JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

THE MINISTRY OF AGRICULTURE AND FISHERIES,
THE GOVERNMENT OF THE UNITED ARAB EMIRATES

THE MASTER PLAN STUDY ON THE GROUNDWATER RESOURCES DEVELOPMENT FOR AGRICULTURE IN THE VICINITY OF AL DHAID IN THE UNITED ARAB EMIRATES

FINAL REPORT

VOLUME ONE: MAIN REPORT

NOVEMBER, 1996

SANYU CONSULTANTS INC.

PACIFIC CONSULTANTS INTERNATIONAL

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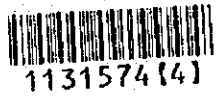
Exchange Rate
(as of January 1996)

US$1.00 = Dh.3.65
Dh.1.00 = US$0.274
US$1.00 = Japanese Yen 106.00

Dh. : UAE Dirhams



PREFACE

In response to the request from the Government of the United Arab Emirates, the Government of Japan decided to conduct a Master Plan Study on the Groundwater Resources Development for Agriculture in the Vicinity of Al Dhaid in the United Arab Emirates (UAE) and entrusted the study to Japan International Cooperation Agency (JICA).

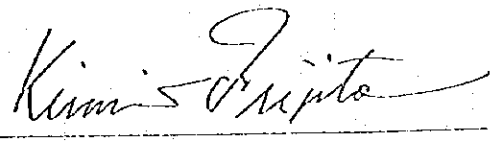
JICA sent a study team headed by Mr. Mitsuru Yoshikawa, Sanyu Consultants Inc., Japan, to UAE three times between April 1995 to September 1996.

The team held discussions with the officers concerned of the Government of UAE and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and enhancement of friendly relations between two countries.

I wish to express my sincere appreciation to the officers concerned of the Government of UAE for their close cooperation extended to the study team.

November 1996



Kimio FUJITA
President,
Japan International Cooperation
Agency

November 15, 1996

Mr. Kimio FUJITA
President,
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Sir,

We are pleased to submit hereby the final report on the Master Plan Study on the Groundwater Resources Development for Agriculture in the Vicinity of Al Dhaid in the United Arab Emirates (UAE). This report incorporates the advise and suggestion of the authorities concerned of the Government of Japan and your good Agency in the formulation of the above mentioned study. Also included are comments made by the Ministry of Agriculture and Fisheries of the government of UAE during discussions which were held in Dubai, UAE.

The study result showed that the existing groundwater use (some 54 MCM/a) in the study area exceeds its sustainable potential (some 22 MCM/a). In case the existing groundwater use is maintained, the groundwater head in the area would be drawn down to 100 m below the ground after 20 years (2015) and the groundwater resource in the area may be dried up after 45 years (2035).

The master plan for agricultural development for the study area was formulated in an aim to introduce water-saving, high-valued and market-oriented type and in two options. The option one is a master plan in an agriculture size (some 2,500 ha) to meet the sustainable groundwater potential. The option two is a master plan in the existing agriculture size (some 4,600 ha) introducing an alternative water resource (some 34 MCM/a of the desalinated water). The economic internal rate of rate for the option one plan showed a feasible extent at 6.5%, and that for the option two plan indicated only 0.4%.

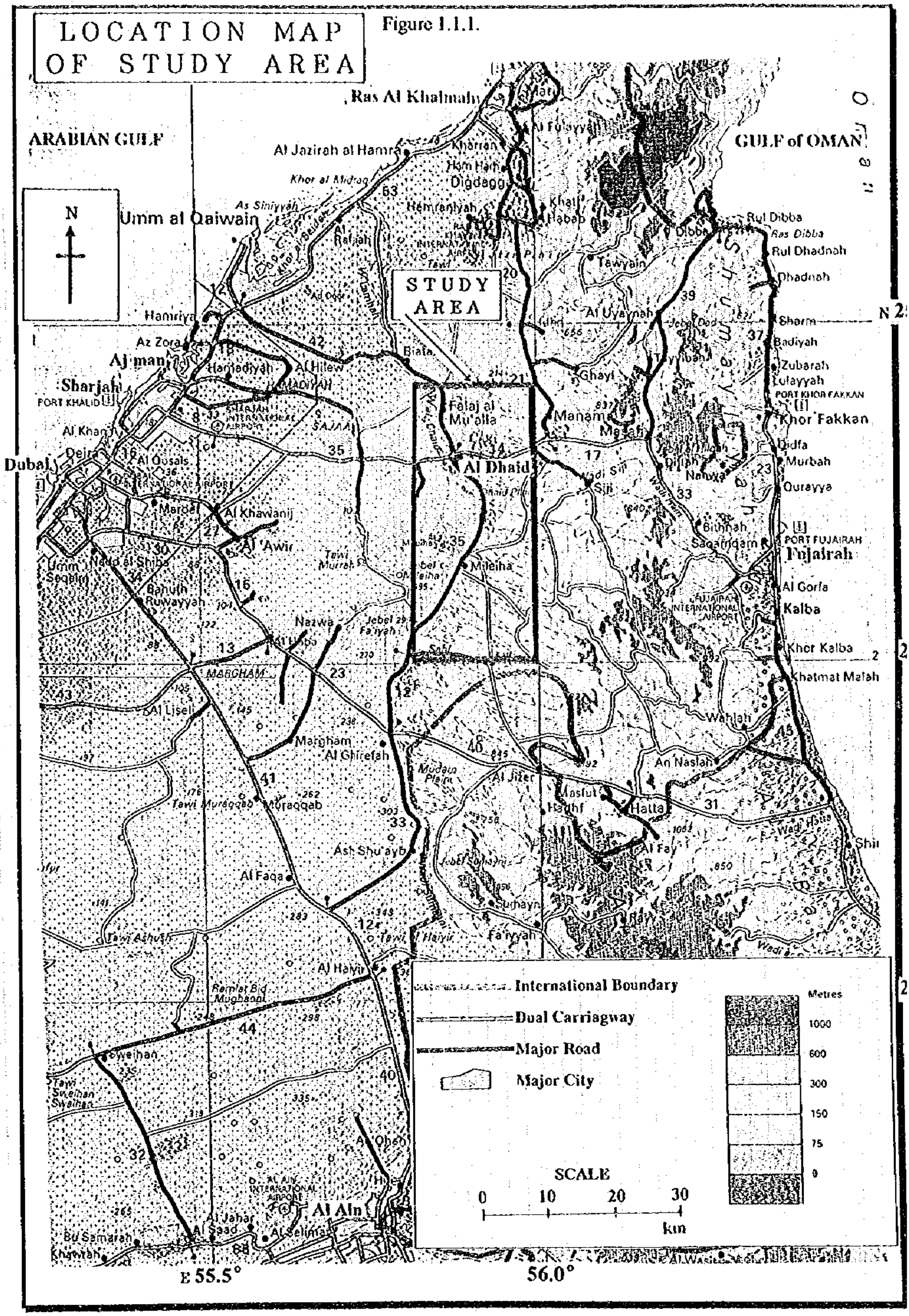
The report consists of four volumes, namely Volume One; Main Report inclusive of Executive Summary, Volume Two; Sector Report, Volume Three Appendices and Volume Four; Supplementary Drawings.

We wish to take this opportunity to express our sincere gratitude to the related officers of your good Agency and the Government of Japan for their effective advise and suggestion for the study. We would like to express our heartiest appreciation to the relevant officers of the Ministry of Agriculture and Fisheries and other agencies of the Government of UAE who are listed in Appendix-2 of Main Report for their close cooperation and warm assistance extended to the study team during its works in UAE.

Very Truly Yours,

吉川 満

Mitsuru YOSHIKAWA
Team Leader,
the Master Plan Study on the Groundwater Resources Development for Agriculture in the Vicinity of Al Dhaid in UAE


LOCATION MAP OF STUDY AREA
Figure 1.1.1.
ARABIAN GULF
GULF of OMAN
STUDY AREA
Ras Al Khaimah
Umm al Qaiwain
Ajman
Sharjah
Dubai
Al Dhaid
Khor Fakkan
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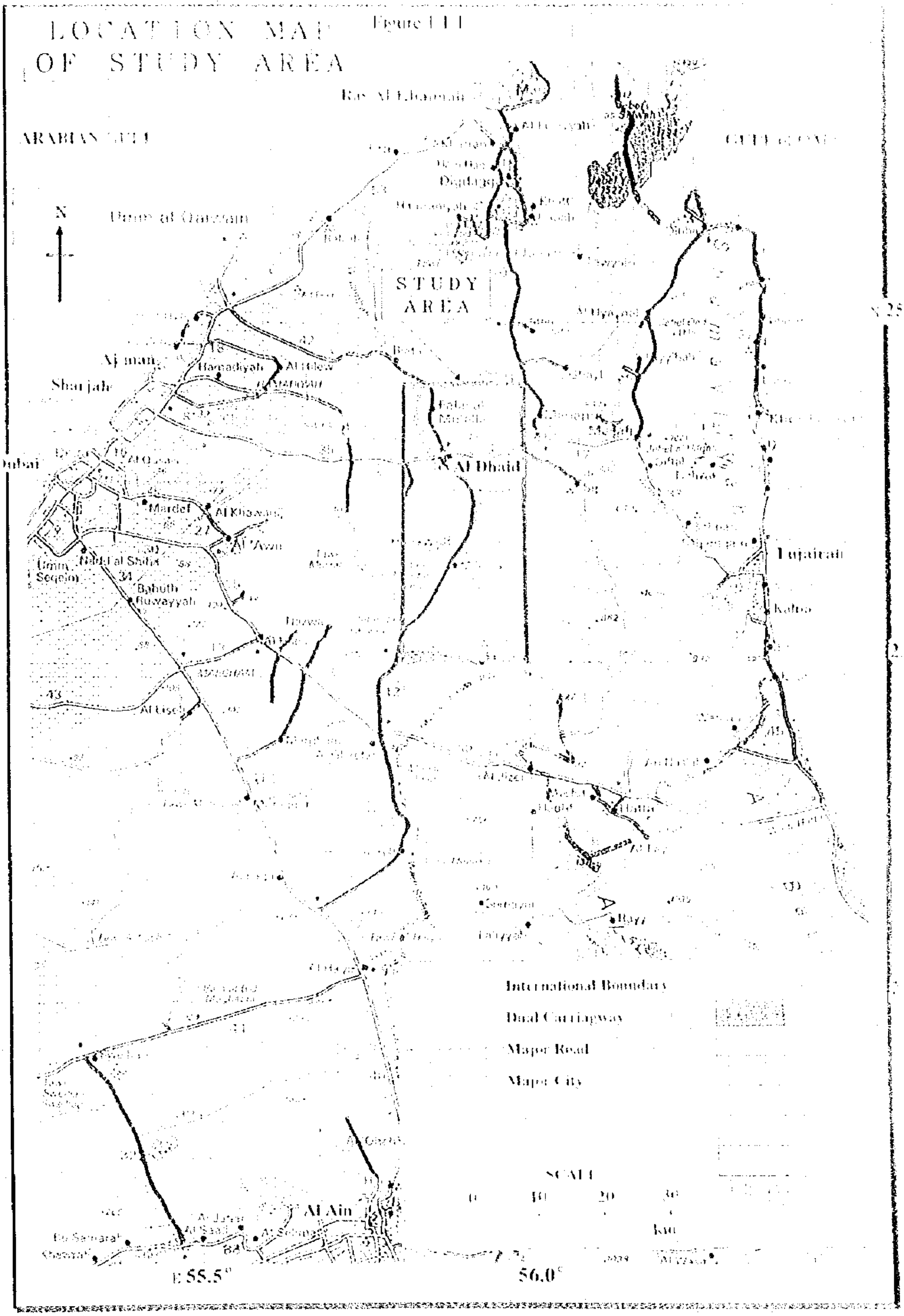

LOCATION MAP OF STUDY AREA
Figure 1.1
ARABIAN GULF
Umm al Qaiwain
STUDY AREA
Ajman
Sharjah
Dubai
Hamadiyah
Mardef
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Al 'Awir
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Umm Seqeim
Bahuth Ruwayyah
Al Lisel
Al Dhaid
Fujairah
Kalba
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Al Ain
Al Jahili
Al Saad
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The Master Plan Study
on the Groundwater Resources Development for Agriculture
in the Vicinity of Al Dhaid in the United Arab Emirates

FINAL REPORT

EXECUTIVE SUMMARY

Conclusion and Recommendation

(1) Conclusion

The Study Area covers some 850 sq. km around Al Dhaid. Currently, the 2,018 farms which possess 4,584 ha of total cropping land in the Area are used for the cultivation of vegetables, fruit trees and field crops.

The existing agriculture in the Area is simply described as a subsistence, low economic efficiency, high water-consumptive type with extensive production of fruit and fodder crops.

The most (90% or more) of farms in the Area are the property of absentee owners and are extensively and conservatively managed by foreign employees. The farm owners usually reside in urban cities and other businesses form their major means of livelihood. The most of them use their farm as weekend retreats, and instruct their farm managers to produce crops solely for on-farm and in-family consumption, not for the market.

The existing water use in the Area totally depends upon groundwater. There are about 8,000 tubewells for irrigation. The depth of tubewells ranges from 9 m to 609 m, the average depth being 130 m. The existing groundwater use reaches some 54 million cubic meters a year (MCM/a) inclusive of some 2.0 MCM/a of domestic water supply. A simulation conducted using a mathematical model constructed under the present study shows that the sustainable potential yield of groundwater is limited at 20 MCM/a.

The existing three-fold over-draft of groundwater resources in the Area has taken place gradually since 1970s, and has had various adverse affects on groundwater such as the drawdown of the groundwater head to 40 m, the deterioration of water quality and so forth.

The simulation shows that, if the groundwater draft is left at the existing level, the groundwater head will drawdown to 100 m below the ground after 20 years (2015) and be completely exhausted after 45 years (2045). This means that, if the groundwater draft is continued at the existing level, agriculture on the current scale in the Area could not be maintained after 2015 unless an alternative water resource is introduced into the Area.

Under these circumstances, a master plan was formulated under the two policy options described below.

Option One: A master plan based on a decreased agriculture size (2,548 ha) that can meet the sustainable groundwater potential (22 MCM/a) inclusive of the potential groundwater augmentation (2 MCM/a).

Option Two: A master plan based on the existing agriculture size (4,584 ha) which introduces an alternative water resource (some 34 MCM/a of the desalinated water).

The aim of the agriculture development plan in both options is to provide sustainable, water-saving, high-income and market-oriented solutions. The project evaluation was made in consideration of socio-economic and environmental factors. The target year of the Project was set at 2015 and takes into account probable variations in agricultural area or water resources.

