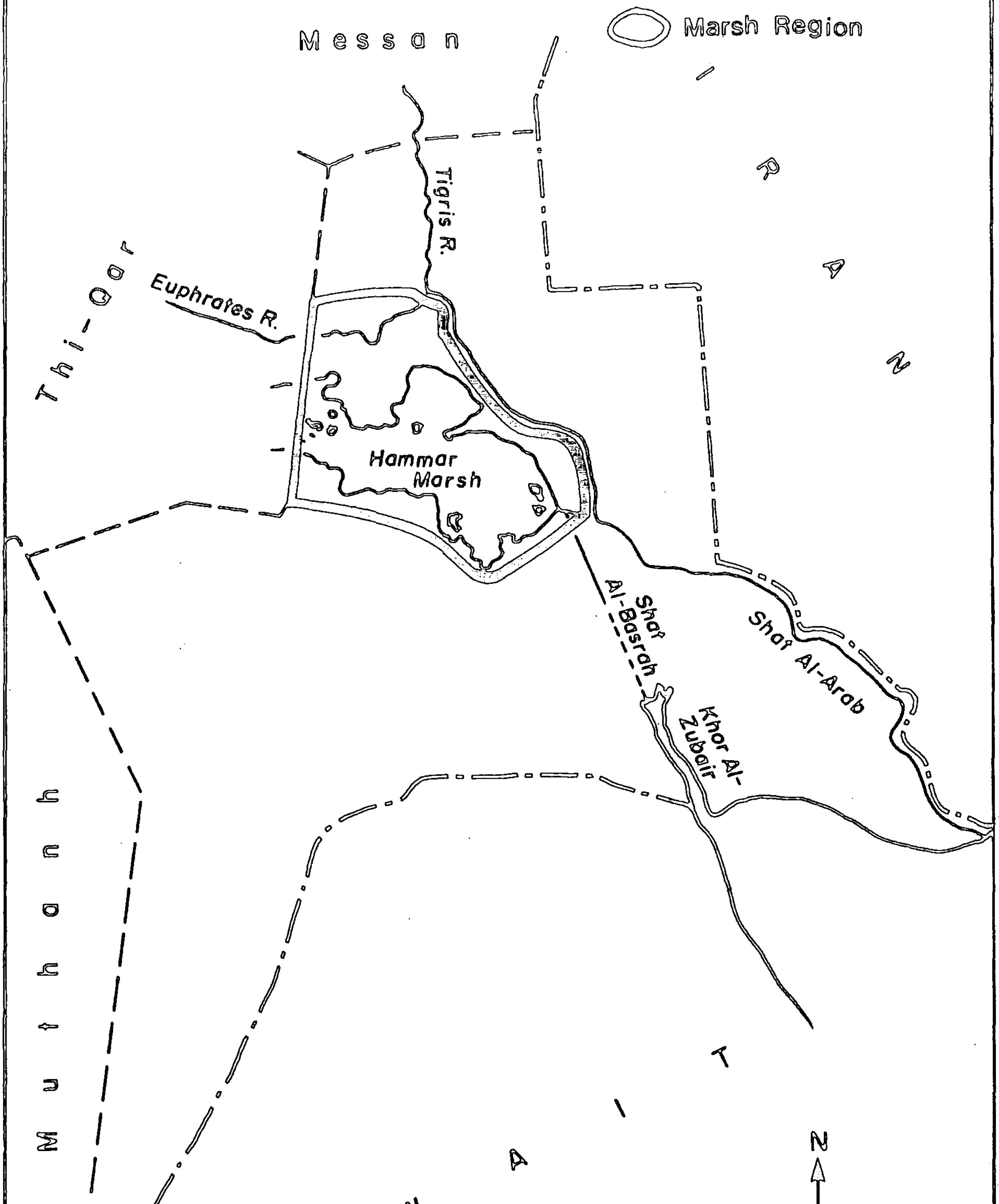
This region, occupying a large depression in the Southern MesopotamianPlain extends from the southern border of Qurnah marshes in the north to the southern border of the Hammar marsh in the south, and from the Basrah - Amarah high-way in the east to the Thi-Qar border in the west.

The Euphrates passes through the northern part of this region from the west to the east where it joins the Tigris river at Qurnah City, (see Fig. 5.1). Generally, this area slopes from the north and west to the south and east, and the water flow follows this general gradient.

This low flat region is susceptible to flooding both from the Euphrates and Tigris rivers. During the flood seasons the water areas extend and submerge nearly all parts of this region, whilst receding into the lower lying parts in the dry seasons. Therefore, only the higher areas which are located in the northern and western parts are exposed during the dry seasons. In these areas the cultivation is practised on the permanent ditch levees which are exposed in the dry seasons.

The depth of the water is generally shallow with the exception of some deep patches of about 6 m depth. The massive water areas, coupled with the high temperature, lead to high evaporation rates which also cause a recognisably high relative humidity and moderate temperatures during winter months. These conditions create an adequate environment for flourishing natural aquatic vegetation, providing a plentiful supply of a suitable fodder for buffaloes, wild

Fig 5·1 LOCATION OF THE MARSH REGION



boars, birds and fish. Consequently, many economic activities are practised - buffalo breeding, hunting, fishing, reed and papyrus gathering and basket and mat weaving.

The permanent ditches serve for irrigation and drainage at the same time. The irrigation and drainage system in this region has not yet been studied although there is some mention in the Polservice report (1978) of the soil and unirrigated soil conditions. In addition, there is one paper in which are discussed generally the factors affecting tomato cultivation in the region - climate, population etc. [1]

This chapter will discuss when, where and how irrigation and drainage are practised, considering the availability and suitability of water and soil for irrigation purposes. A typical farm will be taken as a case study, representing average conditions. Management, the distribution system of water, and crops are considered, followed by the calculation of the theoretical consumptive use and leaching requirement and then the actual water supply. Finally, the results of practising this irrigation and drainage system, as indicated by the water efficiency, soil salinity and crop yield, are evaluated.

5.2 THE WATER RESOURCES

The main water resources in this region, surface and ground water, are discussed separately to point out their availability and suitability for irrigation purposes.

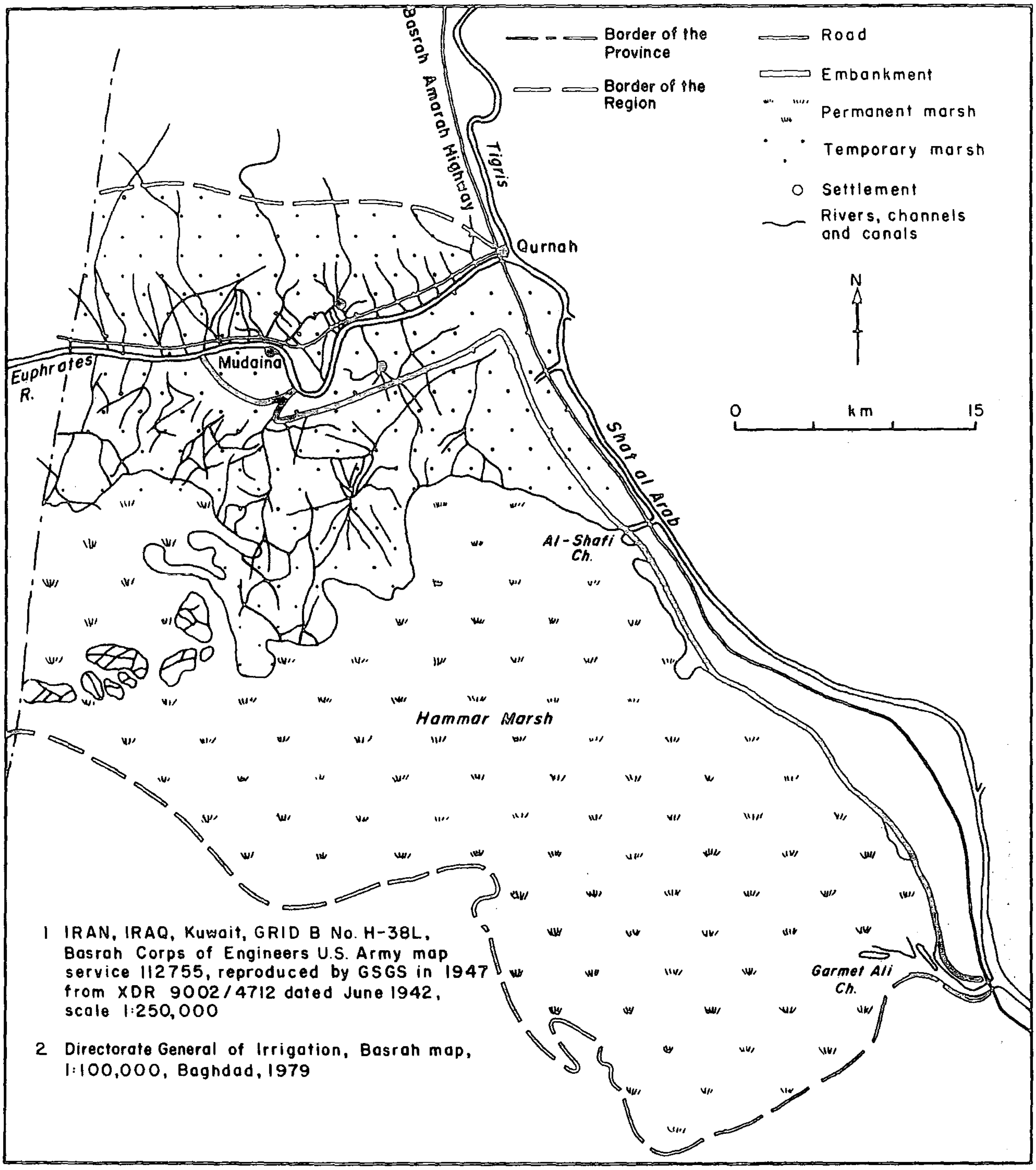
5.2.1 The surface water

This source consists of the last section of the Euphrates river, the eastern basin of the Hammar marsh and in addition many channels and canals.

Downstream from suq Al-Shuokh, the Euphrates river is divided into five branches, four of which terminate in the Western basin of the Hammar marsh. The fifth branch, the so-called Euphrates, is the biggest and indicates the last reach of the Euphrates,(see section 2.2.1.1). This flows eastwards through flat lowlying lands, in the northern area of the Hammar marsh, until its confluence with the Tigris at Qurnah City, (see Fig. 5.2). The total length of the river in this region is 32 km and its width ranges from 260 m at the western border of the province to 120 m at Qurnah City. This difference can be attributed to the variation in the water flow examined in section 5.2.1.1. Its depth varies from 5 m at the western section to 7 m in the Qurnah area. The most important phenomenon is the low interrupted levees of the river, their elevation ranging from 0.70 to 1.5 m. During the flood season the Euphrates waters overflow these levees and submerge the adjacent low lands. Thus, the areas surrounding the river are inundated during the flood season by the Euphrates and Qurnah marsh. In the dry seasons, the excess water from the adjacent areas is drained into the river.

The eastern basin of the Hammar marsh occupies the low areas which are located to the south of the Euphrates river. In the flood season this basin extends from the Euphrates river in the north to the northern border of the Zubair desert in the south and from the eastern embankment in the east to the western border of the province in the west. Accordingly, it then occupies an average area of 2903 km^2 of temporary marsh. However, in the dry seasons, it shrinks to about 595 km^2, forming the perennial marshes, which are concentrated in the central parts of the region. It should be noted that there are a series of higher patches separating this basin and the western

Fig. 5.2 Water Resources in the Region



1 IRAN, IRAQ, Kuwait, GRID B No. H-38L, Basrah Corps of Engineers U.S. Army map service 112755, reproduced by GSGS in 1947 from XDR 9002/4712 dated June 1942, scale 1:250,000

2 Directorate General of Irrigation, Basrah map, 1:100,000, Baghdad, 1979

one. These patches are exposed clearly above the water level as low islands in the dry season.

There are many connecting channels and canals between the Euphrates river and Qurnah marshes such as Nashaba (Al-Hwair), Al-Bashah, Al-Zairah, Abu-el-Ramel, Al-Mughaisil, Hammad, Al-Shellan, Al-Cherdab, Al-Machriyah, Al-Fetheiyah, Al-Sorah, Abu-el-Wallan, Ubeiter, Harthiyah, Huwaish, Abu-Aran and Al-Graiyah. In addition, there are similar channels and canals connecting the Euphrates river and Hammar marsh such as Anter, Al-Dayer, Saleh and Al-Berdanah. These main channels split further into hundreds of small canals ending at the scattered settlements and depressions.

The Hammar marsh is fed from the Euphrates river through many channels which slope with the general dip of the land surface from the north and west to the south and east, (see Fig.5.2). At present the Hammar marsh is drained by outlets into the Shat Al-Arab, the most important ones being the Garmet Ali, Al-Shafi and Omaitsh, (see Fig.5.2). A new canal called Shat Al-Basrah is under construction which will connect the Hammar marsh at Garmet Ali area with the Khor Al-Zubair. It will drain the excess water from the Hammar marsh during the flood seasons. As a consequence, fresh areas will be exposed in this marsh during the dry seasons. This canal will be provided with dams to regulate the water discharge from the Hammar marsh and to prevent the reverse flow of saline tide water from the Khor Al-Zubair.

5.2.1.1 Water discharge : Although 80 km away from the region, Nasiriyah is the nearest gauging station to the western end of the Hammar marsh, calculations of Euphrates water discharge into the marsh have therefore to be based on the assumption that the discharge is uniform between Nasiriyah and the western limit of the region. Table 5.1 and Figure 5.3 show that the mean annual water discharge of the Euphrates at Nasiriyah for the period from 1930-1971 is 475 cumecs. Unfortunately, there is no comparable data available about the water discharges at the other gauges - Qurnah and Garmet Ali for the same period. However, records are available for 1978, and Table 5.1 gives the comparable discharge rates for this year. As the mean for 1978 at Nasiriyah is close to the long term 'mean', then it is reasonable to use the 1978 data from all three stations for comparative purposes.

Table 5.1 and Figures 5.3 and 5.4 show that the mean water discharge of the Euphrates and Nasiriyah is 468.5 cumecs. At Qurnah the discharge might be expected to be higher than that at Nasiriyah due to the water discharged into the Euphrates from Qurnah marsh. However, the reverse is true, at Qurnah the water discharge falls to 280 cumecs, equivalent to only 59.7% of the discharge at Nasiriyah. This can be attributed to the water escaping from the Euphrates to the Hammar marsh. However, the water balance of the Hammar marsh can be calculated from the data shown in Figure 5.5 and Table 5.1 giving the water discharge from the Euphrates into the Hammar marsh as 468.5 cumecs. The water drains from this marsh into the Shat Al-Arab at Qurnah, Garmet Ali, Shafi and Omaitsh at a mean flow rate of 280, 250, 79 and 120 cumecs respectively, giving a cumulative mean flow from the Hammar marsh of at least 729 cumecs. If we add an estimated annual evaporation loss of about 215 cumecs, then the total mean annual discharge from the Hammar is about 944 cumecs, compared with an annual mean inflow from the Euphrates of 468.5 cumecs. The discrepancy of about 475.5 cumecs is undoubtedly accounted for by water discharged from the Qurnah marshes into the Hammar marsh. In effect about 40%

Table 5.1 : Water Discharges and evaporation losses (cumecs) in the region

Gauges and Dates	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug	Sept.	Average
Euphrates at Nasiriyah 1930-1971	174	208	273	370	429	537	821	1178	1047	353	159	145	475
1978	407	363	445	381	350	432	374	652	810	548	418	442	468.5
Euphrates at Qurnah 1978	124	129	170	231	279	322	378	423	445	396	268	194	280
Germat Ali channel 1978	93	75	123	196	246	297	317	364	433	435	240	186	250
Shaffi channel 1978	17	17	29	54	72	93	112	137	160	142	73	45	79
Evaporation loss from Hammar marsh	185	120	50	60	85	130	200	275	410	400	370	300	215

Source : Polservice, Salinity, pp.43 and 62.

Fig 5·3 The Average Water Discharges of the Euphrates at Nasiriyah (cumecs) between 1930-1971 and the Actual Discharge in 1978

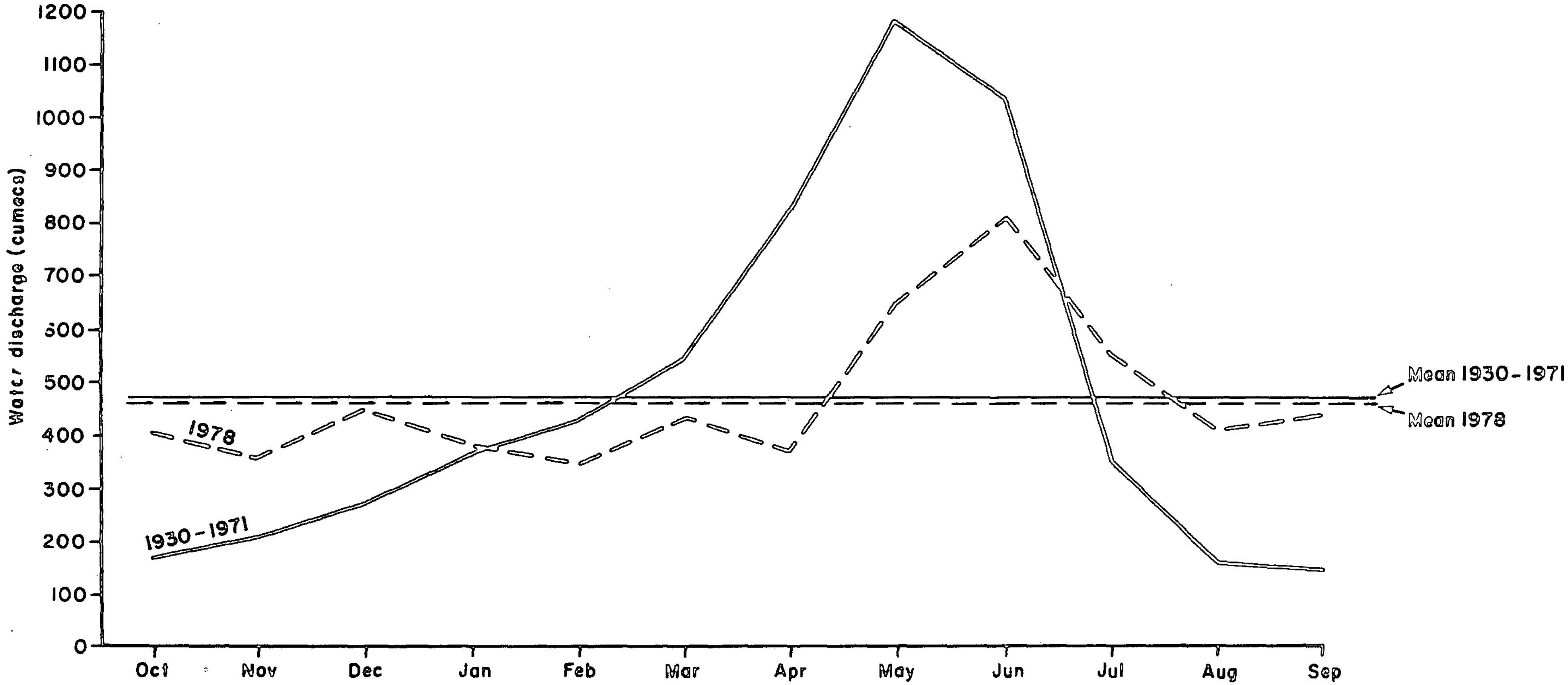


Fig 5.4 WATER DISCHARGES AT QURNAH, GERMAT ALI AND SHAFFI (cumecs) 1978

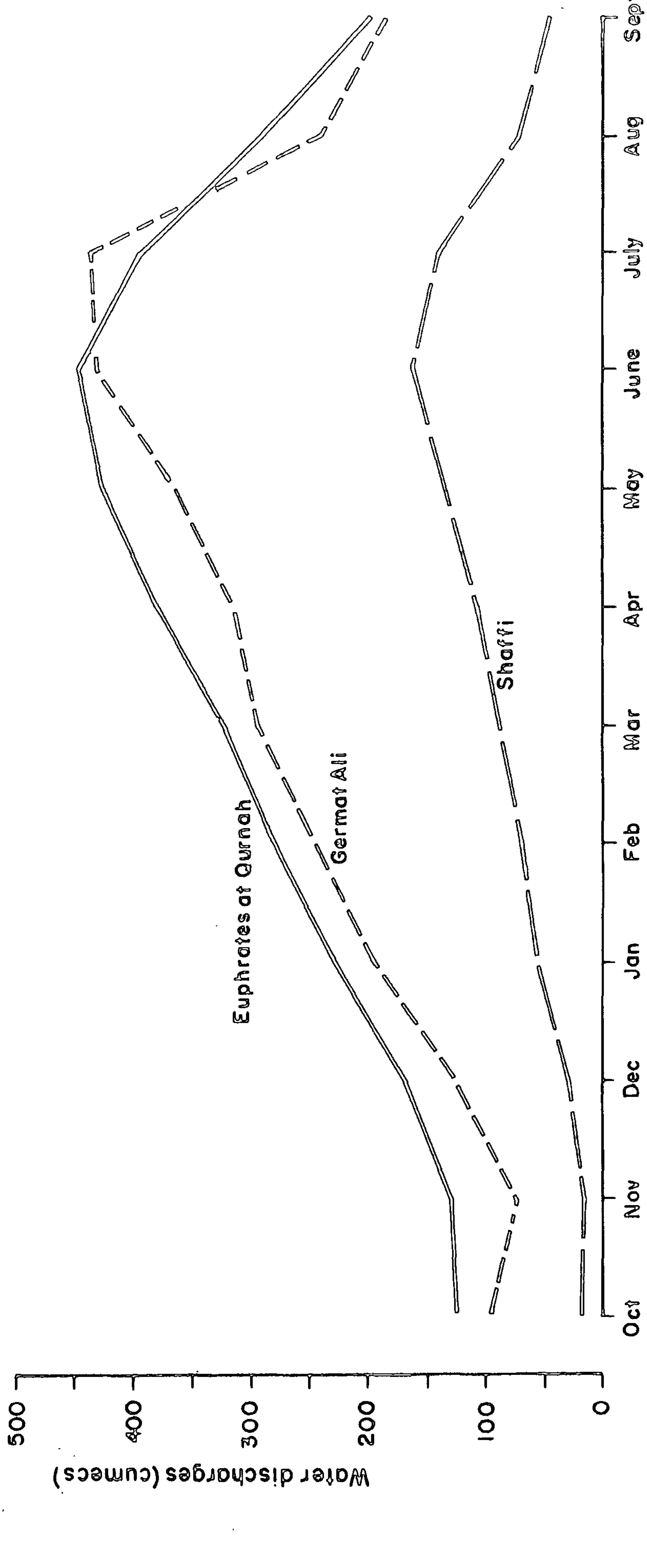
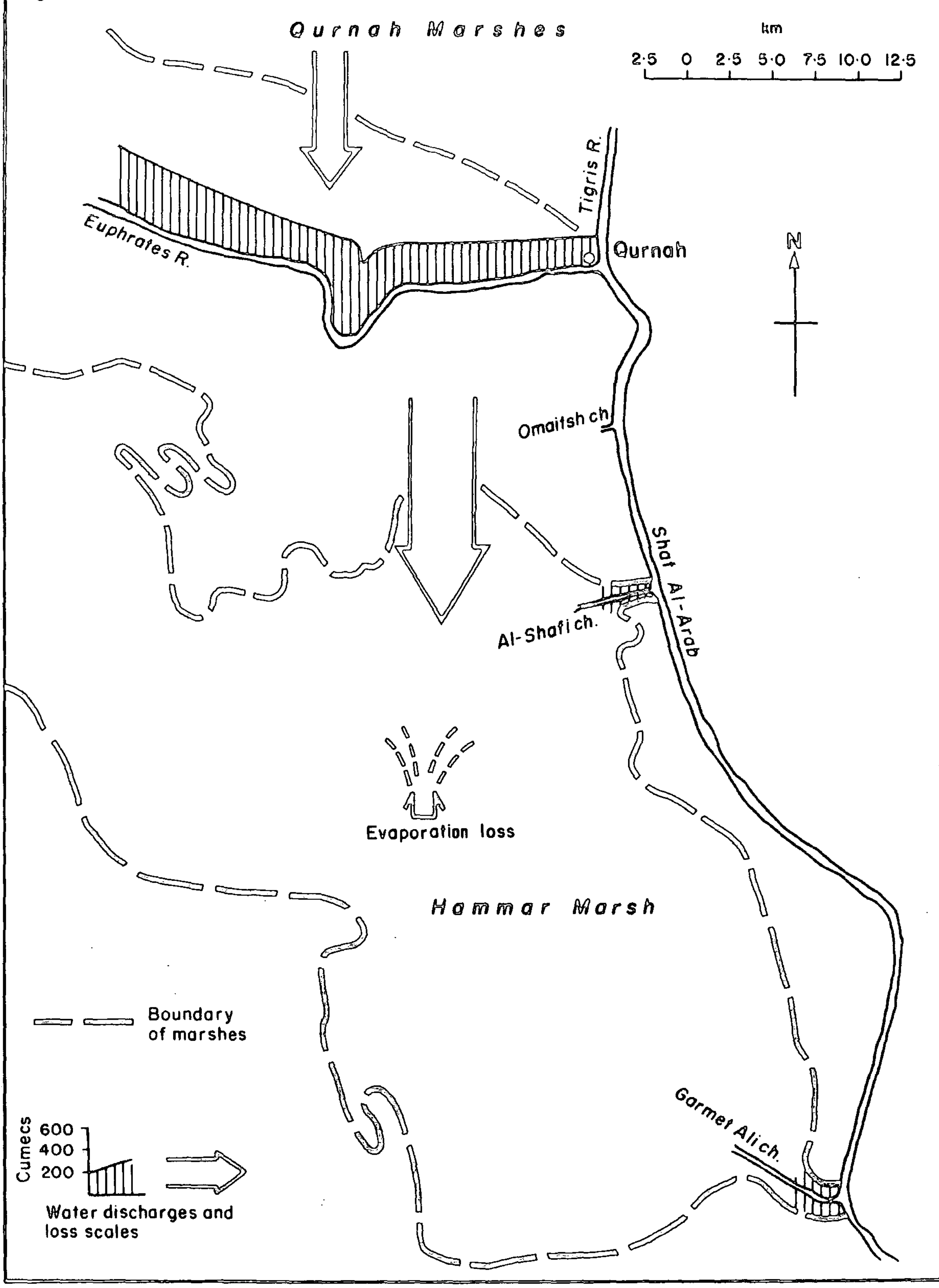


Fig 5·5 WATER BALANCE OF THE HAMMAR MARSH



of the Hammar water comes from the Qurnah marshes, which are originally supplied by the Tigris river. This illustrates the true complexity of the water channel system in this region; in fact the Qurnah marshes, lower Euphrates river and Hammar marshes have to be viewed as a seasonally changing but essentially single surface water system.

The water discharges mentioned above vary from season to season. At Nasiriyah the Euphrates discharge increases gradually from March, reaches its peak in June of 810 cumecs, then decreases until the lowest discharge of 350 cumecs which occurs in February. At Qurnah gauge the water discharge reaches its peak of 445 cumecs in June, the lowest water discharge, 124 cumecs, taking place in October. At Garmet Ali gauge the peak of the water discharge occurs in June and July, later than that of the Euphrates at Nasiriyah because of the diffusion of Euphrates water through the marsh, which takes longer to reach Garmet Ali. However, the lowest water discharge at this gauge also occurs later in November at 75 cumecs. The water regime at Shafi gauge is similar to that at Garmet Ali (see Table 5.1 and Figure 5.4).

5.2.1.2 Water levels : The mean water levels of the gauges previously mentioned change as a result of the variation in the water discharges.

Table 5.2 shows that the mean water level of the Euphrates at Nasiriyah is 4.23 m G.T.S. This increases in the flood season and reaches the highest level in June and July at 5.20 and 4.92 m G.T.S. respectively and decreases in the dry season, reaching the lowest level in February at 3.82 m G.T.S. At Qurnah the mean water level is 1.27 m G.T.S., the highest level being reached in May, June, and July at 1.90, 1.92 and 1.90 m G.T.S. respectively. The lowest

Table 5.2 : Water levels (m G.T.S) in the region

Euphrates at Nasiriyah (1)		Euphrates at Qurnah (2)		Germat Ali gauge (3)		Shaffi gauge (4)	
Date	Level	Date	Level	Date	Level	Date	Level
2.11.77	4.30	6.11.77	0.36	19.11.77	0.15	15.11.77	0.62
3.12.77	3.84	5.12.77	0.74	23.1.78	0.50	10.12.77	0.48
2. 1.78	4.22	4. 1.78	0.96	21.2.78	0.60	9.1. 78.	1.22
7. 2.78	3.82	5. 2.78	1.29	14.3.78	0.72	8.2.78	1.18
1. 3.78	4.03	6. 3.78	1.45	11.4.78	0.87	15.3.78	1.06
1. 4.78	4.15	4. 4.78	1.63	15.5.78	0.72	10.5.78	1.41
10.6.78	5.20	7. 5.78	1.90	13.6.78	0.93	11.6.78	1.49
1. 7.78	4.92	5.6. 78	1.92	16.7.78	0.94	12.7.78	1.49
1. 8.78	4.56	9. 7.78	1.90	14.8.78	0.68	12.8.78	1.05
2. 9.78	4.27	6. 8.78	1.45	12.9.78	0.47	9 9.78	0.80
		5. 9.78	1.05	9.10.78	0.27	10.10.78	0.65
		2.10.78	0.59				

Source: (1) Polservice, Salinity, Table 1-1B-38.
(2) Ibid, Table 1-1B,39
(3) Ibid, Table 1-1B,40
(4) Ibid, ibid.

level at this gauge occurs in October and November at 0.36 and 0.59 m G.T.S. respectively. It should be noted that the water levels increase markedly in the high flood seasons which occur in some years. For example, at Qurnah the extreme high water level reached 3.3, 3.21 and 3.06 m G.T.S. in 1946, 1954 and 1969 respectively. In the dry years the level falls considerably and reached 0.0 to 0.1 m G.T.S. as in 1965, 1974 and 1976. At Garmet Ali the mean water level is 0.62 m G.T.S. this rises to 0.93 and 0.94 m G.T.S. in June and July and falls to 0.15 and 0.27 m G.T.S. in November and December. respectively.

It is significant that the elevation of the ground surface of the temporary marshes is about 1.0 m G.T.S. and in the permanent marsh about 0.50 m G.T.S., whilst, the water level of the Euphrates river at Qurnah and Nasiriyah does not fall to below 1.0 m G.T.S. in the flood seasons whereas in the dry seasons it falls to about 0.50 m G.T.S. This in turn means that in the flood season the Euphrates water and Qurnah marshes water not only submerged all the areas of the region but until the 1970's also the adjacent lowlands to the north and south of the region, with the exception of Mudainah City and the scattered hamlets and the road between Chebaish and Qurnah City.* However, in the dry seasons, the water recedes to the lower parts and consequently the higher areas, which are located to the west and north, are exposed above the water level as well as the areas above mentioned. Therefore, it can be said that in the dry season only these areas exposed above the water level can be cultivated. In addition, the duration of the high and low water level periods at the beginning and the end of the

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* Earth embankments were constructed in the 1970s in the southern border of the Hammar marsh by the IRAQ National Oil Co. which have effectively prevented this extensive flooding.

growing season has an effect on the cultivated areas, irrigation practices and crop yield (see sects. 5.11 and 5.14).

The completion of the Shat Al-Basrah canal mentioned previously by controlling water levels of the marsh will regulate the cultivated area in this region.

The inundation of the cultivated areas in the flood season coupled with the low flow rate of 1.18 m/s lead to the leaching of these lands. The leaching water is carried out from this region into the Shat Al-Arab by the natural drains mentioned earlier, and through this natural processes soil salinity on the seasonally cultivated land falls every flood season (see sects. 5.10 and 5.13).

A further factor influencing the river system of this area is the tidal movement which occurs in the Gulf and extends upstream, through the Shat Al-Arab into the Euphrates river. These movements cause differences in the water level in the Euphrates river, channels and canals ranging from 0.25 m in the flood season to 0.50 m in the dry one. This phenomenon has a significant effect on the irrigation practices (see sect. 5.11).

5.2.1.3 Suspended sediments : The Euphrates river carries large amounts of suspended sediments to this region, the monthly average load at Nasiriyah ranging between 220 kg/s in the dry seasons and 1821 kg/s in the flood seasons (see Table 5.2). Most of this sediment is deposited in this region, therefore, it would be expected that these sediments would gradually fill in the marsh depressions, but although this marsh is known to have come into existence in about 600 A.D. the subsidence associated with the synclinal structural depressions of the earth's crust in this region which explains the origin of the major depressions is sufficiently strongly continuing to maintain the marshes in being.

Table 5.3 : Suspended sediments of the Euphrates at Nasiriyah (1963)

Month	Amount kg/s
October	156
November	205
December	75
January	92
February	96
March	1982
April	2092
May	1950
June	1261
July	967
August	111
September	63

Source: Al-Sahaf, op.cit., p.121.

5.2.1.4 Water quality : The quality of the relevant water resources can be seen from Tables 5.4 to 5.7. The average Ec value of the Euphrates water at Nasiriyah is 1.863 mmhos/cm. It is well known that the Ec values of the twin rivers increase towards the estuary, however, the Ec value of the Euphrates river decreases towards Qurnah and reaches 1.557 mmhos/cm at this gauge. This phenomenon can be attributed to the fresh water discharged from the Tigris river through Qurnah marshes, (see sect. 4.2). In the Hammar water the average Ec value increases to 2.536 and 2.531 mmhos/cm at Garmet Ali and Shafi gauges respectively. The increase results from the concentration of the salts in the Hammar water due to high evaporation rates, and the effect of saline groundwater which is in direct connection with the surface water in this region (see sect.5.2.2).