Master Plan in Option One:

The total cropping area is planned to be 2,548 ha, 56% of the existing area. The proportions of crops in the area estimated to be 1,713 ha (67% of total area) of vegetables, 272 ha (11%) of dates and 564 ha (22%) of alfalfa. The cropping intensity of vegetable is calculated at 140%.

The total annual production by crop in the plan are 67,800 tons of vegetables (265% compared to the existing production), 5,229 tons of dates (18%) and 51,209 tons of alfalfa (37%).

Although the total annual production of crops comes to 65% of the existing amount at 124,200 tons, the total net income increases to 126% of the existing amount at Dh. 273 million (US$ 75 million) exclusive of the additional cost of water incurred by the construction of groundwater augmenting facilities.

By applying modern water-saving irrigation systems (drip, bubbler or sprinkler systems), the total water requirement will meet the sustainable groundwater potential (21.5 MCM/a, 37% of the existing amount).

The project plan consists of:

- the construction of three (3) groundwater recharge facilities (set of recharge dam and recharge trench),
- the construction of groundwater monitoring systems,
- the provision of modern irrigation systems and greenhouses in all the farms; and
- others.

The project cost is estimated at Dh. 1,405 million (US$ 385 million). The project is evaluated to be economically feasible showing an internal rate of return at 6.51%.

Master Plan in Option Two:

The total cropping area is to be same as the existing area, 4,584 ha. The proportions of each crop will also remain the same as they are now; 1,158 ha (25% of total area) of vegetables, 1,825 ha (40%) of dates and 1,601 ha (35%) of alfalfa.

The total annual production by crop are planned at 45,800 tons of vegetables, 35,100 tons of dates and 145,500 tons of alfalfa. With the selection of improved crops, the total annual production of crops comes to 118% of the existing amount at 226,400 tons. The total net income increases to 217% of the existing amount at Dh. 467 million (US$ 128 million), exclusive of any additional water costs.

By application of modern water-saving irrigation systems, the total water requirement will reach 107% of the present amount, 55.4 MCM/a. An alternative water source of 33.9 MCM/a would become necessary in addition to the groundwater potential (21.5 MCM/a).

The mean farm size remains at 2.27 ha. The net income of Dh. 231,000 and an annual water requirement of 27,500 m^3.

The project plan consists of the construction of a water pipeline from Sharjah and the same components as Option One project.

The project cost is estimated at Dh. 3,413million (US$ 935 million). The economic internal rate of return of the project comes to only 0.44%.

(2) Recommendation

In order to merely conserve the natural water resources and maintain agriculture in the Al Dhaid area, we recommend the government to consider the proposed policy options, select whichever they deem appropriate, carry out the necessary legal and administrative measures, and implement a project by the year 2015.

Other recommended administrative measures include the construction of groundwater augmenting facilities as well as groundwater monitoring systems, the provision of modern farm facilities, the promotion of the marketing and processing of agro-products, the strengthening of the existing subsidy program, extension and support services by the government for both the absentee and fulltime farm-owners; and so forth.

In the chain of extension and support services, the specific key issue seems to be the motivation of absentee farm-owners. They have to be encouraged to manage their farms in a modern, water-saving and high-value way to contribute to the nation's agricultural production by marketing agro-products from their farms, and to make efforts to conserve the precious natural water resources of the nation.

1. Introduction

The Government of United Arab Emirates (UAE) made a request in 1988 to the Government of Japan to extend its technical cooperation for groundwater development in the agricultural areas of northern UAE.

In response to the request, the Government of Japan dispatched, through the Japan International Cooperation Agency (JICA), a provisional study team. The team discussed the situation with the Ministry of Agriculture and Fisheries (MAF) of the Government of UAE, and it was mutually agreed that technical cooperation was to cover not only groundwater development, but also the formulation of a comprehensive agricultural development plan in the vicinity of Al Dhaid, which is the area most seriously affected by groundwater depletion.

Thus, the Government of Japan has decided to conduct a "Master Plan Study on the Groundwater Resources Development for Agriculture in the vicinity of Al Dhaid" (the Study). Accordingly JICA dispatched a preparatory study team to the UAE. The scope of work for the Study (S/W) was agreed by and between the MAF and the study team in November, 1994. Based upon the S/W, JICA organized and dispatched a team to conduct the Study (the Study Team) in March, 1995.

The objectives of the Study set forth in S/W are:

[1] to conduct a master plan study on groundwater resources development for agriculture in the vicinity of Al Dhaid in UAE; and

[2] to carry out technology transfer to the counterpart personnel of the Government of UAE during the course of the Study.

The Study Area is to cover an area of 850 km^2 around Al Dhaid.

2. UAE in Overview

(1) The Nation

The UAE is situated in the southeast of the Arabian Peninsula. It is a federation of seven emirates of Abu Dhabi, Dubai, Sharjah, Ras Al Khaimah, Fujairah, Ajman, and Umm Al Qaiwain.

The total land area of UAE is 83,600 km^2. The population in 1993 was 2,083,000 including both nationals and resident aliens.

The supreme organization that formulates UAE's political policies and supervises administration is the Supreme Council. This Council consists of the rulers of seven emirates. The

cabinet is composed of ministers of state who are in charge of 19 ministries, and the Supreme Council affairs.

Each emirate has its own government and governmental organization varies from emirate to emirate. The regional municipalities of emirates provide public services.

(2) Socio-economic Factors

As of 1993, social development indicators show that, except for population growth, the UAE is at the same level as the advanced nations.

In the mid-70s and in 1981, the UAE government elaborated five-year development plans. The plans were quickly overtaken, however, by world oil price trends. At the federal level, the plans were abandoned and each emirate came to follow an independent development strategy.

The GDP as of 1994 was Dh. 135 billion (US$ 37 billion) at current prices. The GDP per capita was Dh. 60,500 (US$ 16,600), one of the highest figures the among the Gulf states. The major public revenues come from crude oil-related sources. As of 1993, these provided Dh. 31 billion, or 80% of total revenues. Expenditures in the same year were Dh. 45 billion.

Total exports in 1993 were Dh. 86 billion (US$ 24 billion) including crude oil (53%), re-export (28%) and so on. Meanwhile, the total imports were estimated at Dh. 73 billion (US$ 20 billion) including machinery and transport equipment (38.4%), manufactured goods (25%), and food and livestock (10%) .

(3) Natural Environment

In terms of ground elevation, the UAE is divided in two zones. The low zone extends from sea level up to an elevation of 300 m. This zone is an area of sand dunes and low-lying coastal land. The mountain zone forms a part of the Oman Mountains. Its eastern edge lies on wide-spread gravel plains, which are locally known as "Bahada".

The UAE has a hot desert climate with high temperatures and infrequent irregular low rainfall. There are 210 rain gauge stations and 20 meteorological stations in the UAE. The station records show that the minimum temperature never goes below 0°C in winter, but the maximum temperature rises to more than 45°C in summer. The mean annual rainfall in the UAE is around 119 mm. However, this level varies greatly from year to year, ranging from 282 mm to 24 mm. Almost 90% of the annual rainfall occurs during the winter and spring. The mean annual evaporation is 3,322 mm.

There is no perennial river in the UAE. It is divided into five drainage zones. Hydrological observation in the UAE started in 1965, and since then 21 main wadi gauges have been installed by the MAF.

Along the southeastern bank of the Arabian Gulf, there are lagoonal deposits locally known as "Sabkha" along the coast. The inland deposits are of flood-driven sand and gravel sediments

and aeolian sands. Below these Holocene deposits, Tertiary limestones are prominently distributed. This strata underwent complex folding due to the tectonic movement in the mid-Tertiary period, and forms isolated hills in Bahada plain. The tectonic movement during this period raised the deep-sea Hawasina formation. The Semail Ophiolites originated in the mid-Cretaceous mantle, and formed the Oman Mountains.

Hydrogeological units in the UAE can be divided into the northern mountains, which chiefly consist the of groundwater-bearing Hawasina Formation; the southern mountains which are made chiefly of Ophiolites with a limited groundwater; and the Bahada plains which produce useful amounts of groundwater.

A detailed and practical soil map of UAE is not available at present. According to the "National Atlas of the UAE", the soils have been classified into three types; Entisols, Inceptisols and Aridisols.

No complete botanical survey of UAE has yet been carried out. The shifting dunes of the western dune plains support almost no vegetation apart from clumps of species such as *Cyperus congromeratus* and *Calligonum comosum* which can survive even when almost buried by shifting sand. The coast areas and sabkhah of the west also support little vegetation apart from salt-tolerant mangroves. In the central desert and the northern emirates, Acacia and trebles grow in relatively high density.

(4) Agriculture and Irrigation

Agriculture in the form of oasis cultivation and animal grazing has been practiced in the UAE for more than 2,000 years. Harsh climatic conditions, such as summer temperatures in excess of 45°C and an annual rainfall of less than 120 mm throughout much of the country is a hindrance to the development of agriculture.

The present development policy for agriculture of UAE seems to achieve self-sufficiency in vegetables and fruits. The MAF is responsible for the management and coordination of the water resources, agriculture and fishery sectors at the federal level. Almost all emirates have their own departments of agriculture and fisheries. For administrative purposes, the MAF divides the country into four agricultural regions–Abu Dhabi, Central, Eastern and Northern. The MAF provides its extension and support services to farms through its regional offices except in Abu Dhabi region. The governmental subsidies for farmers are, in general, moderate although the rates vary according to the emirate.

Under the government's agricultural promotion policy, the total farming area in the country has increased 5.5 times from 13,000 ha to 72,374 ha (actual cropping area; 66,682 ha) during the 16-year period from 1978 to 1994; and the number of farms rose 4.2 times from 5,000 to 21,194 during the 21-year period from 1973 to 1994. The area of farms in 1994 was 3.4 ha.

In 1993/94, total agricultural production from a farming area of 54,512 ha was 1.331 million tons with a value of Dh. 2,416 million (US$ 662 million) . Fruit crops are major product in the agriculture of UAE accounting for 60% of total cultivated area and 39% of total value in 1993/94. Vegetable crops followed with 24% of area and 35% of the value. Field crops occupied third place with 14% of the area and 25% of the value.

The major fruit tree was the Date Palm, which covered 53% in area and accounted for 34% of the value, and followed by Citrus and Mango. The main vegetable crops were Tomato, Cabbage, Eggplant, Chard, Jews mallow, Squash, and Cucumber. The main field crops were fodder crops such as Alfalfa and Rhodes grass, which ranked in third and fourth positions with respective production values of 16% and 9% of all crops.

The Abu Dhabi Region produced the largest amount of fruit and vegetables, 38% and 81% of the total productions of the whole UAE in 1993/94. Meanwhile the Central Region was the largest cultivator and producer of field crops, accounting for 38% of the area and 54% of the production.

Goats are the most common livestock in the UAE accounting for 64% (628,943 head) of the total number of livestock, followed by sheep (25%), Cattle (5%) and Camels (5%) according to 1993 figures. Meat production in the same year was 15,547 tons. Camels accounted for 53% of the total meat amount of meat produced, followed by Goats (24%), Cattle (13%) and Sheep (11%).

Because of the dry climate, high evaporation losses and low rainfall, agriculture in UAE is highly dependent on irrigation. The water sources for the irrigation are limited to groundwater. Traditional irrigation has followed Furrow and Basin methods. By 1993 over 60% of the total cultivation area had introduced modern irrigation systems (75%, drip; 23% sprinklers; and 6% bubblers).

3. The Study Area

(1) Geography and Topography

The Study Area is divided into three topographical sections . A Structural Ridge lies along the eastern edge of the northern UAE. It extends from Ghayl in the north to Hatta in the south. The base rocks underlying the surface are deformed by faulting and arching. The Bahada Plains (gravel plains) are composed of a complex set of alluvial fans at the foot of the Structural Ridge. Plains are found around Al Dhaid, Gharif and Madam. The western edge of the Bahada plain is bounded by a series of foothills stretching north-south. The Structural Plain, which is 50 km wide, is an uneven plain curving downwards at the western end of the structural ridge. It is formed by folded ridges deriving southwards from Falaj Al Mualla and Jabal Ali (Oman Mountains).

(2) Geology, Hydrology and Groundwater

More than 50% of the Study Area is covered by unconsolidated deposits comprised of young coastal, coastal and inland aeolian and fluvial deposits. Quaternary semi-consolidated deposits cover wide tracts of the Structural Plain from the east of Dubai to Jabal Ali. Semi-consolidated to consolidated Upper Tertiary sediments are exposed between Madam and Jabal Ali. These belong to the Miocene Period and are differentiated into two groups:

- Upper Group (Upper Fars Formation) composed of poorly-consolidated sandstone and dolomitic limestone.
- Lower Group (Lower Fars Formation) composed of alternate strata of limestone, marl and gypsum.

Upper Cretaceous rocks cover 15% of the surface of the Study Area. Types of this rock comprise the Hawasina-Semail Ophiolite Complex that forms the mountain ridge between Ghayl and Masufut, and carbonate rocks that are widely distributed south of Manammah. The carbonate rocks form what are known as basic 'boulder beds' in the top portion of the Juweiza Formation, and also include the series of fossiliferous limestone at Jabel Fayah. The MAF (IWACO, 1986) has suggested that the Juweiza Formation may form the foundation of the Study Area down to a depth of 1,000 m.

The extensive and local aquifers in the Study Area are classified into two types; highly productive and moderately productive types. The highly productive aquifer has a specific capacity of 10 m^3/hr/m or more. The moderately productive aquifer has a specific capacity in the range of from 2 to 10 m^3/hr/m. An important aquifer in the Central Agricultural Region is in Quaternary strata which are widely distributed from the western Bahada Plain to the Structural Ridge and is moderately productive. At present the major aquifer is the Juweiza Formation. The transmissivity of the formation is high in between Madam and Dhaid, the highest value that has been indicated is 1,166 m^2/day. To the north of Dhaid, the values are generally lower, coming to 30 m^2/day or less, and the storage coefficient in 0.001 to 0.02. It is a well-known fact that there is groundwater in the fissure systems and the weathered parts of the Hawasina and Semail Ophiolite rocks. The well yields are, however, not more than 210 m^3/hr.

(3) Groundwater

The well hydrographs in the southern part of the Structural Ridge recorded rises of groundwater heads to 20 m in response to the abundant rainfall of 1982. On the other hand, the groundwater heads in the Western Bahada did not show a pronounced response to this rainfall compared to the Structural Ridge. The well hydrographs in Madam and Hamrania show that the groundwater heads have been declining at an average annual rate of 1.0 m to 1.3 m because of the increased use of groundwater for irrigation. The groundwater head in Al Dhaid dropped at an

annual rate of 0.8 m in 1969 and at a rate of 1.5 m in 1985. In the Western Bahada, where the Quaternary aquifer overlies the Juweiza Formation, the groundwater head in Juweiza aquifer is about equal to that in the Quaternary aquifer. Hydrochemical analysis shows that the Mg:Ca ratio of the groundwater from the Structural Ridge to the Western Bahada is about five to one. The deep groundwater of the Western Bahada is a sodium chloride type.

The groundwater balance for the Central Agricultural Region estimated by IWACO in 1985 showed a groundwater draft of 239 MCM/a and a groundwater recharge of 23 MCM/a. The negative balance of 216 MCM/a showed that "Groundwater Mining" had already proceeded to a moderate extent at that time.

(4) Meteorology and Hydrology

In the Study Area, three meteorological and six rainfall stations are operated by the MAF. Based on the climatological records obtained from Falaj Al Mualla and Mileiha stations, the average annual rainfall is around 127 mm in Falaj Al Mualla and 134 mm in Mileiha. The mean annual temperature at Falaj Al Mualla is 27°C. The highest recorded maximum, mean maximum, mean minimum and lowest recorded minimum temperature are 49, 35, 24 and 19°C respectively. At the same stations, the mean relative humidity is 51%. The mean maximum relative humidity is 90% and the mean minimum is 16%. The mean wind speed is 0.9 m/sec, and the mean pan evaporation is 10 mm/day, or 3,442 mm/year.

Three major wadi catchments–Wadis Ghyal, Lamaha and Thiqebah–form the drainage system in the Study Area. The Wadi Ghayl basin occupies an area 79 km^2 in the northeastern corner of the Study Area. The Wadi Lamaha basin covers the major part of the Study Area and has an area of 1,484 km^2. It is sub-divided into six wadi catchments; North Dhaid, South Dhaid, Siji, Khadrah, Shoukah and Hamdah. Wadi Thiqebah basin is a part of the Wadi Guor drainage system, and includes the southern part of the Study Area. In the Study Area, six wadi gauging stations have been operated by the MAF since 1978.

(5) Soils and Vegetation

According to previous studies, the major soil types in the Area are sireozems, non-saline alkali, saline alkali, non-alkali, and wadi gravel soils. The density of vegetation is relatively higher than in other areas. Belts of three to five meter high acacias and other shrubs are also seen.

(6) Socio-economic Factors

The Study Area is spread over five emirates; Sharjah, Umm All Qaiwain, Ras Al Khaimah, Fujairah and Ajman. Sharjah Emirate occupies the largest part of the Study Area. It includes two towns and 14 villages, which belonging to four Districts–Al Dhaid, Al Mileiha and Falaj Al Mualla. In the 1985 census, the total population of Dhaid and Falaj Al Mualla was 18,630.

As of 1990 the Study Area and surrounding areas had 16 public kindergartens and primary schools, and 17 junior high and high schools. There are clinics in three of the towns and a hospital in Dhaid. The majority of population in the Study Area receive water supplied by the Ministry of Electricity and Water (MEW) or the municipality. The MEW provides electricity supplies to households and farms from three power stations inside the Study Area. Apart from school buses, there is no public transport. People usually travel by private car or taxi. The paved dual carriageways pass through the Study Area east to west, and north to south.

The major economic activity in the Study Area is agriculture. Other activities are livestock raising, bee-keeping, retail business, quarrying, and the manufacturing of building materials. There are 479 shops in Dhaid. Of these 100 shops are connected with agriculture.

(7) Agriculture and Irrigation

The Study Area is part of the Central Agricultural Region. According to the MAF statistics (1994), there are 2,018 farm holdings in the Study Area with an arable land area of 6,181 ha. The actual cropping area is 4.584 ha. An average arable area per holding is 3.1 ha.

The cropping is divided into 1,158 ha (58%) for vegetables, 1,825 ha (40%) for fruit trees and 1,601 ha (35%) for field crops. The crop production and its value were 26,000 tons (13%) and Dh. 38 million (12%) from vegetables, 31,000 tons (16%) and Dh. 100 million (31%) from fruit and 141,000 tons (71%) and Dh. 182 million (57%) from field crops. Alfalfa had the highest production value in the Study Area, with 40% of the total, followed by dates (24%), green fodder (17%), squash (4%), tomato (3%) and lemon (3%).

Crops are, in general, sown from September to October and harvested from the end of December to the end of March.

The total area under greenhouse cultivation, at present, is only 3.8 ha in winter and 7.5 ha in summer.

As of 1993, the Central Regional Office of MAF allocated 11 extension personnel to cover 2,911 farms (265 farms/person).

As of 1993, there were 843 dry wells, 8,187 productive wells, 6,585 generators and 3,956 pumps in the Central Region. There are three falajes in the Study Area but they were dry at the time of the study. Each farm in the Study Area has from one to four tubewells. In the northern Dhaid, some farmers are obliged to bring water over a 2 km distance, because the wells in the farm were dry. Some farms have been abandoned due to the financial constraints of bringing in a water supply. In the Study Area 60% of farms have introduced modern irrigation systems such as sprinkler (33%), bubbler (35%), and drip (29%) methods.

4. Survey and Study

(1) Introduction

The major survey and inquiry made under the Study were aero-photo mapping, farm and well inventory survey, soil survey, a series of hydro-geological surveys which included geophysical sounding, core-boring, test-well drilling, infiltration experiments, environmental surveys, and hydrological balance analyses. The major results are described as below.

(2) Farm and Well Inventory Survey

The interview method was used to conduct the farm survey, with the well inventory being conducted simultaneously: 200 farms and 1,100 tubewells on the farms were sampled. Facts clarified by the survey are summarized as below:

Most of farm owners reside in Sharjah, Abu Dhabi and Dubai. The majority engage in other business and visit their farms only occasionally. Less than 10% are subsistence farm owners.

Farms employs an average of 3.5 foreign employees. The average cultivated area is 4.0 ha. Major crops are fruit trees, fodder crops and vegetables. The largest cultivated area is under Dates, 37% of the area, followed by 16% under Alfalfa, and 9% under Rhodes Grass. Major vegetables are Squash and Tomato, followed by Eggplant, Watermelon, and Cauliflower. More than half of the products were consumed at home: 60% of the farms do not sell any crop products. The average crop production was 98 tons per farm in 1994. Fodder crops accounted for 81% of the total production. The net income was Dh. 52,441 per farm with an average 71% of earnings derived from fodder crops, 22% from fruit trees, and the rest from vegetables. On average the farms have 6 tubewells, but operate only about half of them. There are 22 open wells, mainly in Mileiha area, but only on in three of them of them are used. Modern irrigation methods are installed in the Area, bubblers for tree crops accounting for 50%, sprinkler and drip method for other crops at 20% of farms. Most of farms face a shortage of irrigation water, and farms, except Dhaid area, are adversely affected by groundwater salinity.

The numbers of tubewells on farms range from one to 24. Well depths range from 9 to 609 m, the average depth is 130 m. A burst of new well construction started the 1960s and reached a peak in the 1980s. Well life, for abundant wells, is estimated at seven years. Most of the wells were constructed without casing and have neither a lining nor a screen. Pumps are ordinarily set up near the bottom of the wells; the average depth is 100 m. The majority of pumps are of submersible types with capacities of 0.5 to 5.0 L/sec. Water quality has a wide range of variation, from 500 to 10,000 micro-S/cm.

(3) Hydrogeological Survey

(i) Geophysical Survey

Conducted on one N-S and four E-W axes, 130 transient electromagnetic (TEM) soundings and 805 natural gamma ray survey were undertaken.

TEM results, in general, showed a high-low-high series of four resistivity layers. They correlated well in the first and second layers with the Upper Aquifer, with the third layer corresponded to the clay layer (Aquiclude), and the fourth layer to the Lower Aquifer. In the results of the Natural Gamma Ray Survey, 50 anomalies were also detected in the Study Area, and at several stations these coincided with the vertical structure indicated by the resistivity pattern obtained by the TEM survey.

(ii) Core-boring and Test-Well Drilling

Two core-borings, to 200 m and 300 m depths and eight test-well drilling to depths of 70 m to 600 m were conducted in the Study.

The result shows that the stratigraphy is divided into four layers. The first layer consisting mainly of loose sand and gravel extending from the surface to a depth of 20 m. The second layer is mainly composed of semi-consolidated and consolidated gravel and was determined to extend down to a depth of 100 m. Below lower horizon of this, the third layer was discovered to be composed of marl, clay, shale, and claystone. Underlying this was a fourth layer, the basement, comprised of limestone and dolomite mixed with gravel and Ophiolite.

The Lugeon test for the boreholes and the pumping test for the test-wells were conducted. The Lugeon value was one Lu or less. Transmissivity showed a wide range up 290 m^2/day. The storage coefficient was between 0.002 and 0.003.

Geophysical monitoring conducted in both boreholes and test-wells were concerned with both the formation and groundwater. The porosity of the layer thus detected was inferred to be 5% to 40%.

(iii) Hydrogeology

The survey results summarizing the general hydrogeology of the Study Area are described below.

Holocene Sediments (the First Resistivity Layer), which widely cover the Study Area to an average thickness of 20 m, are more deeply overlay the courses of old channels in the east of Wadi Dhaid and Wadi Mileiha. Pleistocene Sediments (the Second Resistivity Layer) consist of a layer of gravelly facies with some clay intercalation. Neogene Sediments (the Second Resistivity Layer) are made up of semi-consolidated to consolidated gravel and minor marl, and sandstone layers with a maximum thickness of 200 m. Paleogene Sediments (the Third Resistivity Layer) mainly consist of an impervious layer of shale, marl, claystone, and dolomite. This formation forms an

impervious layer in the Study Area. Pre-Cretaceous Sediments (the Fourth Resistivity Layer) are correlative to Aruma Group and Semail Ophiolite Complex. There is a pronounced major NNE-SSW trend in the structure which corresponds to secondary faulting that took place along a NE-SW alignment.

The aquifers are classified into the Upper and the Lower Aquifers. The Upper Aquifer consists of Holocene to Pleistocene layers of sand and gravel. The Lower Aquifer is composed of Upper Cretaceous conglomerate and limestone facies. Between the aquifers, the Aquiclude is formed by Paleogene shale and shalely layers are interbedded.

The top portion of the Upper Aquifer acts as un-confined aquifer. The lower part, however, behaves as a semi-confined aquifer. The transmissivity and the storage coefficients are 85 m^2/day and 0.004. Impervious shale layers alternating with limestone and dolomite characterize the Aquiclude. Permeability was assessed to be 1 x 10^{-5} to 10^{-7} cm/sec. In the Lower Aquifer, conglomerate is interbedded between limestone and dolomite layers and forms the most productive aquifer in the Lower Aquifer. The transmissivity and storage coefficient are, on average, 51 m^2/day and 0.0028.

The existence of fissure water was also apparent in the Study Area. The transmissivity and storage coefficients for fissure aquifers are large as 776 m^2/day and 0.024 respectively.

(iv) Hydrochemistry

The electric conductivity (EC) of groundwater in the Study Area shows a wide range from 500 to 10,000 micro S/cm. There is a clear vertical change in water quality. A higher EC and a lower dissolved oxygen content and Redox potential were measured at the deeper horizon. Most of groundwater was categorized to be of a Non-carbonate Alkali type. All the samples obtained from the mountain wadis were of the Carbonate Hardness type.

Some of water samples tested exceeded WHO guidelines in terms of fluoridate, chromium and lead content.

(4) Infiltration Test

The field infiltration experiment was conducted to clarify the infiltration rate of the wadi bed in the Bahada. Three sites were selected at Wadis Siji, Khadrah and Shoukah, where the groundwater tables are relatively shallow. The wadi bed is composed of alternative layers of sand, gravel and silt, and appears to be anisotropic across the horizontal and vertical directions. Infiltration test experiments at each site were made performed by constant water head method in square (1.5 m) test pits at three different depths (1.5 m, 3.0 m and 6.0 m).

Permeability estimated under the assumption that the layers are isotropic shows increasing values depending on the water head in the pit: 1.8E-5 cm/sec (at 1.5 m); 6.6E-5 cm/sec (at 3.0 m); and 1.4E-4 cm/sec (at 6.0m): in the 6-m pit values are 8 times greater than in the 1.5-m pit.

Supposing that the layer is anisotropic, the infiltration rate in a horizontal direction is 2 to 3 times greater than that in the vertical direction. If a recharge trench 1.5 m wide, 6 m deep, and 1.0 km in length is constructed along the three proposed wadi beds, as much as 0.765 MCM/a of water may be infiltrated into the ground.

(5) Groundwater Augmentation

The effects of building (flood detention) dams recharge trenches and underground dams to augment the groundwater recharge in the Study Area are discussed below.

Three recharge dams can be constructed at selected sites in Wadis Siji, Khadrah and Shoukah. Taking the flood return period to be 25 years, the storage capacities would be 2.5, 3.3, and 2.5 MCM respectively. Three recharge trenches each one km long could also be constructed at the same wadis in the Bahada Plain. The dimensions, construction costs and effectiveness of both of above facilities are examined in the master plan study.

An underground dam with a storage capacity of 9 MCM could be constructed at an appropriate site at Wadi Khadrah. However, it would be not included in the master plan study since enough flood runoff, as water source to be stored, is not expected; and it would hardly contribute to groundwater augment.

(6) Hydrological Balance and Groundwater Resources

(i) Hydrological Model

In the formulation of the groundwater development plan in the Study, a mathematical model was constructed and simulation under various conditions were carried out in the Study. The model applies the so-called the "Synthetic Storage Model", in which the hydrological balance in the present state of the Study Area was able to be formulated and used to establish the groundwater development plan.

The hydrologic balance model of the current situation, which synthesizes the surface and sub-surface systems was constructed and forecast analysis was conducted to evaluate the groundwater resources in Study Area and to clarify the appropriate development potential. In the paragraph, the meteoro-hydrologic record, which was used as an input parameter for this simulation is described.

The applicable meteoro-hydrologic parameters in the model are rainfall, evapotranspiration, and groundwater draft. The daily rainfall records of Massafi station from 1977 to 1995 were used. For the evapotranspiration potential, the monthly mean value of pan-evaporation recorded at the Mileiha station was applied. For the groundwater draft, 54 MCM, as of 1995 was adopted.

The parameters which verify the model are for the sub-surface system the "groundwater hydrograph" of each aquifer and the "flood record" for the surface system, both were recorded by the MAF. The period of the verification was the 19-year period from 1977 to 1995.