It should be noted that the completion of the Main Collector Drain, which will drain the Mesopotamian Plain, will discharge about 147 cumecs of the saline water into the Hammar marsh and will, therefore, increase the Ec value of its water. This build up of the soluble salts will have a serious effect on agriculture in this region. Thus, the only viable alternative is for the drain to be carried beneath the Euphrates river, upstream of the Hammar marsh by siphon and then by special canal, to discharge directly into the Khor Al-Zubair, thus avoiding the marsh (see sect.2.2.3).

According to U.S.D.A. (1953) classification of irrigation water, the Euphrates water in the region is considered as medium or class 3 from the viewpoint of salinity and the marsh water as high as class 4 salinity. The Euphrates water can, therefore, be used on soils of moderate to good permeability. In addition, under good management, leaching and drainage, a satisfactory growth of salt

Table 5.4 : Chemical Analysis of the Euphrates water at Nasiriyah (1977-78)

Date of Samp-ling	pH	Ec mmhos/cm	Na me/L	Ca me/L	Mg me/L	Cl me/L	HCo3 me/L	Co3 me/L	So4 me/L	K
2.11.77	7.5	1.828	6.1	2.8	3	5.7	1	0.1	6.3	0.1
7.12.77	7.6	1.919	8.9	6.3	5.7	9.2	2.4	0.1	8.6	0.1
4.1.78	7.8	1.980	7.8	6.4	15.2	9.6	2.8	0.1	9.9	0.1
5.2.78	7.7	2.133	9	6.7	16.9	10.8	3.1	n.d	10.3	0.1
16.3.78	8.0	1.922	8	6.7	15.1	9.7	2.9	n.d	11.1	0.1
7.4.78	8.2	1.744	7.9	4.6	16.7	8.5	2.8	n.d	9.3	0.1
5.6.78	8.1	1.029	4	4.4	11.1	4.6	2.8	n.d	5.0	0.1
1.7.78	8.0	1.841	7.1	6.7	10.3	8.1	2.5	n.d	9.2	0.1
8.8.78	8.2	2.071	8.6	7.4	12.8	10	2.6	n.d	10.6	0.1
2.9.78	7.5	2.035	8.8	8.9	5.3	8.9	2.9	n.d	11.6	0.1
3.10.78	7.8	1.998	5.9	7.0	5.3	8	2.9	n.d	9.3	0.1
Average	7.8	1.863	7.4	6.1	10.6	8.4	2.6	n.d	9.2	0.1

Source : Polservice, Salinity, Table B-164.

Table 5.5 : Chemical Analysis of the Euphrates at Qurnah (1977-78)

6.11.77	7.5	2.545	11.7	6.2	8.2	12.2	3.3	0.1	10.8	n.d
5.12.77	7.6	2.894	9.1	6.1	6.7	13.1	3.9	n.d	13.4	n.d
4.1.78	7.8	1.949	8.1	5.8	2.8	9.7	3.7	n.d	8.6	n.d
6.2.78	7.7	1.978	6.4	5.6	2.3	9.1	4.2	n.d	8.9	n.d
20.3.78	8.5	1.385	5.0	3.9	5.1	5.6	4.7	n.d	7.4	n.d
4.4.78	8.5	1.190	3.6	4.4	3.8	4.6	4.6	n.d	9.5	n.d
8.5.78	8.3	0.880	3.4	3.2	4.2	3.7	4.1	n.d	6.0	n.d
6.6.78	8.4	0.703	2.4	1.4	2.1	2.2	3.9	n.d	5.5	n.d
10.7.78	8.3	0.674	3.0	2.4	3.7	2.7	3.6	n.d	3.9	n.d
7.8.78	7.5	1.206	4.0	3.7	4.5	4.6	4.5	n.d	4.3	n.d
6.9.78	8.1	1.486	5.4	3.6	5.9	6.8	4.8	n.d	5.0	n.d
3.10.78	8.3	2.094	8.5	3.4	11.1	8.8	1.8	n.d	6.6	n.d
Average	8	1.657	5.9	4.1	5	6.9	3.9	n.d	7.5	n.d

Source : Polservice, Salinity, Table B-163.

Table 5.6 : Chemical Analysis of the Germat Ali Channel (1977-78)

Date	pH	Ec mmhos/cm	Na me/L	Ca me/L	Mg me/L	Cl me/L	HCo3 me/L	CO3 me/L	SO4 me/L
20.12.77	7.6	2.723	10.8	5.9	6.2	14.8	2.8	0.2	12.1
23.1. 78	7.8	2.451	10.2	5.9	2.3	12.0	3.6	0.1	10.9
21.2. 78	7.9	2.602	10.4	5.0	4.9	13.5	2.5	0.1	10.9
14.3 78	7.5	2.251	10.9	6.9	6.4	15.2	2.8	0.2	10.5
12.4. 78	8.4	2.405	10.2	5.6	6.3	12.8	2.4	0.1	13.7
16.5. 78	8.5	2.690	10.3	8.4	11.6	19.1	2.4	0.1	12.5
14.6. 78	8.0	2.047	7.4	3.6	7.2	8.9	2.2	0.1	9.2
16.7. 78	8.4	2.515	10.9	5.4	7.6	14.8	3.9	0.1	9.7
14.3. 78	7.9	2.307	10.8	5.2	7.7	12.4	3.1	0.1	10.7
12.9. 78	8.0	2.825	12.7	5.8	11.0	15.7	3.3	0.1	11.7
9.10.78	8.2	3.086	12.4	6.8	7.7	13.5	2.1	0.1	15.7
average	8.0	2.536	10.6	5.8	7.1	13.8	2.8	0.1	11.5

Source: Polservice, Salinity, p.B-162.

Table 5.7 : Chemical Analysis of the Shaffi Channel (1977-78)

15.11.77	7.4	2.314	10.4	5.7	6.2	11.8	2.1	0.2	13.7
11.12.77	7.5	2.529	9.4	6.0	7.9	14.1	2.9	0.1	13.0
9.1. 78	7.9	2.802	8.1	5.0	1.8	9.4	3.3	0.1	9.6
8.2. 78	7.8	2.155	7.7	6.1	3.0	11.8	4.3	0.1	8.6
16.3. 78	7.5	2.275	10.5	7.8	5.7	14.6	3.3	0.1	9.2
10.4. 78	8.2	2.120	8.0	6.1	5.5	12.1	3.6	0.1	11.0
11.5. 78	8.5	3.150	14.6	3.5	10.8	16.7	3.0	0.1	13.2
12. 6.78	8.2	1.749	10.6	3.4	10.2	13.0	3.7	0.1	11.0
12.7. 78	8.1	2.658	12.6	7.0	7.4	16.6	1.5	0.1	10.4
12.8. 78	7.5	2.454	13.1	5.2	9.8	16.6	4.4	0.1	13.2
9.9. 78	8.0	2.989	14.4	6.8	10.0	17.1	4.3	0.1	11.0
7.10.78	8.3	3.186	14.4	8.7	10.0	17.0	3.1	0.1	14.0
average	7.9	2.531	11.1	5.9	7.3	14.2	3.2	0.1	11.5

Source: Polservice, Salinity, p.B-165.

tolerant plants is obtained. Otherwise, salt concentration in the soil will increase with subsequent low yields. The marsh water on the other hand can be used only on soils of good permeability and when special leaching is provided to remove the excess salts and only a limited range of salt tolerant crops can be grown.

The Ec values vary from season to season according to variations in the water discharges. In the dry seasons the Ec values increase, while they decrease in the flood season when more fresh water is provided. At Nasiriyah the highest Ec value occurs in August at 2.071 mmhos/cm and the lowest in June at 1.029 mmhos/cm. However, at Qurnah it increases to the highest value of 2.594 mmhos/cm in December, falling to 0.674 mmhos/cm in July. At Garmet Ali and Shafi the highest values occur in October at 3.086 and 3.186 mmhos/cm respectively, while the lowest occur in June at 2.047 and 1.749 mmhos/cm respectively.

The sodium percentage of the Euphrates river at Nasiriyah is 30.5% and increases at Qurnah to 39.3%. This increase can be attributed to the high sodium content of the waters discharged from the Qurnah marshes into the Euphrates. In the Hammar marsh the sodium percentage increases to 45%. According to the sodium percentage classification suggested by Wilcox (1955), the Euphrates water is considered as good, whilst the Hammar water as permissible for irrigation purposes.

The SAR value of the Euphrates at Nasiriyah and Qurnah is 2.5 and 2.7 me/L respectively, increasing to 4.1 and 4.3 me/L at Shafi and Garmet Ali. According to U.S. Salinity Lab. (1954) classification of the water quality from the SAR and Ec viewpoint, the Euphrates river and marsh waters are regarded as of low sodium hazard throughout the year or class 1. This water can be used on almost all soils with little danger of accumulation of harmful amounts of exchangeable sodium if provided with adequate drainage. The pH value of the river and marsh waters ranges between 7.8 and 8.0 throughout the year.

The RSC of the Euphrates and the marsh waters is less than 1 me/L. According to the Eaton criteria mentioned in section 3.2, these waters can be considered safe for irrigation throughout the year.

Chloride ion content in the Euphrates water at Nasiriyah and Qurnah is 8.4 and 6.9 me/L, this predominates at 13.8 and 14.2 me/L at Garmet Ali and Shafi. The predominant ion is sulphate at 9.2, and 7.5 at Nasiriyah and Qurnah, rising to 11.6 and 11.5 me/L at Garmet Ali and Shafi respectively. Carbonate exists in small amounts of less than 1 me/L in the gauges mentioned above and bicarbonate is also present in small amounts at 2.6, 3.6, 2.8 and 3.2 at these gauges respectively. Earlier studies suggest that the boron level is satisfactory for all crops.(2)

5.2.2 The Groundwater

This source is characterized by abundance and shallowness due to the following factors:

1) A large part of the groundwater which flows beneath the Mesopotamian Plain is channelled into the southern lowlands, of which this region forms part, except for the groundwater in the Zubair Desert which flows toward the north and also becomes concentrated in this region, (see sect. 3.2.3).

2) The seepage water from the Euphrates river, channels and cultivated areas replenishes the groundwater.

3) Additionally, the abundant surface water in this region is in direct connection with the groundwater or in other words it is replenished continuously by the surface water.

Consequently, the groundwater table is found at depths ranging from the surface to about 1.5 m below the ground surface.[3] However, the groundwater fluctuates according to the fluctuations in the surface water resources mentioned above. In the flood season the level ranges from the ground surface to about 0.70 m depth, whilst in the dry season it varies between 0.50 and 1.5 m below the ground surface.[4]

The Ec value is generally high and varies from season to season. It reaches 9.375 mmhos/cm in the dry season and falls in the flood season to 6.825 mmhos/cm,[5] when more fresh water from the surface resources sustains the groundwater. According to U.S.D.A. (1953) classification of the water salinity, this water is considered as being of excessively high salinity for irrigation.

Some leaching of the soils occurs in the flood season, but in the dry season the salinity of the exposed soils increases due to capillary rise from the shallow groundwater table coupled with the high evaporation rates. This phenomenon causes waterlogging and salinity problems for these soils in the dry season with waterlogging only in the flood seasons.

This examination of water quality in this region reveals some significant facts. The surface water is more suitable and available for irrigation purposes than the groundwater, the Euphrates water providing the best from this standpoint. Additionally, the surface water levels govern the cultivated areas and consequently the crop yield. All areas of the region are submerged in the flood seasons and the northern and western parts are exposed in the dry seasons. These exposed areas suffer from both waterlogging and salinity problems due to the shallow saline groundwater table. Accordingly, any cultivation activities are restricted to the western and northern areas and then only in the dry seasons if drainage is adequate. During the flood seasons the soils are leached and new sediments are added, whilst their salinity increases in the dry seasons. Moreover, it should be noted that the inundation of large areas in this region for a large part of the year causes high relative humidity. Although there is no available data about the humidity in this region, the figures from Basrah meteorological station indicate the high relative humidity particularly during winter months (see sect. 1.4.7) although it is possible that it is even higher in the marsh region. The main importance of this high relative humidity to this study lies in its influence on soil moisture content during the dry season, see section 5.11.4, although there will be other effects on crop plants e.g. the encouragement of fungal diseases.

5.3 SOIL CONDITIONS

This region appears to have broadly the same soil characteristics as the lower Mesopotamian plain in which it is set (see sect. 2.1.4). These soils are developed on the sediments which have been brought by the twin rivers and are affected by the low topography which leads to inundation of all these soils in the flood seasons and some of them in the dry seasons. This phenomenon, together with the shallow saline groundwater table, high evaporation and absence of an adequate drainage lead to the creation of a waterlogging problem throughout the year and salinity in the dry seasons. Additionally, the suitable environment provided for the growth of aquatic vegetation produces a high organic matter content of soils in some areas.

Two zones of soils can be recognized on the basis of their periods of inundation as follows:

1. Soils of the temporary marshes : These soils of the higher areas in the northern and western parts, in the flood seasons are inundated and leached, whilst in the dry season they are exposed and suffer from waterlogging and salinity problems.

2. Soils of the perennial marshes : These occupy the deeper areas in the central and southern parts of this region. They are inundated by water throughout the year and consequently can not be utilized for agriculture at the present time.

This is the natural picture of the soils in the region which shows that the first group is suitable for cultivation practices in the dry seasons if the groundwater table can be lowered sufficiently to avoid waterlogging. Accordingly networks of ditches are excavated in these areas and the earth produced is accumulated along their sides forming elevated levees. These soils raised above the groundwater table are less affected by capillary rise and therefore less salinated. Additionally, these soils can be leached properly every flood season by the flood water which submerges them. By these operations the waterlogging and salinity problems are avoided and the soils left in a condition suitable for irrigated agriculture.

For the purposes of comparison, the characteristics of first the irrigated soils and later the unirrigated ones will be discussed.

5.3.1 The irrigated soils

Soil sample sites 1 and 2 in Appendix 5.1 were taken from these levee soils at the beginning of the growing season in 1981, see Figure 5.6.1 and Figure 5.6.2 to show the effects of leaching and irrigation operations on the soil properties (see also sect.5.13 and Fig.5.9).

Fig. 5.6.1 Locations of the Soil Sample Sites

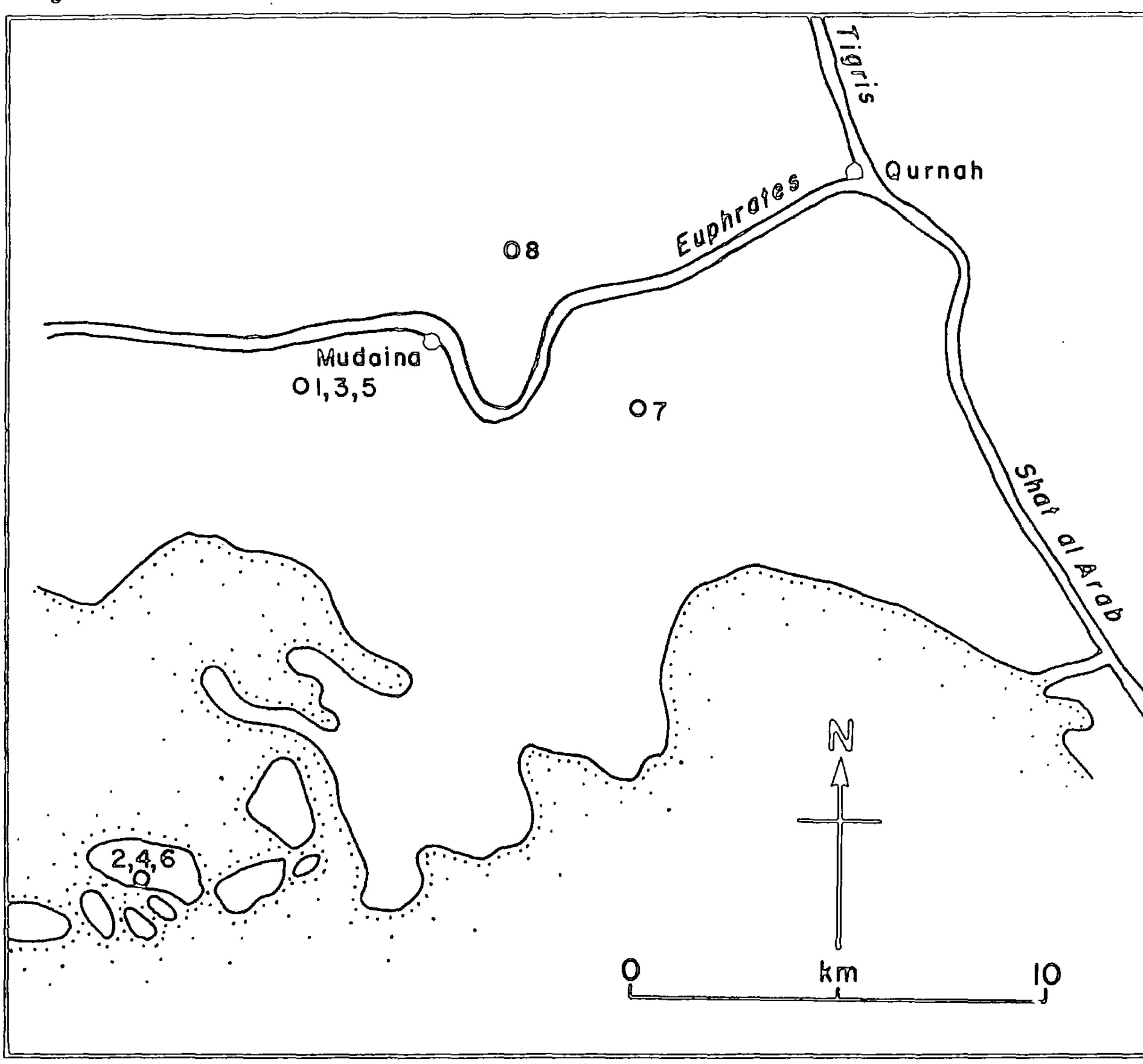
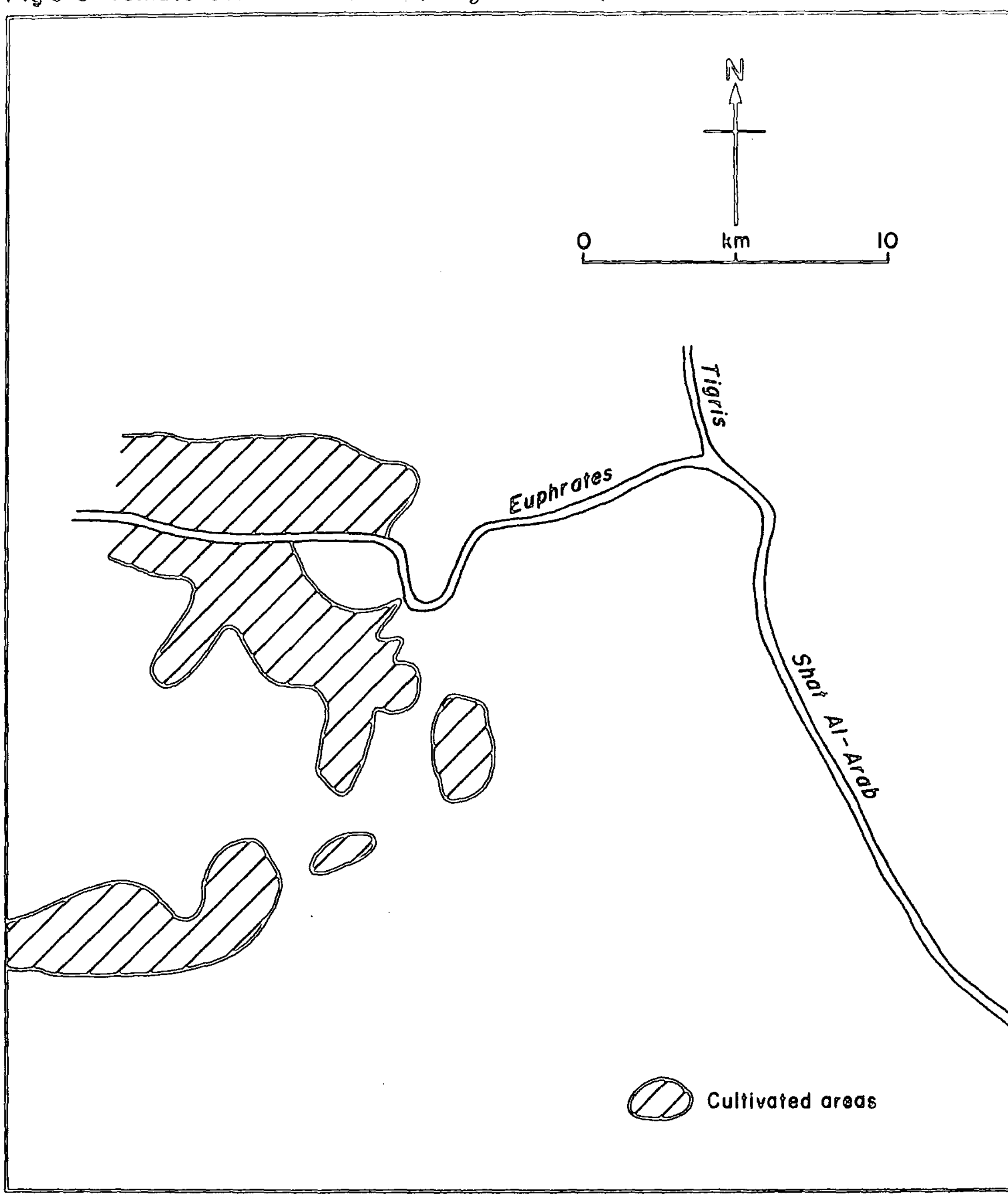


Fig 5·6.2 Tomato Cultivation areas (irrigated soils)



5.3.2 Physical properties :

Analysis of these samples shows that the average silt content is high at 56.5%, clay content 35.5% and sand has the lowest percentage of 8%. Therefore, these soils can be classified as silty clay loams with moderately fine texture. Because of the high correlation between the soil texture and its available moisture content and air movements, the high silt and clay content imparts to these soils a high moisture holding capacity and hence slow drainage rate and poor air movement. Consequently in the upper metre the volume weight (bulk density) is generally high at 1.64 g/cm^3 and the specific weight of 2.61 g/cm^3. Because of the fine pore space of these soils, their void ratio forms more than half the soil volume at 0.59. Their porosity, however, is generally low at 37%, a percentage lying at the lower limit of the general theoretical average which rangesfrom 35 to 55%. (6) It is well known that the high compaction together with the low porosity are not favourable conditions for the plant from the viewpoint of water, air movements and root ramification but management can modify these conditions through tillage, (see sect. 5.7).

The above characteristics show that these soils have high water holding capacity and low infiltration and permeability. The infiltration rates of these soils, as measured by double ring inafiltrometer, are slow at 0.19 cm/hr. Consequently, they have to be irrigated by a method permitting the water to remain on the soils for a long period without runoff or by smaller water applications more frequently. The permeability of these soils is 0.48 m/day. According to Soil Survey Manual Criteria (1951), these soils are considered moderately slow but at the upper limit of the class.

The moisture content of these soils at field capacity is 35.11% and their permanent wilting point is 17.47%. These percentages are higher than the general theoretical estimation at 21.70 and 5.02% respectively.[7] Consequently the available moisture percentage of these soils is relatively high at 17.64%. When wet these soils are sticky and plastic and on the rare occasions when they dry out they shrink and crack. At field capacity, if these soils are compressible by hand leaving a wet outline on the hands and they stick to thumb and forefinger, but with no excess water left on the hands. However, at wilting point they tend to be hard, cracked and difficult to break.[8] In spite of the organic matter content of these soils being generally low at 2%, it is considered high compared with those in the other soils of the province, a result of the vigorous natural vegetative growth in this region.

5.3.3 Chemical analysis

This analysis shows that the lime (CaCo3) content of these soils is generally high and averages 26.6%, while the average gypsum (CaCo4) percentage is low at 3.1%. Lime forms the main source of the calcium and helps to lower the SAR and prevent alkalinization.

The average Ec value of these soils is 3.09 mmhos/cm, which according to the U.S.D.A. (1954) criteria, classes them as non-saline. This results from continuous leaching during the flood seasons together with the presence of a drainage network,(see Figure 5.7). Since the general estimation of the osmotic pressure is about 36% of the Ec value,[9] then their soils have a low osmotic pressure at 1.1 atm., thus posing no problem for water uptake by any crop.

The total cation exchange capacity is 25.9 me/100g, which according to the I.L.A.C.O.B. criteria (1981) mentioned in section 3.2.1.2

can be rated as high. The average SAR is low at 3.79 me/L and the Esp is also low at 4.85. Soils with an Esp less than 15% are considered as free from alkalinity. These soils show a general correlation between Esp and Ec values i.e. when Ec values increase the Esp increasesalso and vice versa. This relationship shows that there is a possibility of leaching both the soluble salts and the exchangeable sodium from the rootzone if adequate drainage is arranged.

Calcium is the predominant cation with a mean of 16.6 me/L though its levels are variable, from 10 to 24 me/L. Magnesium and sodium are present in more or less equal quantities 13.3 and 14.3 me/L. Potassium however is very low at less than 1 me/L. The predominant soluble anion is sulphate at 30.3 me/L with chloride, bicarbonate and carbonate at 12.7, 1.5 and less than 1 me/L respectively. Boron content is sufficient for nearly all boron sensitive plants.[10]

According to the U.S.D.A. Bureau of Reclamation criteria for the determination of soil conditions required for profitable sustained irrigation agriculture, these soils can be considered as relatively profitable. However, in order to apply the U.S. Bureau of Reclamation criteria fully, a consideration of the socio-economic condition of the area as well as the soil properties is necessary. Unfortunately with the currently prevailing situation in the area it was not possible to collect all the necessary socio-economic data, thus an assessment has to be made at the moment on soil criteria alone (but see sect. 5.12). Polservice Co. (1978)[11] also evaluated these soils on the basis of soil characteristics only and considered them as of the third and fourth class. This is due to the deficiencies indicated by high salinity and imperfect drainage. In addition, although these cultivated soils have high moisture holding capacity, are relatively free of soluble salts and are fine textured, they can only be considered as class 3 due to their restricted area, cost of the necessary soil improvement i.e. drains and levees construction, and the specialised irrigation required.

5.4 THE NATURAL VEGETATION

The water, soil and temperature conditions form an ideal environment for the growth of aquatic vegetation. Reeds are the common vegetation in the deeper areas while papyruses and grasses grow densely in the shallow areas, (see Fig.5.7). For example, Pollygonum senegalense (Gat), Cladium mariacus (Jreeh), Ranunculus sphaerospermus (Zeheir al-Bat), Vallisnria spiralis (Khwaissah), Salvinea nalanus (Egzezy), Ceratophyllum demersum (Shumblan) etc. grow vigorously in the ditches and on the agricultural levees. From the point of cultivation and irrigation, the effect of the vegetation is variable. Some of it particularly the reeds and papyruses are used as cover, sheltering the seedlings from the sunshine. However, the vegetation forms an obstacle reducing water flow in the ditches and canals. This phenomenon coupled with the high evaporation rates lead to an increase in salt concentration in the irrigation water. The natural vegetation also competes with the crops in extracting soil nutrients in the cultivated areas. This constitutes a continuous problem for the cultivated areas and unless the vegetation is removed, the crop yields would be seriously reduced.

FIGURE 5.7 The natural vegetation cover in the region

5.5 THE MANAGEMENT

Management of the typical farm in the region is assessed here by an examination of the socio-economic and educational statuses of the farmers and as reflected by water use efficiency, soil salinity and crop yields.

5.5.1 Socio-economic status

The farmer in this region, being the head of an extended family unit as in other rural areas, regards a large family as the basis of his social status in the marshes community, because such a family can derive income from many different activities - cultivation, fishing, hunting, gathering of reeds and papyruses, buffalo breeding and baskets and mat weaving. Additionally, the head of the household can make use of wide relationships with other families through the marriage of his children. Generally, the family provides the labour force available for agriculture in this region. Each family, including up to three generations tend to live close to each other on the higher patches of land or the canal levees beside or near the farms. The adult members of the family cooperate to obtain their livelihood from the nearest available resources. Due to the difficulties of transport, the majority of the farms concentrate near the settlements (see Fig. 5.8).

Rice used to be the main crop in the region and as such occupied most of the farmer's time. However, during the 1960s rice has given way gradually to tomatoes due to the latter's higher cash return. This change involved considerable modification of the whole agricultural system.

Alternative sources of income e.g. from unskilled work, are available in Qurnah and Basrah cities which are near the region. However,

FIGURE 5.8 : A typical farm settlement

investigations in the area showed that its people, with the exception of those living in Garmet Ali area, are not keen on obtaining these jobs, even though they are more lucrative than farm work. The main reason for this is the lack of an efficient transport network between the scattered hamlets and these cities. The only main road in the region is the Mudaina - Qurnah road which runs parallel to the Euphrates river. Although motor boats can navigate the river and the larger channels, the main means of transport in the region are the small canoes, paddled in deep water and poled in shallow water. Travelling by such means is slow and the journey from a hamlet to Qurnah or Basrah cities requires the use in all of canoe, motor boat and finally car. Because of these reasons, Qurnah and Basrah cities do not constitute as strong centres of attraction of labour from this region as they do for the Tigris region.

The majority of the agricultural holdings are rented from the government agricultural offices, very low rents are levied to support the farmers in cultivating the lands. There were 2,000 holdings in 1980,[12] about 40% of which were privately owned. Generally, the areas of these holdings range from 2 to 10 donums and investigations in the region have shown the majority to be 5 donums. In spite of the effect of the water levels in determining the area which can be cultivated every year, see section 5.2.1.2, the family size can form another factor influencing these areas, the larger the family the larger the area that can be cultivated. However, the economic status of the farmer also constitutes a third factor affecting the farm size. The higher the economic status, the larger the cultivated area. It is worth while mentioning that cultivation in this region requires higher input in terms of effort, money and labour than in the other regions in the province, due to the nature of the preparation, cultivation and irrigation operations as noted below.

5.5.2 Educational status

Generally, the farmer in this region is on the same educational level as the farmer of the Tigris region (see section 4.4.2). The farmers do not follow or pay sufficient attention to the agricultural programmes which are communicated by the radio, T.V, etc. Additionally, the curricula of the schools in this region show no interest in the agricultural subjects and are the same as those taught in the schools of the urban areas. Thus, the farmers depend largely on their craft skills and inherited knowledge and traditions to successfully cultivate their farms. Although the farmers realize the importance of drainage operations in improving the soil properties, they do not appreciate the significance of the leaching and they do not utilize all the levees for agriculture (see sect. 5.8). Irrigation and cultivation therefore still continue to follow traditional methods, all operations being conducted manually. However, inaccessibility and extremely difficult physical conditions also limit the extent to which the traditional system could be changed by, for example, mechanisation.

We can summarise the position thus. The farmlands are concentrated on the higher areas near the settlements. Tomato cultivation is the main occupation in the region. The region has a potentially adequate labour pool but the farmer's technical ability is generally low and he follows traditional methods in cultivation and irrigation.

5.6 CHOICE OF AND PREPARING THE LAND

A number of factors influence the choice of land for cultivation: firstly, the site must be as high as possible above the general ground level so that it is exposed as soon as possible as flood water recedes. Secondly, it must be close to a canal which will serve both as a water source and transportation route. Finally, it must be close to the settlement so that it can be easily tended throughout the growing season.

After choosing the land, preparation is the first step in cultivation. In this region preparation consists only of removal of natural vegetation by cutting. This operation has to be practised during the dry season when the lands are exposed. It takes about two weeks and costs about ID 70 (£126)(*) in wages for the workers for a typical 5 donum farm. All other data given below refers to this typical unit. Land does not need any levelling because it is already naturally flat.

5.7 THE DISTRIBUTION SYSTEM

As a result of the waterlogging and salinity problems in the exposed areas, the groundwater table has to be lowered and the soil level raised. This is in order to prevent capillary processes depositing salts from the groundwater in the root zone and to raise the soil above the surface water. In order to achieve this the farmers employ a traditional system of cultivation as follows:

After site selection and clearance a network of ditches is excavated (see Fig. 5.9). A main ditch is dug round the site linking at both ends with a canal which in turn links with a major

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(*) The prices in this chapter are according to the current price of the pound in 1982 which was equal to ID 0.555.