(ii) Current Hydrologic Balance

The hydrologic balance during the 19 years up to the time of the Study Area was analyzed.

An annual average basin rainfall was estimated to be 155 mm/a. Out of these, 143 mm/a (92% of rainfall) was lost by evapotranspiration. The surface runoff from the Area was 0.2 mm/a (0.1%). The groundwater recharge was only 12 mm/a (7.7%).

(iii) Simulation

To evaluate groundwater resources, adopting the hydrological model construct, a series of simulations were made with models based on the following four cases:

Case-1: with the present groundwater draft, the lowest groundwater head at -300 m, without recharge facilities,

Case-2: with the maximum possible draft, the lowest head at -100m, without recharge facilities,

Case-3: with the maximum possible draft, the lowest head at -100m, with recharge trenches; and

Case-4: with the maximum possible draft, the lowest head at -100m, with recharge dams and trenches.

(iv) Groundwater Resource

The simulations yielded the results described below.

The sustainable yield was evaluated as 19.5 MCM/a. If the current groundwater draft of 54 MCM/a continues, the groundwater resources in the Area may be exhausted by 2040, or within 45 years. If groundwater augmenting facilities are constructed, an extra groundwater recharge of 1.97 MCM/a may be expected. Consequently, the sustainable groundwater usage in the Study Area is evaluated to be 21.67 MCM/a.

(7) Soil and Land Use

The soil survey and soil laboratory tests were conducted to cover the whole Study Area. The soil survey was conducted using 65 reconnaissance and 66 detailed test pits, with soil sampling from the detailed pits. Soil samples thus taken were sent to a laboratory for physical and chemical tests that included clay mineral analyses.

The Study Area can be morphologically divided in to three zones: 1) Moving sand dunes or a rather stable desert zone spreading along the western and northern edges of the Study Area;
2) A zone of rocky outcrops, mainly distributed at the foot of the eastern mountain area; and

3) a gravel plain between the aforementioned two zones. The soils of the gravel plain can be classified according to their gravel contents. Those soils are deposited as a shallow layer on calcareous basement, or occasionally the hard pan, and salt accumulation caused by rainfall or irrigation water appears in these gravelly layers. Except in the zone close to the dunes, the soils in the gravel plain form the soil for the fluvial gravel layer, which usually appears within 70 cm of the surface. There are many farms on the gravel plain in the Study Area. It is normally used for the cultivation of tree crops because it has such a thin top-soil. The salt accumulation in farms is apparent in the coarse sand and gravel layers from which saline groundwater extracted for irrigation.

The soils in the Study Area are, in general, correspond to the description given below. The average contents of the sand in the soil is 87% and clay forms 4%. Most of the clay is composed of palygorskite or illaite. The pH value of soil ranges from 7.6 to 9.3. The electric conductivity measures an average of 650 μS/cm and reaches a maximum of 4,400 μS/cm. Exchangeable Ca^{++} and SO_4^{++} also register high values . The organic carbon content is very small, averaging 0.3%.

Only 18% of the land in the Study Area is used for cultivation, public facilities and so forth: 82% the remaining land is occupied by dunes and outcrops of rock.

(8) Agriculture

The present condition of agriculture of the Study Area was clarified through the Farm Inventory Survey and MAF Statistics (1994). MAF statistics show there were 2,018 farms and 4,584 ha under cultivation in the Study, and the average cultivation area for individual farms is 3.1 ha. Tree crops occupy 40% of total cultivation area, followed by the field crops (35%), and vegetables (25%). The major crops in the Study Area are Date Palms and Alfalfa. Recently greenhouses with drip irrigation system have been installed in the Study Area. Some of them are equipped with cooling systems. Field crops are estimated to account for 79% of the net value of agricultural products in the Study Area, followed by tree crops (11%), and vegetables (10%).

Total water consumption in the Study Area was estimated at 52 MCM in 1994. Field crops consumed 48% of this, followed by the tree crops (46%), and vegetables (6%).

In order to clarify water saving factors and identify the most beneficial crops, an indicator of net income by unit water consumption (NI/WC) was estimated for each crop. The indicators show that the field crops and vegetables give the highest value at Dh. 7.2 /m^3, followed by tree crops at Dh. 1.1 /m^3.

The cost-benefit analysis for livestock in the Study Area shows that livestock rearing is not economical except for Antelopes and poultry. Livestock breeding in the Study Area should be limited to animals for on-farm or in-family consumption and for investment purposes.

The agriculture in the Study Area is characterized by the domestic consumption of crops and inefficient farming which depends mainly on field and tree crops which consume much water. This pattern has developed because the owners of most farms reside in urban areas and engage other major businesses; the daily management of farming is left to foreign employees. The farm owners do not pay so much attention to the efficiency of their farms and rely an easy to manage and extensive cultivation methods which can be managed by foreign workers in the owners' absence. On the other hand, a few devoted farmers in the Study Area have introduced modern irrigation systems, more beneficial vegetable crops and greenhouse cultivation.

(9) Irrigation

The only water source for irrigation is groundwater in the Study Area. Due to the over development of agricultural land and over extraction of irrigation water, the water table in the Area has dropped the and its quality has deteriorated.

The field measurement of groundwater made at 1,250 wells during the Well Inventory Survey shows a wide range of EC, between 500 and 37,700 μS/cm. Laboratory analysis shows that the groundwater is categorized by C3-S2 to C4-S3 in the irrigation water class. In comparison with the data from 1977-1980, the quality of groundwater in the Area has clearly decreased.

According to an irrigation water survey by UNDP/FAO/MAF in 1977, an average annual groundwater extraction per ha was 49,000 m^3. In the survey, the farm using drip irrigation methods used 21,000 m^3/ha/annum and those using lined canals used 34,000 m^3/ha/annum. The groundwater extraction survey made in the summer in 1995 showed an average water use for the net cultivation and farm areas estimated at 129 and 61 m^3/ha/day.

With government support and under a subsidy system, water saving irrigation facilities have been set up on farms in the Study Area. Most of the vegetable cultivating farms have installed drip irrigation systems. In many cases, however, the related facilities are incomplete due to the financial constraints of farming. The drip irrigation system is also applied in the greenhouses. Basin irrigation is the most common method for the fodder crop cultivation in the Study Area. Most of farms have lined their distribution channels from the water tank to the basin or furrow irrigation plot. Unlined earth channels, however, remain in the Study Area. Fixed type sprinkler systems are installed in some alfalfa cultivation farms. The bubbler system for tree crops, especially Date Palms, has been introduced. The traditional irrigation method for Date Palms, or individual tree basin irrigation with open canals, are common in the Study Area.

The irrigation efficiency for perennial crops (Date Palm and Alfalfa) is estimated at 47% to 63% based on the field survey results of the Study.

The gross irrigation water requirement, inclusive of vegetables, tree and field crops, is estimated at 12,000 m^3/ha/annum, based on the irrigation water requirements of each crop and the current cropping pattern in the present Study Area.

Intake rate tests were made at 19 selected points in the Study Area. The basic intake rate varies from 4.4 mm/hr and 211.5 mm/hr. The basic intake rate in the gravel plain depends on the thickness of the top soils. Gravel soils with spaces filled by fine particles shows a low basic intake rate.

(10) Environment and Women

The Arabian peninsula is the zone of contact between three of the world's major zoogeographical regions. It is at the center of the Eremic desert zone. Consequently, a great variety of flora and fauna can be found in the UAE. Reptiles, especially, are quite common because the prevailing arid conditions provide an ideal environment for their proliferation, and the appropriate heat level required to maintain their body temperatures. These reptiles survive on little food as they have low metabolic rates. Human activity, however, such as overgrazing and hunting, has recently brought about many changes in the natural flora and fauna. The lowering of the water table has also had a damaging impact on them.

Before 1993, environmental management activities in the UAE were the responsibility of the Higher Environment Committee which was part of the Ministry of Health. In 1993, the Federal Environment Agency (FEA) was set up under the federal law. As of 1995, the Agency had six staff who were working towards the preparation of a definitive environmental law.

Among other regulations related to the Study, there is a MAF decree which bans the application of highly toxic chemicals and chemicals which leave residues after farming.

The UAE has ratified the convention on International Trade in Endangered Species of Wild Fauna and Flora, and signed the United Nations Convention on the Law of the Sea, the Basel Convention, and the Convention on Biological Diversity. Of the animals inhabiting the Study Area, the only species listed by the Convention on International Trade in Endangered Species of Wild Fauna and Flora are *Uromasyx spp,* and there are no fauna listed by the conventions on Biological Diversity in the Study Area. There are no areas for the conservation of natural resources and no sites registered under Conservation for the Protection of the World Cultural and Natural Heritage.

Almost all the agricultural field works in the Study Area are carried out by foreign workers; local women take practically no part in them. Due to diverse factors, this situation is not expected to change in the future. In other sectors, on the contrary, women's participation in the labor force and the number of female students has been increasing remarkably in recent years. For example, at the UAE University women students are now in the majority. Since the government has embarked on a policy which encourages female participation in the labor force, the number of women

personnel working in the government has increased, particularly in the ministries of health, education, and labor and social affairs.

(11) Technology Transfer

Opportunities for the transfer of technology arose at various occasions during the Study period. During the field survey, discussions with counterpart personnel have provided them with a basis for understanding the practical application of technology. Workshops were also conducted to give a grounding in the latest technology that was used in the Study: the workshops were conducted by the Study Team. Furthermore, for topics which required more intensive training courses were conducted in Japan at JICA's training courses for counterparts.

5. The Master Plan

(1) Basic Strategy

The basic strategies recommended the Study for agriculture and water development are set out in the two policy options below:

Option One: The agricultural development plan is to be kept within the limits of the sustainable development potential of groundwater in the Study Area.

Option Two: Agricultural development plan will maintain the current extent of cultivation. To support the plan, water resources to supply the necessary demand in excess of the sustainable yield of groundwater will be supplemented by the introduction of an alternative water source.

The agricultural development plans in both options aim at a type of agriculture that is sustainable, water-saving, high-income and market-oriented.

If the present groundwater usage rate continues, it is forecast that the groundwater head in the Study Area will go down to 100m below ground level by 2015. Consequently, the target year for the achievement of the plan is set at 2015, 20 years from the present.

(2) Water Resource Development

(i) Groundwater Resources

The model simulation forecasts that, if the current groundwater use remains at 54 MCM/a, the groundwater head in the Area may be drawn down to 100 m depth by 2015 and totally exhausted by 2040. The master plan includes a groundwater development scheme to decrease the draft to a sustainable level by the target year, 2015.

The following basic course was mapped out to formulate the scheme:

- the groundwater draft is set to within a sustainable yield;
- the gradual planned shifting of the from the present level to the sustainable yield;

- the controlled groundwater head is to be set at a realistic level, 100 m depth;
- the level of pump installation is to be restricted at the control head; and
- others.

The model simulation indicated that the sustainable groundwater yield is 19.5 MCM/a which is one third of the present yield, 54 MCM/a.

Three sets of recharge dams with recharge trenches at Wadis Siji, Khadrah and Shoukah are recommended for the groundwater augmenting plan. Remarkable results, yielding as much as 1.97 MCM/a are expected from this plan. If this amount of 1.97 MCM/a was added to the 19.5 MCM/a of the sustainable yield, a total sustainable groundwater yield of 21.5 MCM/a would be available for the Groundwater Development Plan.

(ii) Alternative Water Resources

An alternative water resource of 33.9 MCM/a (1.4 m^3/sec) required for Option Two plan is to transport desalinated water produced in a plant in Sharjah for 58 km via a proposed pipeline. The water cost would be Dh. 10/m^3 or US$ 2.76/m^3, including the production cost (US$ 1.27) and the delivery cost (US$ 1.49).

(3) Agricultural Development Plan

(i) Land Use and Water Sources

In the Option One plan, the total cultivated area will be reduced in line with the need to reduce the irrigation water requirement to the sustainable groundwater yield. The ways of reduction of cultivating area would be 1) equal restriction of cultivating area in all existing farms and 2) restriction of the farms where inefficient irrigation methods are applied.

In the Option Two plan, the entire cultivated area in 1994 is to be maintained. Insufficient water resource would be supplemented by desalinated water.

In either option, new farm development or the expansion of the existing cultivation area will not be allowed.

(ii) Farming Plan

In order to select appropriate crops for the Study Area, an indicator was estimated for the net income per unit water consumption (NI/WC). The NI/WC for each crop was estimated by the farm inventory survey, MAF statistics and the results of cropping experiments in UAE.

The crops which demonstrate an NI/WC value more than Dh. 10 /m^3 are, in principle, selected as recommendable for the master plan.

The NI/WC of some vegetables exceeds the defined criteria. Tree and fodder crops have NI/WC values of less than Dh. 10 /m^3. On the other hand, high-quality Dates to be produced by high yield varieties are included in the plan, since Dates are traditional staple in the national diet.

Alfalfa is considered to be the next most important crop to vegetables and Dates since it is one of the major fodder crops for traditional livestock.

In the **Option One Plan**, the proposed cultivation area for vegetables is determined in meet the requirements of a population of one million for 300 g/capita/day. This would be a total production of 67,600 tons. The proposed cultivation area for Dates is proposed to be extensive enough to maintain the present total net income for tree crops. The proposed cultivation area for Alfalfa is based on balancing the irrigation water requirement with that of vegetables and Dates.

Taking into consideration the said plan and the availability of water resources, the total cultivation area in Option One is planned to be 2,548 ha. Out of this, 1,713 ha, or 67%, is set aside for vegetables, 272 ha (11%) for Dates and 564 ha (22%) for Alfalfa. The expected total production is 124,238 tons (65% of present). Of the total planned production, 67,800 tons (265% of present) will be provided by vegetables, 5,229 tons (18%) by Dates, and 51,209 tons (37%) by Alfalfa. Nevertheless, the production will be less than at present; the total net income is expected to be Dh. 273 million (126% of present condition), Dh. 187 million (841%) from vegetables, Dh. 25 million (100%) from Dates, Dh. 61 million (36%) from Alfalfa.

The gross irrigation water requirement is estimated to be 6.2 MCM/a (208% of present conditions) for vegetables, 2.0 MCM/a (9%) for Dates, 13.3 MCM/a (40%) for Alfalfa and 21.5 MCM/a (37%) as the total gross irrigation water requirements.

In the **Option Two Plan**, the total cultivation area and areas allocated to vegetables, Dates and Alfalfa are to be as same as the present condition. But the cropping pattern should follow that in the Option One plan. Thus, out of total cultivation area of 4,584 ha, 1,158 ha (25% of total cultivation area) would be allotted to vegetables, 1,825 ha (40%) to Dates and 1,601 ha (35%) to Alfalfa. The expected annual production is 226,405 tons (118%), with 45,836 tons (179% of present) of vegetables, 35,094 tons (118%) of Dates, and 145,475 tons (107%) of Alfalfa. The expected annual net income would be, exclusive of the water cost, Dh. 467 million (217%), with Dh. 126 million (568% of present) from vegetables, Dh. 167 million (671%) from dates, and Dh. 174 million (103%) from alfalfa.

The gross water requirements would be 55.4 MCM/a (107%), with 4.19 MCM/a (141% of present) for vegetables, 13.4 MCM/a (63%) for Dates, 37.8 MCM/a (112%) for Alfalfa. To supply this total irrigation water requirement, it would be necessary to supplement the sustainable groundwater potential with 33.9 MCM/a of desalinated water.

(iii) Irrigation Plan

It is necessary to plan to achieve highly profitable and sustainable agriculture through the effective use of groundwater and other water resources. Also, it is necessary to further extend the

water-saving irrigation methods, and to strengthen the extension and support services along with the subsidies that the MAF has been providing to farmers.

Based on the Penman method and using meteorological data gathered at Falaj Al Mualla and Mileiha, the potential evapotranspiration (Eto) was estimated to be 2,232 mm/a. Taken together with the results of the infiltration rate tests, and other factors such as the present methods of water-saving irrigation, irrigation intensity and so on, the irrigation plans recommend a) drip irrigation for vegetables, both in open fields and in greenhouses; b) bubbler irrigation for tree crops; and c) sprinkler irrigation for fodder crops. Filter, strainer, and intermixture systems are to be installed for all types of irrigation system.

The irrigation water requirement has been determined after considering, among other factors, the crop water requirement, effective rainfall, leaching of water, and irrigation efficiency. As the rainfall is small in amount and of uncertain regularity, it is considered to be effective only for leaching requirements, but not for the irrigation water requirements. The irrigation efficiencies are taken to be 0.85 for drip, 0.75 for both bubbler and sprinkler. In light of the emitter interval and drip outlet interval, the actual irrigated area of drip irrigation for vegetables is to be 50% of cultivation area. Taking into account the amount of area required for farm roads, the actual irrigated area under sprinkler irrigation for fodder crops is estimated to be 90% of the area cultivated. Taking in consideration the number of trees and the area of basin irrigation, the actual irrigated area of bubbler irrigation for Dates is estimated 30% of the area under cultivation.

The monthly net irrigation water requirement is based on estimates of crop water requirements and the actual irrigated area. The monthly gross irrigation water requirement is calculated based on monthly net irrigation water requirements and irrigation efficiency, after taking the actual irrigated area into account. The total gross irrigation water requirement in the Option One plan becomes 21.5 MCM/a and in Option Two, 55.4 MCM/a.

(iv) Improvement of Infrastructures

In this plan, an examination was made of the feasibility of improving the agricultural infrastructure, such as flood dikes, the road network for agricultural activities and marketing, and marketing facilities for the products. Most of the existing farms are already surrounded by dikes which have made use of surplus gravel materials at the time of land reclamation. Specific dike work is not considered to be necessary in the project. Three asphalt-paved trunk roads run through the Study Area. Access roads from the trunk roads to the farms have already been provided. No specific improvement of the road network is considered to be necessary.

To secure advantages with regard to selling prices, it is necessary to install marketing facilities in the Area. The construction of a collection center with collecting, selecting, cooling, storage, and shipping facilities is planned at Al Dhaid.

(v) Agriculture Supporting Services

It is impossible to promote agricultural development in the Study Area without the businesslike participation of farm owners who have an awareness that they are using a precious and limited water resource. Consequently, the governmental agricultural extension services would play an important role. Furthermore, agricultural supporting services by the government, such as those described below, would also be a key factor in ensuring the smooth implementation of proposed cropping plan.

Adjustment of Cultivation Area

Over-production of certain vegetables may be caused by the concentration of high-profit crop cultivation. To control such over-production, it is necessary to adjust the cultivated area among the farms, especially for vegetables. The extension staff must provide the support necessary to bring about the successful adjustment of the cultivation area among the farms.

Establishment of Input Supply System

It is necessary to establish a supply system of input that exactly corresponds to the needs of farms. Especially, the supply system for high quality Date seedlings should be improved.

Technical Extension Services

There are five extension units that are staffed one to two extension officers the Study Area. Currently, they are mainly engaged in the distribution of fertilizers, agricultural chemicals and seeds. It is necessary to strengthen the technical extension services for vegetable cultivation and irrigation technology. It is necessary to increase the number of the extension staff by two people per unit.

Practical Experiments

It is necessary to recommend suitable crops, the best farming practices and appropriate irrigation methods to the farmers which based on the results of practical field experiments. Systematic experiments on these subjects were conducted by UNDP/FAO in 1982 to 1983, and it is recommended that such experiments should continue at the agricultural experiment centers in the Central Region. The implementation of research and development of suitable crops and related technology, and its extension to the farmers is recommended in the plan.

Training of Farmers

The establishment of a system for the training and guidance of farmers by the government is proposed in the plan. Crop production, post-harvest and food processing technologies, and the introduction of new varieties and kinds of crops, and the supply of marketing information are important subjects to be included in the training. The agricultural experiment center may be used as the training facility.

Strengthening of Governmental Subsidy System

Several low priced vegetables are imported into UAE and local agriculture is forced to compete with these cheap imports. The current technical and financial assistance by the government should be maintained and expanded.

(vi) Marketing and Processing

Marketing System and Organization

At present agriculture in the Study Area is mainly for in-farm or in-family consumption. The establishment of a marketing system and organization are indispensable to bring about a shift towards a market oriented system. Organization, facilities and equipment, such as trucks for collecting and shipping, may be required. Farmers would then be able to enjoy a much greater income from their activities than they currently do.

Processing of Agricultural Products

To increase added value of crops and to take up the surplus production, the processing of agricultural products is proposed. Bottled Cucumber pickles, Tomato purée and Tomato juice, and dried and packed dates are most attractive candidates for processing.

(vii) Farmers Organization

For the smooth and effective production and sale of large quantities of agricultural products, it is necessary to establish a farmers organization under the supervision of MAF. The main activities of such a organization would include collaborative purchasing of agricultural inputs and equipment, the setting up of collecting and shipping facilities, group shipping, the construction and operation of agricultural processing facilities, adjustment of cultivation plans, supplying information on marketing, and agricultural technology.

(4) Groundwater Monitoring and Database

In order to manage the groundwater resources in the Study Area, a groundwater monitoring and database system is proposed in the plan.

(i) Monitoring System

In the Study Area, 12 observation wells have already been set up by MAF.

Meteorological and flood gauging stations have been in operation for a long time.

Monitoring systems, which would include these existing observation stations should be organized in relation to the model of groundwater balance employed in this Study. The model could then be revitalized as a model and used to control and manage the groundwater resources in the Study Area.

The observation items in the Monitoring System would cover meteorology, hydrology (surface flood), groundwater (head, quality), and groundwater use. To collect other data necessary to be used in the Groundwater Monitoring System, supplemental stations must be installed in the areas yet covered by the existing stations. To automate the routine work in observation, transducers or other automatic recording devices should be used.

For meteorological observation, the ten existing stations and five new rain-gauges are to be included in to the system.

For hydrological observation, six new wadi-gauge stations are to be installed in addition to the existing six wadi-gauges.

There are six groundwater observation wells around the Study Area. The total of 22 sites, which are built into the system, includes 17 stations to monitor the groundwater head of upper aquifer, six for the lower aquifer and five for the measuring the water quality,.

To operate the management model, the estimation of groundwater withdrawal for irrigation is necessary every few years

(ii) Database Plan

To provide the necessary useful information, the database is to be such that it is accessible by all users, including the observer, the database manager and the operator of the management model. A small-size computer network, a so-called Local Area Network (LAN) is to be dedicated to this purpose. The basic software to used provide the Database system would be a Conventional Relational Data Base. The software must be applicable to the basin model constructed in the Study and to the other needs of the Plan.

(5) Project Plan

The proposed project is to consist of plans concerning water sources, farm facilities, monitoring systems and so forth.

(i) Water Source Plan

Groundwater Augmentation Plan:

In order to augment the groundwater recharge in the Area, three sets of flood-detention dams and recharge trenches are proposed at the selected sites in Wadis Siji, Khadrah and Shoukah. The storage capacities are designed to be 2.6, 3.3 and 2.7 MCM respectively to cope the floods over a 25-year return period. The dam heights are to be 20.5, 16.5 and 27.5 m respectively.

Alternative Water Source Plan:

In the Option Two plan, an alternative water source of some 34 MCM/a is required. The water source would be desalinated water delivered from Sharjah by a pipeline system. The system is consist of a 58 km delivery line and 46 km of distribution lines.

(ii) Farm Facility Plan

The farm facilities required for a typical farm are designed to include water sources, water distribution systems, on-farm tanks, greenhouses and so forth.

(iii) Marketing Facility

With regard to marketing facilities, a center building equipped with cold-storage, transportation equipment and others functions is included into the project.

(iv) Project Cost and Project Implementation Plan

Project Cost

The project cost for the Option One plan, including the construction of facilities for groundwater augmentation, farm and groundwater monitoring, and marketing, administration, and consulting expenses, and including contingencies is estimated at US$ 385 million or Dh. 1,405 million. The cost of the Option Two plan, including all of those costs in the Option One plan, and the construction cost of pipelines to supply alternative water ,is estimated at US$ 935 million or Dh. 3,413 million.

Project Implementation Plan:

The target year of the master plan is set forth at 2015 as previously stated. Taking the optimum investment schedule into account, the required period of project implementation for Option One and Two plans are eight (8) and nine (9) years respectively.

(v) Operation and Maintenance Plan

The operation and maintenance (O&M) of facilities provided by the project are to be conducted by MAF, individual farmers and a third sector that is to be established. MAF is to be responsible for the O&M of public facilities such as the recharge augmentation facilities, the monitoring system and the pipeline for alternative water source. The O&M of farm facilities are to be conducted by the individual farmers with support services provided by MAF. The O&M of marketing facilities is to be carried out by a third sector that is yet to be established, the likely candidate would be a farmers organization under the guidance of the MAF.

(6) Project Evaluation

(i) Methodology

In the present project, the methodology applied for benefit analysis consists in identifying and evaluating the project costs and benefits that will arise with the project, under either of the two development options, and comparing them with the situation as it would be without the project.

This project is considered acceptable if the internal rate of return (IRR) exceeds the opportunity cost of capital in the UAE. For practical purposes, the cost is considered to be 5%, which is the same as the rate that is charged by commercial banks for their loans.

(ii) Costs and Benefits of the Project

The costs of the project which are subject to project evaluation shall cover the costs required for the initial investment, operation and maintenance and replacement.

The project benefits include the increase of agricultural production benefit. The annual benefits of the project in the Option One plan are estimated at US$ 61.3 million and in the Option Two plan, US$ 125.1 million.

(iii) Financial Evaluation

It is supposed that the cropping area and income level may decrease in along with the decrease in groundwater by the project target year of 2015. A project life of 50 years is applicable after the commencement of the project. Project benefits are expected to accrue within five years of the completion of recharge facilities.

Based on the conditions mentioned above, the financial IRRs of Option One and Two plans are estimated to be 6.5% and 0.4% respectively.

From these results, the IRR for Option One plan is deemed feasible. But, that for Option two plan appears to be less feasible as a public project.

(iv) Sensitivity Analysis

Sensitive analysis was conducted based on the results of evaluation mentioned above. If the project cost were to escalate by 10%, or the construction work be delayed by one year; or the production to decline by 10%, the FIRRs are estimated at 5.0, 6.5 and 5.1% respectively.

(v) Financing Plan

If two-thirds of initial investment costs are financed by a loan and one-third by the government, the maximum amount to be repaid would be US$ 166 million or Dh. 606 million at year 2005.

(vi) Socioeconomic Effect

The project is attractive not only in terms of profitability, but also as a key factor in the conservation of water resources and the promotion of the rational use of water. It must be added that this rational use of water would be accompanied by an anticipated increase in income levels which, in turn ,could be a stimulating factor for the regional economy, by increasing the opportunities for employment and providing as promising potential for post-harvest processing.

(7) Environmental Assessment and WID

(i) Environmental Assessment

An initial environmental examination (IEE) on the social and natural environmental impacts related with the implementation of the project have been assessed.

The implementation of the project would not entail any resettlement of inhabitants, or relocation of existing economic activity or traffic and public facilities, or the splitting of communities, destruction of cultural property or water rights, or worsening public health conditions.

Application of agricultural chemicals may increase along with development resulting from groundwater development. Taking into account the amount of chemicals, they would have little effect on groundwater and human health.

According to the chemical analysis of groundwater made through the Study, high concentrations of fluoride and chromium have been detected in the southern part of the Study Area. It is necessary to look for other drinking water sources in the area as soon as possible to avoid hazarding health.

The project does not generate any wastes or residual materials, so there is no risk of hazards to or changes in topography and landscape.

The salinization of soil is, in general, affected by water quality and irrigation methods. By applying the rational, water-saving irrigation methods proposed in the project, salt damage could become minimal. Monitoring of salt accumulation in the soil, however, remains essential for sustainable agricultural development.

The project mainly aims at the conservation and rational development of groundwater. Consequently, only a positive effective to groundwater would be produced by the project., Monitoring of groundwater, however, would be necessary.

There are no rivers or lakes in which drainage water would be discharged.

The project does not contemplate new farm land expansion. Consequently, the project will not affect to the indigenous species of flora and fauna.

These construction works are not large enough to have any effect on the local climate. Neither are there any sources of air pollution, offensive odors, or nuisance from water and soil. Noise and vibration will occur only during well drilling activities. Such work will not, however, affect human activities because the work sites are very far from the major residential towns. Land subsidence is not expected to occur after drawing groundwater because the land foundation consists of limestone and sandstone which do not have the same yielding nature as clay.

From the IEE, an environmental impact assessment (EIA) is necessary during the further study stage, especially with regard to groundwater and soil.

(ii) Women's Role in the Development

In recent years, the government has launched a policy of promoting the role of women in society. The project should involve women in the following sectors.

Management of Marketing Information

The Study recommends the establishment of a market information system. The work, the management and transmission of information would be suitable tasks for women in the present-day social and cultural context of UAE. It is recommended that women should allowed to adequately participate in such activities.