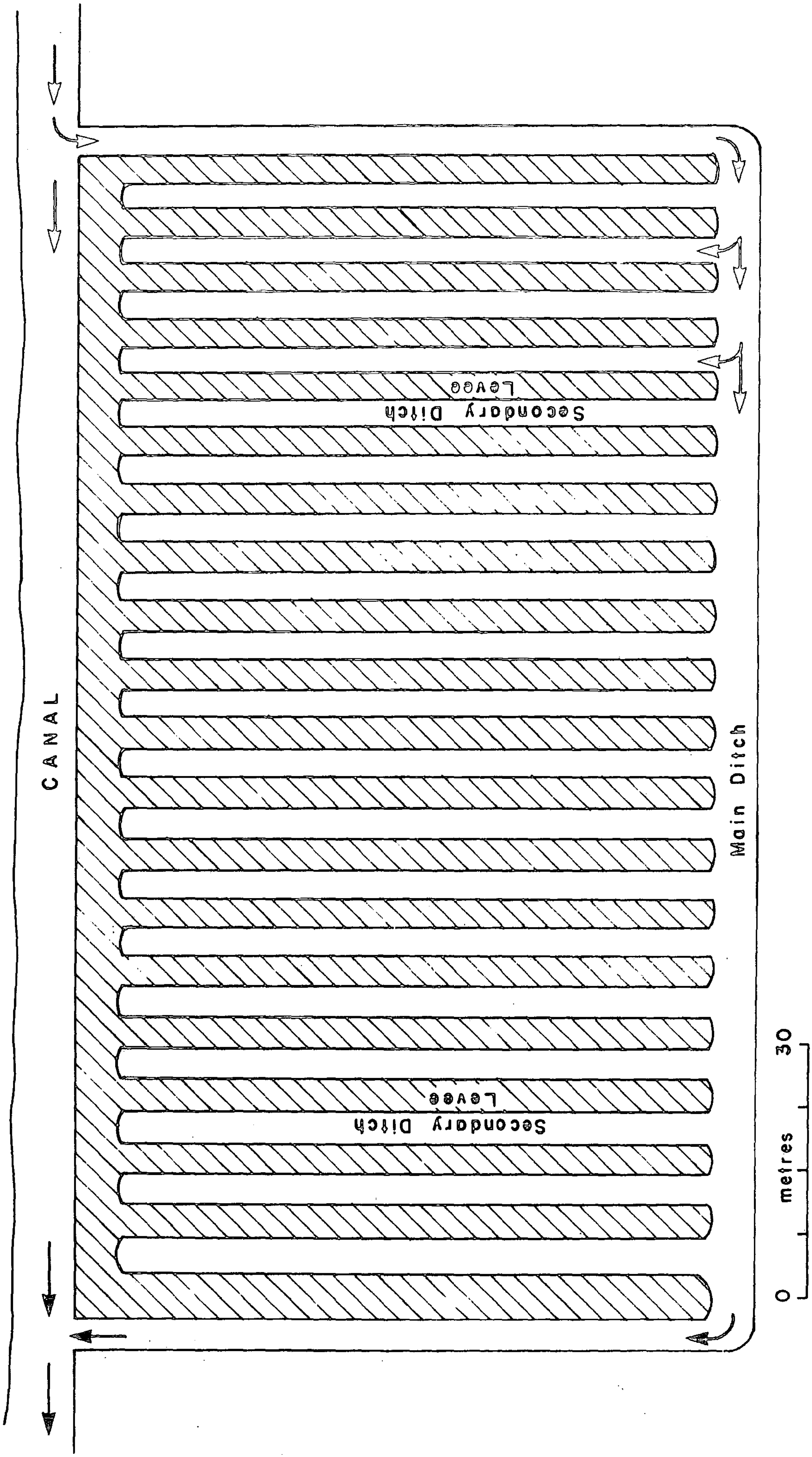


Fig. 5.9 The Distribution System of the Typical Farm

channel or river. This earthen, open unlined ditch is called locally dayer. It is excavated to divert the irrigation water from the canal into secondary ditches and to protect the farm from animals - wild boars, buffaloes and donkeys. Its width ranges from 3 to 4 m, wide enough to allow a canoe to pass through easily. Its depth ranges between 2 to 2.5 m. From this ditch the secondary ditches which are called locally Garmat (singular Garma) are excavated at right angles and parallel to each other (see Fig. 5.9). The typical farm consists of 35 secondary ditches, these are 1 to 3 m apart, 20 to 80 m length, 1 to 3 m width and with average depth of 1.50 m. It was noticed that in the higher areas these ditches are dug deeper and narrower than those in the lower areas. In the first case the ditches are dug deeper to make the water available for irrigation and narrower because the levees are already high and they don't need as much earth from the ditches. In the latter case, the ditches are shallower because the water in these ditches is high enough to be used for irrigation, and they are wide because the earth produced from the ditches is required to increase the levees elevation to lead to early exposure as the flood level falls. The water level in these ditches is the same as that in the main canal. These permanent ditches are dug and cleaned by hand shovel, this reflecting the availability of labour and the lack of suitable amphibious digging and cleaning machines. Digging of the main and secondary ditches cost ID 1400 (£2522) and ID 2400 (£4324) respectively as wages for the workers. This operation can be achieved in about 12 weeks by 5 workers. The pattern of cultivated levees, as shown in Figure 5.9 , can be represented by a normal one-sided comb.

The water level in the ditches is observed by the farmer in November and December to see whether the irrigation water is available in these ditches to a depth of at least 0.50 m during these months. If not the ditches have to be deepened until the required depth is achieved for the water to be available for irrigation. In such cases the excavated earth is added to the levees to ensure early exposure in the following growing season. The farmer also observes the levees at the end of the flooding season in order to compare the time of their appearance with that of the other farms to see whether they are exposed at least as early. If not, they have to be built up. However, the ditches are usually cleaned every two years to remove accumulated sediments and vegetation and to maintain the height of the levees. This operation also adds fresh sediments and organic matter to the levees.

The levees, locally called metoon (singular matin), are 1 to 1.5 in height and 1 to 3 m in width. The typical farm consists of 36 matin, that in turn means about half of the farm area is wasted in ditches (see Fig. 5.10). It is interesting to note that construction of the levees by the farmer imparts better soil physical characteristics in terms of infiltration, aeration and drainage compared with the natural ones in the region.

After completion of the distribution system the farm is left to be inundated in the following flood season - March until June - and the soils on the levees are thereby leached. At the beginning of the next dry season the farm is ready to be cultivated providing the levees are exposed in June or July and if not then the levees have to be raised further again and the farm left for another season. In the latter case the earth used to build up the levees is taken from the main ditch. The farmers were asked why they did not take the earth from the secondary ditches. They suggested if they did that the

FIGURE 5.10 : The sheltered seedbeds

ditch depth will increase more than the height of normal man and in such case it is difficult to irrigate the crops which sometimes require the irrigator to stand in the ditches. Deep secondary ditches also cause movement difficulties from one part of the farm to another.

When the levées are exposed at the beginning of the next dry season they are cleaned of the vegetation which grew during the flood season. Following this small holes are dug, of the order of 30 cm across at the surface tapering to 15 cm at the base and some 15 cm deep, with a volume of 0.005 m^3, usually 50 cm apart on both sides of the levees or in the central parts of the levees if these are narrow. These holes are for planting tomato seedlings and the typical farm will have some 10,656 holes which take about a week to dig and cost ID 60 (£108).

From the foregoing discussions it has been pointed out that digging of the ditches or raising and forming the levees is still practised manually which would be extremely expensive in monetary terms if family labour was so costed. Although limited technical inputs are characteristic, and as long as more than 50% of the farm area has to be given over to ditches which need cleaning continually, this method of utilizing the land in cultivation seems to be appropriate to this region. Furthermore it is virtually impossible to design any system which would take less land out of cultivation, and such fragmentation prevents mechanisation.

5.8 THE CROPS

Tomatoes are the foremost crops in this region in terms of their cultivated area and profitability. They yield higher cash returns compared to those crops which used to be cultivated in the region - rice and vegetables. Fieldwork in the region showed that the cultivation and irrigation of this crop are carried out by most of the family members - 10 to 50 year old, (see Fig. 5.15). However, cultivation of this crop is not without some risk as yields can be reduced by adverse conditions in the growing season.

The average timing of the plant growth stages (F.A.O. classification, 1971) and identified in section 3.6 is as follows:

5.8.1 The initial stage

This stage occurs from June until about the 15th July, and lasts 31 days during which the seeds are sown in three seedbeds of 2 x 3 m size. These beds are chosen in the highest part of the farm on the side of the mound where the farmer lives. The seedlings grow best under a temperature range of between 25 to 32°C, typical for this time of the year. Temperatures, however, occasionally rise above 32°C reaching up to 45°C.(13) Therefore, the seedlings are covered by a light shelter made of papyrus to protect them from sun scald, see Figure 5.11, which can seriously damage the seedlings. If this happens then the farmer buys seedlings from other farmers who have a surplus. The farmers were asked why they did not sow the seeds later, in August for example, to avoid this phenomenon. They suggested that if they did that the crop would be inundated in the following March before it matured and at the same time if the flood season occurred late and the crop matured they would yield low profits because other regions start to market their tomatoes at the beginning of the summer season.

At the end of this stage when the levées are exposed the seedlings are transplanted into the small excavations on the side of the levees (see Fig. 5.11). In some years the water level continues to be high, submerging the levées until July or the beginning of August. In this case the seedlings are left to waste in the seedbeds

FIGURE 5.11 : Transplanted tomato seedlings protected by date palm fronds

because the farmer does not transplant them in August for the reasons mentioned above. At other times the levees are exposed in June or July but the water level in the ditches remains high and this causes waterlogging in the root zones. In such cases the water level is lowered by reverse pumping from the ditches into the major canal, (see Fig. 5.15).

5.8.2 The developing stage

Extends from mid-July until the beginning of September, about 55 days. At the beginning of this stage the seedlings are transplanted in the small excavations and surrounded by small pieces of palm fronds to protect them from the sunshine,(see Fig. 5.11). From 4 to 6 seedlings are transplanted in each excavation. After two weeks they are thinned so as to allow only the most healthy ones to grow free from competition.

5.8.3 The mid-season stage

Takes about 61 days, from the middle of September until the beginning of November. In the first ten days of this stage the levees are tilled and cleared of any weed growth. The palm fronts are removed and in order to irrigate the plants, bigger excavations of 0.008 m^3 in size, are dug by sickle round each plant. Additionally, small excavations of 0.002 m^3 are dug in between the bigger ones. A mixture of fertilizers and soil is added to these intermediate excavations to provide the plants with nutrients (see sect. 5.11.3).

5.8.4 The late stage

This stage runs from the beginning of November until the middle of February and thereby takes about 100 days. In March, the water level starts to rise and then submerges the levees. The crops mature from December until the end of this stage. The main reason for early crop-maturing is the mild winter in this region. However, a temperature decrease to about 11°C in some nights particularly over a 23 day period during pollination can drastically reduce yields. In addition, if the temperature falls to freezing point, as often occurs on two or three nights in January and February, it leads to plant damage. The plants are therefore protected with plastic sheets during this period (see Fig. 5.13).

5.9 THE CONSUMPTIVE USE

Unfortunately there is no Meteorological station in this region, Basrah station is the nearest and therefore their potential evapotranspiration rates will be used when calculating the net irrigation requirements for the typical farm of 12,500 m^2 area, (see sect. 1.4.9).

Consumptive use of water in irrigation is usually calculated for the gross vegetative areas because the distribution system usually occupies a small part of the farm area, but in the case of the typical farm in this region, the distribution system occupies about 57% of the total farm area. Therefore, it is appropriate to exclude it from the calculation of the consumptive use of the typical 5 donum farm on which 5,328 m^2 would represent the statistical average of the area of the levees.

Table 5.8 shows that the evapotranspiration rates vary from month to month. These rates decrease in December, January and February to 53.5, 52.6 and 78.4 mm respectively and they rise to a peak in June, July and August of 256.5, 259.5 and 242.2 mm as temperatures rise.

Calculating the consumptive use for the tomato crop, with

Table 5.8 : Consumptive Use of Water for Tomatoes in the Typical Farm

Month	Et mm	Et for tomatoes kc = 0.68	Et of tomato area m	Notes
June	64.0	32	170	15 days
July	171.1	119.5	636	
August	198.6	168.8	899	
Sept.	201.0	213.6	1138	
Oct.	157.7	181.3	965	
Nov.	46.3	40.4	215	
Dec.	13.3	3.3	17	
Jan.	13.1	3.2	17	
Feb.	13.0	3.2	17	
Total			4679	

Note : consumptive use is calculated according to modified Penman formula, see p.44.

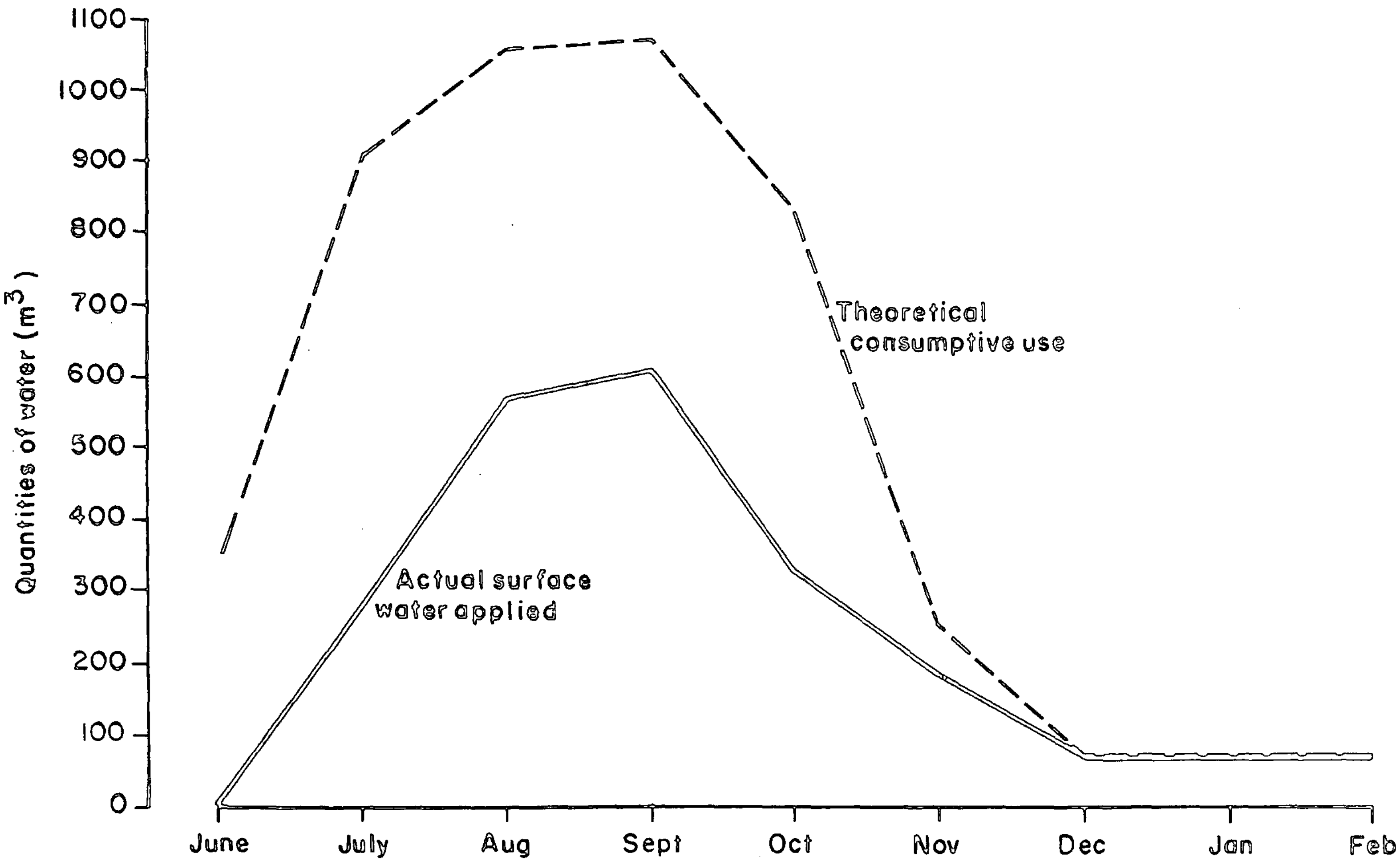
FIGURE 5.12 : Plastic sheeting on the levees providing the tomatoes with protection against frost. (Note the regrowth of weeds)

respect to its growth stages shows that the net water requirement increases gradually from the first stage and reaches its peak in the developing stage. Then it starts to decrease in the mid-season stage and reaches the lowest value in the fruit or late stage, (see Fig.5.13). The total water required to irrigate the tomato crop in the typical farm during the growing season of 246 days is 4,679 m^3.

5.10 LEACHING REQUIREMENT

In the light of the low Ec value of these irrigated soils it is unnecessary to apply a large surplus of leaching water. However, the water which is used for irrigation has a general average Ec value of about 2.121 mmhos/cm. Using this water to irrigate these moderately fine textured soils under high evaporation rates will certainly lead to increase the soil salinity if adequate leaching does not take place. Thus, to keep the Ec value of these soils below the limit of 3.0 mmhos/cm requires some leaching of the soluble salts which are deposited by evaporation of this irrigation water. Calculating this amount of water required for leaching, according to the Thorne and Peterson method (sect. 3 . 9) shows that 68.6% more water should be used than is theoretically required to bring the soil to the field capacity and to maintain the soil Ec at 3.0 mmhos/cm. Consequently, the total water required for leaching these soils during the growing season, depending on the consumptive use value, is 3,209.7 m^3, giving a total theoretical requirement of 7,888.7 m^3 of water per growing season.

Fig 5.13 THE THEORETICAL CONSUMPTIVE USE COMPARED TO ACTUAL WATER APPLIED



5.11 THE WATER SUPPLY

Although the Euphrates water is more suitable for irrigation than that of the marsh, the non-uniform distribution of the higher lands suitable for cultivation means that not all farms are in a position to use only Euphrates water e.g. those in the western areas.

The quantity of the applied water and the irrigation times vary according to the variation of the crop growth stages as follows:

5.11.1 The initial stage

In this stage the tomato seeds in the seedbeds are irrigated every day. Irrigation of these beds is done with a tin which is called Tanaka, of 20 x 30 x 20 cm size. This tin is carried by the farmer to the nearest canal and is filled with water which is poured slowly onto the seedbeds. The average quantity of water carried in this tin is about 0.008 m^3. Each seedbed is irrigated by an average of 5 tins per day. Thus, the total water applied to irrigate these beds amounts to 0.12 m^3 per day or, in terms of the whole of this stage, 3.72 m^3.

5.11.2 The developing stage

In this stage the duration of the standing water level determines the cultivated areas. If the water level is high the exposed areas which can be cultivated are smaller and vice versa. For example, the water level in the flood seasons of 1969 and 1972 was high at 3.06 and 2.72 m G.T.S. respectively, so that the cultivated areas in these years were 1,000 and 1,260 donums respectively. However, since the water level in the flood seasons of 1971 and 1973 was 1.92 and 1.16 m G.T.S. the cultivated areas increased to 2,000 and 2,250 donums respectively.[14] Thus, the cultivated areas are in reverse proportion to the water level.

The crops are irrigated by the so-called Deliyah which consists of a wooden pole of 150 to 200 cm length and 5 cm in diameter, at the end of which there is secured a small tin of about 0.003 m^3 size. This deliyah is held from the other end by the irrigator, who stands on the levee sides, (see Fig. 5.14). The tin is then sunk into the water of the ditch and then lifted and poured slowly into the nearest excavations. The average quantity of the water carried by this tin is 0.002 m^3 and each excavation is given three tinfulls twice a week. The total amount of water applied to each excavation is 0.006 m^3 per irrigation and the quantity of water applied on the typical farm in this stage amounts to 1022.97 m^3.

It was noticed that the total quantity of water in each excavation infiltrated and evaporated after about 14 to 16 hours, 10 cm of water disappearing after about 10 hours. This average is more rapid than the infiltration rates of the soils (see sect.5.3.1). This is because of the special conditions produced in forming these levee soils. According to the Van Beer criteria (1974), infiltration rates of these soils are considered as somewhat favourable - slow. However, using irrigation water of 2.121 mmhos/cm Ec value under the hot conditions for the period mentioned above will undoubtedly lead to increasing the Ec value of these soils (see sect. 5.13) which in turn may cause a reduction in infiltration rates.

It is worthwhile mentioning that in some years, e.g. 1972 and 1975, the levées were exposed as usual at the beginning of the growing season and the seedlings were transplanted on the levees but the water level in the ditches remained high at about 30 cm below the levees. This level had to be lowered to prevent waterlogging of the root zones which would cause damage to the seedlings. In this case the junctions of the main ditch with the canal are closed

FIGURE 5.14 : Irrigation by deliyah

(Note the proliferation of weeds competing for water and nutrients)

by earth blocks and a pump is installed at the end of the main ditch to pump the water from this ditch into the main canal (see Fig.5.15). This operation may have to continue for 2 to 6 weeks until the water level is sufficiently low.

5.11.3 The mid-season stage

Two types of excavations are dug in this stage, as noted in section 5.8.3. Both are watered by deliyah, at the same time, twice a week in the last 20 days of September. When the small excavations are irrigated the fertilizers are dissolved and carried laterally by the water to the adjacent root zones. The average quantity of water applied to each small excavation is 0.0009 m^3 and for each big excavation is 0.006 m^3. Consequently, the total water applied for the typical farm in each irrigation is 73.5 m^3 and in terms of 20 days of September is 419.9 m^3.

During the remaining period of this stage - 41 days - from October until the 10th of November, the excavations are irrigated once a week and the total water applied for the typical farm in this period amounts to 430.4 m^3. Thus, the quantity of water applied during the whole stage totals 850.3 m^3. The time needed for the excavations to dry out at this stage averages 12 hours. This average is shorter than that in the developing stage with respect to the same depth of applied water - 15 cm. This can be attributed to the better infiltration capacity which is created after tilling for the levees during this stage. However, the time required to dry up 10 cm of the applied water is about 8 hours, and according to the Van Beer criteria, this rate is borderline between somewhat favourable and favourable.

FIGURE 5.15 : Pumping of excess water from the main ditch into the main canal

5.11.4 The late stage

In this stage the plants are not irrigated, but they grow naturally. Irrigation is stopped in order to speed up maturation of the crops. The plants survive during this longest stage in which the fruits begin to mature because of the high relative humidity and the water standing in the ditches and retained in the soil.

It is well known that in some parts of the world the atmospheric water - dew, fog, clouds and high relative humidity - contributes significantly to the sustenance of plants. In fact this phenomenon needs further study in this region to show the extent of the humidity contribution. It is at this last stage that the relative humidity reaches the highest values, see sect. 1.4.7 and this certainly reduces the strength of forces causing evapotranspiration and consequently reduces water requirement. Additionally, the high relative humidity moistens the soil surface from which the plants may extract a part of their required moisture through their shallow roots. A study conducted by Bowen (1938) [15] showed that most crops withdraw about 50% of the required moisture from the top 30 cms of the soil. By this stage of growth moreover, the tomato plants have developed a root system to at least 180 cm,[16] and can directly tap the water that infiltrates laterally from the ditches. The water level in the ditches fluctuates according to movements of the water during tide and ebb. During the tide more fresh water infiltrates laterally into the levees and during the ebb the excess water drains into the ditches.

However, it should be noted that in some years e.g. 1973 and 1974, the water in the ditches and the canal receded relatively far from the farms which were located on small canals distant from the river or main channels. Consequently, the groundwater in the levees fell to an extent that the plants could not survive without irrigation. In this case further small excavations of 1.0 m in diameter and 0.70 m depth are dug, in each secondary ditch in which the groundwater can collect. This water is then used for irrigation using the deliyah in the normal way. The local farmers agreed that irrigation of this type during the last growth stage led to a markedly decreased yield.

However, in some years the water level rises early - at the end of January or the beginning of February. This phenomenon causes waterlogging in the root zones which adversely affects the crop yield. Therefore, the water level has to be lowered by pump in the same way as in the developing stage, (see Fig. 5.15).

Thus, during this final growth stage irrigation is rarely used, sufficient water being obtained by absorption from the air and extraction from the groundwater. It is therefore impossible to determine the actual amount of water used. However, the theoretical demand based on consumptive use is 287 m^3 in this stage, so these two sources must supply at least that amount noting that now there is no leaching requirement, (see Fig. 5.13).

It has already been stated that the water level in the ditches affects the irrigation of the plants at the beginning and the end of the growing season. The total applied water for the typical farm during the growing season is about 2163.7 m^3 which equals only 46.2% of the theoretical consumptive use and only 27.4% of the theoretical total required water for irrigation and leaching to keep the soil at an Ec value of 3.0 mmhos/cm. Therefore, the deficit of about 5,725 m^3 which must be satisfied by atmospheric humidity and groundwater, not only in the last growth stages but also in the developing and mid-season stages. This fact in turn means that the water applied through irrigation is insufficient for leaching and this will lead to an increase in soil salinity. We may assume that soil salinity would be doubled by the low rate of applied as opposed to plant-available moisture, (see sect. 5.12). It also implies that about 3,695 m^3 of the water required by plants during the growing season is provided by groundwater and atmospheric humidity. This quantity is equivalent to 72.6% of the total water required for the plants on the typical 5 donum farm and the remaining 27.4% is provided by surface irrigation.

The above calculations suggest that there is no water loss except for that caused by evaporation. Consequently, the water use efficiency of this system can be considered high but is low from the viewpoint of effective leaching which results in a buildup of soil salinity during the growing season.

5.12 DRAINAGE

The ditch network on the typical farm is used both to supply the irrigation water and at the same time operates as a drainage system draining the excess water from the levées during the ebb and preventing the rising of the groundwater during the growing season. The drainage water is drained from the secondary ditches first into the main ditch and then into the canal, the water moved by the tidal flow in the main ditch.

5.13 SOIL SALINITY

In order to show the effects of the irrigation and leaching operations in the growing and flood seasons, soil samples 3 and 4 in Appendix 5.1 were taken from the same locations as soil samples 1 and 2, (see Fig. 5.6 and section 5.3), these were taken in the end of the growing season before the levees were inundated. Analysis of these samples shows that the average Ec value had doubled to 6.05 mmhos/cm, the SAR increasing from 3.7 to 5.0 me/L. This is due both to ineffective leaching and the fact that in the growing season the Ec value of irrigation water increases particularly in the ditches due to high evaporation rates and slow water flow resulting from the dense vegetation growth.

Soil samples 5 and 6 in Appendix 5.1 were taken from the same locations, see Figure 5.6 at the beginning of the following growing season in 1982 after the flood water had receded. The analysis of these samples shows that the average Ec value had decreased again to 2.7 mmhos/cm, the SAR falling to 3.2 me/L. This is because of the effect of the leaching which was carried out naturally by the flood water from March until June. There is also a general fall in the levels of soluble cations and anions following inundation (see soil samples 5 and 6, Appendix 5.1).

5.14 THE CROP YIELD

The yield of tomatoes is affected indirectly by both physical and cultural factors, particularly the water levels at the beginning and end of the growing season, sun scald, the family size and the economic status of the farmer.

With the exception of 1973, 1977, 1978 and 1979 no continuous record of crop yield is available. For those years the tomato production was 28,000,000; 8,971,395; 147,730,380 and 14,800,000 kg respectively.(17) These figures show clear differences from year to year which can be attributed to the variations of the factors discussed above.

Fieldwork measurements and interviews showed that the average yield of tomatoes from each plant is about 1.35 kg. That means the total yield from the typical farm is 14,385.6 kg or 2,877.1 kg per donum. This average is higher than the general average in Iraq at 2,258 kg/donum. (18)

The crop in this region matures early in late November to February when no mature tomatoes from other regions, with the exception of Zubair region, reach the markets. Consequently, the crop yields a high cash return. Thus, this region together with Zubair provides the Iraqi markets with tomatoes at a time when the other producing areas are unable to do so.

Discussions with the local farmers showed that the total average cash return from tomatoes in the typical farm is about ID 4307.5 (£7,760). However, Table 5.9 shows that the total hypothetical expenses for crop cultivation are about ID 5,287 (£9,526), this on land farmed effectively for the first time.

Table 5.9 : 5 donum farm - total expenses for tomato cultivation (ID)

Details	ID
Wages for cutting and removing the vegetation	70
Wages for digging the main ditch	1400
Wages for digging the secondary ditches	2400
Wages for digging the small excavations	60
Prices of fertilizers and pesticides	80
Wages for tillage and removing vegetation	292
Wages for digging the bigger and small excavations	85
Prices of the plastic sheets and iron arches	500
Irrigation wages	400
Total	5,287

Hypothetically, therefore, the farmer in the first growing season loses about ID 979.5 (£1,764). However, it should be noted that the farmer and his family undertake a large part of the cultivation - digging and irrigation. The money value of this work was estimated at ID 2,036 (£3,668) but as in many such cases, family labour is not assessed in cash terms. The monetary expenditure as perceived by the farmer is therefore reduced to ID 3,251 (£5,857). The total profit of the farm in the first season as seen by the farmer is then ID 1,056.5 (£1,903).

Most of the above expenditure would not be incurred in the seasons following the establishment of the farm, such as that on plastic sheets and iron supports and wages for digging the ditches. This reduces expenditure in the second season by about ID 4,300 (£7,747) and consequently leads to greater profit.

The harvested crop is transported from the farm to Mudainah and Bahlah marketing centres which are located in the northern part of the region. The crops are collected into plastic boxes of 60 x 40 x 40 cm size, these are then transferred from the farm by small canoes to bigger ones at the nearest channel or river. Then these boxes are transferred to the nearest marketing centre, either Mudainah or Bahlah and from these centres the boxes are taken by lorry to the different Iraqi markets. With the exception of a few hundred kilograms which are consumed locally, all the crops are marketed.

The marketing processes face some difficulties which have an adverse effect on crop quality when it reaches the consumption centres. These are caused by the variety of transportation methods used in getting the crop to markets as each transfer and handling of boxes causes some damage. As neither the markets or retailing areas or the transport media are air conditioned, the tomatoes lose quality. Further difficulties arise as the farmers sometimes do not receive the boxes at the required times. Thus, the final factor influencing the profitability of the crop is that concerning satisfactory transporation and marketing to ensure a maximum part of the crop arrives for sale in good condition.

5.15 THE UNIRRIGATED SOILS

These soils are located in the flat low lying areas which are exposed in the dry season. Although these soils are leached during the flood seasons, they suffer from waterlogging and salinity in the dry seasons due to the high groundwater table and absence of adequate drainage. Thus, the salinity of these soils can be strongly associated with the salinity of the shallow groundwater from which salts continually rise during the dry season to the soil surface through capillary action.

Soil samples 7 and 8, Fig. 5.6 and Appendix 5.1 were taken from unirrigated soils. Their analyses show that the average Ec value is 31.3 mmhos/cm increasing at the top horizon to 38 mmhos/cm. According to U.S.D.A. (1954) classification of the soil salinity, these soils are considered strongly saline. This average equals about 10 times that in the irrigated soils, (see sect. 5.3.2). The exchangeable sodium is 5.4 me/100g which is higher than that of the irrigated soils. The average SAR value of these soils constitutes about 5 times of that in the irrigated soils, reaching 20 me/L. The average Esp is also high at 21.6%. Therefore, these soils can be considered as saline-alkaline.

However, leaching of these soils can reduce both the Ec and Esp values as in the case of the irrigated soils, (see sect. 5.13). Thus, these soils can be reclaimed and cultivated if leaching and adequate drainage take place. However, with the high levels of exchangeable and soluble sodium it is likely that addition of gypsum to these soils during leaching would be necessary in order to maintain and improve the soil structure. The massive increase in Ec is reflected in a large increase in the amount of soluble cation and anions in the soil, see samples 7 and 8, Appendix 5.1.

5.16 CONCLUSION

It has already been pointed out that the western and northern parts of the region are the only areas which can be cultivated due to their exposure above water during the dry season and their low soil salinity produced by annual submergence leaching. The cultivated areas and crop yield are governed by the water levels.

No cultivation activities can be practised without adequate drainage due to the waterlogging and salinity problems. The irrigation ditches also serve as a drainage network which preserve the cultivated raised levees from the above problems. More than half of the farm area is taken up by the permanent ditches.

Irrigation and cultivation operations are carried out manually. Vigorous wild vegetative growth is a serious problem for cultivation and irrigation.

In this region the cultivable soil is scarce and water is abundant but neither is used optimally. The width of the levees is about 3 m and the utilized side areas are not more than 1.0 m. In addition, the plentiful water is not used for leaching in the growing season because of the high cost of irrigation and levees are only leached naturally during the following flood season.

It is noteworthy that in this region only 27% of the water required by the plants is met by applied surface irrigation, the remaining 73% obtained from atmospheric humidity and "subsurface irrigation". Therefore, the leaching effectiveness in the growing season is poor and consequently soil salinity then increases until it is lowered naturally in the flood season. Given the heavy application of labour, yields per plant or cultivated area are not high.

It is recommended that farmers use narrow levees of 1 to 1.5 m to save the high wages for their construction as long as the plants are set only on their sides. In addition, the irrigation operation could be achieved by a pump and flexible hose to water the individual plants. However, the main problem of variable water levels which faces cultivation and irrigation in this region will remain until the completion of the Shat Al-Basrah channel which will regulate the water levels in this region. Moreover, the changes which are taking place in Iraqi society are bound to lessen the effective availability of family labour which is used now on an uncosted basis. In future the effective return per labour unit will have to rise if production is to be sustained.

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(13) Al-Rawy, A.Z., Tomatoes cultivation in Iraq, General Directorate of Horticulture, Vegetables Department, Report No.19, Baghdad, 1971, pp.7-8, (In Arabic).

(14) Al-Sarieh, A.J., op.cit., p.80.

(15) Thorne, D.W. and Peterson, H.B., op.cit., p.142.

(16) F.A.O. Irrigation Practices and Water Management, op.cit.,p.53.

(17) Registers of the General Agricultural Directorate in Basrah Province, Agricultural Data, 1980, unpublished (In Arabic).

(18) Al-Rawy, A.Z., op.cit., p.4.

CHAPTER 6

THE SHAT AL-ARAB REGION

6.1 INTRODUCTION

This region occupies the south-eastern part of the province and is located on both sides of the Shat Al-Arab river (see Fig.6.1).