Campaign for Water Conservation:

Women can also participate through teaching their children about the importance of the conservation of groundwater resources. In this context, it is recommended that the project should involve the women in the campaign to get across the concept of the sustainable use of the precious water resources in the Area.

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ABBREVIATIONS

AGCC	:	Arab Gulf Cooperation Council
FAO	:	Food and Agricultural Organization of the United Nations
GOJ	:	The Government of Japan
GUAE	:	The Government of UAE
JICA	:	Japan International Cooperation Agency
MAF	:	The Ministry of Agriculture and Fisheries, GUAE
MAFF	:	The Ministry of Agriculture, Forestry and Fisheries, GOJ
MOP	:	The Ministry of Planning, GUAE
MOEW	:	The Ministry of Electricity and Water, GUAE
MPMR	:	The Ministry of Petroleum and Mineral Resources, GUAE
OAPEC	:	Organization of Arab Petroleum Exporting Countries
UAE	:	United Arab Emirates
UNDP	:	United Nations Development Program
UNESCO	:	United Nations Educational, Scientific and Cultural Organization
WED	:	Water and Electricity Department

AJN	:	Ajman
AUH	:	Abu Dhabi
DXB	:	Dubai
FUJ	:	Fujairah
RAK	:	Ras Al Khaimah
SHJ	:	Sharjah
UAQ	:	Umm Al Qaiwain
W. Ashwani	:	Wadi Ashwani
W. Dhaid	:	Wadi Dhaid
W. Ghel	:	Wadi Ghel
W. Hamdah	:	Wadi Hamdah
W. Idayyah	:	Wadi Idayyah
W. Isfay	:	Wadi Isfay
W. Khadrah	:	Wadi Khadrah
W. Shokah	:	Wadi Shokah
W. Sifuni	:	Wadi Sifuni
W. Siji	:	Wadi Siji
W. Thiqebah	:	Wadi Thiqebah
W. Lamhah	:	Wadi Lamhah

GLOSSARIES

amsl	:	above mean sea level
approx	:	approximately
°C	:	degree(s) centigrade
cm	:	centimeter(s)
cm^2 or sq. cm	:	square centimeter(s)
Dh	:	UAE dirham(s)
		Dhs 1.00; US$ 0.274
donum	:	equivalent to 0.1 ha
EC	:	Electric Conductivity
ECe	:	Electric Conductivity of Soil
EIA	:	Environmental Impact Assessment
El	:	elevation above sea level
g	:	gram(s)
gal	:	imperial gallon(s); 4.546 lit
GL	:	ground level
h lit	:	hectoliter(s)
ha	:	hectare(s)
hr/ha	:	hour per hectare
kg	:	kilogram(s)
kg/ha	:	kilogram per hectare
km	:	kilometer(s)
km^2 or sq. km	:	square kilometer(s)
kwh	:	kilo-watt(s) hour
lit or l	:	liter(s)
lit/s	:	liter per second
m	:	meter(s)
m/s	:	meters per second
m^2 or sq. m	:	square meter(s)
m^3 or cu. m	:	cubic meter(s)
m^3/ha	:	cubic meters per hectare
m^3/km^2	:	cubic meters per square kilometer
m^3/s	:	cubic meters per second
max	:	maximum
MCM	:	million cubic meter(s)
MCM/a	:	million cubic meter(s) per annum

meq	:	milliequivalents
Mgal	:	million gallon(s) per annum
min	:	minimum
mm	:	millimeter(s)
mm/day	:	millimeters per day
mm/mnth	:	millimeters per month
mm/yr	:	millimeters per year
Mw	:	mega-watt(s)
Mwh	:	mega-watt(s) hour
no	:	number
O&M	:	Operation and Maintenance
ppm	:	parts per million
%	:	percent
SAR	:	Sodium Absorption Ratio
TDS	:	Total Dissolved Solids
ton	:	ton(s)
ton/ha	:	tons per hectare
US$	:	US dollar
		US$ 1.00: Dhs. 3.65
WID	:	Women In Development
$\mu S/cm^2$	:	micro siemens per square centimeter, unit of electric conductivity

CHAPTER ONE : INTRODUCTION

1.1. Background

1.1.1. General

Backed by favorable revenues from oil in the 1970s, the United Arab Emirates (hereinafter referred to as "UAE") actively invested in the provision of a social infrastructure. The economy of UAE was depressed in the 1980s due to the stagnation of international oil prices and regional instability caused by the Iraq-Iran War and the Gulf War.

The Government of UAE has pursued a policy that promotes diversification of the national economy towards stability and self-sufficiency, and away from an economy so heavily dependent on oil. To this end, it has made agriculture an important nucleus of the national economy and has therefore provided various subsidies to assist in agricultural development. Such development has not, however, progressed smoothly because of various constraints in the natural and social environment, such as the arid climate, limited availability of water and soil resources, shortage of labor and so forth. In addition, the unregulated exploitation of groundwater for irrigation has led to a drop in the groundwater level, a deterioration in groundwater quality, the abandoning of cultivation due to the salinization of farmland and so forth.

Given these circumstances, in 1988 the Government of UAE formally requested the Government of Japan to extend technical cooperation with regard to groundwater development in a major agricultural area covering some 1,500 km^2 in the northern UAE.

Through the medium of the Japan International Cooperation Agency (hereinafter referred to as JICA), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, in response to this request, the Government of Japan dispatched experts in November 1992, and then a provisional study team in February 1993. The provisional study team discussed the situation with the Ministry of Agriculture and Fisheries (hereinafter referred to as MAF) of the UAE Government, and it was mutually agreed that the technical cooperation that was to be extended should include not only groundwater development but also the formulation of a comprehensive agricultural development plan covering an area of 850 km^2 in the vicinity of Al Dhaid, which is the area most seriously affected by groundwater depletion and the abandoning of farms.

For this reason, the Government of Japan has decided to conduct a "Master Plan Study on Groundwater Resources Development for Agricultural Purposes in the vicinity of Al Dhaid" (hereinafter referred to as "the Study"), in accordance with the relevant laws and regulations in force in Japan. Accordingly, JICA dispatched a preparatory study team to UAE in October 1994.

The scope of work for the Study (hereinafter referred to as "S/W") was agreed upon between MAF and the study team in November 1994, based upon which, JICA organized and dispatched a team (hereinafter referred to as the "Study Team") to carry out the Study.

1.1.2. Objectives of the Study

The objectives of the Study set forth in S/W are:

[1] to conduct a study on the development of groundwater resources for agricultural purposes in the vicinity of Al Dhaid in UAE; and

[2] to carry out a transfer of technology to UAE Government personnel during the course of the Study.

1.1.3. Study Area

The Study Area covers an area of 850 km^2 in the UAE within the boundaries of latitude 25° 00'N to 25° 25'N and longitude 55° 49'E to 56° 00'E, as shown in Figure 1.1.1.

1.2. Scope of the Study

1.2.1. General

The study is to be carried out divided into the following stages:

[1] Preparatory Work:	March 1995
[2] Field Survey (I):	April to July 1995
[3] Homework (I):	August to September 1995
[4] Field Survey (II):	November 1995 to January 1996
[5] Homework (II):	May to September 1996

The flow chart of the work stage by stage is shown in Figure 1.1.2., and outlined in the following paragraphs:

1.2.2. Preparatory Study

[1] Collection and Review of Data

[2] Formulation of a Basic Strategy and Plan of Approach.

[3] Preparation of an Inception Report.

[4] Preparation of Equipment Necessary for the Study.

1.2.3. Field Survey (I)

[5] Explanation and Discussion of Inception Report and Plan for the Transfer of Technology

[6] Collection and Review of Data and Information

[7] Geological Field Survey away from Motor Roads

[8] Geophysical Prospecting

[9] Core Boring and Geophysical Logging

[10] Hydrochemical Analysis of Groundwater

[11] Soil Survey

[12] Laboratory Analysis of Soil

[13] Irrigation Survey

[14] Well and Farm Survey

[15] Aerophotographic Mapping

[16] Identification of Feasibility of the Project

[17] Preparation and Discussion of Progress Report (I)

1.2.4. Homework (I)

The study team submitted a Progress Report (I) and discussed the framework of the next stage of the project with JICA. Based on the results of the discussion, it was decided that the following items were to be the object of the next stage:

[18] Analysis of Data and Information thus far Collected

[19] Identification of Potential for Development, Areas of Need and Obstacles to Development

[20] Formulation of a Strategy for the Development of Groundwater

[21] Formulation of a Basic Strategy for Agricultural Development

[22] Formulation of a Basic Strategy for Groundwater Monitoring, and Introduction of a Database Plan

[23] Identification of Subsequent Areas of Work

[24] Preparation of an Interim Report

1.2.5. Field Survey (II)

[25] Explanation and Discussion of Interim Report

[26] Collection of Supplemental Data and Information

[27] Supplementary Field Survey in the Agricultural Sector

[28] Supplemental Hydrogeological Survey

[29] Drilling of Test-Wells

[30] Survey related to Environment and WID

[31] Preparation and Discussion of Progress Report (II)

1.2.6. Homework (II)

[32] Analysis of Additional Data and Information

[33] Formulation of a Groundwater Development Plan

[34] Formulation of an Agricultural Development Plan

[34-1] Water Resources Plan

[34-2] Land Use Plan

[34-3] Farming Plan

[34-4] Irrigation Plan

[34-5] Infrastructure Plan

[34-6] Planning and Designing of Facilities

[34-7] Plan for Operation and Maintenance of Facilities

[34-8] Agricultural Support Plan

[34-9] Marketing and Processing Plan

[34-10] Farmers' Organization

[34-11] Environmental Conservation Plan

[34-12] WID Consideration

[35] Groundwater Monitoring and Database Plan

[36] Evaluation and Recommendations

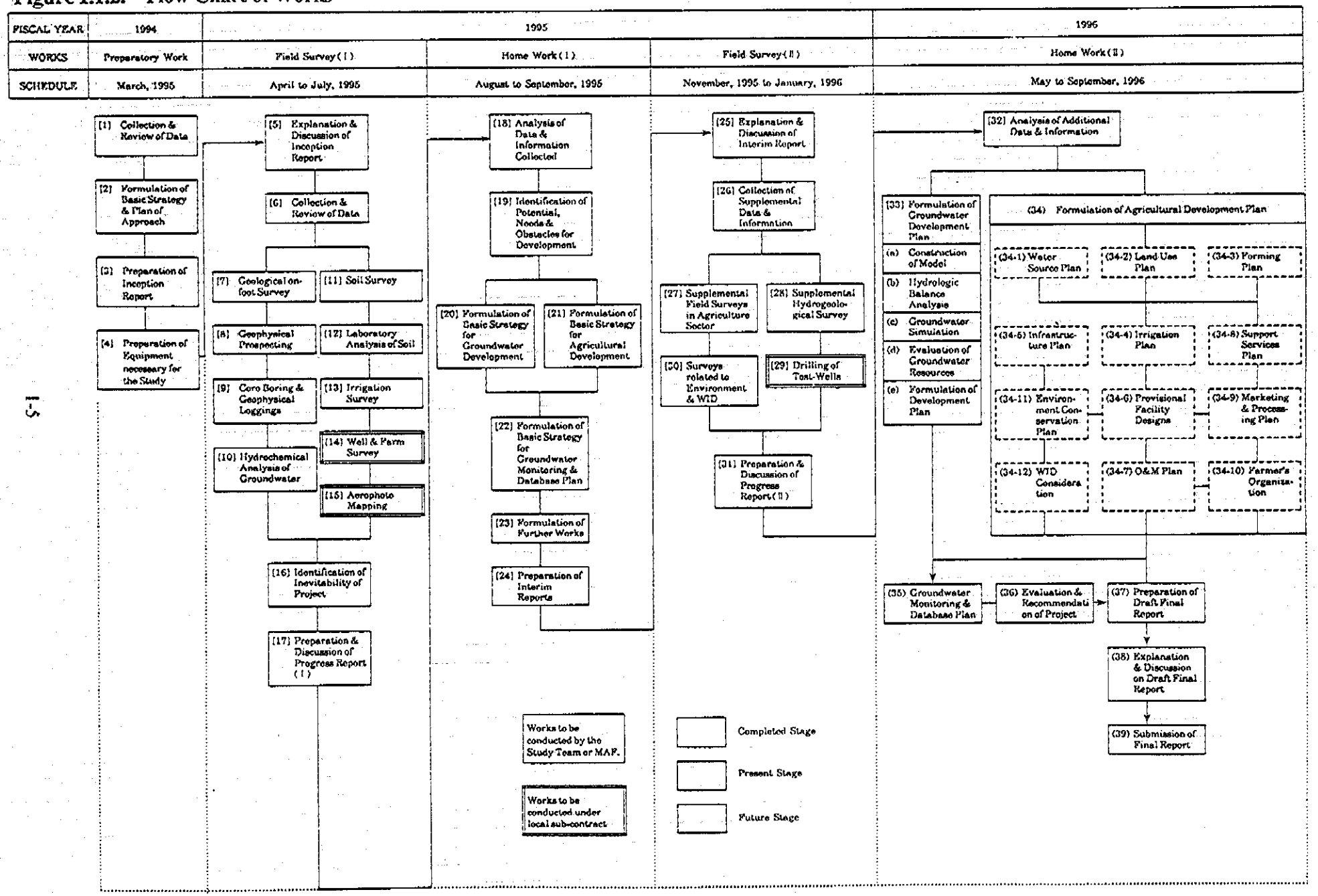
[37] Preparation of Draft Final Report and Report on Transfer of Technology

1.2.7. Draft Final Report and Final Report

[38] Explanation and Discussion of Draft Final Report

[39] Submission of Final Report and Report on Transfer of Technology

Figure 1.1.2. Flow Chart of Works



CHAPTER TWO: UAE IN OVERVIEW

2.1. The Nation

2.1.1. Geography

The United Arab Emirates (hereinafter abbreviated as "UAE") is located at the southeast of the Arabian Peninsula and lies between approximately 22° 50' to 26° N latitude and 51° to 56°E longitude. UAE is bounded by the Arabian Gulf to the north, Oman and the Oman Gulf to the east, Oman and Saudi Arabia to the south and by Qatar and Saudi Arabia to the west. UAE is a federal nation comprised of the seven emirates of Abu Dhabi, Dubai, Sharjah, Ras Al Khaimah, Fujairah, Ajman and Umm Al-Qaiwain.

Fujairah, bounded by three other states, lies on the Gulf of Oman in the north-western part of the Indian Ocean, while the other six emirates stretch along the Arabian Gulf located between Western Qatar and the Musamdam Peninsula. The total land area including the islands in the Arabian Gulf is about 83,600 km^2.