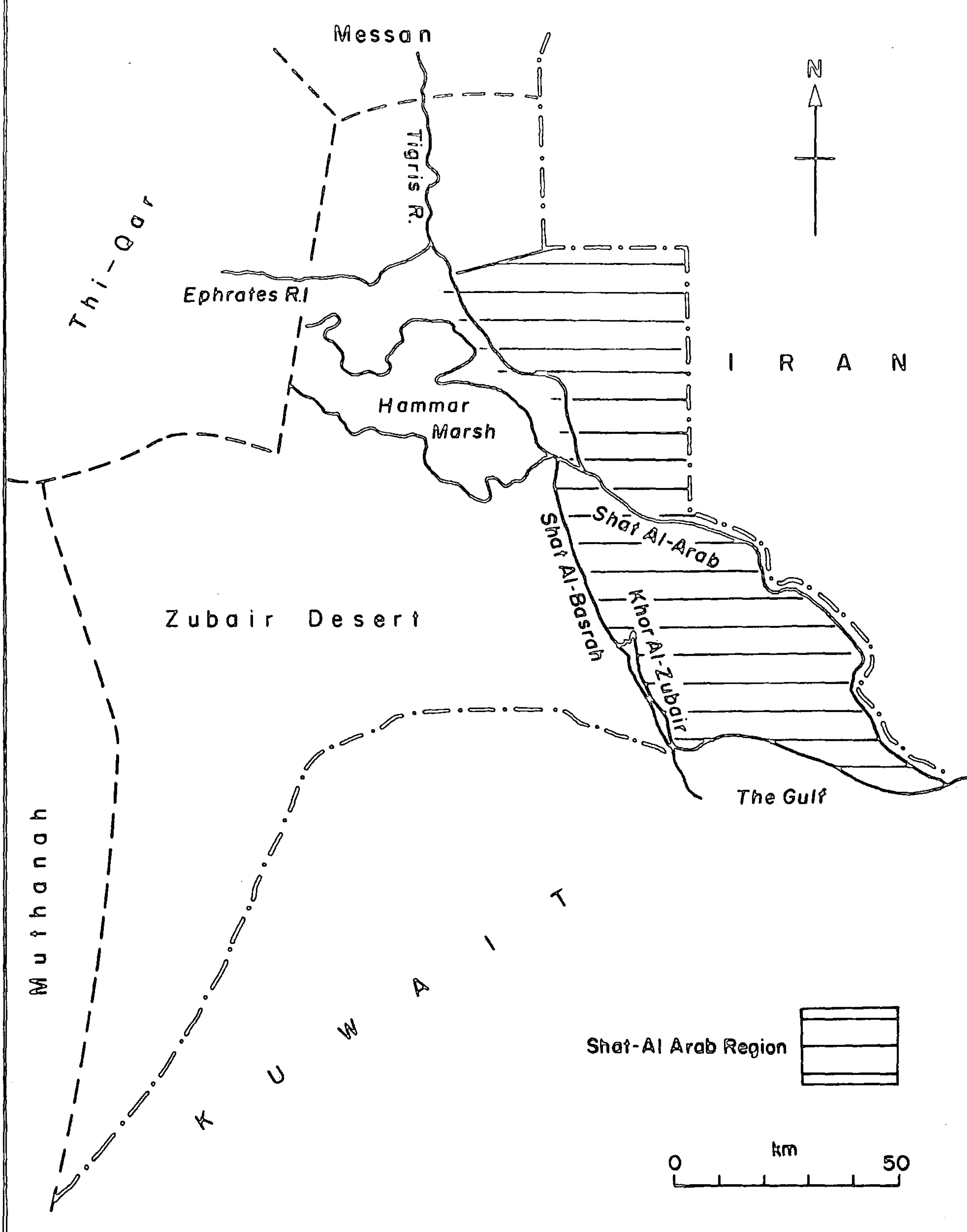
Generally this region slopes gently from 2 m G.T.S. in the north to about 0.50 m G.T.S. in the south and from 2.5 m G.T.S. on the Shat Al-Arab banks to about 1.0 m G.T.S. in the surrounding low areas, with corresponding water flows.

Since the 8th century A.D irrigated land has occupied both the Shat Al-Arab levees and some adjacent lowlands in the western part of the region, but at the present time is restricted only to the Shat Al-Arab levees. These levees are irrigated by 'lateral' irrigation controlled by tidal ebb and flow movements in the Gulf which extend into the Shat Al-Arab and then into the numerous canals and ditches which join the river. The irrigation canals and ditches serve for irrigation during tide and for drainage during ebb.

The main crop in this region is the date palm though there are a few small areas in between the date palms which are cultivated for fruit and vegetables. However, this region has special importance in Iraq in terms of the numbers of date palms and the quantity of dates produced.

Apart from surveys of soil and water conditions carried out by T.A.M.S Co. (1954), Nippon Koei Co. (1971) and Polservice (1978) and a general study of the irrigation and drainage of the central part of this region by the author in 1979,[1] no detailed study has been made of the irrigation and drainage system as a whole.

Fig 6·1 LOCATION OF THE SHAT AL-ARAB REGION



This chapter first discusses water and soil conditions, then considers the date palms as the main crop. It deals with the role of farm management and its effect on the number and productivity of the palm and on soil salinity. This chapter will also consider the general distribution system of irrigation water and the water supply for the palms. It will assess the effectiveness of drainage, soil salinity and yields as evidence of the effectiveness of the irrigation and drainage system. Finally, are discussed the abandoned once-farmed lands.

6.2 WATER RESOURCES

Surface and groundwater resources will be discussed separately in order to show their availability and suitability for irrigation.

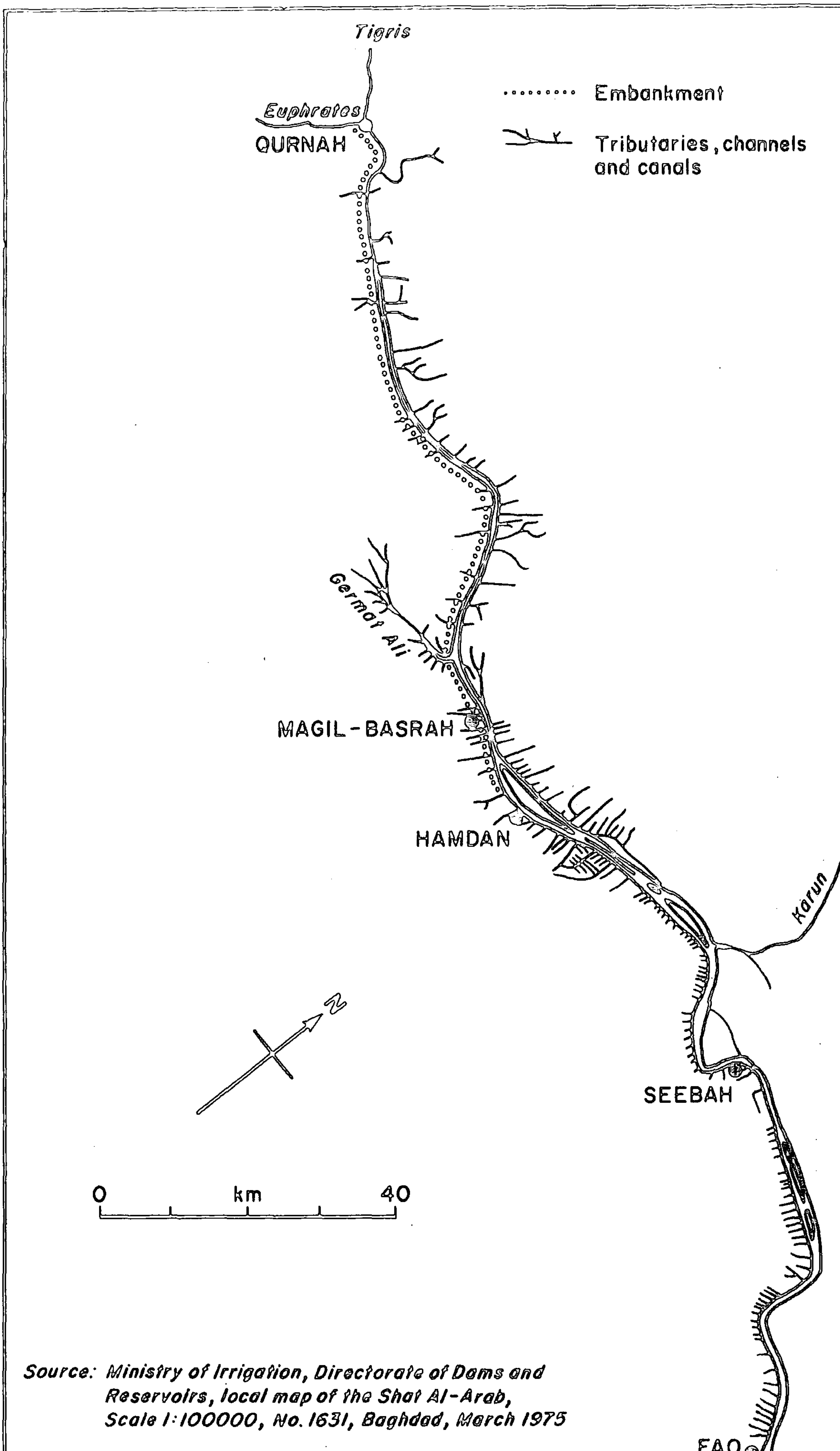
6.2.1 Surface water

The Shat Al-Arab river and its branches are the main water sources in the region under discussion. As the Shat Al-Arab is formed by the confluence of the Tigris and Euphrates at Qurnah it therefore has an enormous catchment area including most of Iraq and parts of Syria, Turkey, and Iran. The total basin area amounts to 808,000 km^2.

From Qurnah the river flows in a wide valley in a south-easterly direction. On its way from Qurnah to the Gulf at Fao, further water is received from the Hammar marsh via the Shafi, Omaitsh and Garmet Ali drains, and from Huwiza marsh via the Swaib channel, (see sects. 4.2 and 5.2). There is also one main tributary, the Karun river which comes from the east and joins the Shat Al-Arab in its southern section (see Fig. 6.2).

The total length of the river from Qurnah to Fao is 195 km, and its width ranges from 400 m at the upper reach to 1500 m at its mouth. Its depth also varies from 8 m in the northern section to

Fig 6·2 The Shat Al-Arab River



Source: Ministry of Irrigation, Directorate of Dams and Reservoirs, local map of the Shat Al-Arab, Scale 1:100000, No. 1631, Baghdad, March 1975

22 m near Fao. This river becomes the international border between Iraq and Iran 6 km north of the Karun river confluence.

The Karun river which lies entirely in the territory of Iran originates from the Zagros mountains and is fed by numerous tributaries of which the Diz is the largest. It has a total basin area of 63200 km^2. The annual discharge of the Karun river at Ahwaz is 762 cumecs of which 60% is discharged into the Shat Al-Arab and the other 40% is discharged directly into the Gulf by the Bahmusher channel.(2)

6.2.1.1 The Water discharges: The hydrological regime of the Shat Al-Arab is directly associated with the water regime of the Tigris, Euphrates and the Karun river. Downstream from Qurnah about 57.5% of the Shat Al-Arab water is from the Euphrates and 42.5% from the Tigris. At Fao gauge the volume of the Shat Al-Arab water has been boosted by the Karun river, which accounts for 33.3% of the volume.

Figure 6.3 shows that the mean annual discharge of the Shat Al-Arab at Maqil for the period 1952 to 1967 was 665 cumecs.(3) Unfortunately there is no available data for water discharge for the same period at the other gauges i.e. Swaib, Fao and Karun outlet. The only common year is 1978 for Maqil and Swaib and from 1948 to 1960 for the Karun outlet.

Table 6.1 and figure 6.4 show that the water discharge of the Shat Al-Arab increases downstream due to the increasing numbers of tributary channels discharging into the river. Downstream from Qurnah the water discharge of the river is 487 cumecs, increasing to 584 cumecs downstream of Swaib channel. This quantity further increases to 919 cumecs at Maqil and it reaches 1377 cumecs at Fao.

Table 6.1 : Mean monthly water discharge (cumecs)

Gauge	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
Shat Al-Arab d/s Swaib 1978 (1)	224	228	315	463	577	687	815	924	969	862	562	392	584
Shat Al-Arab at Maqil 1978 (2)	230	317	495	797	916	1082	1191	1313	1506	1463	963	653	919
Karun outlet 1948 - 1960 (3)	130	170	370	410	490	910	1060	880	480	300	180	170	458

Source: (1) Polservice Co., The Shat Al-Arab project, Surface Water Study, Vol.VII, part A, Basrah, 1978, p.49.

(2) Ibid, ibid.

(3) The Highest Agricultural Committee, Water Budget of Iraq, Study No.1-1, Baghdad, 1977, Table no.4.(in Arabic).

Fig 6·3 WATER DISCHARGES OF THE SHAT AL-ARAB AT MAQIL 1952-1967

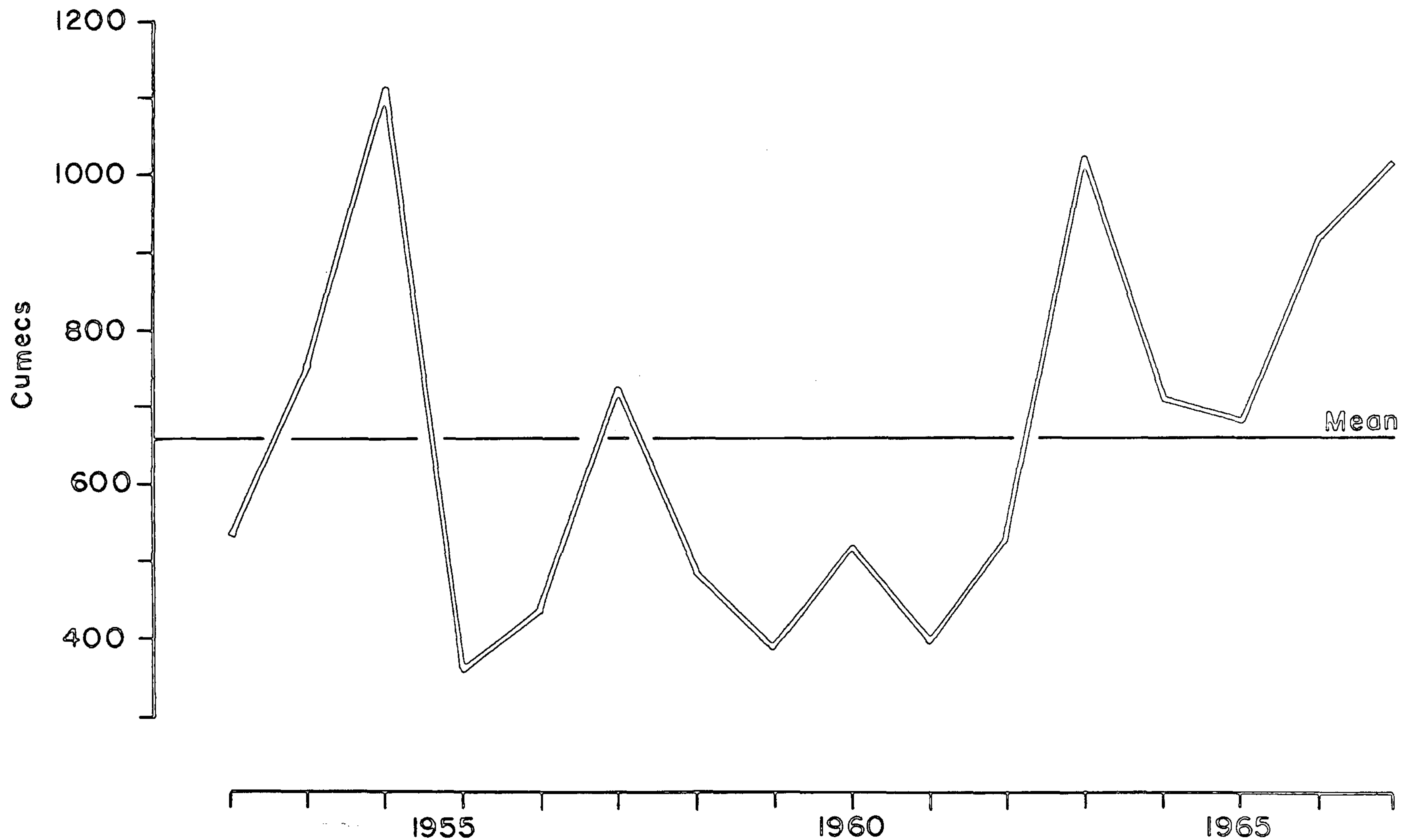
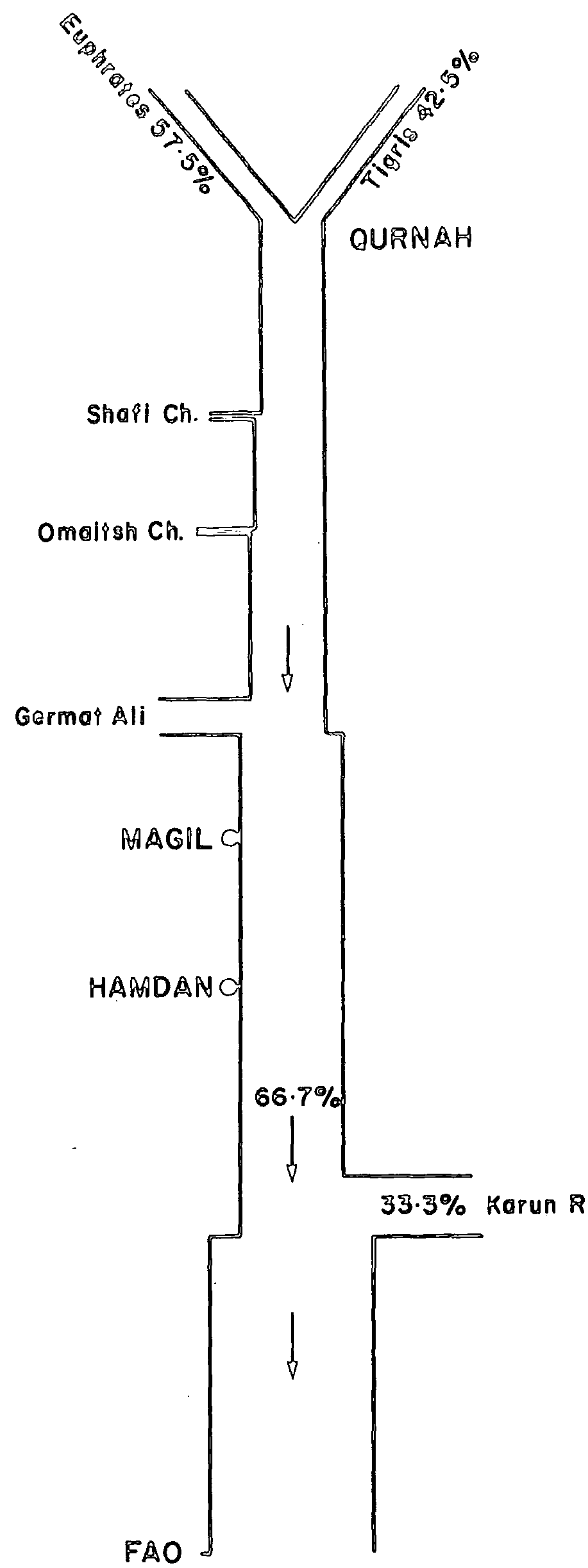


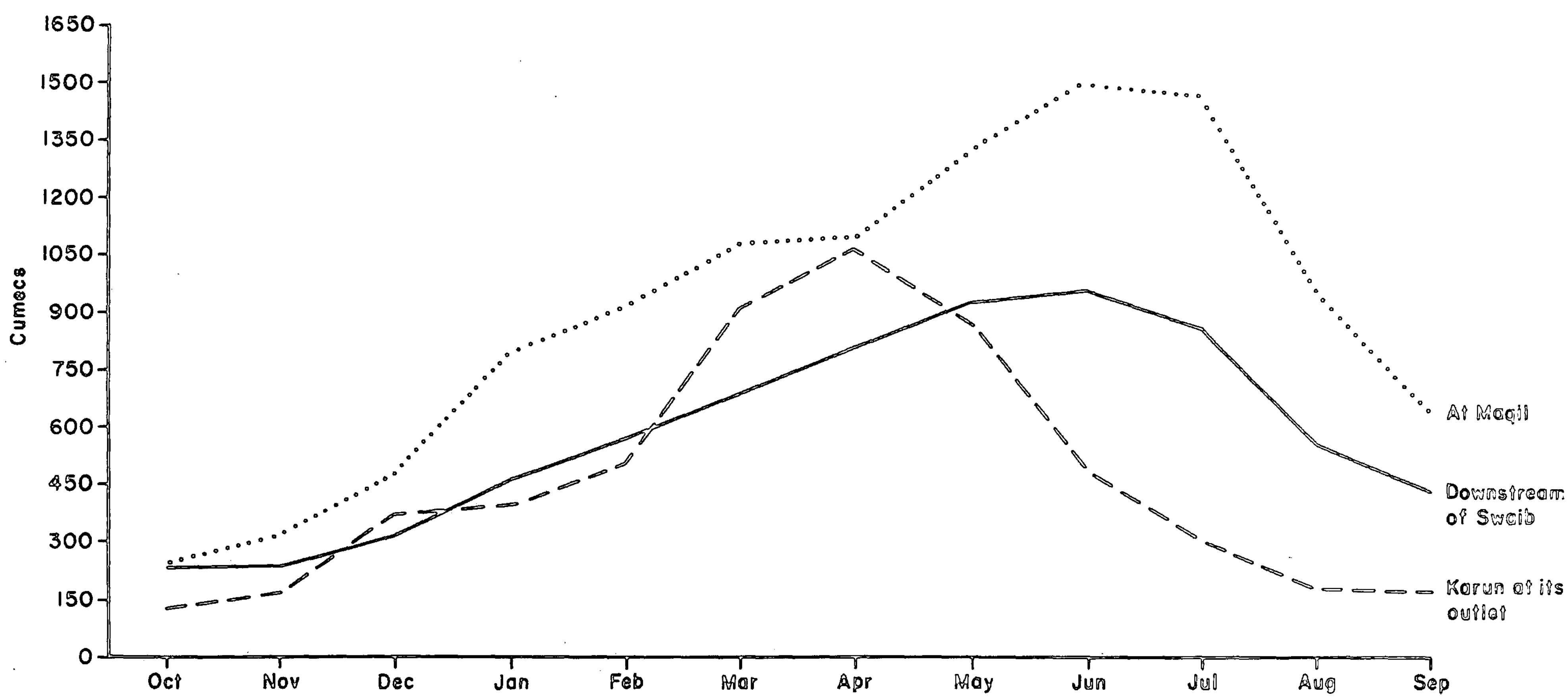
Fig 6·4 The Shat Al-Arab Water Discharges



The discharge of the Shat Al-Arab has decreased recently due to the various river control and storage works in the upper sections of the Tigris and the Euphrates, (see sect. 2.2.1.2) and those constructed on the Karun river and its tributaries such as Diz dam and reservoir which has a storage capacity of 3.3 milliard m^3. Moreover, it is planned to construct another nine dams and reservoirs on the Karun and its tributaries with a total storage capacity of 18.9 milliard m^3. This will decrease the water discharge of the Karun into the Shat Al-Arab to about 220 cumecs, (4) and also have an adverse effect on the water salinity of the Shat Al-Arab, (see sect. 6.2.1.4).

The water discharge of the Shat Al-Arab varies annually according to the amount of precipitation in its catchment area. In flood years such as 1946 and 1969 the mean discharge at Maqil increased to more than 4500 cumecs and in dry years, e.g. 1971 and 1972, it decreased to about 363 cumecs.(5) However, there is also a seasonal variation in keeping with the seasonal variations of the water discharges of the Tigris, Euphrates and Karun. Table 6.1 and Figure 6.5 show that the discharge of the Shat Al-Arab at downstream Swaib increases gradually from January and reaches its peak in May and June at 924 and 969 cumecs respectively. This is due to the flood peak of the last sections of the Tigris and the Euphrates occurring in these months, (see sects. 4.2 and 5.2). At Maqil the flood peak takes place later, in June and July at 1506 and 1463 cumecs respectively. This is because of the effect of the Germat Ali water discharge which reaches the peak in June and July, (see sect. 5.2). At Fao the flood peak of the Shat Al-Arab is affected by the Karun water regime, and occurs early in April and May with 2251 and 2193 cumecs respectively, (see Table 6.1).

Fig 6·5 Mean Monthly Discharges of the Shat Al-Arab and the Karun River



The lowest water discharge of the Shat Al-Arab at downstream Swaib, Maqil and Fao occurs in OCtober, 224, 230 and 360 cumecs respectively.

It should be noted that the continuous increase of water abstraction from the Tigris, Euphrates and the Karun river has caused not only a decrease in the Shat Al-Arab water discharge but also has increased its salinity. The Shat Al-Arab water discharge volume in turn affects the degree of mixing between the Gulf and the Shat Al-Arab waters in that when the discharge of the Shat Al-Arab decreases the mixing of the new water with the saline water of the Gulf also decreases and a large stream wedge of saline water moves far upstream. Measurements on the Shat Al-Arab at Fao were carried out by the Iraqi Port Administration in the period from 1970 to 1972. Calculation of the degree of mixing between these waters showed that during the flood seasons the waters are partly mixed or even well mixed, (see table 6.2).

Additionally, the distance of tidal movement penetration upstream into the Shat Al-Arab and the tributaries depends on its water discharge i.e. the penetration increases in the dry seasons and decreases in the flood seasons. For example, on the 24th of June 1978 when the water discharge of the Shat Al-Arab at Maqil was 1961 cumecs, a wedge of Gulf water moved upstream in the river to within 5 km of Fao. However, on the 16th September in the same year when the water discharge of the Shat Al-Arab at Maqil was 886 cumecs, the saline wedge from the Gulf penetrated into the river to about 14 km from Fao.(6) This in turn means that, in future, when the proposed hydraulic structure and irrigation projects are completed on the Tigris, Euphrates and the Karun river, the Gulf saline water will penetrate further up into the Shat Al-Arab.

Table 6.2 : Degree of Mixing between the Gulf and the Shat Al-Arab waters

Date	Classification of mixing		
25.1.1970	The waters are highly stratified		
29.3.1970	"	"	"
25.5.1970	"	"	"
29.7.1970	"	"	"
3.9.1970	"	partly mixed	
3.11.1970	"	"	"
13.12.1970	"	"	"
24.6.1971	"	highly stratified	
24.1.1972	"	partly mixed	
4.3.1972	"	highly stratified	
11.11.72	"	"	"

Source : Polservice Co., Study of Salinity problem, Vol.VIII, part A, p.17.

6.2.1.2 The water levels : The Shat Al-Arab water levels are also influenced by the interplay between the water discharges of its tributaries and the tidal ebb and flow movements which occur in the Gulf.

Table 6.3 shows that during the flood seasons the water levels are generally high, the highest level downstream of Swaib channel in April is 0.97 m G.T.S. and at Maqil in June, 1.89 m G.T.S. The lowest water level is found at downstream of Swaib in October at 0.27 m G.T.S. and at Maqil in December at 0.41 m G.T.S.

The tidal movements in the Shat Al-Arab are indicated by a twice daily rise and fall, the daily tidal cycle being 24 hours and 50 minutes. The mean tide water level at Fao and Maqil during the flood season is approximately 3.0 m and 1.5 m respectively, whilst in the dry seasons they increase to 3.1 m and 1.9 m respectively due to a decrease in the water discharge of the Shat Al-Arab in these seasons. This variation of the water levels between tides and ebbs is very important for irrigation and drainage purposes in this region as will be explained below (sect. 6.9). The mean lowest water level of the Shat Al-Arab for the period from 1930 to 1978 at Fao and Maqil was -1.78 and -1.16 m G.T.S. respectively and the mean highest level in the same period was 1.87 and 1.70 m G.T.S. respectively.(7) However, the extreme highest tide level was 2.08 and 2.50 m G.T.S. respectively and the extreme lowest ebb level at Fao was -2.15 m G.T.S. and at Maqil -1.68 m G.T.S. Generally, in the flood season the average difference between ebb and tide at Fao and Maqil is 2.96 and 1.43 m respectively, whilst in the dry season the average difference is 3.11 and 1.93 m respectively.(8)

Table 6.3 : Water levels of the Shat Al-Arab 1977-1978 (m GTS)

Gauge	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Oct.	Nov.	Dec.
d/s Swaib mean level	0.63	0.62	0.91	0.97	0.83	0.89	0.71	0.53	0.38	0.27	0.36	0.52
Maqil mean level	0.95	1.15	1.42	1.60	1.81	1.89	1.79	1.35	1.oo	0.77	0.50	0.41

Source: Polservice Co. Shat Al-Arab Project, The Hydrological Investigation of the Shat Al-Arab, Annual Report, Vol.11, part B, Basrah, 1978, p. 11B-14.

6.2.1.3 Suspended sediments : Although the Tigris and the Euphrates deposit most of their sediments in the marsh areas before they reach the Shat Al-Arab, large amounts remain to be carried by this river every year. The Iraqi Port Authority estimated these quantities to be more than 4 million cubic metres, 2 to 3 million cubic metres being brought by the Karun river.(9) However, the presence of many longitudinal islands, and sedimentary bars in the Shat Al-Arab, as well as the great amount of sediment dredged from the lower section of the river every year, about 3 million cubic metres, are clear evidence of the quantities involved.

6.2.1.4 Water quality : Tables 6.4 and 6.5 show that the average Ec value of the Shat Al-Arab water increases southward, with a mean of 1.640 mmhos/cm at downstream Swaib and 2.031 mmhos/cm at Maqil. This is due to the saline water discharged into the Shat Al-Arab by Shafi, Omaitsh and Garmet Ali, (see sects. 4.2 and 5.2). The mean of 2.031 mmhos/cm at Maqil for the period November 1977 to October 1978 is considerably higher than that for the same gauge 20 years previously, in 1957 the mean Ec was 1.273 mmhos/cm.(10) This increase can be attributed to the growing number of upstream drainage projects in the central and southern parts of Iraq which eventually return charged into the Shat Al-Arab, (see sect.2.2.3). At Fao there is no available data on water salinity for 1978 but the average Ec of the Shat Al-Arab water at this gauge during the period 1967-1969 was 2.947 mmhos/cm.(11) However, at the present, it is expected that the salinity in this gauge is higher than the above average due to an assumed reduction in water discharge and the increasing intrusion of the Gulf saline water which has an Ec of 46.875 mmhos/cm,(12) this in addition to the saline drainage water

Table 6.4[1] : Chemical Analysis of the Shat Al-Arab d/s Swaib 1977-1978

Date	Ec mmhos/cm	pH	Na me/L	Ca me/L	Mg me/L	Cl me/L	HCo_3 me/L	Co_3 me/L	So_4 me/L
2.11.1977	2.202	8.0	10.4	4.4	7.6	10.6	3.2	0.2	10.0
27.12.77	2.464	7.5	9.4	6.1	5.4	12.3	3.5	0.2	11.7
7.1. 78	1.811	7.9	6.9	4.6	7.6	8.7	3.7	0.2	8.5
1.2. 78	2.008	7.7	7.3	4.8	2.8	8.4	4.4	nil	7.9
7.3. 78	1.321	7.6	5.1	4.2	5.4	5.7	3.6	0.6	8.5
19.4.78	1.080	8.5	3.7	4.1	2.3	3.9	4.2	nil	8.0
9. 5.78	9.00	8.4	3.5	4.7	4.0	3.4	4.2	"	7.5
7. 6.78	0.882	8.5	3.1	1.4	3.4	2.8	4.2	"	6.3
10. 7.78	0.818	8.3	2.7	3.1	3.2	3.0	3.4	"	4.9
7. 8.78	0.941	7.6	3.7	5.4	3.2	4.2	4.0	"	6.3
6. 9.78	1.392	8.0	5.2	4.0	4.2	6.3	4.6	"	5.7
3.10.78	1.888	7.8	7.7	5.5	6.6	8.9	3.9	"	9.5
Mean	1.640	7.9	5.7	4.3	4.6	6.5	3.9	0.1	7.9

Table 6.5[2] : Chemical Analysis of the Shat Al-Arab water at Maqil 1977-1978

29.11.77	2.788	8.1	10.6	6.2	5.9	15.1	2.5	0.4	11.5
29.12.77	2.399	7.7	9.5	5.9	4.6	12.1	3.3	0.7	13.8
14. 1.78	2.481	7.7	10.0	4.9	4.3	14.3	3.2	nil	13.8
12. 2.78	2.429	7.8	9.1	5.1	5.1	13.5	2.5	0.1	3.4
11. 3.78	1.762	7.5	7.5	5.1	2.0	9.0	3.7	nil	9.4
12. 4.78	2.180	8.4	9.2	5.0	6.5	11.8	2.7	"	11.9
16.5. 78	2.270	8.3	13.4	7.8	9.5	16.3	2.8	"	12.9
15.6. 78	1.932	7.8	8.2	4.7	6.5	8.9	2.4	"	12.5
29.7. 78	1.718	8.2	6.6	3.6	4.8	8.1	1.5	"	7.1
15.8. 78	2.186	7.7	10.4	4.4	8.9	11.9	2.4	"	10.6
13.9 78	1.883	8.2	8.2	4.7	5.8	9.3	5.1	"	7.2
10.10.78	2.773	7.8	11.8	5.8	10.9	11.7	2.5	"	13.8
Mean	2.031	7.9	9.5	5.2	6.7	11.8	2.8	0.1	10.6

Source: (1) Polservice Co. Shat Al-Arab Project, Hydrological Investigation on Surface Water, Annual Report, Vol.11, part B. Basrah, 1978, pp.118-168.

(2) Ibid, p.175.

from the canals which join the river on both sides along its course. According to the U.S.D.A. (1958) salinity classification of irrigation water, in the upper and central reaches the Shat Al-Arab is considered medium to high salinity class 3. This water should be used only on soils of moderate to good permeability. Regular leaching is usually needed to prevent serious salinity, special management for salinity control will often be needed, and plants with moderate to good salt tolerance should be selected. However, the river water in the lower section can be regarded as high salinity class 4. This water can only be used for irrigation on soils of good permeability and where special leaching is provided to remove excess salts. Only salt-tolerant crops should be grown.

The Ec values of the Shat Al-Arab water have a seasonal variation according to the water discharges i.e. they increase in the dry seasons and decrease in the flood season. Downstream of Swaib the Ec reaches its highest value in December at 2.46 mmhos/cm and at Maqil in November at 2.788 mmhos/cm. At both gauges the Ec decreases to the lowest values in July at 0.818 and 1.718 mmhos/cm respectively.

The sodium percentage of the Shat Al-Arab water downstream of Swaib is 39.1% increasing to 45.4% at Maqil because the water discharged into the Shat Al-Arab from Shafi, Omaitsh and Garmet Ali has a high sodium content, (see sects. 4.2 and 5.2). According to the sodium percentage classification suggested by Wilcox (1955), the Shat Al-Arab water downstream of Swaib is considered as good for irrigation purposes whilst at Maqil it is regarded as only just permissible. The SAR value of the Shat Al-Arab downstream of Swaib is 2.7 increasing to 3.9 at Maqil and further increasing to 7.8 at Fao in 1967-1969. According to U.S. Salinity Laboratory Staff (1954) criteria, see Sect. 2.2.1.1.5, the Shat Al-Arab waters are considered as having low sodium hazard.