2.1.2. Population

The latest population census at a national level was conducted in 1995. According to estimates by Ministry of Planning, however, the population as of 1993, including nationals and resident foreigners, was as follows:

Land Area/Population by Emirate (Estimate by Ministry of Planning, 1992,1993)

Emirate	Area (km^2) *	Population (X 10^3)	Pop. Density (per km^2)	% of Total	
				Area	Population
Abu Dhabi	67,340.0	871	12.9	86.7	41.8
Dubai	3,885.0	548	141.1	5.0	26.3
Sharjah	2,590.0	342	132.0	3.3	16.4
Ras Al Khaimah	1,683.5	141	83.7	2.2	6.8
Ajman	259.0	83	320.5	0.3	4.0
Fujairah	1,165.5	68	58.3	1.5	3.3
Umm Al Qaiwain	777.0	30	38.6	1.0	1.4
Total	77,700	2,083	26.8	100.0	100.0

Source : "Annual Statistical Abstract 1992, and Statistical Review 1993", Ministry of Planning,
* excluding islands

The largest emirate is Abu Dhabi, which has the lowest population density among the emirates; Ajman Emirate, which has the smallest area, shows the highest population density. Dubai

and Sharjah, the second and third largest emirates, show similar population densities. The areas of the emirates reflect their economic importance. 85% of the population is concentrated in Abu Dhabi, Dubai and Sharjah.

The proportion of sexes in the population in 1993 was estimated at 1 million 251 thousand male and 832 thousand female. The male population accounts for 60% of the total population because of male immigrants. The age structure is as follows:

Age Groups	Population
0 - 4	298,000
5 - 9	264,000
10 - 19	270,000
20 - 29	396,000
30 - 49	747,000
50 - 64	82,000
Over 65	26,000

Source : Ministry of Planning

The age pyramid has a large bulge in the 20 to 60 years category (58% of the total population according to an estimation by the Ministry of Planning), the age period at which most people work. Average population growth has been around 3.5% per annum, which is one of the highest growth rates in the world.

A high proportion of the local population are immigrants. Although there are no definitive figures available, it has been estimated that around 80% of the population are immigrants. Indian, Pakistani, Iranian, Omani, and Asian nationals represent the highest proportion of immigrants; Indian and Pakistani nationals are estimated to account for 80% of the total immigrant population.

2.1.3. Government Organization

UAE is formulated by seven emirates which are the fundamental political unit within indigenous UAE society. A UAE federal government organization chart is shown in Figure 2.1.1.

(1) The Supreme Council

The national constitution which was of a provisional nature till 1995 and was reviewed at five year intervals. Under the constitution, the president and his deputy have to seek re-election every five years. The president and vice-president are elected by the Supreme Council. This Council consists of the hereditary rulers of the seven emirates. It has full power to decide all policy issues on internal and external affairs, and approves all federal laws including the annual budget as well as appointing the UAE Federal Government.

(2) Federal Government

In terms of constitutional importance, the Council of Ministers, the Government of UAE, comes second to the Supreme Council. The Council of Ministers initiates federal legislation, and is headed by the Prime Minister. There are 19 ministries.

(3) Local Government

Each emirate has its own government, the organization varying from emirate to emirate. The municipalities provide such administrative services as issuing registrations.

2.2. Socioeconomic Factors

2.2.1. General Social Development Indicators

The table below gives some social development indicators from 1975 and 1993:

Item	1975	1993
Life expectancy (years)	63.0	72.0
General fertility rate	5.9	5.4
Crude birth rate (000)	27.5	27.4
Crude death rate (000)	8.6	2.1
Infant mortality rate (000)	32.0	16.6
Urban population (%)	77.7	83.9
Access to public health facilities(%)	82.0	100.0
Access to safe water (%)	84.0	100.0
Access to the sewerage system (%)	50.0	88.0
Birth attended by health personnel (%)	90.0	98.0
Adult literacy (10 years and over)	56.1	83.3
Average years of schooling (years)	4.1	7.1

Source : Ministry of Planning

The table indicates that progress has been achieved in the areas of life expectancy, health care, and education; it also shows that the urban sector, measured by percentage of urban population, has increased.

2.2.2. Social Infrastructure

(1) Education

Primary school in UAE starts at the age of six years, is compulsory and lasts for a total of six years. Secondary school is not compulsory and consists of six years of schooling divided into two cycles of three years. In 1977, UAE University was established together with other educational

institutes to provide the required facilities for a higher level of education. As far as government school concerned, the number of students was 278,836 in 1993 compared with 139,840 in 1982; the number of teachers and educational administrators was 11,751 in 1982 and increased to 23,421 in 1993; there were 347 schools in 1982 while in 1993, the number was 560 in 1993. The ratio of male students and teachers to female students and teachers is around 2:1 and has been constant throughout the period 1975-93. The figures show an impressive growth in the education system. Other indicators in the table above show that, as a result of improvements in the education system and in facilities, the adult literacy rate had increased from 56.1% in 1975 to 83.3% by 1993, and the average years of schooling had gone up from 4.1 years in 1975 to 7.1 years by 1993.

(2) Health

Since 1971, health policies in UAE have sought to provide medical care for everyone living in the country. The improvements in living and health conditions and facilities has made it possible to raise life expectancy, bring down the crude death rate and the infant mortality rate, and improve access to public health. Furthermore, the improvements in sanitary conditions has been shown by an increase in the percentage of the population which now has access to safe water and to sewerage systems.

(3) Electricity and Water Supply

a) Electricity Supply

The electricity industry is owned and operated by the government under the responsibility of the Ministry of Water and Electricity and the emirate owned organizations such as the Dubai Electricity Company. At present, there are more than 2,150 km of overhead transmission lines and 584 km of underground cables. There are 48 power stations throughout UAE; over 50% of these are fueled by diesel. The main load distribution center is located on the outskirts of Dubai. In 1992, 191.1 billion KWH were generated as against 136.7 billion KWH in 1987.

b) Water Supply

During the mid-70s domestic demand in the Emirate of Abu Dhabi increased at a rate of between 20% and 50% annually; on the other hand, groundwater levels dropped. Thus, desalination plants had to be built in order to satisfy the increasing demand. At present there are over 30 desalination plants. The largest desalination plant is in Dubai and produces 22,730 m^3/day. Desalinated water accounted for 82% of total water production in UAE in 1989. In 1992 total water production was 102 billion gallons (463.7 MCM).

(4) Transportation

At present there are more than 3,170 km of main roads together with many other asphalt roads and minor graded roads. Public bus services operate in urban areas, but private cars are the most frequently used form of passenger transport, followed by taxis.

UAE is an important maritime trade point and has the following four major international ports: Port Rashid and Port Jabal Ali (Dubai Emirate), Port Zayed (Abu Dhabi Emirate), and Port Khalid (Sharjah Emirate). Other ports handling international trade are: Port Fujairah (Fujairah Emirate), Port Saqr (Ras Al Khaimah Emirate), and Port Khor Fakkan (Sharjah Emirate).

2.2.3. Economic Aspects

(1) Economic Policies

a) Economic Development Planning

In the mid-70s and in 1981, the Federal Planning Ministry elaborated two five-year development plans under which most state industrial investment and infrastructure improvement projects were to be coordinated by the federal authorities and allocated between the emirates.

In the last five year plan an annual growth rate in GDP of 9.6%; was planned. With an annual increase of 4.8% per capita income. The plan concentrated on the manufacturing sector, in order to attain a balance in growth with other industries and the diversification of sources of income, and the annual growth rates expected were 27% for manufacturing, 13.3% for electricity, 10.3% at agriculture, livestock and fisheries, and 15% for government services including health, education, security, etc.. Investments contemplated under the plan were as follows: 29% of total investments for the manufacturing sector; 17% for the transport, storage, and communication sector: 14% for government services; 14% for crude oil and other quarrying industries; 10% for water and electricity; 8% for real estate; and 2% for agriculture. As these figures show, the plan clearly aimed to develop mainly the manufacturing sector as the base for economic development. Agriculture, however, played a minor role. The plan emphasized the role of the government as the main promoter of economic activities, as is shown by the fact that the investments planned to be made by the government represented 82% of total investment. However, the plans were quickly overtaken by world oil-price trends, the sharp price rises of 1978-79 and price falls in the mid-1980s, and have never been implemented. Development planning at the federal level was abandoned and replaced by a system in which each emirate follows an independent development strategy. The result has been a costly duplication of facilities in some emirates and lack of infrastructure in others.

b) Foreign Trade and Exchange Policies

Because of the limited development of non-oil industry and the heavy dependence on imports, the authorities have opened up the economy to foreign competition. There are few restrictions on imports and access to the market is free. Tariffs are not imposed on imports of foodstuffs and some medicines, and raw materials originating from other members of the GCC. In Dubai and Sharjah ports all transit goods are exempted from duty.

UAE Dirham is pegged at a fixed rate to the American dollar. The parity of US$ 1.00 = Dh. 3.65 has been maintained for a long time. There is no restriction on the exchange of foreign currencies and foreign firms do not need to declare their foreign exchange transactions to the government.

c) Taxes

Corporation taxes (20%) are rarely enforced and are limited to foreign banks and oil companies.

Indirect taxes are levied on a number of goods and services, including annual rents, medical services used by expatriates, hotel services and entertainment activities. Municipal taxes on annual rents are usually 5% on private homes and 10% on commercial properties.

(2) Brief Overview of the Recent UAE Economy

a) Gross Domestic Product (GDP)

Tables 2.2.1. and 2.2.2. give information about some economic variables and the GDP respectively.

The GDP per capita is one of the highest among the Gulf countries (Dh. 60,500, equivalent to US$ 16,000) as is the disposable income (Dh. 48,600, equivalent to US$ 13,000). The GDP for 1994 was Dh. 134.8 billion (equivalent to US$ 36.9 billion) at current prices. The contribution of the non-oil sectors in the GDP has grown from 54% in 1990 to 67% in 1994. Even so, the oil sector contributes 33.4% to GDP, followed by the public sector (12,1%), wholesale and retail trade, restaurants and hotels, construction, and manufacturing (Figure 2.2.1).

b) Investment and Consumption

Total investments in 1994 came to Dh. 33.76 billion, a mere 2% up on the 1993 level. Of this private investment was Dh. 21.06 billion (62% of total investment) and government investment, Dh. 12.7 billion (37%). Private investment projects include quarrying, manufacturing, and transportation. The average growth rate of investment for the period 1990-94 has been 9% .

Final consumption figures for 1994 were Dh. 95.793 billion, 10% up on the 1993 level. Government consumption figures were Dh. 24.52 billion (26% of total consumption), while private sector consumption was Dh. 71.273 billion (84% of total consumption). Consumption has been growing at an average rate of 9% for the period 1990-94.

c) Public Finance and Foreign Trade

As can be seen from the table below. the main public revenues come from crude oil-related sources:

(Unit : million Dh.)

	1991	1992	1993
Revenue from Oil Sector	38,919	36,507	31,314
Revenue from Other Sectors	8,886	10,895	7,856
Total Revenue	47,805	47,402	39,170
Expenditure	56,509	45,735	45,206
Balance	- 8,704	1,667	- 6,036

Source : Annual Economic Report 1994, Ministry of Planning

The trade balance achieved a surplus of Dh. 13.8 billion in 1993. While the percentage of crude oil exports represented only 53% of total exports in 1993 compared to 74% in 1985, the percentage of re-export goods has increased. Main import items are manufactured goods (24.8% of total imports), machinery and transport equipment (38.4%), and food and livestock (9.7%). (Table 2.2.2).

d) Employment

The table below shows that the percentage of the labor force relative to the total population has decreased from 52.7% in 1975 to 47.5% in 1993, while the share of the female labor force has increased from 3.3% to 18.5% and the proportion of scientists and technicians from 7.5% to 11.2% over the same period.

Labor Participation Indicators	1975	1993
Labor force to total population (%)	52.7	47.5
Female labor force (%)	3.3	18.5
Scientists and technicians (%)	7.5	11.2
Labor force (%)		
In agriculture	4.6	6.5
In industry	10.0	10.1
In services	29.6	39.5
In other industries	55.8	43.9
Unemployment rate	2.0	1.3

Source : Ministry of Planning

In 1994, there were 906,580 workers in UAE. 86% of them worked in the Abu Dhabi, Dubai, and Sharjah emirates.

2.3. Natural Environment

2.3.1. Geography and Geomorphology

UAE is comprised of seven emirates with a total area of about 83,600 km^2 lying between approximately 22° 50' and 26° N and 51° and 56°E. Fujairah, enclaved with three others, lies on the Gulf of Oman in the north-western part of the Indian Ocean. The other six emirates stretch along nearly 650 km of the southern Arabian Gulf. The terrain of UAE shows different characteristics between the western and eastern regions. The western region is mainly comprised of low plains with the highest elevation at 150 m to 250 m, while the eastern region is dominated by mountain ridges with a maximum elevation of 1500 m, and with a number of desiccated wadis. Especially along Wadis Al Basseirah, Bih and Ham, a deep valley is formed. In terms of morphological characteristics, two regions: (1) an eastern mountain region with a sub-mountainous zone of outwash plains and (2) a western desert region divided into a coastal belt and inland desert, are divided as described in following paragraphs:

(1) The Eastern Mountain Region

The eastern mountain region, stretching 80 km N-S and 30 km E-W, forms a part of the Hajar Mountain (or Oman Mountain Range) in the neighboring state of Oman. It has a Paleozoic core of metamorphic and basic igneous rocks flanked by latter limestone successions. The highest peak in UAE territories rise to 2,400 m and to 3,000 m in Oman. Two outcrops separated from the Hajar, Jabel Fayah and Jebel Sumaini, are Cretaceous and there is an Oligocene formation, Jebel Hafit, near the important oasis complex of Al Ain. The mountainous areas are cut by wadis and forms a terrace which may support vegetation. Many of the wadis are periodically scoured by torrential floods and in some there is a small perennial flow.

(2) Western Desert Region

In the west of the Eastern Mountain Region, an alluvial belt (called the Bahada Plain) separates the mountains from the Aeolian Sands of the western dune country. It is called the Jiri plain in the north and subsequent sub-divisions southwards are known as Dhaid, Gharif and Madam. The plains are the most fertile and agriculturally productive area in UAE. In the west of the Bahada Plain, a plain of the main alluvial belt, a plain of uncultivable sandy desert and shingle flats merge into the northern sands, extending coastward with a series of low Miocene ridges and intervening gravel and salt flats called Sabkha. Sabkha are former embayments of the sea cut off at the strand line to form great evaporating pans of gypsum, other evaporites and wind-born sand. The kinds of land-forms in the coastal area is different between Dubai (the east of UAE) and Abu Dhabi (the

west of UAE). In the east, there is an emergent coastal plain of Miocene low-lying hill, tidal flats, sabkha, sands spits and lagoons, while in the western part of the country, a monotonous terrain of sabkha and coastal sand lies along the coast.