This water can be used on almost all soils with a little danger of accumulation of harmful amounts of exchangeable sodium if provided with adequate drainage.

The SAR values vary from one season to another. In the flood season at downstream of Swaib and Maqil they reach 1.5 and 3.2 respectively whilst in the dry season they increase to 4.3 and 4.4 respectively.

The R.S.C. of the Shat Al-Arab water is about 1.0 me/L which according to the Eaton criteria (1950) may be regarded as safe for irrigation throughout the year. The average pH value is 7.9.

Sodium content of the Shat Al-Arab downstream of Swaib 5.7 me/L somewhat higher than calcium at 4.3 me/L and magnesium at 4.6 me/L. Sulphate is the predominant anion at 7.9 me/L, with subsidiary chloride at 6.5 me/L and bicarbonate at 3.9 me/L. At Maqil sodium remains the dominant cation at 9.5 me/L but sulphate is replaced by chloride as the dominant anion at 11.8 me/L compared to 10.6 me/L for sulphate. Boron concentration in the Shat Al-Arab water has been shown in a previous study to be of no danger to all semi-tolerant nearly all boron sensitive plants.[13]

Thus from the preceding discussions it can be seen that both the water discharge and quality of the Shat Al-Arab vary seasonally and spatially. In the flood seasons the discharge increases and the salinity decreases while the reverse is true in the dry seasons. Additionally, the average differences between tide and ebb in the flood and dry seasons is 2.19 and 2.52 m. respectively.

6.2.2 Groundwater

Generally, groundwater in this region is abundant and shallow particularly in the western lowlands. This is because firstly, the groundwater of the Mesopotamian plain flows in a southward direction through this region on its way to discharge into the Gulf, (see sect. 2.2.4). Secondly, a part of the groundwater in the Zubair desert flows eastwards towards this region, (see sect. 3.4) and thirdly, the groundwater in this region is replenished continually by the Hammar marsh and the Shat Al-Arab and its tributaries.

Consequently, the groundwater level is found at shallow depths ranging from the ground surface in the western lowlands to a depth of 2.5 m in the Shat Al-Arab banks and the eastern areas.[(14)] The seasonal fluctuation in the groundwater level is affected by the water level in the Shat Al-Arab and its tributaries, thus, it rises in the flood season and falls in the dry seasons. Generally, the amplitude of the fluctuation of the groundwater table in the irrigated levee soils which are affected by tidal movements ranges from 0.41 to 0.69 m and in the surrounding area from 0.82 to 1.24 m.[(15)]

As the Shat Al-Arab is the main source of replenishment for the groundwater, salinity of this water is lowest near the river and increases in the surrounding lowlands. The average Ec values near the river range from 8000 to 14000 mmhos/cm and increases in the surrounding areas to between 36000 and 54000 mmhos/cm.[(16)] According to the U.S.D.A. (1953) classification the groundwater in this region is considered as being excessively saline and should not be used for irrigation.

The groundwater salinity varies from season to season according to the variation of the water replenishment from the sources mentioned above. During the flood seasons in the levees area the Ec value falls to between 6000 and 12000 mmhos/cm and increases in the dry season to range from 10000 to 27000 mmhos/cm. In the surrounding areas the Ec also falls in the flood seasons to between 28000 and 76000 mmhos/cm.[(17)] The high salinity and shallow level of the groundwater in the lowland areas causes salinisation and waterlogging of their soils as explained later in section 6.9.

Thus, the water resources in the region whilst being naturally extensive in volume are severely restricted by salinity levels, rendering the groundwater of no use for irrigation. Hence the only suitable water resources for irrigation are the surface waters of the Shat Al-Arab and its tributaries.

6.3 SOIL CONDITIONS

Soils of this region are formed from alluvium brought by the Tigris, Euphrates, Shat Al-Arab and Karun rivers which have built up the Mesopotamian Plain. Although these soils have similar characteristics to those of the rest of the Mesopotamian Plain, they have been adversely affected by the flooding from the Shat Al-Arab, the Hammar and Huwiza marshes and the Khor Az-Zubair. A combination of high evaporation rates, flooding, the capillary rise of saline groundwater and poor drainage results in the majority of the soils in this region being saline.

Two groups of soils can be distinguished : irrigated and abandoned with characteristics dependant upon location, salinity and the source of the sediments.

6.3.1 The irrigated soils

These soils are found in a narrow belt on both sides of the Shat Al-Arab, see figure 6.6, the width of the belt ranging from 0.5 to 20 km. These soils are developed on the river levees formed from sediments deposited by the Shat Al-Arab and its tributary, the Karun river and as such they occupy areas that are slightly raised above the general level of the surrounding plain.

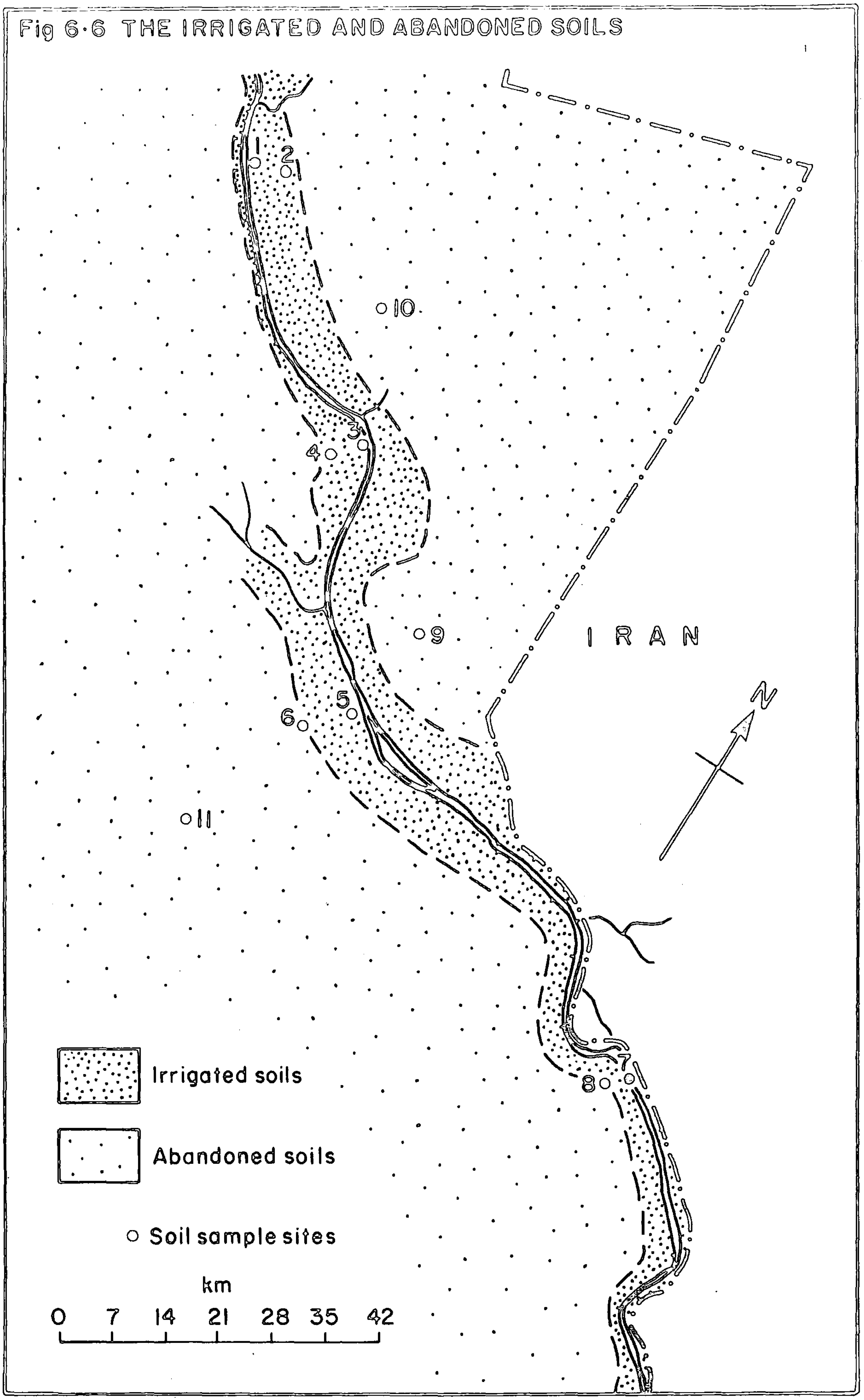


Fig 6·6 THE IRRIGATED AND ABANDONED SOILS
2
10
3
4
9
IRAN
N
5
6
11
7
8
Irrigated soils
Abandoned soils
Soil sample sites
km
0 7 14 21 28 35 42

6.3.1.1 Physical properties : Soil samples 1 - 8 in Appendix 6.1 were taken from different parts to show the basic soil characteristics and the effects of irrigation, (see Table 6.6).

Analysis of these samples shows that the average silt content is high at 58.9%, the clay content average is 35.3% and sand at 4.4%. Thus, these soils can be classified as silty clay loam with a moderate fine texture. Owing to the high silt and clay contents it is to be expected that the available moisture is high and air movement is low.

In the upper two metres the bulk density ranges from 1.42 to 2.679/cm^3 and the void ratio of these soils is more than $\frac{1}{3}$ of the soil volume and ranges from 0.79 to 0.88. Porosity ranges from 44% to 47%, percentages located within the general theoretical average for loamy soils which is from 35% to 55%,[18] indicating a high water holding capacity.

Infiltration rates, as measured by double ring infiltrometer range from 0.18 to 3.1 cm/h which is slow to moderate. Thus, these soils generally require an irrigation method which permits the water to remain on the soils for a long time or frequent application of small amounts of water. Permeability of these soils is about 0.48 m/day which according to the Soil Survey Manual Criteria (1951), is considered moderate, (see sect. 4.3.1).

The moisture content at field capacity of these soils ranges from 30.46 to 31.38% and at permanent wilting point between 16.70 and 17.69%. The field capacity and permanent wilting point of these soils is high compared with the general theoretical estimation for loamy soils at 5.02%.[19] Because of the high silt and clay content of these soils the available moisture is relatively high at about 13.73%.

These types of soils show stickiness, expansion and plasticity when wet and they become cloddy and cracked when dry. At field capacity, when compressed in the hand they leave a wet outline and stick to the thumb and forefinger, but leave no excess water on the hand. At wilting point these soils tend to be hard, baked, cracked and difficult to break down into powder.[20]

Although these soils are utilized in cultivation, the organic matter percentage is generally low averaging 0.82%. This is because the date palms, the main crop, add very little organic matter to the soil.

6.3.1.2 Chemical Analysis : Table 6.6 shows that the average lime ($CaCo_3$) percentage is 27.4% and it's fairly uniform at all locations. Gypsum ($CaSo_4$) percentage is 4.1% and it shows variability both within profiles and at different locations.

The average Ec value of these soils is 12.3 mmhos/cm, this however conceals variations both vertically and spatially from north to south. For example samples 1 and 2 (cultivated and marginal) in the north show top horizons Ec of 5.38 and 11.46 mmhos/cm reaching with depth 2.16 and 30.8 mmhos/cm respectively. Generally, the samples 1 - 8 show general increasing of Ec values from the north to the south and from the river levees to the marginal areas due to increased salinity of irrigation water, see sections 6.2.1.4 and 6.9. The average Ec value in the north is 7.25 mmhos/cm and in the south is 22.0 mmhos/cm and the average Ec in the banks area is 7.9 mmhos/cm and in the marginal area is 16.67 mmhos/cm, (see Table 6.6 and Fig. 6.6). According to the U.S.D.A. (1954) classification of soil salinity, these soils are generally considered moderately saline and range between slightly saline in the north and strongly saline

Table 6.6 : Summary of the Irrigated soil samples Nos 1 - 8*

Soil Sample No	Sand %	Silt %	Clay %	Gyp-sum %	Lime %	pH	Ec mmhos/cm	CEC me/100g	Ex.Na me/100g	O.M. %	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	So4 me/L	HCO3 me/L	SAR me/L	Esp %
1	6	60.4	33.6	2.2	21.6	7.8	3.39	12.2	1.69	0.81	17	13.8	0.68	14.4	16.5	28.8	2	3.6	14.2
2	3.4	59.6	37	1.8	27.2	8.0	11.17	15.3	6.7	0.44	17.6	20	2.0	122	126	42	1.4	26.7	49
3	6.4	54.0	39.6	2.15	30.2	7.5	6.15	21.6	3.52	1.38	32.8	16.8	0.1	39	41	46.7	0.8	7.8	16.2
4	3.4	59.6	37	14.5	32.12	7.9	15.29	19.5	3.79	0.47	38.4	23.2	2.2	149.2	109	103.8	0.8	26.8	19.4
5	2.6	56.6	40.6	2.6	17.8	7.7	5.44	16.8	3.11	1.14	27.2	22.4	1.0	31.2	36	45.6	1.3	5.8	18.6
6	6	49.0	35	1.8	27.4	8.1	13.1	15.3	6.7	0.44	17.6	20.0	2.0	79.7	76	42.2	1.4	18.4	43.7
7	6	68.8	25.4	6.2	38.8	7.8	16.91	16.2	5.0	0.97	46	74	3.4	87.4	149.9	58	1.6	11.2	30.8
8	1.8	63.4	34.8	2.0	24.4	8.0	27.12	11.1	3.2	0.93	52	50.4	3.6	253.8	235	125.8	1.3	35.4	28.8
Average	4.4	58.9	35.3	4.1	27.4	7.8	12.31	16	4.2	0.82	31	30	1.8	97.0	98.6	61.6	1.3	16.9	27.5

* Overall mean of all samples (40) and mean for each location).

in the south and between slightly saline but at the upper limit in the banks area and strongly saline in the marginal area but at the lower limit. The average pH value is 7.8 and it ranges between 7.7 for the soils near the river to 7.9 in the soils of the marginal area.

Even though the soils have a mean clay content of 35.3%, the average C.E.C. levels are medium at 16.0 me/100g, (see sect. 3.2.1.2). This is due in part to the low organic matter content. The average exchangeable sodium is 4.2 me/100g, but its levels are variable within and between the soil samples ranging from 0.84 to 11.2 me/100g, see samples 1 - 8. The SAR averages16.9 but variable ranging from 1.2 - 72.1. The average Esp is generally high at 27.5, though again varying considerably between 1.1 and 74.6. All the profiles sampled had at some point an Esp exceeding 15%, and all can be considered as aklakine. However, the soils farthest from the river tend to have the highest Esp. According to the U.S.D.A. classification of soils, from the viewpoint of salinity and alkalinity, soil is considered as saline - alkali if the Ec value is more than 4 mmhos/cm, the Esp value is more than 15% and the pH value is less than 8.5.[21]

The average soluble sodium content is 97 me/L which predominates over calcium and magnesium at 31 and 30 me/L respectively. The average chloride content is 98.6 me/L which predominates over sulphate and bicarbonate at 61.6 and 1.3 me/L respectively, (see Table 6.6). Boron content is sufficient for nearly all boron sensitive plants. [22]

According to the U.S.D.A. Interior Bureau of Reclamation criteria for determination of soil conditions required for profitable sustained irrigated agriculture, see section 3.2, these soils may be regarded as relatively profitable. However, in terms of the capability classification of the U.S. Bureau of Reclamation, these soils can be classed as grade 3 or 4. Grade 3 soils being found near the river where salt concentration is lower and drainage better than in the grade 4 in the marginal areas.[23]

6.4 THE NATURAL VEGETATION

The moisture, temperature and soil conditions are such that both aquatic and terrestrial plants thrive. In the irrigation canals and ditches the vegetation is dominated by bulrushes (Typha angustata), chollan (Cyperus spp.), Murran (Panicum repans) and other floating aquatic species. These reduce the water flow and increase salinity, with the overall effect of lowering the discharge capacity of the ditches and canals. In the areas between the ditches the principal natural species are Medicago spp, shok (Lagonyechiun farctums) and agool (Alhagi maurorum), and these grow vigorously in neglected areas forming obstacles to cultivation, irrigation and drainage. Removal of this vegetation requires costly manual labour.

6.5 THE CROPS

In terms of area and yield date palms are the main crop in the region, though there are small areas cultivated for vegetables and other fruit trees.

The date palm area totals 130,000 donums which is equivalent to 90% of the total cultivated area in the region and 69.5% of the province.[24] In this region there are about 6,545,000 palms,[25] which represent 30.6% of the total data palms in Iraq, and their production constitutes 11.8% of the total date production of Iraq. As well as being the highest concentration of palms in Iraq, it is reputedly the highest concentration of palms in the world.

For centuries the date palms have been cultivated by traditional methods on both sides of the Shat Al-Arab, under soil, water and management conditions which were more appropriate than at the present time, as will be explained in sections 6.8 and 6.9.

Date palms are cultivated on the ditch sides at 5 m intervals (see Fig.6.7) in an area extending from 0.400 km to 10 km on either side of the Shat Al-Arab.

The farmers in this region recognise the following stages of palm growth:

- The offshoot (Farakh) which is either still joined to the palm or just planted.
- The young palm (Nashwah) which starts to bear dates and offshoots.
- The mature palm (Rabaiya) which has ceased to bear offshoots and bears only dates.
- The old palm (Tawila) when it is tall, at about 10 to 20 m, past its prime, with low productivity and does not bear offshoots.

Climatically, date palms require a prolonged summer without rain or high humidity. Generally, they require high temperatures for good growth and fruiting, yet they have considerable cold tolerance. However, at temperatures below 9°C palm growth is negligible. The very low temperature recorded in the region from 9th to 31st January 1964 when it fell to -7°C caused damage to the offshoots and stopped palm growth.(26) Date palms blossom when the temperature does not fall below 18°C. Rainfall during pollination causes an increased incidence of a disease caused by the fungus Maugrniella schaettae and this leads to damage to the spathes of the palms. If it occurs during the ripening and fruiting stages it causes checking, blacknose,

FIGURE 6.7 : Date palms on the ditch sides

splitting and rotting of the dates and eventually decreases the quality of the dates and hence price.

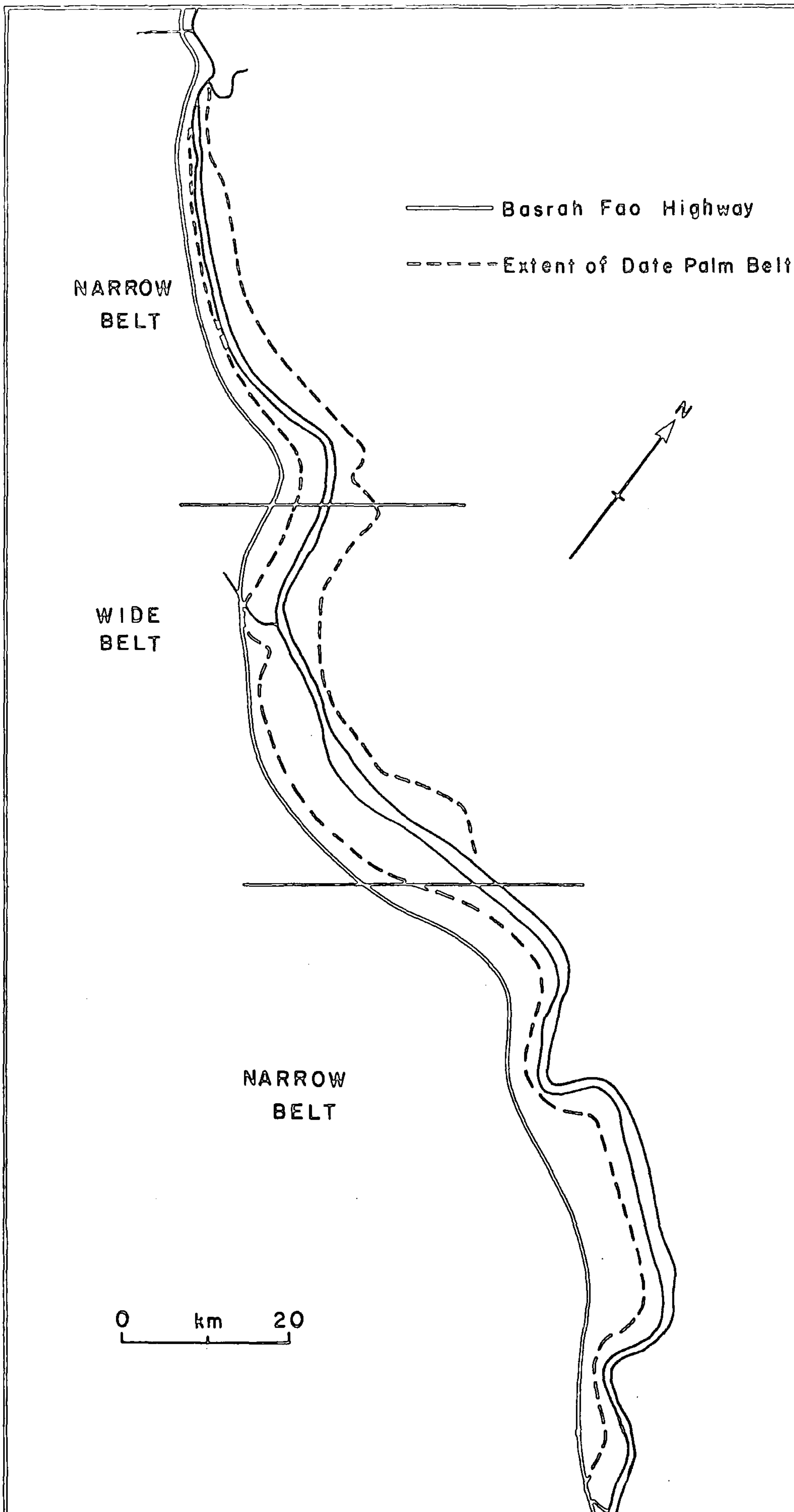
An expressive Arab proverb says that the date palm grows best "with its feet in running water and its head in the fire of heaven". Californian experiments confirm this, and showed that withholding moisture during the development and ripening period reduced the yield by 17.5%.(27) Palms growing under chronic moisture deficiency produced fewer and smaller bunches of dates which adversely affects their price. However, waterlogged soils and those which are too dry also provide unfavourable conditions. The average rooting depth of the date palm ranges from 3 to 12m, 80% of the required water being extracted from the top 2 m.(28)

The date palm can survive and grow for about 50 years with no tillage of the surrounding area whatever, yet it may not give a good yield unless the adjacent land is thoroughly cultivated.

As a result of the favourable conditions - soil, water and management - under which the date palm have been cultivated in the past in this region, their density at present ranges between 50 to 75 palms per donum. However, since the 1950s the continuous neglect of the date palm area has led to an increase in soil salinity, to the filling up of the irrigation ditches with sediments and the number of trees has continuously declined. The total area under the date palms in 1952 was 222,700 donums falling to 130,000 donums by 1978, their numbers falling from 13,360,000 to 6,560,000 during the same period.(29)

The date palm belt is located on both sides of the Shat Al-Arab, (see Fig. 6.8). However, at the western side of the northern section of the Shat Al-Arab, the belt becomes narrow and disappears in places. This is because of the annual inundation of this part

Fig. 6·8 The Date Palm Belt



by the Hammar flood water, until the construction of embankments in the 1970s. In the southern sections, the belt is also narrow due to reduced sedimentation of the Shat Al-Arab which leads to lower and narrower levees on which the date palms are cultivated. There is also the additional problem of the tide water from the Gulf which floods the lowlands adjacent to these levées.

6.6 MANAGEMENT

The level of management of the date palm holdings in this region is best assessed through a discussion of the socio-economic and educational status of the farmers, the overall effectiveness of the management being reflected in the soil salinity and crop yields, (see sects. 6.11 and 6.12).

6.6.1 Socio-economic status

Most people in this region, as in other rural areas, live in large extended family units, the members of which live in close proximity to each other. Therefore, it can be said primarily that there is a considerable potential labour force available for palm cultivation and management. However, the majority of this potential labour pool is drawn to the nearby cities of Basrah, Qurnah, Abu Al-Khaseeb and Fao where many urban unskilled and skilled jobs are available and pay higher wages than agriculture. As a result of the ease of communications, the workers are able to work in these cities and still live in the rural area.

Although the region's population continues to grow, the number of farmers has fallen from 260,282 in 1957 to 167,094 in 1970[30] as the result of migration out of agriculture. At the present time only 15% of the agricultural workers in this region are engaged with date palms,(31) and as investigations in this region have shown, only the old men and school children now work in date palm gardens. Women are responsible for the gathering of dates and their transfer to the stores during the harvest period when more labour is required than at other times, but otherwise do not contribute to the husbandry.

Date palm holdings in this region vary from less than one to two hundred donums. The smallest holdings are in the central section whilst the largest are in the northern and southern areas. This is because the central section contains the oldest palm cultivation area in the region, which has been sub divided into small holdings as a result of the complex historical relationships between the cultivators and the landowners. The number of holdings in 1977 was 23,984, the majority of them private, equivalent to 75% of the total holdings, the other 25% being government owned.(32)

Because of the attraction of the city jobs, most of these farms have been neglected for the last three decades. Additionally, management of the date palms requires a high labour input which is not only costly but now rarely available; coupled with this is the complicated traditional relationships between the cultivator farmers and the owners, according to which the farmers obtain only 20% to 50% of the total date yield.(33) These factors have resulted in the expansion of neglected areas, reaching 86,840 donums in 1978 equivalent to 66.8% of the total date palm area. Some of these neglected areas belong to absentee landlords who live in the cities of Basrah, Zubair or even in Kuwait or Saudi Arabia and they visit their holdings only for a few days per year. It is not only private landowners who are guilty of neglect since about 3,000 donums of these areas are attached to the Ministry of Finance, 31,409 donums attached to the Ministry of

Agriculture, 3,063 donums under the supervision of Waqif Ministry and the other 3,169 donums under supervision of Incapable Properties Office.(34)

6.6.2 Educational Status

The farmers in this region depend mainly on traditional practices in the management of the date palm. The majority of the literate men can find alternative work thus leaving mainly illiterate and elderly workers to manage the date palms, obviously an unsuitable base for a commercially sound agriculture. The farmers have inherited a network of irrigation and drainage systems from their forefathers according to which the date palms are irrigated and drained naturally with only minimal and regular maintenance of the system, (see sect. 6.9). However, during recent years due to the scarcity of labour, this system has been gradually neglected. There have been no improvements made nor any noticeable new areas taken into cultivation and traditional methods of management are still followed.

Farmers now appear to concentrate on the quantity of palms and not the quality of dates. This has led to the crowding of trees, retention of large numbers of old palms which are unproductive, the filling up of the ditches in the marginal areas, lack of tillage of the earth between the palms, salt accumulation, poor drainage and lack of insect and disease control. These problems cause a further decrease in both the number of palms and their yields.

All cultivation and harvesting operations are carried out manually, using primitive hand tools for pollination, thinning, cutting of the fronds and their bases and picking the dates, etc. These operations require a high labour input by workers who demand relatively high wages. According to the farmers who were questioned about the absence of machine tools, alleged that landowners were not willing to provide them and that in any case the particular operations need machines of a special design to cope with the intersected areas, (see sect. 6.8). The technical advantage of using some machinery is clear, each worker in this region can manually pollinate 600 to 700 palms in 45 days at a cost of ID 0.094 (£0.16) for each palm in 1980, whilst a pollination machine can pollinate 3,750 palms in the same period at a cost of about ID 0.020(£0.036) for each palm. [35]

Nevertheless, the farmers in this region realize the need for heavy irrigation by fresh water in order to ensure a high yield, for tillage and the avoidance of using saline drainage water, but lack of investment and labour prevents them from ensuring that these practices are upheld.

It is clear from the foregoing that the data palm areas are suffering from neglect and poor management; traditional labour intensive methods of cultivation are still the only ones used even though skilled labour is scarce. The results are to be seen in the decreased quantity and quality of the crop, (see sect. 6.11).

6.7 CONSUMPTIVE USE OF WATER

As long as this area can be irrigated naturally with little effort, the accurate calculation of the consumptive use of water for the date palm area is relatively unimportant. However, it will be significant in the future when the plan to change to pumped or drip irrigation systems is implemented.

The irrigation system in this region consists of many canals and ditches, (see sect. 6.8). The total area of these ditches and canals is about 27,040 donums which equals 20.8% of the total cultivated area of the date palms. This high percentage must be excluded in calculations of the consumptive use. Table 6.7 shows that the theoretical total water required to irrigate the date palm is 7,780 m^3 per donum per year. However, in Abadan area, in Iran on the eastern side of the lower section of the Shat Al-Arab, experiment shows that the total consumptive use for the date palms is some 2350 m^3 per donum per year. (36) This is considered more reliable

Table 6.7 The theoretical consumptive use (mm)

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
148.3	148.3	148.3	148.3	148.3	296.2	296.2	296.2	444.8	444.8	593.2	296.2	3262

Source: The Higher Agricultural Committee, Aggregation of the Irrigation Methods, Baghdad, Al-ershad, 1977, p.44.

than in Table 6.7 which however shows that the consumptive use varies from season to season due to variations in the temperature, wind speed, etc. Generally, its values increase in summer - during June, July and August - in which the water required is equivalent to 47% of the total quantity. The lowest amount is required during the period from October to March.

6.8 THE DISTRIBUTION SYSTEM

Some fifteen centuries ago, the ancient people in this region utilized the tidal ebb and flow phenomena by establishing a well-engineered constant distribution system for water, (see sect.6.13.2). This system has been maintained until recently in the now cultivated lands by continuous cleaning of canals and ditches, those which have not been cleaned being filled up by sediments.

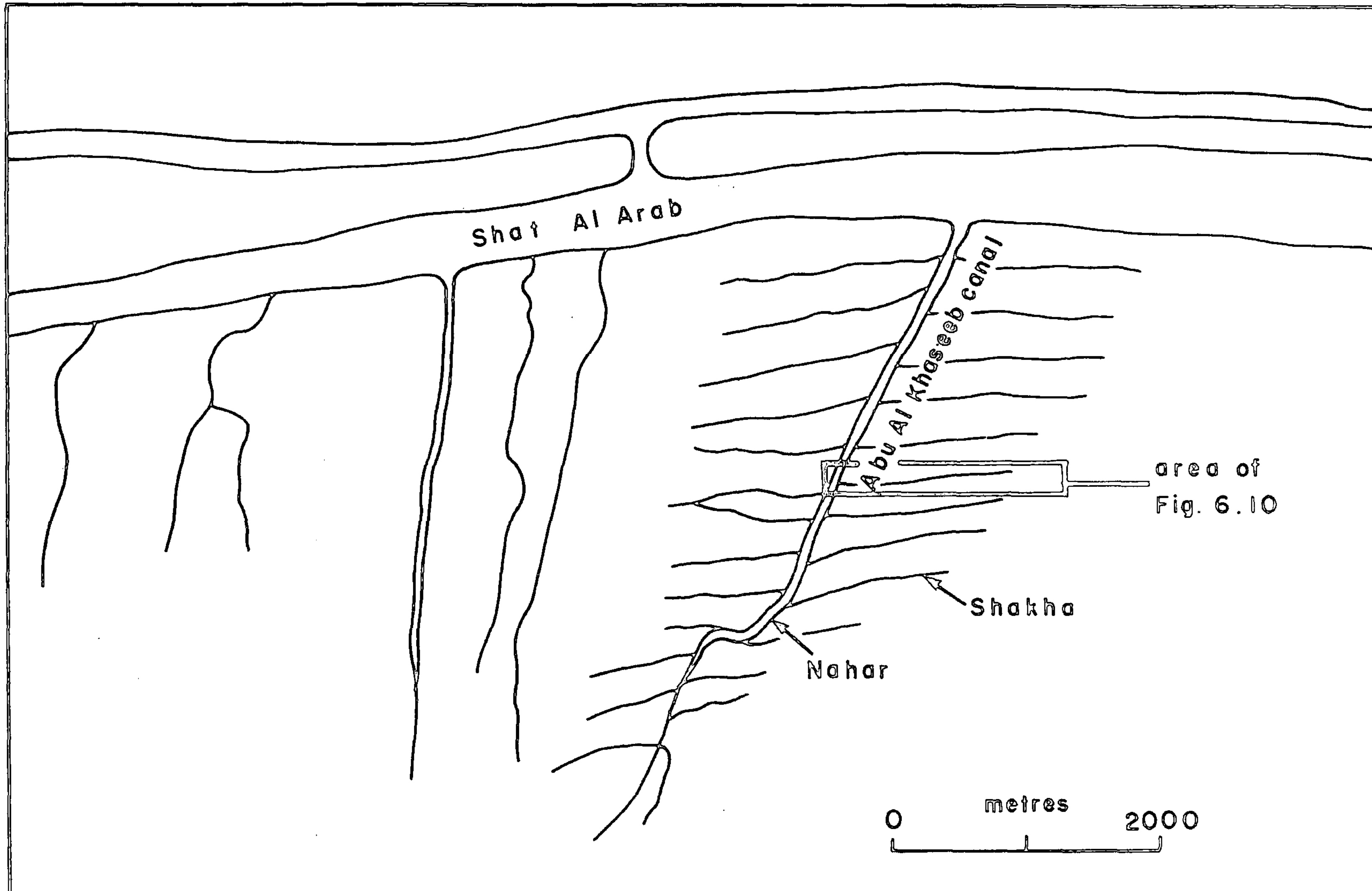
The system consists of main canals branching at right angles from the Shat Al-Arab. There are some 635 canals, of which 165 are on the eastern side of the river and the rest, 470 canals, on the western side. These canals can be classified into two groups : First, there are those called locally nehran (the singular naher means river). Their length ranges from 4 to 8 km, 5 to 43 m in width and 5 to 3 m in depth. The second group are called locally shwayikh (the singular shakha meaning small river). They range from 1 to 4 km long, 3 to 14 m in width and 4 to 2 m in depth,(see Fig. 6.9). Many smaller canals called locally abwat (the singular abu means father) also branch at right angles from the main canals. Their length ranges from 200 to 700 m, 2 to 3 m in width and the average depth is 2 m. Finally, smaller ditches called esaba' (the singular esba' means finger) branch from the abwat at right angles. Their length ranges from 5 to 12 m, 1.5 to 2 m in depth and 1.5 m as average width and they are 6 to 10 m apart, (see Figs. 6.3, 6.9 and 6.10).

These canals and ditches were excavated manually between the 7th and 12th centuries when labour was plentiful and cheap, see section 7.6.13, and they were called by names of their excavators or the places through which they pass. Typically, the area occupied per donum by these ditches and canals is 520 m^2 on 20.8% of the total area cultivated under the date palms in the region.

All of these canals and ditches are connected with each other by an accurate engineering system of gradients allowing them to fill up by water during the flowing tide and serving as drains during the ebb

The general slope of these canals is towards the Shat Al-Arab and their gradient ranges from 2 to 4 cm per 100 m. In other words these canals slope in an opposite direction to the general slope of the ground surface from the river banks to the farthest areas, (see Fig.6.11).

Fig. 6·9 Local Map for Abu Al Khaseeb Canal



Basrah Irrigation Area, Nasiriyah Irrigation Area, local map for cleaning of Abu Al Khaseeb river, n.d., scale 1:50000

Fig. 6·10 Canal(A) and Abu and ditches

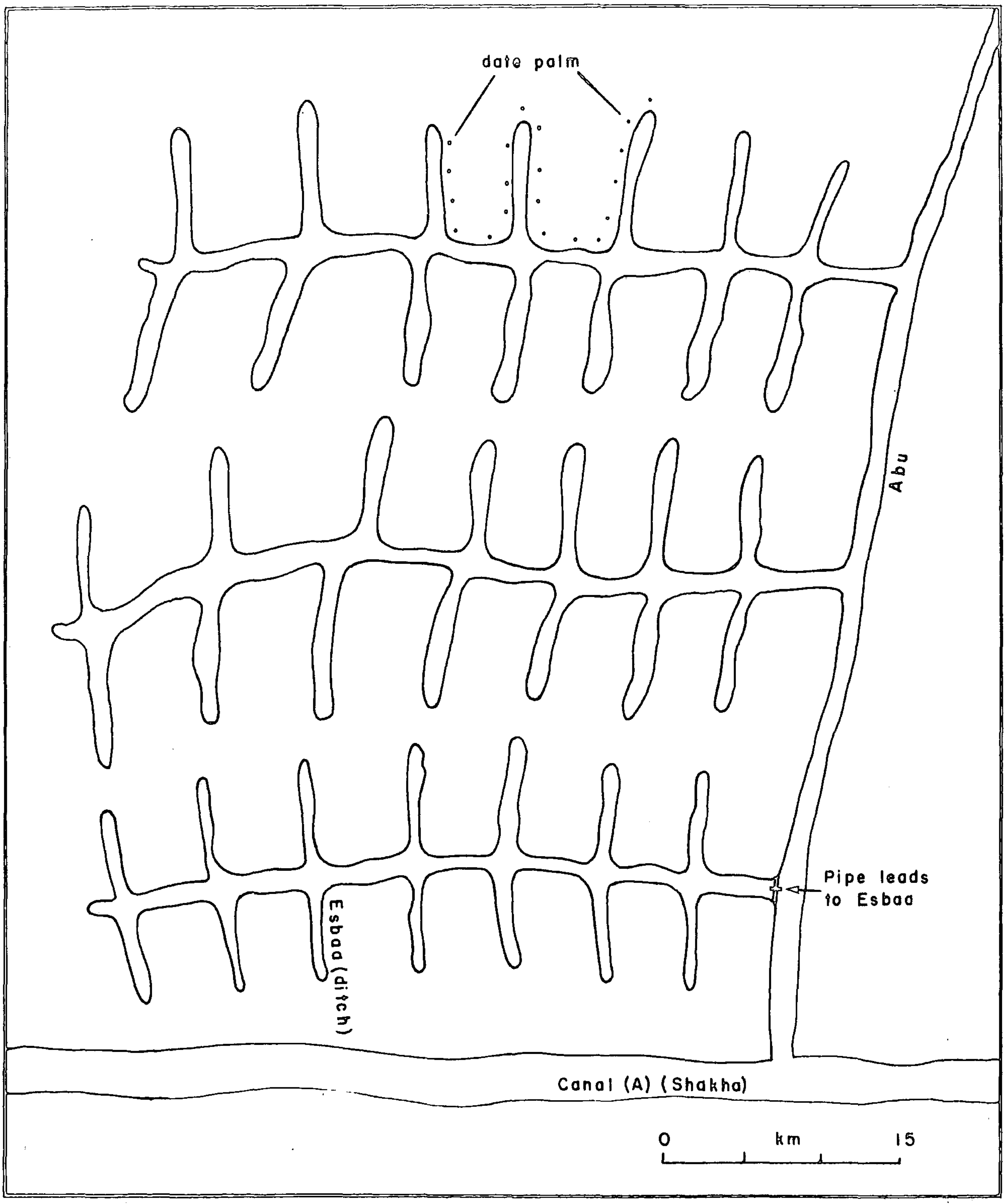
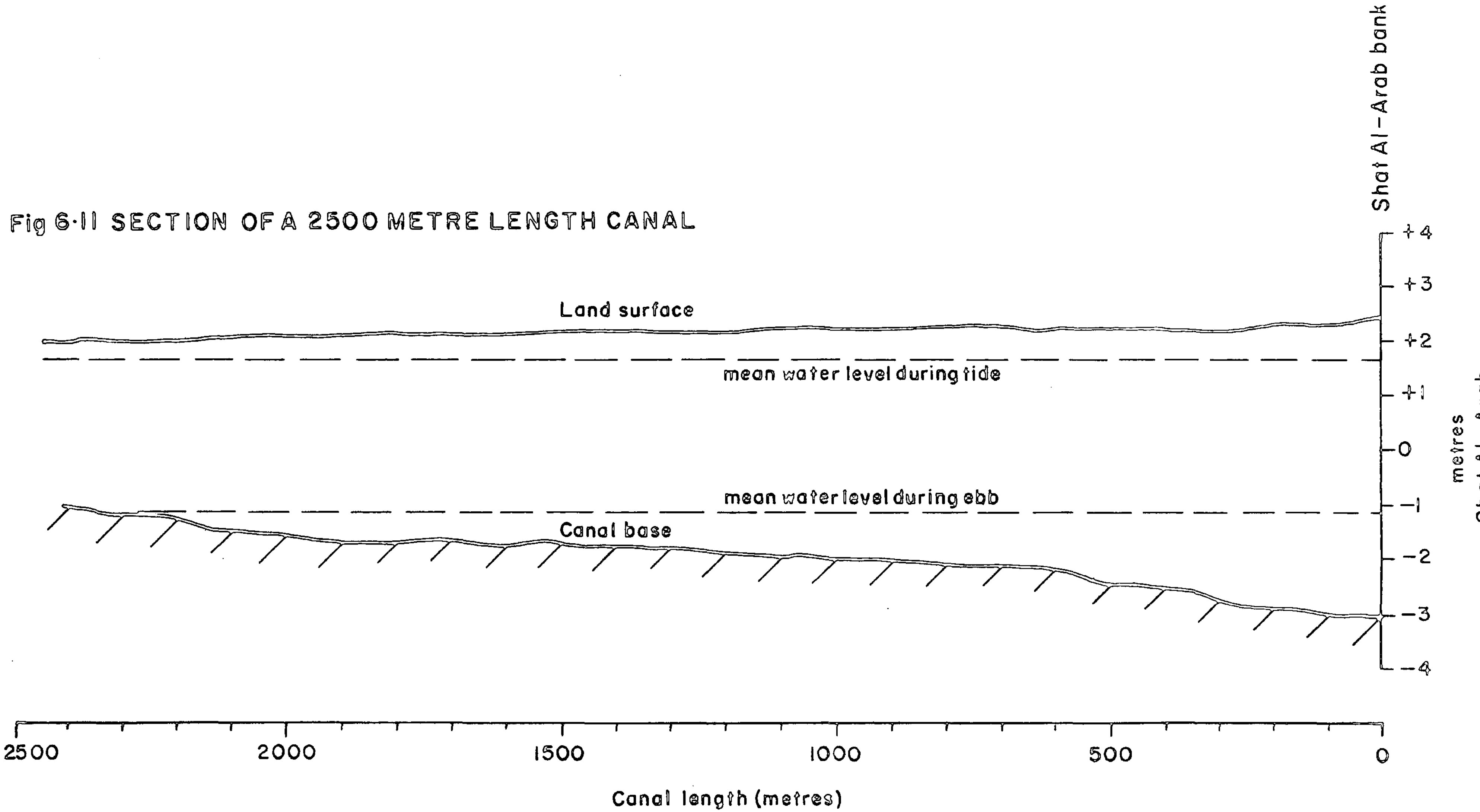


Fig 6·11 SECTION OF A 2500 METRE LENGTH CANAL



Therefore, these canals are deepest near the river banks than in the marginal areas in order to facilitate the drainage of water into the Shat Al-Arab, and at the same time to avoid the appearance of the groundwater at the base of the ditches in the marginal areas.

It should be noted that in the more intensively farmed areas the ditches are connected to the abu by buried pipes ardiba. These pipes are 30 cm in diameter and 1.5 to 2.0 m in length. These pipes can be closed by a piece of hemp cloth being pushed in one end. This is done at the beginning of each tide to prevent the charged water pushed ahead of the rising tide from entering the ditches, (see sect. 6.9). They can also be closed when the farmer does not want to irrigate the palms, particularly in winter time.

Excavation of the numerous canals and ditcheshas caused the partition of the cultivated areas into multiple small divisions which range in area from 50 to 150 m^2 (see Figs. 6.10 and 6.12). These are connected with each other by narrow paths which are located between the ditch ends. This minute compartmenting of the area makes it impossible to use machinery and consequently the farmers have to use now inappropriate traditional methods and hand tools, (see sect. 6.11). An additional problem is that these wide open unlined ditches suffer water losses by seepage, evaporation and deep percolation.

In the neglected areas the discharge capacity of the ditches and canals is very slow because of the collapse of their sides due to rain and the effect of fish such as the boshlambo (bearded mud skipper) and large rats; the vigorous growth of aquatic vegetation also greatly reduces flow. These factors not only decrease the tidal inflow but also delay the drainage outflow, which leads to concentration of saline drainage water in these ditches and eventually

FIGURE 6.12 : The cultivated area is divided into many small compartments

may cause waterlogging and salt concentration in the soils. Thus, if the neglect continues it leads to filling of these ditches sedimentation and killing of the palms, (see Figs.6.13 and 6.14).

To counter this problem, in 1962 it was enacted, under Irrigation Law No. 6 that cleaning of ditches which have a discharge capacity of 1 m^3/s or more must be undertaken by government offices, whilst those with a capacity of less than 1 m^3/s must be managed by the owners.(37) However, because of scarcity and high cost of labour, the majority of the owners have not met their obligation under the law. Therefore, to remedy this, on the 18th August 1971, the Higher Agricultural Committee of the province enacted a law stating that the tenant farmer has a right to take an additional 5% of the yield and fronds if he cleans the ditches.(38) However, this has not had the desired effect and the neglect continues.

It should be noted also that the cleaning of the main canals by government agencies together with neglect of the ditches has led to a lowering of the base of the main canals relative to the base of the ditches; this delays entry of the tide water from the canals into the ditches in the neglected areas.

It is clear from the foregoing that the distribution system of water to crops occupies 20.8% of the total cultivated area and it is unique in utilizing the tide and ebb phenomena for irrigation and drainage. However, this system is suffering from neglect which greatly reduces its efficiency, and the resultant fragmentation of the land area by the numerous ditches has increased costs of farming tremendously by requiring high labour inputs and in preventing the use of machinery.

FIGURE 6.13 : Remains of ditches in the marginal areas

FIGURE 6.14 : The neglected date palms in the marginal areas

6.9 WATER SUPPLY

The water supply for irrigation does not require the farmer to make any decisions about timing, amount of water to apply or the duration of irrigation, the whole process being controlled by the tidal regime of the Gulf and then the Shat Al-Arab.

When the tide rises in the Gulf, the water of the Shat Al-Arab is pushed back, entering into the main canals and then into the ditches. This tidal flow movement continues for about six hours, during which the clean ditches are filled by water averaging 1.5 m in depth compared with the neglected ditches at 0.30 to 1.0 m depth.

The date palm roots obtain required moisture by the lateral movement of the water from the ditches into the soil,this irrigation system and its extension into Iran is considered to be unique in the world, because elsewhere irrigation normally requires energy inputs or complex diversion works.

It should be noted that the effectiveness of the tidal input to the ditches varies with the wind direction. When there are strong northerly winds blowing in the region, this acts against the inflowing tide thus lowering high water mark. Conversely, when an easterly wind blows, this pushes in the tide thus raising high water mark. Consequently the neglected ditches are not filled when the prevailing winds are northerly but the water level in these ditches reaches a depth of 1.5 m when the winds are easterly.

However, when the ebb takes place in the Gulf during the following six hour period the water level in the Shat Al-Arab recedes and consequently the water drains from the ditches into the main canals and finally into the Shat Al-Arab. Hence, the canals network serve for both irrigation and drainage purposes. The water flows from the Shat Al-Arab into these canals and is returned to the river along the same canals. This phenomenon leads to increasing water salinity downstream.

Investigations carried out in the region showed that irrigation of the cultivated area served directly by second main group canals shwaikh is much better than that achieved by nehran. This is because filling and drainage of the ditches and canals of the shwaikh which are located near the river take less time because of the shorter distance and faster water flow obtained compared with the ditches in the marginal areas which are irrigated by the nehran.

More serious problems arise in the marginal areas and areas of neglected ditches where water flow is reduced either due to distance from the river or lack of maintenance of ditches, (see sect.6.8). Slow drainage flow does then not reach the Shat Al-Arab and in some cases not even to the main canals during the ebb. The salt charged water is then pushed back again in front of the following tide into the ditches of marginal and neglected areas. Thus, these areas are successively irrigated by increasingly saline water, in a self destroying system where marginal areas become increasingly saline. The resulting build up of salts in the soil has an adverse effect on both the quality and yield of the palms. Therefore, in the marginal and neglected areas the average yield from each palm is about 15 kg compared to 50 kg near the river banks. Additionally, the quality, size of the dates and the prices of holdings in the marginal and neglected areas are low compared with those near the river banks.

It was also noticed that the properly managed holdings are not irrigated at the beginning of the tide, the ardiba - pipes - being blocked off to prevent the saline water pushed in front of the tide water from entering the ditches.

To show the effects of this system on water salinity, water samples were taken from the canals at Qurnah, Hamdan and Seeba, see Figure 6.3 in the 1981 July flood season and the October 1982 dry season. Analysis of the samples shows the following: (see table 6.8).

Table 6.8 Water salinity of the canals (mmhos/cm)

Location	July flood season				October dry season			
	Near the river		Marginal area		Near the river		Marginal area	
	tide	ebb	tide	ebb	tide	ebb	tide	ebb
Qurnah	0.825	0.883	1.100	1.805	1.900	2.100	2.520	2.780
Hamdan	1.886	1.889	5.830	5.880	2.330	2.400	6.310	6.380
Seeba	2.290	2.220	3.410	3.780	2.800	2.782	3.230	3.450

This reveals a number of important points:

a) At sites near the Shat Al-Arab, there is little difference between the Ec value of water during tide and ebb at any time of the year. This is because since these canals are shorter and near the river, they are filled and emptied quickly during tide and ebb. The figures also highlight the increasing salinity of the Shat Al-Arab (near river samples) as the river flows south of Qurnah,(see section 6.2).

b) In the marginal areas, as a result of a combination of neglect and distance from the river, the Ec values of the canal water are generally higher than those near the river.

c) The Ec values of the canal water in the marginal areas do not show the increase south of Qurnah shown by the river side samples. They increase in the central part - Hamdan - where the distance from the river is at a maximum compared to both the northern and southern sections.

d) The highest Ec values are found in the marginal ditches during ebb in the dry season whilst the freshest water is in the flood season during flow tide near the river.

Water salinity builds up the soil salinity, see soil samples 1 - 8 (Appendix 6.1). Where the date palms are irrigated twice a day throughout the year, problems of waterlogging and salinization can occur and adversely affect the date palm quality and quantity.

It should be noted that the date palms require more water during the period from June until August whilst less water is needed during the rest of the year.[39] However an experiment was carried out in the central part of this region in 1966 to evaluate the effectiveness of the tidal irrigation and drainage system on the date yield by comparing it with a pumped furrow irrigation system. In a small area 90 palms were irrigated by the tidal system and a further 90 palms were irrigated by pumped furrow irrigation. The experiment showed that the average date yield from each palm, the average date bunches and the average weight of 50 dates from the palms irrigated by tidal irrigation were 10 kg, 2 bunches and 240 g respectively, while those yielded from the palm irrigated by pumping-furrow irrigation were 22 kg, 4.6 bunches and 340g respectively. In addition, in Abadan in Iran - the pumping-furrow irrigation method increased the date yield from 21 kg to 52kg.[40] Thus suggesting that greater yields could be obtained by changing the irrigation systems currently in use.

It is worth noting that small areas between the ditches are used to grow vegetables on small furrows and irrigated either by pumps or the <u>delu</u> or <u>manzah</u>, (see Fig. 6.15).

FIGURE 6.15 The delu

From the foregoing it is clear that the irrigation water salinity increases in two directions : from the banks of the Shat Al-Arab to the marginal areas and from the north to the south. Soil salinity is indirect and date yields in inverse ratio to these trends (see sects. 6.11 and 6.12). In addition, the tidal irrigation system can be considered now as inappropriate for the commercial production of dates compared with the pumped furrow irrigation system.

6.10 DRAINAGE

It has already been mentioned in the above section that the canals and ditches network serves for both irrigation and drainage purposes.

During the ebb excess and drainage waters are drained into the ditches, canals and finally into the Shat Al-Arab by gravity. However, due to the neglect of a number of the ditches the drainage water flows slowly and is returned back into these ditches ahead of each successive tide water front, particularly in the marginal areas, (see Fig.6.16). This causes salinization and waterlogging of the soils, (see sect. 6.12).

The drainage operation in the dry seasons is more effective than in the flood seasons because the water quantities in the ditches are lower and therefore take a shorter time to reach the main canals on the Shat Al-Arab.

Construction of the numerous ditches to an average depth of 1.5 to 2 m causes a lowering of the saline groundwater table by a similar amount. Thus, these ditches represent good drains for the areas which are located between them, but the problem of neglect remains and any attempt to increase the date palm yield and improve it must concern itself firstly with cleaning of these ditches.

FIGURE 6.16 The concentration of drainage water during ebb

6.11 THE DATE YIELD

Although the number of date palms in this region decreased from 13,399,772 palms in 1952 to 6,545,000 palms in 1978, i.e. a drop of 51.2%, this region still has the highest number of date palms in Iraq, (see Table 6.9). Despite this fact the date yield in this region has decreased markedly during the last three decades. In 1950 the date yield was 154,228 tons equivalent to 32.9% of the total yield in Iraq,[41] and by 1980 the date yield was about 70,460 tons. This quantity formed only 11.8% of the total yield in Iraq.

The factors involved in this decline in yield and number of palms can be summarised as follows:

a) The nature of the irrigation and drainage system of the recent years is unsuitable for commercial data production. For example, the average yield of the dates per palm in this region in 1980 was 12.3 kg which is less than half the average in Iraq at 32.9 kg and equivalent to about 25% of the average yield in Babil province - in central Iraq where, as in other provinces, surface irrigation is practised (see Table 6.9).

b) Neglect of the ditches and canals resulting in their filling with deposits and eventually preventing sufficient water reaching the palms, causing poor growth and death of a number of palms each year, (see Figs. 6.11 and 6.12). For example, in 1978, there were 186,000 trees died in this region.[42] This is equivalent to 2.8% of the total number of the palms in this region and 55% of the total number of palms that died in Iraq in the same year.

c) High water and soil salinity. The average Ec of the Shat Al-Arab water is 2.026 mmhos/cm in the flood season and increases in

Table 6.9 : Date palm number and production of dates

Province	Number in 1978	Production in 1980 (tons)
Taameem	1,000	-
Dyalah	1,865,000	42,970
Baghdad	1,644,000	61,530
Anbar	1,052,000	31,350
Babil	3,390,000	147,890
Karbala	260,800	118,860
Kadisyah	867,000	43,000
Muthanah	311,000	8,180
Wasit	622,000	13,790
Messan	263,000	4,980
Thi-Qar	940,000	1,458
Basrah	6,545,000	70,460
Salah el-Deen	194,000	3,250
Najaf	1,061,000	36,110
Total	21,403,000	596,920

Source : Ministry of Planning, General Bureau of Statistics, Results of the Survey of the Date Palm numbers and production in Iraq, Baghdad, 1981, pp.5 and 10.

the dry seaon to 3.249 mmhos/cm when the date palms require more water, (see sect. 6.11). The water salinity increases in the marginal areas to 4.111 mmhos/cm. Additionally, the average Ec values of the irrigated soils is 12.2 mmhos/cm. This average increases southward and from the river banks to the marginal areas, (see Sect. 6.12). According to Maas and Hoftman's (1977) classification of the effects of salinity on crop yield, the date palms give good yields if the soil and water salinity is below 4 and 2.7 mmhos/cm respectively. The yield decreases by 10% if the soil salinity reaches 6.8 mmhos/cm and the Ec value of irrigation water reaches 4.5 mmhos/cm. The yield further decreases by 25% if the soil and water salinity is 11 and 7.3 mmhos/cm respectively.(43) Thus, the date yield decreases with increasing soil and water salinity, (see tables 6.1 and 6.8).

d) Investigation in the region has shown that a great number of the date palms are old tawila and have very low productivity at about 10 kg per palm and this quantity is rarely collected. In addition these palms were planted simultaneously at a high density (5 m apart) and thus there is no progressive replanting to ensure continuous production. They do not bear offshoots and therefore the special cultivation of new offshoots is a very slow operation.

e) The low educational and economic status of the farmers together with the scarcity and high wages of labour, division of the cultivated area by ditches and the farmers low share in profits are all contributary factors to low yields.

f) The cash return from the date yield is generally low compared with that from other crops, (see sects. 4.12 and 5.14). Production of 30 kg of dates in 1980 cost ID 0.644 (£1.16) and the cash return from this quantity was ID 1.112 (£2.0), thus the profit was about

ID 0.468 (£0.84).[44] The average yield from each palm in this region in 1980 was 12.2 kg which in turn, according to the above price, means that the average profit was about ID 0.197 (£0.35) per palm whilst for example the price of crude salt dug from the adjacent sebakh was ID 0.615 (£1.10) per 12.2 kg. Thus, the total profit from the dates was less than that obtained from crude salt. The total profits from the date yield per donum amounts to ID 12.3 (£22.16) per year. This income is very low compared with that which can be obtained from unskilled jobs in the near cities. These low profits do not encourage the farmers and the owners to improve the date palm yield.

g) Additionally, the official purchase price of dates by the production and Marketing Office is generally low and variable. Table 6.10 shows that the price of dates in 1955 was ID 15.55 (£28) per ton, this fell to ID 6.40 (£11.5) per ton in 1957, increasing in 1964-1965 to ID 20.05 (£36.1) per ton and falling again in 1970 to ID 17.05 (£30.7) per ton. These low and variable prices of the dates, together with the above factors, give the farmer little incentive to improve his management and rather it leads him to look for other sources of income e.g. cultivation of vegetables or fruit or collecting salt from the adjacent lowlands or work in non-agricultural jobs.

There are unfortunately no official agricultural schemes for the improvement and extension of the date palm area in this region.

6.12 SOIL SALINITY

As a result of the inadequacy of the present irrigation and drainage system the water salinity has increased with a consequent increase in the soil salinity.

Table 6.10 : The Purchase price of Dates to the Production and Marketing office of the Dates

Year	Price ID per ton
1955	15.35
1956	8.63
1957	6.40
1958	9.74
1959	12.78
1960	-
1961	19.92
1962	19.92
1963	19.12
1964	20.05
1965	20.05
1966	12.05
1967	16.20
1968	16.20
1969	16.05
1970	16.05
1971	16.40
1972	17.05

Source: Habeeb, K. and Al-Sokouty M. and Rasheed, W.H. op.cit., p.135.

Soil samples 1 - 8 (Appendix 6.1) show that the soil salinity increases in the same directions as the water salinity, from the Shat Al-Arab banks to the marginal areas and from north to south. The average Ec value of the banks area is 7.9 mmhos/cm increasing in the marginal areas to 16.5 mmhos/cm. This is due to the poor drainage in the marginal areas, whilst in the areas near the river banks the inflow and outflow is quicker and the water is fresher. The north-south increase in soil salinity is shown by the increase from 7.2 mmhos/cm at Qurnah to 10.17 mmhos/cm in the Germat Ali area to 22.0 mmhos/cm in the Seebah area. This increase can be attributed to the increased water salinity, (see sect. 6.9).

The SAR values of the soils increase also in the same direction as the Ec values. The average SAR value reaches 7.2 at the bank areas increasing to 22.8 in the marginal areas. The increasing sodium content of the soil is responsible for the high SAR values. The Esp also increases from north to south and from the river banks to the marginal areas. The average Esp in Qurnah area is 28.7 increasing in the Seebah area to 29.8. This average reaches 19.6 in the bank areas and increases to 27.9 in the marginal areas, (see Table 6.6).

According to the U.S.D.A. (1953) classification of the soil salinity, these soils are considered saline-alkali.

It is believed that the soil salinity has markedly increased during the last few years, since the construction of the flood control schemes in the upper reaches of the Tigris, Euphrates and on the Karun river. Previously the Shat Al-Arab periodically flooded this area thus being leached the water drained back to the river via the ditch system. At present the lack of leaching has resulted in the rising salinity of the soils.

6.13 THE ABANDONED SOILS

These soils extend on both sides of the Shat Al-Arab levees into the flat lowland areas. These are divided into eastern and western parts as follows:

6.13.1 The eastern area of abandoned soils is developed in sediments deposited by the Shat Al-Arab and in the Huwiza marsh. It extends from the Iraqi-Iranian border in the south and east to the southern border of the Tigris region in the north and the Shat Al-Arab levées in the west.

Before the protective embankments were constructed in the 1970s these soils were subject to annual inundation by flood waters from the Huwiza marsh and the Shat Al-Arab. This area has poor drainage and therefore the continuous evaporation of the flood and rain water has left salts on the soil surface. For this reason these soils have been abandoned.

The average Ec value of these soils is 50.4 mmhos/cm, this equals 4 times the average Ec of the irrigated soils. The average SAR value is 43.7 and the average Esp is 38.7, (see soil samples 9 and 10 in Appendix 6.1). According to the U.S.D.A. (1953) classification of soil salinity, these soils are considered extremely saline and alkaline.

6.13.2 The western area of abandoned soils extends from the Gulf in the south to the southern border of the Hammar marsh in the north and from the Shat Al-Arab levées in the east to the Khor Al-Zubair and the eastern border of the Zubair desert in the west. The soils of this area are again developed in alluvium deposited by the Shat Al-Arab, Hammar marsh, the old Euphrates and the Gulf.

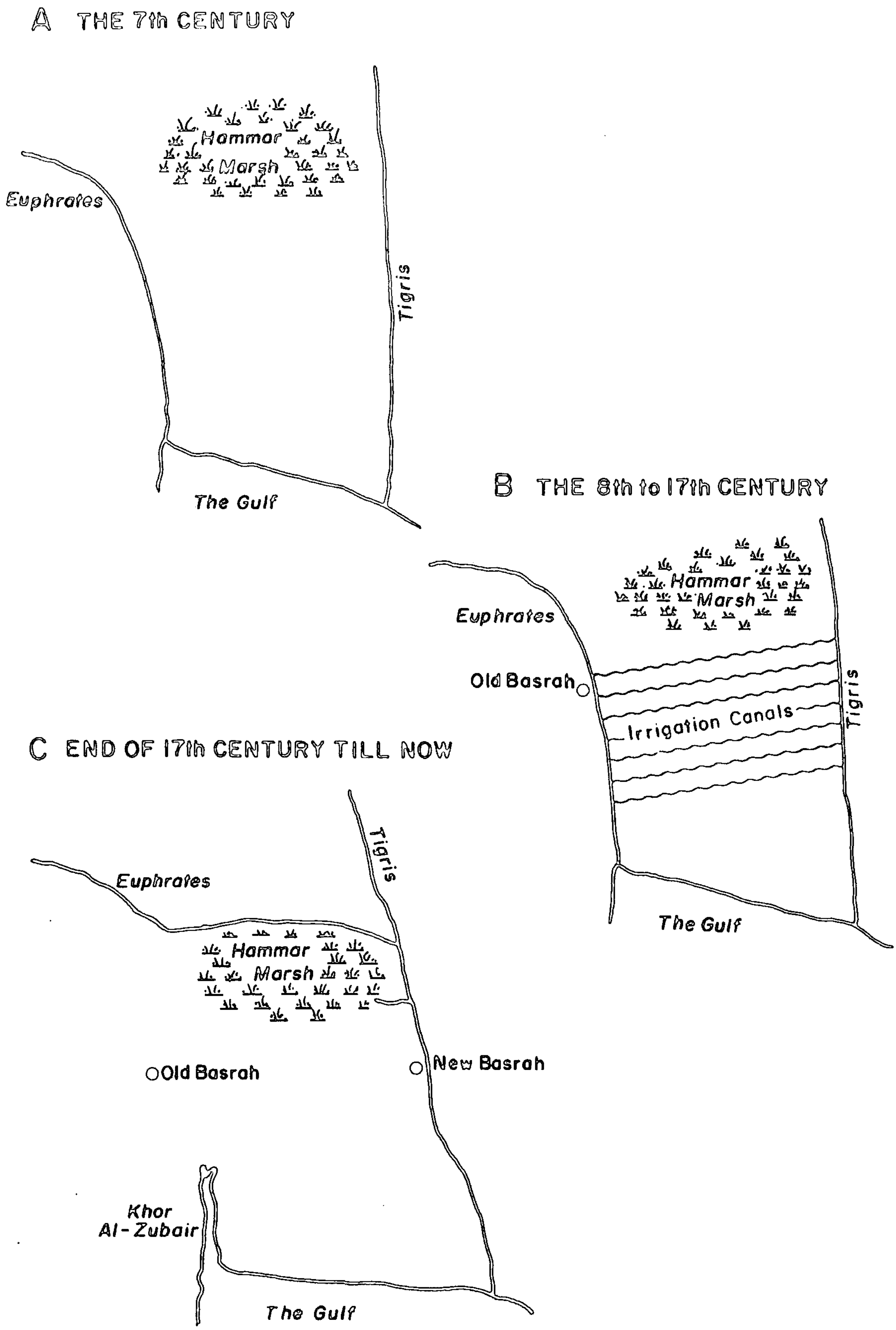
Historically, this area was not utilized before the Hijrah (622 A.D.),[45] because the old Euphrates, which used to flow along in the western margin of this region to discharge its water into the Khor Al-Zubair, (see Fig.6.17) used to seasonally flood the whole area. Flood waters were also received from the Hammar marsh and the Shat Al-Arab - which was called Dijla el Awrah.

In 14 A.H. (635 A.D.) the Muslim leader Utba bin Ghazwan arrived in this area from the Arabian Peninsula and ordered the citizens of Old Basrah city , which was located near to the present Zubair City, to cultivate the then Sebakh area. Every citizen reclaiming an area had the right of ownership without payment. For this reason, as well as the availability of African slave labour in Old Basrah, the citizens were encouraged to undertake reclamation of the soils and establish an irrigation and drainage system.[46] They made efficient use of the natural phenomenon of tide and ebb in the Shat Al-Arab. Many ditches and canals were excavated, firstly on the river levees where date palms were planted on their sides and then this network was extended throughout the Sebakh area to join the old Euphrates thus reclaiming a large area. Unfortunately there is no mention in the historical sources of the period during which the work was completed but we do know that a large system of ditches and canals was constructed between the Shat Al-Arab and the old Euphrates with the following objectives [47] (see Fig.6.17).

a) To lower the groundwater level in the area.

b) In the flood seasons this network of ditches and canals drained the excess water from the old Euphrates into the Shat Al-Arab, this water scouring the ditches clean of deposits.

Fig 6·17 THE TIGRIS - EUPHRATES DRAINAGE ALIGNEMENT IN HISTORIC TIMES



c) Irrigation of the cultivated areas between the ditches was by tidal water from both the Shat Al-Arab and the Old Euphrates in a system similar to that operating today. During ebb the excess and drainage water drained into the Shat Al-Arab.

As a result of the reclamation and the adequacy of the irrigation and drainage system that was established, this area gave abundant yields of vegetables and fruit particularly during the Abbasid age which started in 750 A.D.

During the 17th century, several events took place which had disastrous consequences for the area. Firstly, a severe flood of the old Euphrates river caused it to break its banks near the Hammar area, and subsequently to change its course and discharge into the Hammar marsh - as it does at the present time. Secondly, in the old Basrah area, the city was subjected to continuous attacks by the bedouin and Persian tribes. Thirdly, there was a further spread of diseases in this area.[48]

The effects of the above factors can be summarised as follows:[49]

a) Emigration of the farmers and the citizens from old Basrah City to the present site leaving the irrigation and drainage system to become neglected.

b) The Shat Al-Arab which previously drained only the Tigris river had now to carry Euphrates water through the Germat Ali channel as well. This led to increased flooding from the Shat Al-Arab during the flood seasons, which adversely affected the cultivated areas on both sides.

c) Diversion of the old Euphrates into the Hammar marsh caused flooding of this marsh in the flood seasons and thus inundation of the area under discussion.

d) This area also became subject to tide water inundation from the Khor Al-Zubair particularly when there were south-easterly winds, (see sect.1.4.5).

The above factors led to the abandonment of the irrigation and drainage system in this area and all that is seen today as a series of rectangular lines on the land surface. The area was gradually resalinized and reverted to Sebakh.

The farmers, however, tried to protect the rest of the cultivation area which is located on the river levees, see Figure 6.8, from the Hammar marsh and the Khor Al-Zubair floods by constructing earthen embankments along the line between the levees and the sebakh area, (see Fig. 6.18). They also tried to use the Hammar marsh and the Khor Al-Zubair waters for scouring the ditches. Therefore small gaps were made in the embankments at points nearest to the end of the canals. These gaps were opened during ebbs to allow the Hammar marsh and the Khor Al-Zubair waters to discharge into the canals to clean the accumulated sediments from the ditches and canals and hence to the Shat Al-Arab.

However, these waters from the Hammar marsh and the Khor Al-Zubair were held back by construction of the Basrah-Fao highway in the 1940s along the marginal parts of the present cultivated areas. This together with construction of earth embankments on the southern border of the Hammar marsh and northern area of the Khor Al-Zubair stopped this ditch flushing system using the Hammar and Khor Al-Zubair waters. Thus, the area became used for salt collection from some ill defined shallow depressions.

Soil sample No.11 was taken from this area; analysis shows that the Ec value is 94.75 mmhos/cm, the SAR value at 115.2 and the

FIGURE 6.18 : The remnants of the earth embankment

Esp is 48. It is believed that the main source of the soil salinity of these soils is the capillary rise of the saline groundwater. This can in part be checked by use of the Polynov (1956) equation for calculation of the salt regime index(s) which is as follows:[50]

$$s = \frac{\text{Groundwater Cl/So}_4}{\text{Surface soil Cl/So}_4}$$

when:

- s < 1 the index points out that upward capillary movements the groundwater is continuous and process of salinization takes place
- s = 1 or very close to 1, it means that the groundwater level in the critical depth and process of salinization and desalinization is in equal balance.
- s > 1 means the soil is in desalinization stage from viewpoint of the groundwater.

Calculation of Cl/So_4 of the groundwater and the surface soils in the area is 7.6 and 7.7 me/L[51] respectively. Thus, the result is 0.9. This according to the above equation means that there is a continuous rising of the saline groundwater to the surface which leaves the salt after evaporation. However, other factors also caused salinization of these soils such as the evaporation of the Hammar and Khor Al-Zubair waters which periodically flooded this area. These waters under hot, arid conditions and poor drainage left the salt on the soil surface.

6.14 CONCLUSION

It has been shown that water, soil and management deterioration has affected the efficiency of the irrigation and drainage system in the region and led to a decrease in palm numbers and productivity. The water and soil salinity increases in two directions; from the river banks to the marginal areas and from north to south. The ditches and canals suffer from neglect due to scarcity and high wages of the labour along with unsatisfactory relationships between the farmers and the land owners.

The distribution system of water, which was established 13 centuries ago, occupies a large area in the cultivated lands, by which the date palms are irrigated twice a day by tide and ebb movements which enter into the canals and ditches from the Shat Al-Arab and leave these ditches and canals by gravity. Experiments suggest that for the commercial growing of dates this age-old system which has in any case deteriorated is now not as appropriate as furrow irrigation by pumped water.

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CONCLUSION

In this thesis the irrigation and drainage systems in Basrah Province have been described, analysed and evaluated in terms of their efficiency, and their effects on soil and water resources. The descriptive element is made necessary by the paucity of detailed studies of irrigated farming in Basrah province in spite of the fact that the province is a nationally important area for agricultural production. The province is particularly important in that it now supplies the Iraqi markets with most of their winter tomatoes and almost 12% of the national production of dates. However, present and potential production is threatened by the widespread deterioration of soils through salinization and a decline in water quality. This has already led to the abandonment of large areas of cultivable land and the downward trend appears to be continuing.

The survey shows that this deterioration cannot be analysed effectively merely in general terms which assume homogeneous conditions in Basrah province. In actuality the critial spatial variation, within the province, of topographical, hydrological and soil conditions are associated with distinctively different regional systems of irrigation farming. Each of these identified systems has to be analysed separately if there is to be effective understanding of what is happening in the province as a whole. At the same time it has to be recognised that, particularly in the case of hydrology and water resources, each region within the province is inextricably part of a wider complex system which embraces not only the whole of Basrah province but ultimately the whole Tigris-Euphrates catchment area - extending beyond the boundaries of Iraq.

The first level of regional differentiation that has to be made within Basrah province is that between the riverine lands to the east, lying around the Tigris, Euphrates and Shat Al Arab, and the extensive non-fluvial area to the west. This latter western region, which slopes gently downwards from the west and south, has virtually no permanently flowing surface streams and soils are generally derived in situ from the underlying Dibdibba formation parent material. Subsurface groundwater is only available at shallow depths in a few isolated depressions, within which sandy loams, of relatively high permeability, have developed. All irrigated farming is concentrated in these depressions where there is a coincidence of accessible ground water and relatively good soils.

The characteristics of the eastern part of the province, on the other hand, are almost totally determined by fluvial processes. The whole area is covered by alluvial sediments deposited by the Tigris-Euphrates river systems. The general low gradient slope is from north to south in accord with the main direction of river flow, this interrupted only by the higher ground of past and present river bank levees and the slight depressions occupied by the great marshes of Hammar and Qurnah. The main contemporary river channels are bordered by levees from which the ground slopes away from the river banks. Detailed soil characteristics, textural, structural and salinity/alkalinity can vary considerably over short distances, associated with these geomorphological variations, but in general soils are silty clay loams of relatively low permeability. For purposes of irrigated farming ample water is available from the surface flows of the major rivers. The position is however complicated by the fact that the Shat Al-Arab is a tidal river and also by the fact that surface water flow is not totally confined to the main river channels but also passes through an interconnected network of marshes. The whole of these riverine lands in the eastern half of Basrah province are necessarily affected by the seasonality of the river regimes, by large scale changes over time in river channel alignment (although such historical changes are not studied in this thesis), and by the changing tidal interface between fresh river water and saline Gulf seawater.

A second level of regional differentiation follows from the spatial complexity of the eastern riverine area of the province, and the basic physical characteristics of the west. This differentiation is very clear in the development of distinctive regional systems of irrigation and drainage. The present pattern of irrigation and drainage systems is of course the result of farmers' perceptions of what is possible and necessary for irrigated farming in any particular region - i.e. management. The quality of perception and management is affected by some common factors but there are also some regional variations. Generally, farmers in Basrah province are uneducated and lack ability and knowledge of farming and irrigation technology except that which has been traditionally acquired. The idea of water use efficiency is not understood and farmers still do not realize the importance of drainage, how to improve soil productivity or the need to reclaim the abandoned soils. In irrigation and cultivation operations the farmers depend on their own and inherited experiences and use simple tools and methods. In particular, the farmers tend to overirrigate, in some cases deliberately, with the intention of removing excess salts. Without adequate drainage this only aggravates salinity problems.

With the exception of the Marshes Region farming is regarded as a secondary source of income; however in the Marshes Region it provides the main income for the farmer's family and involves most members of the family. In the southern Tigris and the Shat Al-Arab regions only the old men, women and school children are now available for agricultural work, as the main male labour force is drawn to the cities - Basrah, Qurnah and Abu-Al-Khaseeb where it can obtain higher wages. The relatively high wages paid in farming in the Western Region on the other hand attracts workers from the adjacent provinces - Muthanah and Thi- Qar - and also Egyptian migrant workers.

The average size of the farm varies from region to region and this in many ways reflects the ways in which the use of traditional irrigation and husbandry techniques can limit the scale of operations. This in turn severely limits the volume of income which can be raised on a single holding and further decreases the attractiveness of farming in comparison to other economic opportunities which have become available during recent years.

Whilst the general low level of management of water and soils can be held responsible overall for the deterioration and abandonment of cultivable land it is also clear that the particular regional adaptation which farmers have made to the resources actually available have been appropriate in many ways.

In the western region farmers have only been able to use the sandy loam soils in the depressions. These coarse textured soils have low water holding capacity and therefore are seen by the farmer to require heavy applications of irrigation water. The soils are free from alkalinity, only slightly saline and have a low sodium adsorption ratio but also have low organic matter content. Unfortunately, the groundwater which alone is available for irrigation is of poor quality because of its excessively high salinity and medium sodium adsorption ratio. In the past animal drawn wells to some extent limited the amount of water which could be extracted and applied but the introduction of pumps has resulted in an increase in the volume of water which can be drawn from the costly hand-dug wells and applied to the land. The result has been a more rapid increase in water and soil salinity. The local farmers' response has not been to apply water more efficiently but to use a special form of "rotating cultivation" in a more or less fixed total farm area centred on a pumped well.

In the southern Tigris region river water of medium salinity and low sodium adsorption ratio is pumped from the river on to the bordering areas. The silty clay loams of moderately fine texture have slow to moderate infiltration rates and high water holding capacity. As in the similar Mesopotamian Plains to the north, the absence of drains and the unnecessarily high water application volumes in conditions of high evaporation rates, has led to soils becoming strongly saline. The worst affected areas are the lowest lying lands away from the river levees and where waterlogging can also be a problem. There are considerable areas now abandoned however, where soils are free from alkalinity and have low sodium adsorption rates and which under reasonable management would be placed in Class 3 in terms of suitability for irrigation.

In the Shat Al-Arab region a unique system of irrigated farming is practised. The cultivated areas are irrigated by the natural gravity flow from the high level of freshwater in the river created by upstream daily tidal movements and equally naturally drained by the reverse fall during the ebbs. The combined distribution and drainage canals, of ancient construction, slope in the opposite direction to the ground surface slope i.e. towards the river banks. Water quality is of medium to high salinity, rising towards the mouth of the river. Soils are similar in general to these in the Lower Tigris region but are alkaline and of moderate salinity, the salinity increasing both southward and away from the river banks. Their condition depends entirely on how well the delicate natural irrigation and drainage balance is maintained.

The Marshes region has yet another unique use made of the natural, in this case seasonal advance and retreat of flood waters. Here water is derived ultimately from the Euphrates. The only cultivable land is that which is exposed during the dry season and those soils which are appropriately submerged during high water seasons remain of low salinity as the result of the natural leaching which takes place. The farmer utilises what is really a subsurface irrigation system by planting crops as floods recede and which they draw on the water table remaining at the base of the root zone. The farmer has to maintain or build up land which is at a critical suitable height in relation to flood and dry period water levels.

In all the irrigation and drainage regions in the province furrow irrigation is practised. However, the dimensions and functions of these furrows vary and they can be classified into two groups : Firstly, in the Western and Southern Tigris regions, small temporary furrows are used only for irrigation; secondly, in the marshes and the Shal Al-Arab regions, bigger permanent furrows - ditches - are used both for irrigation and drainage. All of these channels and furrows are unlined and lead to considerable seepage, producing a loss of water for irrigation and an excess of water in undrained lower lands.

The different systems identified above are associated with regional variations in farm size. In the Marshes region the average holding size is only about 5 donums, mainly because the preparation of land for cultivation is difficult and expensive. However, in the Southern Tigris region the average farm area is 10 donums, land preparation being easier and cheaper. In the Shat Al-Arab region the average area ranges from 1 to 200 donums, the size of each farm being governed by complicated historical relationships between owners and the farmers. However, in all of the above regions the availability of labour or the family size has also an effect on the farm size i.e. the larger the family the larger area and vice versa. In the Western Region the quantity of water produced from the well governs the farm area i.e. the more fresh water produced the larger the farm area and vice versa (the average farm area is 3.6 donums).

The evaluation of the effectiveness of the various irrigation and drainage systems for present conditions and the requirements for improving the systems can be summarised as follows. In the Marshes region suitable land is scarce and water is abundant but neither are used efficiently.

The channel ditches are permanent and have to serve several purposes; to lower the groundwater table; making irrigation water available; and providing drains for the natural leaching operation which takes place during the flood seasons. These costly ditches occupy more than 50% of the total farm area and are supplied with water naturally from the main canals. Measurements of the water applied showed that only 27% of the theoretical water required for irrigation and leaching is satisfied by irrigation water and the other 73% is met by the groundwater and the relative humidity. As a result of high evaporation rates, insufficient leaching during the growing season and the use of moderately saline irrigation water, soil salinity is doubled during this season. The main problems facing this system are the irregular fluctuations in the changing seasonal water levels and in the discharge of water drained from the main collector into the Hammar marsh. The problem of regulating water levels will be resolved when the Shat Al-Basrah canal is completed; it will drain water from the Hammar marsh into the Khor Al-Zubair and an irrigation canal which should be constructed from the Shat Al-Basrah to the Fao area, (see Fig. C.1). It is suggested that the Shat Al-Basrah canal should be provided with a barrage downstream of the proposed western irrigation canal in order to avoid the probable intrusion of the tide saline water from the Khor Al-Zubair into the Hammar marsh and to supply the proposed western irrigation canal with sufficient water. These canals will lead to a larger cultivable area being exposed in the marshes region and to a decrease in the water discharge into the Shat Al-Arab. The main collector should be diverted from the Hammar marsh to cross the Euphrates river by siphon at Ur station, then taken by lined canal south of the Hammar marsh and terminating in the Shat Al-Basrah downstream from the barrage. It is hoped that these suggested solutions are carried out because of the present and potentially greater agricultural importance of this region which, together with the western region, supplies tomatoes to the Iraqi markets during winters. With the continued seasonal fluctuations in water levels, it is unlikely that the present sub surface irrigation system could be replaced by one of the more efficient sprinkler/drip systems.

Second, the present irrigation and drainage system in the Western region necessitates that in order to prevent the build up of levels of soil and water salinity, the farmed area is continually shifted around the well and from well to well. This system causes deterioration of the soil and water resource and if continued it will eventually lead to a decrease of the cultivable area and the region will lose its

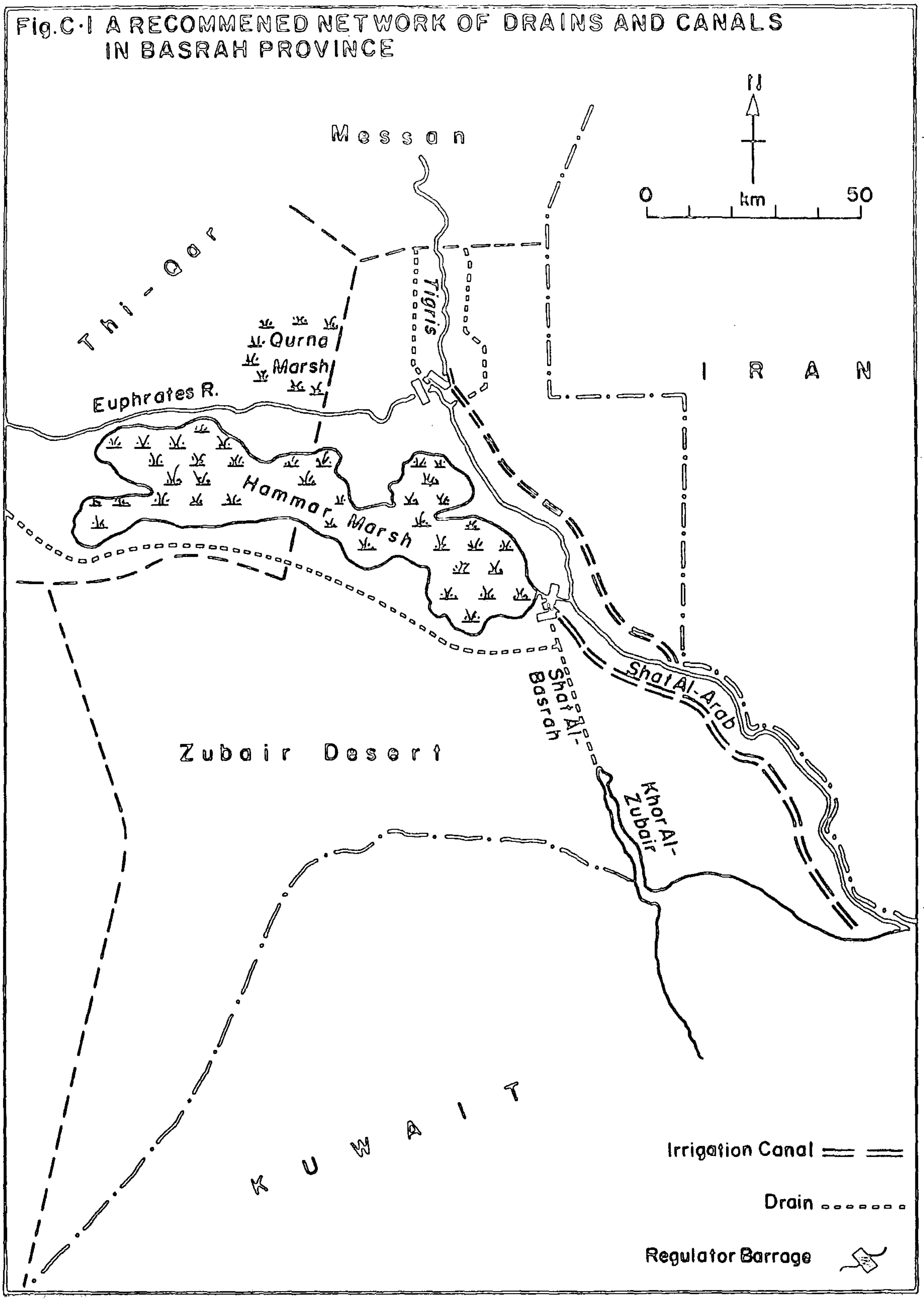
Fig.C·1 A RECOMMENED NETWORK OF DRAINS AND CANALS IN BASRAH PROVINCE
N
0
km
50
Messan
Thi-Qar
Tigris
IRAN
Qurna Marsh
Euphrates R.
Hammar Marsh
Shat Al-Arab
Shat Al-Basrah
Zubair Desert
Khor Al-Zubair
KUWAIT
Irrigation Canal
Drain
Regulator Barrage

importance as an area producing tomatoes and potentially other vegetables. Soil salinity is the result of excessive irrigation as is practised in this region. Measurements of the water supply showed that the actual water applied was 40900 m^3/donum which is equivalent to about 6 times the theoretical water required for irrigation and leaching. Use of excessively saline water together with the high evaporation rates leads to an increase in the soil salinity and pollution of the groundwater. Moreover, as a result of poor management, high infiltration rate and permeability water losses are high and equal to about 55% of the total applied water. Consequently the irrigation water efficiency is extremely low at 44%. Therefore, it is necessary to use an alternative system which uses less water; drip trickle irrigation would use about 50% less water than the traditional furrow system. This however would require a major educational programme for the farmers which emphasized the value of drip irrigation for row crops to the conservation of soil and water resources. The initial cost of training and the purchase of the necessary equipment would probably have to be by the government.

In the Shat Al-Arab region all depends at the moment on the labour demanding very careful and precise maintenance of the irrigation-drainage ditches. Most ditches are neglected because of the lack of labour which has led to an increase in soil and water salinity and a consequent decrease in quantity, quality and productivity of the date palms. This region will face a serious problem of diminished fresh water supply after the completion of upstream irrigation projects and hydraulic constructions on the Tigris, Euphrates and Karun, and the construction of the Shat Al-Basrah. A decreased flow of fresh water in the river will lead both to greater tidal intrusions of sea water from the Gulf and to greater upstream penetration. This would very seriously add to the current deterioration of the cultivated areas and of data palm production and productivity. It is suggested therefore that the Shat Al-Arab river be utilised in the future mainly as a drain for the Shat Al-Arab and southern Tigris regions. Irrigation water should then be supplied from two new irrigation canals (see Fig. C.1) One would divert water from the Tigris river in the Qurnah area and run southeastward to irrigate the cultivable area on the east side of the Shat Al-Arab; this would require construction of a barrage on the Tigris river downstream of this canal which would also prevent the intrusion of tidal saline water from the Shat Al-Arab into the Tigris, (see Fig.C.1). A second canal would run from the Shat Al-Basrah downstream of the Garmet Ali area to irrigate the cultivated area on the west side of the Shat Al-Arab. Experimental evidence has already shown that the practice of furrow irrigation to irrigate the date palms has led to an increase in palm productivity greater than that now obtained under the tidal system. A radical change from the present decaying system is needed. It is suggested that the present ditch network should be filled in, the abwat being left as field drains into the main canals which would serve collectors to drain water into the Shat Al-Arab. These collectors should be provided with sluice gates at the junction points with the Shat Al-Arab, which will be opened during ebb to discharge the drainage water and closed during high tide to prevent tide water from entering the collectors. The cultivated areas on both sides of the Shat Al-Arab would be supplied with water pumped from secondary canals which would bifurcate from the proposed irrigation canals. On the land now in use, the old and often neglected date palms should then be replaced in densities which would make it possible to apply mechanised and improved technologies which have been shown to raise date palm productivity. In order to prevent the pollution of the Euphrates by tide water from the Shat Al-Arab a barrage should be constructed on the Euphrates in the Qurnah area. The areas between the Shat Al-Arab and the two proposed irrigation canals can then be leached and reclaimed as cultivable land. In the long term even greater efficiencies in water use could be obtained by replacing the proposed furrow irrigation system with a drip system.

Finally, the irrigation and drainage system in the Southern Tigris Region which involves the use of furrow irrigation is practised during summer and basin irrigation during winter, similar to that used in the Mesopotamian Plain. Measurement of the water applied, all of which has to be pumped from the Tigris shows that the actual water applied was 10,044 m^3/donum and 5,638 m^3/donum in the summer and winter growing seasons respectively. These quantities are equivalent to 4 and 5 times the theoretical water required for irrigation and leaching in summer and winter respectively. As a result of poor management, seepage, leakage and high evaporation rates water losses are high and consequently irrigation water efficiency is low at 22% and 28% during summer and winter respectively. Use of excessive irrigation water of medium salinity together with the absence of adequate drainage has led to a rise of the saline groundwater table, and by capillary action and high evaporation rates soil salinity has increased and has led to abandonment of about 56% of the total area of this region. Besides the soil salinity problem, the region also suffers from a shortage of labour, a shortage which cannot be rectified until productivity and farm incomes rise. Furthermore, these problems will be exacerbated in the future with the reduction in the discharge of the Tigris in this region due to upstream development of barrages and irrigation projects. Therefore it is essential that steps are taken now to ensure the maintenance of irrigated agriculture in this region. In order to do this two main drains (see Fig. C.1) should be constructed. The first on the eastern side of the Tigris which would discharge into the Swaib channel and the other on the western side which would drain into the Euphrates river in the vicinity of Qurnah. In order to leach the irrigated lands and the abandoned areas between the Tigris and these main drains, either field ditch drains or outsurface pipe drains (as those in the state farm) should be constructed to feed into the main drains. With the predicted decrease in discharge of the Tigris and the need to use some of its water to irrigate lands to the east of the Shat Al-Arab, it is essential that the water demand is reduced. This can be achieved by replacing the traditional furrow and basin irrigation system with drip systems. Such a change would require a move out of cereal cultivation to vegetables or crops more suited to drip irrigation, farmer education will also be necessary. Further steps can be taken to preserve the water quality of the Tigris at low flow by installing a series of sluice gates on the outlets from the Qurnah and Hawiza marshes, which would permit discharge of these drainage waters only during the flood season.

It can be concluded, therefore, that the existing irrigation and drainage farming systems, although ingenious at a relatively low level of technology, are in present circumstances leading inevitably to the destruction of useful land and water resources. In the riverine lands of the eastern area of Basrah province large-scale hydraulic works will have to be designed coherently for the area as a whole. In addition, regionally appropriate farm-scale new irrigation and drainage systems will have to be introduced. This latter change implies not only engineering improvements but a total transformation of established rural socieites. The detailed requirements for such a transformation lie beyond the scope of this thesis but unless they, together with the other improvements noted above, are satisfied, agriculture in Basrah province will continue to decline.

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APPENDIX 1.1 Experimentally Determined Constants for the Radiation Equation

RS = (a + b n/N)RA

Source	Location or Range of locations	Constants a	b	a+b	Latitude °
As listed by Linacre (.967)					
Black *et al* (1954)	Stockholm and Fairbanks	0.22	0.52	0.74	59+65 N
Monteith (1966)	Lerwick, U.K.	0.23	0.56	0.79	60 N
Penman (1948)	Rothamsted,U.K.	0.18	0.55	0.73	52 N
Baier *et al* (1965)	Canada	0.25	0.62	0.87	52 N
Black *et al* (1954)	Kew, U.K.	0.19	0.57	0.76	51 N
von Wijk (1963)	Gemfloux, Belgium	0.15	0.54	0.69	51 N
von Wijk (1963)	Versailles, France	0.23	0.50	0.73	49 N
	Mean	0.21	0.55	0.76	54°
Tanner *et al* (196)	Wisconsin, U.S.A.	0.18	0.55	0.73	43 N
de Villele (1965)	El Aounia	0.28	0.43	0.71	37 N
de Vries (1958)	Deniliquin, Australia	0.27	0.54	0.81	36 S
Demagnez *et al* (1963)	Tunisia	0.16	0.59	0.75	35 N
Prescott (1940)	Canberra,Australia	0.25	0.54	0.79	35 S
Black *et al*(1954)	Dry Creek,S.Africa	0.30	0.50	0.80	35 S
Page (1961)	Capetown,S.Africa	0.20	0.59	0.79	34 S
	Mean	0.23	0.53	0.76	36°
Glover *et al* (1958)	Durban, S.Africa	0.25	0.50	0.75	30 S
Yadov (1965)	New Delhi, India	0.31	0.46	0.77	29 N
Glover *et al* (1958a)	Pretoria,S.Africa	0.25	0.50	0.75	26 S
Glover *et al* (1958a)	Windhoek,S.W.Africa	0.26	0.52	0.78	23 S
Page (1961)	Tananarive,Madagascar	0.30	0.48	0.78	19 S
Smith (19-9)	Jamaica	0.31	0.49	0.80	18 N
	Mean	0.28	0.49	0.77	24°
Fitzpatrick (1965)	Kimberley,S.Africa	0.33	0.43	0.76	16 S
Cockett *et al* (1964)	Central Africa	0.32	0.47	0.79	15 S
Page (1961)	Dakar, Senegal	0.10	0.70	0.80	15 N
Yadov (1965)	Madras, India	0.31	0.49	0.80	13 N
Davies (1965)	Kano, Nigeria	0.26	0.54	0.80	12 N
Smith (1960)	Trinidad	0.27	0.49	0.76	11 N
Stanhill (1963)	Benin City (1), Nigeria	0.26	0.38	0.64	7 N
	Mean	0.26	0.50	0.76	13°

APPENDIX 1.1 (Cont)

Source	Location or Range of locations	Constants a	b	a+b	Latitude°
Davies (1965)	Accra,Ghana	0.30	0.37	0.67	6 N
Black et al (1954)	Batavia(Djakarta)	0.29	0.59 (2)	0.88	6 S
Page (1961)	Kinshasa,Zaire	0.21	0.52	0.73	4 S
Page (1961)	Singapore	0.21	0.48	0.69	1 N
Glover et al (1958b)	Kabete,Kenya	0.24	0.59	0.83	1 S
Page (1961)	Kisangani,Zaire	0.28	0.40	0.68	1 N
Rijks et al (1964)	Kampala,Uganda	0.24	0.46	0.70	0
	Mean	0.25	0.49 (3)	0.74	3°
Constants developed from studies involving multiple locations					
Fritz and McDonald (1949)	All in U.S.A.	0.35	0.61	0.96	-
Black et al (1954)	Tropics to polar	0.23	0.48	0.71	-
Kateer (1955)	Canada	0.355	0.68	1.035	-
Glover and McCulloch (1958)	0-60°	0.29 cosϕ (4)	0.52	-	-
Hounam (1963)	Australia,12-43°S	0.26	0.50	0.76	-
Davies (1965)	West Africa,5-15°N	0.19	0.60	0.79	-
Page (1961)	40 N-40°S	0.23	0.52	0.75	-
As listed by Chidley et al (1970)					
Drummond and Kirsten (1951)	Capetown,S.Africa	0.29	0.50	0.79	34 S
Stanhill (1961)	Eastern Mediterranean	0.32	0.47	0.79	31 N
Chidley et al (1970)	Saudi Arabia	0.36	0.47	0.83	-
Kimball (1914)	Virginia, U.S.A.	0.22	0.54	0.76	37 N
Black et al (1954)	Salt Lake City,U.S.A.	0.20	0.47	0.67	41 N
Others					
Stanhill (1965)	Israel (daily)	0.36	0.43	0.79	31 N
Stanhill (1965)	Israel (weekly)	0.39	0.38	0.77	31 N
Stanhill (1965)	Israel (monthly)	0.41	0.36	0.77	31 N
Scholte Ubing (1959)	Netherlands	0.18	0.54	0.72	52 N
Robertson (1971)	Los Banos, Philippines	0.24	0.54	0.79	15 N
Idso (1969)	Phoenix,Ariz.,U.S.A.	-	-	0.78	33 N

(1) Davies (1965) gave 0.28 and 0.33 for a and b respectively

(2) Table by Linacre (1967) indicated 0.29 for Batavia, a likely error since Chidley and Pike (1970) give 0.59 for Djarkarta, the same location

(3) Based on revised figure for Batavia

(4) ϕ is the latitude in degrees

Source, Doorenbos, J.D. and Pruitt, W.O., op.cit., p.179.

APPENDIX 3.1

The analytical procedures adopted for the soil and water samples are those laid down in the U.S. Salinity Lab. Handbook (1954) for the chemical properties of soil and water, and U.S.D.A. Soil Survey Laboratory methods and procedures for collecting soil samples (U.S.D.A. Washington 1972) for soil physical properties.

Chemical Analysis

Acidity measurement - pH   Measurement was made on a saturated soil paste, using a glass electrode (method 21a)

Electrical conductivity   measurements on saturated extract (Ec)(method 3a)

Gypsum   was determined by precipitation with acetone (method 22b)

Lime/Carbonate   was determined from Acid Neutralization (method 23c)

Exchangeable Sodium   using ammonium acetate extraction and determination on an atomic absorption spectrophotometer (method 18)

Cation Exchange Capacity   was determined by using sodium acetate and ammonium acetate extraction and an atomic absorption spectrophotometer (method 19)

Organic matter   wet oxidation using a modified Walkley and Black procedure (method 24)

Esp   by calculation

SAR   by calculation

Calcium and Magnesium   by titration with ethylenediaminetetra acetate (method 7)

Soluble Sodium and potassium   on saturated extract and determined on an atomic adsorption spectrophotometer (methods 10a and 11a)

Chloride by titration with silver nitrate (method 13)

Sulphate by precipitation as Barium sulphate (method 14a).

Carbonate and Bicarbonate by titration with sulphuric acid (method 12)

Mechanical Analysis (particle size) by pipette method

Soil texture classification U.S.D.A.

Physical Analyses

Bulk density on undisturbed core sample by

Porosity by calculation

Wilting point)
) pressure membrane apparatus
Field capacity)

Available moisture by calculation

Permeability on undisturbed cores (method 34a) of US Salinity laboratory handbook.

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APPENDIX 3.2 Soil samples of Chapter Three

Soil Sample No. 1 Uncultivated/Al-Berjsiyah-Chwidbda

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp(1) %	SAR(2) me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	So_4	HCo_3
0-18	7.7	2.71	78.16	7.04	14.8	2,69	22.4	3.1	19	0.60	16.3	0.5	26	4	2	0.3	7.5	21	3.2
18-35	7.6	2.66	72.74	0,85	26.4	4.04	20	1.0	29	0,26	3.4	0.7	20	14	3	0.3	5	30	2.4
35-75	7.6	3.21	74.04	7,95	18.0	2.64	22	0.79	20	0.20	3.9	0.7	20	10	3	0.2	5	36	2.4

(1) Esp is obtained by the following equation $\frac{100 \times Ex.Na}{CEC}$

(2) SAR is obtained by the following equation $\frac{Na}{\sqrt{\frac{Ca + Na}{2}}}$

Soil Sample No 2 Uncultivated/Al-Berjisiyah-Chwibda

Depth cm	pH past	Sat. Ext EC mmhos /cm	Sand %	Silt %	Clay %	Gypsum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Ca	Mg	Na	K	CL	So_4	HCo_3
0-14	7.6	3.39	78.88	10.11	2.0	3.37	10.4	0.5	16	0.4	3.1	6.2	26	6	25	0.2	12.5	41	2.3
14-38	7.6	1.67	79.31	2.28	18.4	3.40	9	2.08	17	0.1	12.2	8.6	16	2	26	0.5	10.0	32	2.4
38-78	7.9	1.17	82.89	6.7	10.4	2.04	9.2	0.35	16	0.1	2.1	5	8	2	11	0.2	7.5	11	2.4

Soil Sample No. 3 Uncultivated/Al-Berjsiyah-Chwibda

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	So_4	HCo_3
0.16	7.95	4.36	high gypsum			4.5	9	0.02	39	0.74	0.05	2.3	34	2	10	0.3	5	52	1.6
16-38	7.7	4.89	73.85	5.50	20.64	4.67	19	3.2	23	0.04	13.9	4.2	20	2	14	0.6	12.5	20	3.2
38-72	7.8	5.24	high gypsum			3.31	18.8	2.04	25	0.04	8.1	1.2	32	28	7	0.6	2.5	62	2.4

Soil Sample No. 4 Uncultivated/Al-Najmy

0-20	7.45	10.58	73.85	5.50	20.64	3.91	27.2	1.29	22	0.40	5.8	7.5	36	38	45	2.10	60	60	1.6
20-42	7.7	11.31	67.24	24.11	8.6	3.22	27.6	1.80	33	0.39	5.4	15.2	26	10	64	2.10	60	69	3.2
42-84	7.8	11.13	70.15	11.22	18.63	16.29	23.4	2.7	38	0.019	7.1	7.6	28	46	46	0.90	35	82	3.2

Soil Sample No. 5 Uncultivated/Al-Najmy

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-17	7.6	2.44	78.10	11.88	10.02	1.96	9.2	0.67	26	0.12	2.5	2.5	36	4	11	0.3	7.5	42	1.6
17-34	7.55	3.07	high gypsum			27.4	13	0.08	28	0.64	0.2	3.1	36	4	14	0.3	12.5	40	1.6
34-73	7.6	3.12	"	"		26.03	10	0.17	19	0.45	0.6	2.9	36	4	13	0.2	10	40	3.2

Soil Sample No. 6 Uncultivated/Al-Najmy

0-18	7.4	8.65	70.53	7.38	22.8	2.57	16	1.58	35	0.16	4.5	2	38	34	12	1.20	37.5	54	2.4
18-40	7.7	8.95	high gypsum			3.73	19.8	1.0	22	0.13	4.5	13.2	12	4	37	0.7	17.5	33	2.4
40-85	7.65	5.55	78.24	5.51	16.24	4.72	18.8	1.31	23	0.11	5.6	3.7	20	12	15	1.9	20	24	3.2

Soil Sample No. 7 — Uncultivated/Safwan

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gypsum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-10	7.9	0.9	83.01	3.94	13.04	6.17	13	0.36	20	0.20	1.8	0.8	8	4	2	0.1	5	5	2.4
10-34	7.7	0.99	85.51	12.04	2.44	8.22	11.6	0.33	23	0.050	1.4	1.1	8	6	3	0.1	10	13	3.2
34-88	7.6	1.94	75.14	4.05	20.2	5.46	13.2	0.27	20	0.019	1.3	1.7	12	4	5	0.1	5	8	2.4

Soil Sample No. 8 — Uncultivated/Safwan

0-17	7.8	1.44	82.95	7.0	10.04	4.08	14.2	0.35	20	0.080	1.7	0.6	12	6	2	0.1	10	8	2.4
17-35	7.8	1.99	79.33	2.06	18.8	4.77	14.6	1.02	16	0.04	6.3	1.4	14	2	4	0.5	5	13	2.4
35-76	7.8	1.86	76.69	4.30	19.0	4.09	13.8	0.29	20	0.13	1.4	1.6	10	2	4	0.5	5	12	2.4

Soil Sample No. 9 Uncultivated/Salwan

Depth cm	pH past	Sat. Ext EC mmhos/cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-14	7.9	5.33	high gypsum			4.11	5.8	0.65	17	0.16	3.8	2.9	38	10	14	1	7.5	53	2.4
14-35	7.75	5.48	34.96	37.95	27.8	4.02	14.6	0.69	22	0.082	3.1	2.3	24	14	10	0.3	7.5	37	3.4
35-84	7.65	4.21	high gypsum			12.95	16	0.1	28	0.012	0.3	11.1	28	12	49	0.2	10.0	76	3.2

Soil Sample No.10 from the surrounding areas/uncultivated soil*

Depth cm	pH past	Sat.ext EC mmhos/cm	Mechanical Anal Sand %	Silt %	Clay %	Gypsum %	Lime %	Exch Na me/100g	C.E.C. me/100g	Exch Na %	O.M. %
0-12	7.4	2.1	71	29	0	1.54	15.4	1.5	5.4	27.8	0.3
12-32	7.55	2.08	high	gypsum		10.50	14.0	2.3	8.6	26.5	0.3
32-60	7.6	2.05	"	"		11.53	3.6	2.01	14.2	14.2	0.2

* Samples Nos.10-12 acquired from :

Basheir, S. Report on reconnaissance of soil survey of Al-Zubair area, State Organization for Soil and Land Reclamation, Basrah, 1978, pp.6-11.

Soil Sample No.11 from the surrounding areas

0-25	7.4	1.90	78	9	13	14.72	10.6	1.12	5.4	15.9	0.4
25-40	7.55	2.18	high gypsum			41.12	6.4	1.42	7.8	18.2	0.13
40-70	7.65	2.52	"	"		48.0	2.6	1.54	7.6	20.3	0.09

Soil Sample No.12 from the surrounding areas

Depth cm	pH past	Sat.ext EC mmhos/cm	Mechanical Anal.			Gypsum	Lime	Exch Na me/100g	C.E.C. Me/100g	Exch Na %	O.M. %
			Sand %	Silt %	Clay %						
0-14	7.75	2.08	74	18	8	1.47	19.2	0.86	5.24	16.4	0.37
14-52	7.45	2.0		high gypsum		23.21	11.3	0.77	8.1	9.5	0.17
52-92	7.45	2.45		" "		13.85	7.0	1.44	13.6	10.6	0.11

Soil Sample No. 13 — One year/cultivated/Al-Berjsiyha-Chwibda

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-16	7.9	3.54	76.44	1.15	22.4	3.33	7	0.26	31	0.48	0.8	1.0	30	2	4	0.2	5	29	1.6
16-35	7.9	4.63	78.04	3.23	18.72	2.71	8	1.76	30	0.54	5.8	0.9	34	6	4	0.3	5	36	1.6
35-60	7.8	4.54	high gypsum			4.82	13	1.81	29	0.17	6.2	3.1	32	8	14	0.5	7.5	43	3.2

Soil Sample No.14 — One year/cultivated/Al-Berjsiyha-Chwibda

0-15	7.9	19.87	62.77	32.90	4.32	3.29	23.4	0.06	26	1.58	0.2	34.0	26	14	150	2.80	102.5	85.8	5.6
15-30	7.8	8.58	75.59	22.4	2.0	11.29	20.0	0.71	29	0.89	2.4	16.3	24	6	62	1.20	30	59	4
30-60	7.8	9.42	72.4	14.87	12.72	20.40	16.4	9.5	29	0.20	32.7	7.8	38	22	39	0.70	25	71	3.2

Soil Sample No. 15 One year/cultivated/Al-Najmy

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-15	7.75	13.58	73.25	21.5	5.24	3.99	23.6	0.10	33	1.32	0.3	15.1	40	20	82	1	40	101	2.4
15-30	7.7	7.75	74.43	4.04	22.52	3.32	22.6	1.30	33	0.45	3.9	5.9	30	16	28	0.30	7.5	64	2.4
30-60	7.75	5.98	73.24	4.31	22.45	1.25	24.6	5.26	26	0.15	20.2	4.5	26	8	18	0.20	5.0	44	3.2

Soil Sample No. 16 One year/cultivated/Al-Najmy

0-15	7.9	4.59	66.49	5.5	28.0	31.52	17.8	0.5	17	0.89	2.9	8.2	18	4	33	0.5	17.5	35	3.2
15-30	7.9	4.52	63.78	4.22	32.0	23.25	14.4	2.2	18	0.51	12.2	3.2	26	12	14	0.40	10	42	1.6
30-60	7.9	13.43	high gypsum			26.02	4.0	0.1	20	0.11	0.5	5.1	20	2	17	0.3	7.5	30	1.6

Soil Sample No. 17 | One year/ cultivated/ Safwan

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal.			Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L				Anions me/L		
			Sand %	Silt %	Clay %								Ca	Mg	Na	K	CL	SO_4	HCO_3
0-15	7.85	16.25	85.53	1.18	13.28	4.0	9.2	5.1	16	1.58	31.8	35.1	38	22	190	0.5	90	158	2.4
15-30	7.85	4.61	84.84	13.15	2.0	4.06	8.6	2.8	18	0.89	15.5	10.5	24	4	39	0.2	22.5	42	2.4
30-60	7.9	2.21	87.82	2.57	7.6	2.71	3.8	0.51	22	0.20	2.3	11.0	10	6	31	0.1	10.0	45	2.4

Soil Sample No. 18 | One year/cultivated/Safwan

0-15	7.5	5.43	43.22	12.29	4.48	4.71	18.4	0.08	26	0.33	0.3	5.9	34	6	26	1.20	20	45	2.4
15-30	7.8	4.48	78.45	3.34	18.2	4.06	20.8	0.05	29	0.13	0.1	7.6	20	4	26	0.5	12.5	35	2.4
30-60	7.6	5.96	89.61	0.3	10.09	14.32	18.2	0.06	18	0.11	0.3	8.5	18	16	35	0.2	12.5	54	2.4

Soil Sample No. 19 Two years/cultivated/Al-Berjsiyha-Chwibda

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal.			Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L				Anions me/L		
			Sand %	Silt %	Clay %								Ca	Mg	Na	K	CL	So_4	HCo_3
0-15	7.5	20.32	71.29	2.9	25.8	3.26	26.8	0.30	24	1.01	1.2	22.5	34	46	142	3.50	150	74	1.6
15-30	7.6	8.22	72.56	1.23	26.2	1.95	24.2	1.48	18	0.45	8.2	13.9	30	14	64	1.20	40	68	1.6
30-60	7.5	7.32	8.95	6.25	84.8	3.28	25.6	4.5	26	0.34	17.3	10.4	26	14	46	0.90	35	48	3.2

Soil Sample No. 20 Two years/cultivated/Al-Berjsiyah-Chwibda

0-15	8	12.64	78.05	6.8	14.6	2.67	12.4	1.7	16	1.31	10.6	5.2	30	8	22.5	1.5	50	203	11.2
15-30	7.75	5.96	73.32	16.23	10.44	4.04	8.8	1.23	22	0.07	5.5	6.6	38	2	33	0.5	22.5	47	3.2
30-60	7.4	6.33	74.83	23.16	2.0	3.33	20.4	2.3	28	0.11	8.2	7.0	24	12	31	0.1	17.5	47	2.4

Soil Sample No. 21 — Two years/cultivated/Al-Najmy

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-15	7.95	5.4	87.32	2.27	10.4	1.97	13	1.54	38	0.53	4.0	4.0	34	6	18	0.7	10	46	1.6
15-30	7.9	8.64	89.30	0.29	10.4	7.47	9.6	1.96	33	0.32	5.9	3.8	36	4	17	0.5	7.5	48	2.4
30-60	8.05	6.49	89.58	5.01	10.4	4.76	12.6	1.71	34	0.12	5.0	3.5	13	11	19	0.1	12.5	28	3.2

Soil Sample No.22 — Two years/cultivated/Al-Najmy

0-15	7.9	4.22	86.79	2.8	10.4	6.10	20	2.09	33	0.95	6.3	0.9	24	12	4	0.7	2.5	35	2.4
15-30	8.0	3.09	90.41	3.99	5.6	6.83	9	1.03	30	0.55	3.4	1.9	12	8	6	0.5	5	35	1.6
30-60	8.1	3.18	87.09	2.48	9.6	3.39	8.6	1.32	30	0.14	4.4	3.2	16	4	10	0.7	5	33	2.4

Soil Sample No. 23 Two years/cultivated/Safwan

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal.			Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L				Anions me/L		
			Sand %	Silt %	Clay %								Ca	Mg	Na	K	CL	So_4	HCo_3
0-15	7.3	6.09	89.61	0.34	10.04	4.77	15.2	0.21	18	0.11	1.1	14.8	14	6	46	0.2	25	38	3.2
15-30	7.7	9.03	81.14	3.25	15.6	2.64	15.4	0.18	23	0.23	0.7	20.0	20	10	76	0.6	40	64	2.4
30-60	7.9	6.61	84.9	12.29	2.8	4.09	18	0.33	17	0.012	1.9	14.2	10	4	37	0.1	22.5	27	2.4

Soil Sample No. 24 Two years/cultivated/Safwan

0-15	7.8	2.74	78.97	7.02	14	6.77	8.9	0.1	23	0.32	0.4	23.0	24	28	115	0.5	55	110	2.4
15-30	7.9	2.28	78.86	12.33	8.8	4.75	15	0.1	20	0.12	0.5	15.2	18	8	55	0.2	30	48	3.2
30-60	7.9	6.01	80.84	4.35	14.8	6.10	11.2	0.7	18	0.012	3.8	10.0	20	16	42	0.2	17.5	58	2.4

Soil Sample No. 25 One year/cultivated/subsurface irrigation

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-18	7.9	1.99	89.44	6.96	3.6	2.63	11	1.68	17	0.41	9.8	1.4	44	8	7	6.5	45	70	1.6
18-46	8.1	5.49	84.58	5.01	10.4	1.98	8.6	1.62	38	1.15	4.2	6.6	24	12	28	0.2	17.5	46	0.8
46-78	8.3	9.97	71.32	5.08	23.6	2.02	6.2	3	39	1.34	7.6	22.8	4	12	64	0.5	7.5	13	2.4

Soil Sample No. 26 One year/cultivated/Drip irrigation

0-15	7.8	9.22	94.54	3.46	2.0	2.64	8	2.26	35	0.38	6.4	9.1	36	12	44	0.2	35	56	1.6
15-38	8.1	4.90	85.58	2.25	12.16	2.70	7	2.28	38	0.52	6.0	8.5	20	4	29	0.2	12.5	39	1.6
38-76	8.1	2.99	89.39	1.17	2.44	2.72	6.2	1.69	39	0.46	4.3	7.9	10	2	19	0.5	7.5	21	2.4

APPENDIX 4.1 Soil Samples of Chapter Four

Soil Sample No. 1 Irrigated Soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-28	6.3	29.4	4	76	20	1.7	31.0	1.0	26.4	1.7	3.8	13.6	60	308	186	1.0	240	315	0.8
28-77	6.4	15.5	3	27	70	2.3	30.6	0.9	21.2	1.2	4.3	20.7	28	48	128	0.9	87.5	126	0.8
77-104	7.1	7.9	7	67	27	0.2	28.8	1.6	23.0	0.6	6.9	3.2	28	24	16.4	1.0	17.5	50	1.2

Soil Sample No. 2 Irrigated Soils

0-20	6.7	29.4	11	60	39	2.2	39.4	2.3	18	1.7	12.5	31.5	40	92	256	0.5	202	186	0.8
20-35	7.2	43.2	30	44	26	2.1	38.8	2.4	26	1.2	9.2	15.1	32	64	105	1.0	75	126	1.2
35-78	6.8	11.2	4	64	32	1.9	37.8	2.8	19.4	0.6	14.4	21.1	40	48	140	1.0	157	71	0.8

Soil Sample No. 3 Irrigated Soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-17	7.1	11.6	4	69	27	2.7	31.0	2.8	30.2	0.9	9.2	8.5	40	56	59	0.5	75	80	0.8
17-30	6.8	7.8	4	65	31	1.7	29.6	1.5	26	0.6	5.7	6.3	56	12	36	0.5	42	62	0.8
30-60	6.8	12.1	5	66	30	2.3	29.2	0.5	22	0.5	2.4	10.9	44	48	48	1.0	80	68	0.8

Soil Sample No. 4 Irrigated Soils

0-25	7.5	24.3	2	54	44	0.8	25.2	8.4	67.0	1.6	12.5	10.7	43.6	78.8	84	n.d.	113.6	84	11.2
25-75	7.6	2.2	2	50	48	0.5	29.8	4.6	71.5	n.d.	6.4	5.7	18.8	3.4	19	n.d	18.2	15	8.8
75-105	7.6	2.1	1	55	44	0.4	29.6	4.3	70.0	n.d	6.1	5.5	16.6	2.2	17	n.d	15.2	18	6.4

Source : Polservice Co., part 3-4. op.cit., p.105.

Soil Sample No. 5 — Irrigated Soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-20	7.8	10.7	2	52	46	0.1	27.1	2.9	28.5	1.5	10.1	8.4	41	73	64	n.d	87	55	6
20-37	7.7	9.7	2	56	42	0.1	n.d	4	36.8	n.d	10.8	9.5	33	66	67	n.d	72	47	6
37-80	7.6	7.1	2	52	46	0.1	23.7	2.4	36.9	n.d	6.5	5.7	30	63	39	n.d	49	37	6

Source : Polservice, Part 3-4, op.cit., p.116.

Soil Sample No. 6 — Irrigated Soils

0-15	7.7	8.5	6	56	38	0.2	27.8	2.4	21.2	1.8	11.3	10.1	33	45	63	n.d	52	54	8.8
15-28	7.7	4.6	4	58	38	0.1	29.3	1.0	19.4	1.8	5.1	4.8	26	20	23	n.d	20	26	11.2
28-55	7.8	5.4	4	64	32	0.1	28.7	1.4	22.2	n.d	6.3	5.6	29	24	29	n.d	19	39	12.8

Source : Polservice, Part 3-4. op.cit., p.118.

Soil Sample No. 7

Irrigated soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-17	7.4	29.1	16	54	30	0.6	28.5	4.2	27.8	1.7	15.1	13.2	78	108	127	n.d.	234	105	6
17-34	7.7	16.5	14	46	40	0.6	29.3	3.7	26.5	1.3	13.9	11.6	44	70	88	n.d.	140	84	5
34-75	7.8	12.6	10	48	42	0.6	29.6	3.5	30.9	n.d	11.3	10.0	30	57	66	n.d	82	74	4

Source : Polservice, Part 3-4, op.cit., p.122.

Soil Sample No. 8

Abandoned soils

0-20	6	66.5	15	54	41	10.1	27.4	1.7	27	1.3	6.2	48.1	80	296	660	2	677	358	0.8
20-34	6.7	38	12	44	46	5.3	28.4	1.1	28	0.7	4.1	14.8	68	156	266	2	315	175	0.8
34-75	6.7	19	10	49	41	4.8	25.2	6.7	27.5	0.5	24.2	16.3	48	84	133	0.5	118	146	1.2

Soil Sample No. 9 Abandoned soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal.			Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L				Anions me/L		
			Sand %	Silt %	Clay %								Ca	Mg	Na	K	CL	SO_4	HCO_3
0-20	6.5	43.2	6	68	26	4.48	38.2	2.8	22.0	1.5	12.9	24	96	196	290	1	440	142	0.8
20-35	6.3	11.23	5	34	61	4.27	37.8	5.3	27.8	1.3	19.0	7.9	32	64	55	0.5	70	81	0.8
35-78	6.7	6.73	5	63	32	0.62	37	2.3	23.4	0.9	9.7	5.7	36	24	31	0.2	35	56	1.2

Soil Sample No. 10 Abandoned soils

0-20	6.5	55.3	4	64	33	5.1	38	0.8	17.4	1.3	4.8	35.8	68	292	480	4	525	288	0.8
20-38	6.9	15.5	13	79	9	4.3	32	0.9	21.8	1.3	4.2	11.8	36	88	93	0.5	100	117	1.2
38-80	7.2	6.4	1	67	32	0.9	33	1.2	24.0	0.8	5.0	6.2	32	24	33	0.3	30	59	1.2

Soil Sample No. 11

Abandoned soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal. Sand %	Silt %	Clay %	Gyp-sum %	Lime %	Ex.Na me/ 100g	C.E.C me/ 100g	O.M. %	Esp %	SAR me/L	Cations me/L Ca	Mg	Na	K	Anions me/L CL	SO_4	HCO_3
0-16	7.7	48.9	28	50	22	0.6	36.2	5.8	19.5	1.8	29.7	39.6	67	148	411	0.1	456	154	4
16-40	7.6	43.8	39	35	26	0.6	31.2	3.2	21.5	0.59	14.8	39.1	49	120	360	0.1	361	138	6
40-63	7.7	21.4	16	52	32	0.5	32.9	6.2	27.1	n.d	22.8	24.4	43	75	188	0.1	148	107	5

Soil Sample No. 12

Abandoned soils

0-20	7.7	60.0	12	54	34	0.1	32.5	1.3	21.1	0.9	6.1	5.3	39	21	29	1.0	38	39	6
20-50	7.7	17.5	12	42	64	0.5	23.9	7.3	33.2	0.5	21.9	20.0	10	22	80	0.5	82	41	4
50-90	8.2	15.5	8	50	42	0.7	24.8	4.4	22.2	n.d	19.8	18.0	28	35	101	n.d	90	49	4

APPENDIX 5.1 Soil samples of Chapter Five

Soil Sample No. 1 Irrigated Soils

Depth cm	pH past	Sat. Ext EC mmhos /cm	Mechanical Anal.			Gyp-sum %	Lime %	Ex.Na me/100g	C.E.C me/100g	O.M. %	Esp %	SAR me/L	Cations me/L				Anions me/L		
			Sand %	Silt %	Clay %								Ca	Mg	Na	K	CL	SO_4	HCO_3
0-18	7.5	3.44	10.9	38.3	50.6	4.6	28.8	1.09	23	2.72	4.7	3.6	14	8	12	n.d.	6.2	27	1.6
18-30	7.5	3.30	18.6	44.6	36.6	3.3	28.8	0.4	22	2.72	1.8	4.5	10	12	15	n.d.	10	24	3.2
30-67	7.6	3.57	5.8	56.0	38.0	3.2	26.0	1.19	29	1.10	4.1	4.9	12	12	17	n.d.	15	24.4	1.6

Soil Sample No. 2 Irrigated Soils

0-20	7.7	3.0	4	69	27	3.5	27.4	1.07	30.8	2.36	3.47	3.13	22	18	14	n.d	18.7	34.4	0.8
20-38	7.5	2.8	4	65	31	2.4	25.2	0.95	20.6	1.78	4.61	3.13	24	16	14	n.d.	13.7	39.4	1.2
38-72	7.9	2.3	5	66	30	1.2	23.8	3.16	30.2	1.50	10.4	3.5	18	14	14	n.d	12.5	32.7	0.8

Soil sample No.3 Irrigated soils

Depth cm	pH	Ec mmhos/cm	CEC me/100g	Ex.Na me/100g	O.M. %	Ca me/L	Mg me/L	Na me/L	Cl- me/L	SO4 me/L	HCO3 me/L	SAR me/L	Esp %
0-18	7.8	5.43	23	1.92	2.09	12	32	23	15	50	2.4	4.9	8.3
18-30	7.8	4.89	28	2.27	1.61	16	20	13	7.5	39	3.2	3.06	8.1
30-67	7.7	9.77	28	0.84	1.01	40	24	30	35	59	1.8	5.3	3

Soil sample No. 4 Irrigated soils

0-20	7.9	7.75	20	0.96	2.09	20	36	25	17.5	60	3.2	4.7	4.8
20-38	7.7	4.43	25	0.10	1.74	20	18	25	17.5	33	3.2	6.6	0.4
38-72	7.9	4.03	24	0.20	1.03	20	12	20	10	28	2.4	6.0	0.8

Soil sample No.5 Irrigated soils

Depth cm	pH	Ec mmhos/cm	CEC me/100g	Ex.Na me/100g	O.M. %	Ca me/L	Mg me/L	Na me/L	Cl me/L	SO4 me/L	HCo3 me/L	SAR me/L	Esp %
0-18	7.5	2.64	26.6	1.27	1.46	20	16	11	10	36.2	1.2	2.5	4.7
18-30	7.6	2.2	21.4	1.15	1.47	16	8	10	10	22.8	0.8	2.8	5.3
30-67	7.5	3.1	23.4	0.76	1.05	18	16	20	16.2	36.9	0.8	4.8	3.2

Soil sample No.6 Irrigated soils

0-20	7.5	3.3	25	1.02	1.09	28	16	14	12.5	39	0.8	2.9	4
20-38	7.6	3.0	23.4	0.47	1.87	20	10	15	13.7	23.2	0.8	3.8	2
38-72	7.6	2.8	24.2	1.6	2.0	20	14	10	9.2	18.4	0.8	2.4	6.6

Soil sample No.7 Unirrigated soils

Depth cm	Sand %	Silt %	Clay %	Lime %	Gyp-sum %	pH	Ec mmhos/cm	Ex.Na me/100g	O.M. %	CEC me/100g	Ca me/L	Mg me/L	Na me/L	HCo3 me/L	Cl me/L	So4 me/L	SAR me/L	Esp %
0-10	29	53	18	22	2.1	7.7	35	7.0	3.75	34.4	40	230	214	8	278	220	18	20
10-35	8	50	42	35	0.5	7.8	20	5.3	1.05	31.2	36	138	139	6.4	146	161	15	17
35-70	6	44	50	42	0.1	8.0	19	5.1	-	29.8	38	116	131	6.4	119	175	15	17

Soil sample No.8 Unirrigated soils

10-16	18	44	38	48.3	n.d.	7.1	41	7.4	n.d.	29.2	50	236	286	7.2	468	150	24	25.4
10-16	14	54	32	34.2	n.d.	7.4	37	4.6	n.d	19.6	30	230	254	1.2	468	130	22	23.7
16-30	10	62	28	23.7	n.d.	7.5	36	3.5	n.d.	13.1	32	182	266	7.2	410	130	26	27.0

APPENDIX 6.1 Soil Samples of Chapter Six

Soil Sample No. 1 Qurnah area - near the river

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/ 100g	GEC me/ 100g	O.M. %	Ec mmhos/ cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	So_4 me/L	HCo_3 me/L	SAR me/L	Esp %
0-15	6	70	24	1.75	19.2	2.21	11.2	1.02	5.38	7.9	12	44	1	26	30	50	3.2	4.9	19.7
15-35	6	49	45	2.58	21.4	2.27	9.6	0.93	3.52	7.8	20	10	1	12	16.25	25	2.4	3.1	23.6
35-74	6	51	43	2.62	21.6	0.96	15	0.72	2.65	7.8	18	4	1	11.5	12.5	22	1.2	3.4	6.4
74-112	6	68	26	1.90	24	1.4	11.8	0.69	3.24	7.8	24	4	0.2	12.4	13.75	24	2.4	3.3	11.8
112-185	6	64	30	2.63	22.2	1.64	16.6	0.69	2.16	8.0	11	7	0.2	10.2	10	18	0.8	3.4	9.8

Soil Sample No. 2 Qurnah area - marginal area

0-18	5	59	36	1.53	25.8	8.1	14.6	0.4	11.46	8.1	40	48	5	250	210	131	1.2	37.7	55.4
18-42	5	64	31	1.83	27.4	9.13	15.4	0.78	4.85	8.0	12	24	2	81	77.5	41	1.2	19.1	59.0
42-73	2	68	30	1.93	28.8	6.27	8.4	0.39	6.17	8.0	8	10	1	27	35	9	1.6	9.0	74.6
73-108	2	57	41	1.87	28.2	4.5	21.8	0.39	5.29	8.1	16	6	1	22.5	30	15	0.8	6.7	20.6
108-190	3	50	47	1.88	27	5.94	16.6	0.27	30.8	8.2	12	12	1	232	282.5	15	2.4	67.0	35.7

Soil Sample No. 3 — Germa area - near the river

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/100g	GEC me/100g	O.M. %	Ec mmhos/cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	SO_4 me/L	HCO_3 me/L	SAR me/L	Esp %
0-12	4	73	23	1.73	31	2.64	21.4	0.97	5.46	7.6	32	20	nil	32	37.5	45.7	0.8	6.2	12.3
12-30	5	64	31	2.52	29.6	2.8	21.4	1.03	4.05	7.7	20	24	"	20	20	43.2	0.8	4.2	13.0
30-48	3	71	26	1.82	29	1.66	25.6	2.11	3.88	7.6	20	20	"	22	25	36.2	0.8	4.9	6.4
48-105	1	70	29	2.49	26.8	0.55	22	1.71	4.14	7.5	24	16	"	26	22.5	42.3	1.2	5.8	2.5
105-180	2	69	29	2.19	34.6	9.95	18	1.1	13.23	7.5	68	4	"	95	100	66.2	0.8	15.8	55.2

Soil Sample No. 4 — Germa area - marginal area

0-15	3	78	19	28.1	26.6	7.7	16	0.4	44.1	8.1	40	72	7	540	385	266	1.2	72.1	48
15-37	11	39	50	21.8	29	2.85	13.4	1.13	9.77	8.1	40	4	1	70	60	64	0.8	14.9	21.2
37-62	7	42	51	1.35	34	5.3	14	0.4	8.43	8.0	52	8	1	42	30	72	0.8	7.6	37.8
62-114	6	38	56	11.42	35	2.29	14.4	0.2	7.05	7.9	28	20	1	51	35	64	0.8	10.4	15.9
114-195	5	73	23	10.09	36	0.84	40	0.26	7.14	7.8	32	12	1	43	35	53	0.8	9.1	2.1

Soil Sample No. 5 Tanooma area - near the river

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/100g	GEC me/100g	O.M. %	Ec mmhos/cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	SO_4 me/L	HCO_3 me/L	SAR me/L	Esp %
0-10	3	60	37	4.3	18.6	3.9	15	1.54	9.7	7.5	50	42	1	77	75	95	0.8	11.3	26
10-42	3	42	55	2.45	19.2	3.1	18.4	1.42	6.17	7.6	28	30	1	25	37.5	46	1.6	4.6	16.8
42-78	4	61	35	2.46	19.6	3.24	17	0.96	4.05	7.8	16	24	1	22	30	32	1.6	4.9	19.0
78-122	2	58	40	1.90	15.6	3.08	16.6	0.90	3.35	7.8	20	10	1	12	15	28	0.8	3.1	18.5
122-187	1	62	36	1.89	16.4	2.27	17.4	0.90	3.96	7.8	22	6	1	20	22.5	27	2	5.3	13.0

Soil Sample No. 6 Tanooma area - marginal

0-15	17	62	21	19.6	12.4	4.1	11.8	0.84	30.87	8.1	48	140	2	232	282.5	139	1.6	23.9	34.7
15-40	18	79	3	19.41	15	1.42	17.6	0.72	15.87	7.9	36	68	1	93	112.5	85	0.8	12.8	8.0
40-80	24	60	16	17.5	13.6	2.4	12	0.39	7.49	7.8	32	32	1	30	42.5	52	0.8	5.3	20.0
80-120	27	58	14	1.69	25.6	2.63	15.6	0.57	6.26	7.7	24	32	1	11	30	37	1.6	2.0	16.8
120-190	20	62	18	4.48	16.2	3.22	12.8	0.75	5.38	7.8	28	32	1	6	27.5	38	1.6	1.2	25.1

Soil Sample No. 7 — Seebah area - near the river

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/100g	GEC me/100g	O.M. %	Ec mmhos/cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	So_4 me/L	HCo_3 me/L	SAR me/L	Esp %
0-17	57	23	20	9.29	35.8	8.5	15	0.57	52.9	7.8	100	232	5	325	537.5	123	2.4	25.5	56.6
17-45	8	79	13	14.66	34.2	5.2	16	1.65	12.34	7.8	44	44	3	62	87.5	65	1.6	9.3	32.5
45-78	9	47	43	3.59	39.8	4.5	18.4	1.41	10.58	7.8	40	56	3	39	82.5	55	1.2	5.6	24.4
78-125	2	50	48	1.75	42.6	3.79	16	0.7	5.29	7.9	24	32	3	6	20	44	1.6	1.1	23.5
125-194	4	46	50	1.95	42.0	3.25	16	0.56	3.52	8.0	12	6	3	5	22.5	3	1.6	1.0	14.6

Soil Sample No. 8 — Seebah area - marginal

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/100g	GEC me/100g	O.M. %	Ec mmhos/cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	So_4 me/L	HCo_3 me/L	SAR me/L	Esp %
0-15	3	59	38	2.95	23.0	2.2	9.8	1.51	60.94	7.9	104	112	15	600	585	246	0.4	57.7	22.4
15-37	2	60	38	2.02	25.6	11.2	17.6	1.21	34.40	7.9	72	48	2	280	295	106	0.6	35.1	6.3
37-82	2	80	18	2.28	27.4	1.5	17.4	0.84	16.71	8.0	56	16	3	148	130	95	1.6	24.1	8.6
82-112	1	55	44	1.68	23.2	1.08	15	0.63	11.79	8.1	14	42	2	118	82.5	93	1.6	22.3	7.2
112-188	1	63	36	1.07	22.8	0.15	13.4	0.45	11.79	8.1	14	34	1	123	320	89	1.6	25.1	1.1

Soil Sample No. 9

Abandoned soils - eastern part

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/100g	GEC me/100g	O.M. %	Ec mmhos/cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	SO_4 me/L	HCO_3 me/L	SAR me/L	Esp %
0-10	22	46	32	3.1	37.8	6.6	25.8	1.29	29.9	7.6	84	176	0.1	276	446	60	13.6	24.2	25.5
10-25	22	48	30	2.2	23.0	7.5	25.0	1.29	47.3	7.6	90	236	0.8	380	592	83	13.6	29.9	30.0
25-35	22	46	32	3.1	23.6	9.8	33.0	0.8	33.6	7.6	75	198	nil	344	463	102	14.0	29.6	29.6
35-70	14	48	38	0.3	25.4	7.8	31.0	0.7	25.2	7.6	73	121	"	237	273	90	15.0	24.1	25.7
70-110	8	48	44	0.6	29.6	n.d.	33.2	0.9	14.7	7.7	56	102	"	163	172	79	10.4	18.5	n.d.

Soil Sample No. 10

Abandoned soils - eastern part

0.1	20	56	24	1.1	34.7	22.0	31.5	1.06	104.2	7.3	117	246	nil	1163	1223	152	5.3	86.7	6.9
10-30	8	50	42	0.6	32.6	11.0	22.2	0.78	62.0	7.4	52	260	"	800	660	218	9.6	64.1	4.9
30-55	2	49	49	0.3	22.6	9.7	23.6	0.64	47.1	7.2	32	134	"	436	468	71	5.6	47.8	41.1
55-85	2	53	49	0.4	36.4	11.0	26.1	0.20	60.8	7.1	40	154	"	524	612	67	7.2	53.2	4.2
85-110	6	57	39	0.4	36.2	11.0	23.2	0.32	75.6	7.1	50	210	"	690	832	84	7.2	60.5	4.7

Soil Sample No. - 11 Abandoned soils - western part

Depth	% Sand	% Silt	% Clay	% Gyp-sum	% Lime	Ex.Na me/100g	GEC me/100g	O.M. %	Ec mmhos/cm	pH	Ca me/L	Mg me/L	K me/L	Na me/L	Cl me/L	SO_4 me/L	HCO_3 me/L	SAR me/L	Esp %
0-15	3	78	19	7.18	17.6	17.2	13.4	1.0	117.96	7.7	80	128	18.6	1330	1160	396	0.8	131.6	12.8
15-38	2	70	28	2.68	23	3.3	17	0.84	113.0	7.9	128	96	18.2	1450	1125	566	1.2	138.0	19.4
38-79	1	59	40	1.07	22.8	6	18	0.81	70.77	7.9	72	72	15	775	755	179	0.4	91.3	33.3
79-105	1	73	26	1.03	19.4	4	24.2	0.69	83.55	7.9	64	104	15	1000	910	273	0.4	109.1	16.4
105-140	1	62	37	1.71	19.4	5.8	13.6	1.51	88.47	7.7	88	80	15	975	945	213	0.4	106.4	42.6