The dunes are divided into two according to origin: (i) those found along the coast are composed of white carbonate sands formed from fragments of marine shell; (ii) those found inland, which from the threshold of the Rub Al Khali, are red and formed of weathered quartz rocks. The shoal dunes are relatively small and to some extent fixed by vegetation. To the interior they increase in height and vegetation is almost non-existent. Very little surface water exists in the larger hollows between the dunes. In Liwa Oasis, the shallow groundwater recharged by the rain fallen in its own catchment makes the water source.

2.3.2. Meteorology and Hydrology

(1) Meteorology

a) General

UAE has a hot desert climate with high temperatures and infrequent irregular low rainfall. It has two seasons: a long dry summer with very high temperatures between April and November and a winter period between December and March, of mild to warm temperatures and a slight to moderate rainfall. Summer mean temperatures across the country reaches 35°C in July, while the average monthly rainfall in the same month is 2 mm. January is the coolest month with a national average temperature of 18°C; February is the wettest month with an average monthly rainfall of 42 mm. General features of climate in different regions of UAE are shown in Figure 2.3.1.

There are more than 132 meteorological observation stations which are operated principally under MAF and other governmental agencies such as air navigation agencies and the university. Of the 132 stations, there are 19 fully-equipped meteorological stations, and the others are rainfall stations.

b) Temperature

The minimum temperature never goes below 0°C in winter, but the maximum temperature reaches more than 45°C in summer. In July, the hottest month of the year, the temperature reaches up to 50°C. Mean annual temperatures are more or less uniform with slight local variations, most noticeably in the mountains to the east, where higher altitudes result in a mean temperature of 27°C. The coolest temperatures occur in Ras Al Khaimah and Liwa and neighboring parts of the interior, where the winter mean minimum can be less than 10°C. Interior areas also experience the biggest diurnal range in temperature.

c) Sunshine Hours

The mean maximum sunshine hours appear in May, with 11.5 hours and a mean minimum of 8.4 hours occurring in December. The skies are relatively cloud-free throughout the year.

d) Relative Humidity

The relative humidity levels are higher along the eastern coastal plain and adjacent to the Arabian Gulf coast and decrease south and eastwards and over the eastern mountain range. The mean annual relative humidity in the east coast exceeds 60%, while in Al Ain the level is less than 45%. The diurnal variation in relative humidity is extremely high and ranges from 100% in early morning to 2% in late afternoon.

e) Winds

The winds tend to be light or light-to-moderate and the mean annual wind speed is less than 10 knots. There is a tendency for winds to be stronger between March and August and predominantly from the north-west and south or south-east. The strongest winds are felt along the coast of the Gulf of Oman, followed by the mountain region, the Arabian Gulf coast, and the desert foreland, while the lighter winds are in the interior.

f) Rainfall

An average annual rainfall in UAE is around 119 mm. However, this level is highly variable year by year. For example, for the year 1982, the annual mean rainfall was 282 mm while in the mountain region the rainfall was over 450 mm in some parts. On the other hand, the year 1984 had an annual mean rainfall of only 24 mm and recorded a level of only 1.6 mm in Abu Dhabi; the highest level reached during that year was just over 100 mm in the mountain region. Rainfall distribution is lowest in the west and south of UAE, increasing towards the north and east over the gravel plains and foothills before reaching Al Ain. The highest annual rainfall total, regardless of whether it is a wet or dry year, falls over the eastern mountains where the mean annual rainfall rises to 160 mm compared to less than 40 mm in Liwa.

Almost 90% of annual rain falls during Winter and Spring and the wettest months are usually February and March where 60% of the rainfall is recorded. Summer witnesses only a few monsoon rainfalls.

g) Evaporation

The evaporation rates exceed rainfall totals all over UAE. For example, in Al Ain evaporation rates peak in July at over 13 mm per day, falling to around 4 mm per day in December and January. Mean annual evaporation is 3,322 mm against a mean annual rainfall of 119 mm.

(2) Hydrology

a) Hydrological Observation Networks

The hydrological observation in UAE started in 1965. 21 main wadi gauges were installed under MAF mainly in the mountain and gravel plain regions. In addition to the main stations, a number of spot gauging sites cover most hydrological zones. The observation results were presented in the "Hydrology Vol. No. 3 1980-1991" [MAF, 1993].

b) Hydrological Zones

There is no perennial river in UAE. UAE can be divided in to the following five drainage zones;

- East coast catchments drain to Gulf of Oman
- Wadi Bih catchments drain to Arabian Gulf depending on flood scale
- Wadi Lamaha catchments drain to Arabian Gulf
- Internal drainage catchment covering Al Ain
- Wadi Sumaini catchment.

c) Runoff

An annual runoff coefficient against the average catchment rainfall varies year by year and location by location. According to the hydrological yearbook of MAF, the maximum and minimum runoff coefficients were estimated at 48% and 0.1%. It is possible to say that the runoff coefficient in wadis with catchment areas of 100 km^2 and 1,000 km^2 is 14% and 2 %, respectively.

d) Sedimentation

No sedimentation collection and analysis has been made at any wadi. The depth of sedimentation accumulation has been measured in several reservoirs. According to the observation, the sediment volumes in the reservoirs were 1% to 4.2% of total flood volume.

2.3.3. Geology, Hydrogeology and Groundwater

The territory of UAE basically forms an inherent part of the Arabian Plate which is bound by the Red Sea Rift System to the west and the Arabian Gulf to the east. The Oman Mountain Chain is through to originate from the plate subduction process which was responsible from the emplacement of the Semail Ophiolite (refer to Figure 2.3.2.). The Oman mountain thrust front which is characterized by the complicated nappe structure, is occasionally interrupted by tectonic depressions of which the Dibba fault zone is one of the most important, while in the Arabian Peninsula, it made up of a plateau of crystalline basement and sedimentary cover which is gently

inclined to the northeast. The turbulence influenced by the subduction zone exists in the vicinity of the Oman Mountain. As referred as the geomorphological divisions mentioned above, the geology of UAE is also divided into two regions: (1) Eastern Mountain and (2) Western Plain, based on their geological composition and origin.

(1) Eastern Mountain

This region constitutes a morphological and geological parts of the Oman Mountain Chain. It is mainly covered with an allochthonous and para-autochthonous metamorphic and ophiolite rock series. The autochthonous rocks constitute an integral part of the Arabian platform to the east and north. They range in age from Cambrian to Cretaceous. These autochthonous formations were already folded and partly uplifted where they were overridden by the successive thrust sheets of the allochthonous rocks. The emplacement of the allochthonous rocks activated the pre-existing major faults and produced minor faults. Overthrusting took place onto an irregular topography of pre-existing autochthonous formation by a subduction process. It had attained its structure in two phases, both taking place during the Late Cretaceous. The initial displacement phase is characterized by the subduction of an oceanic plate beneath the continental shelf of the Arabian Plate. This resulted in an unstable sedimentary environment off the Arabian shelf with turbidites (Hawasina). A later emplacement phase was dominated by an uplift of the elements along various levels of a plane towards the west. This resulted in a pile of nappes completely imprecated of which the westernmost represent autochthonous or para-autochthonous units and the easternmost represent completely allochthonous units. A folding of the thrust sheets resulted in a series of relatively simple large scale anticlines and synclines trending generally N-S to NE-SW and plunging southward.

(2) Western Plain

The territory of the Western Plain forms an inherent part of the Arabian Plate, and is composed of a series of sedimentary rocks from Cambrian to Cretaceous. The intensity of folding shown varies from place to place. By intensity of folding, this geologic province divided into three triangles as follows:

- The west of the Mender - Abu Dhabi line; very intensive folding formed in Miocene, the province contains the main oil fields.
- Mender - Abu Dhabi - Dubai triangle; less folded and generally poor in geological events.
- Al Ain - Dubai - Ras Al Khaimah triangles; intensive folded and intensely faulted.

The difference in geological structure is due to the geologic structure from both orogenic actions of the Oman Mountain and Qatar - South Far Arch. The Western Plain is bounded by both

arches and is simultaneously influenced by the action of sedimentation and consequent individualization of the basin. In addition, the Central Arabian Arch and the Rub Al Khali Basin are also concerned in the forming of these structures. These structures plunge gently northeast towards the Arabian Gulf. General thickening of sedimentation is observed in this direction indicating an increasing rate of subsidence.

2.3.4. Soils and Vegetation

(1) Soils

Information concerning soil types classification varies depending on the system adopted; there is no unified or detailed soil map of UAE available at present.

a) Soil Classification of FAO

According to "World Soil Resources" [FAO, 1991], the soil in UAE is classified into the following five main soil groups, and their distributions are shown in Figure 2.3.4.

- Calcisols, Combisols, Luvisols (CL): soils with lime accumulation mainly in arid and semi-arid areas,
- Leptosols (LP): shallow soils with rock outcrops predominantly occurring in desert and mountain regions,
- Solonchaks, Solonetz (SC): saline and sodic soils,
- Arensols (AR): deep sandy soils, mainly windblown sands newly fixed by vegetation, and
- Shifting Sands: moving sand dunes.

b) Soil Classification in the Atlas of UAE

The United Arab Emirates University prepared the soil association map shown in the "National Atlas of the United Arab Emirates", which was elaborated using different sources such as images from LANDSAT-5, geological and geomorphologic maps, and measured soil sections taken from several parts of the country [UAE University (1993)]. It classified into three soil associations; Entisols, Inceptisols and Aridsols.

(2) Vegetation

A complete botanical survey of UAE has not yet been carried out. Vegetation zones are therefore difficult to define and boundaries are indistinct, especially considering that rapid changes in vegetation patterns can occur with erratic rainfall.

The shifting sand dunes of the western dune plains can support almost no vegetation apart from clumps of species such as *Cyperus congromeratus* and *Calligonum comosum* which may

survive even when almost buried by shifting sand. The coast areas and sabkha of the west also support little vegetation, which is mainly halophytic.

In the central desert, plant cover increases towards the north-east, with the increase in rainfall. Trees become more common, and Acacia forest remnants, witnesses of a wetter past, survive between Ash Shiweb and Al Hiyar, and inland of Jabal Ali. The fertile alluvial plains are capable of supporting quite a dense cover. Jiri plain with their sands and silts and high water table are particularly well covered. The permeability of Dhaid, Madam and Al Ain plains is, however, affected by a caliche horizon below the gravel.

The northern emirates, with their increased rainfall, are the most thickly vegetated and support the greater number of species. The summer showers which can occur in the mountains are important for the germination of many species, such as *Tribulus*. Generally, biological activity in UAE soils is low, but mountain soils may be quite rich.

2.4. Agriculture and Irrigation

2.4.1. General

Agriculture has been practiced in UAE for more than 2,000 years. Traditionally, it was based on nomadic pastoralism with some oasis cultivation. Harsh climatic conditions like summer temperatures exceeding 45°C and annual rainfall of than 150 mm throughout much of the country makes it difficult to develop agriculture.

The present agricultural policy of UAE continues to be aimed towards self-sufficiency in vegetable and fruit production. The climate and soil conditions of UAE at present preclude large-scale economic production of cereals and livestock, although research into economic methods of production continues. The agriculture sector in UAE has been developed from 13,000 ha of agricultural land existing in 1971, to 72,374 ha in 1994; and from 5,000 farm holdings in 1973 to 21,194 in 1994.

2.4.2. Agricultural Administration

(1) Ministry of Agriculture and Fisheries

The Ministry of Agriculture and Fisheries (MAF) has responsibility and coordinates the agriculture, stock breeding, fishery, and water resources affairs in UAE at the federal level. Its organization chart is shown in Figure 2.4.1. Almost all emirates have their own department for agriculture and fisheries.

(2) Agricultural Region of Ministry of Agriculture and Fisheries

For administrative purposes, MAF has divided UAE in four agricultural regions: Abu Dhabi, Central, Eastern and Northern regions. The regions cover the following areas:

Agricul. Region	Areas Covered
Abu Dhabi	Liwa, Bida Zaid, Ghaithi
Central	Al Dhaid, Al Mileiha, Al Awer, Hatta, Falaj Al Mualla, Masufut, Al Muneei, Khadrah
Northern	Hamrania, Khat, Shamel, Digdaga, Sham, Athen
Eastern	Fujairah, Kalba, Morbeh, Khorfakan, Dhadna, Dibba, Massafi, Hamrania

Agricultural and livestock affairs in the Abu Dhabi Emirate are conducted by the Department of Agriculture and Livestock of the Government of the Abu Dhabi Emirate. The rest of the emirates are under the direct jurisdiction of MAF for agricultural and fisheries matters.

(3) Agricultural Development Policy and Budget of MAF

As stated in the previous sub-chapter, the federal government does not implement any long-term national development plan. Also, a long-term agricultural development plan is non-existent, but it is understood that MAF focuses the agricultural development through the expansion of a modern water-saving irrigation system and greenhouses (plastic houses) and vegetable production, as stated in the unrealized Five Year Development Plan (1981-1985).

The annual budget of MAF was Dh. 118 million in 1994, of which 70% was allocated for personnel expenditure. The budget for project implementation has been declining since the 1993 fiscal year.

2.4.3. Agricultural Area and Number of Agricultural Holdings

(1) Agricultural Area

In the period 1993/94, there were 72,374 ha of agricultural land in UAE: 66,682 ha (92%) cultivated and 5,692 ha (8%) uncultivated. Of the cultivated area, 11,096 ha (17%) is dedicated to shifting cultivation, 173 ha (0.3%) to greenhouses, 22,584 ha (34%) to crops and vegetables, 32,829 ha (49%) to fruits. Of the uncultivated area, 4,031 ha (71%) is wasteland, and 1,661 ha (29%) were occupied by buildings. The area under greenhouse per holding in the Abu Dhabi and Northern Regions is relatively larger than in other regions (Figure 2.4.2).

(2) Number of Farms

In 1994 there were 21,194 farms in UAE: 7,612 (36%) in the Abu Dhabi Region, 5,124 (24%) in the Central Region, 2,957 (14%) in the Northern Region, and 5,501 (26%) in the Eastern Region. In the last eight years, the number of holdings and the area of agricultural land and cultivated land rapidly increased at the rates of 19%, 77% and 133% respectively (Figure 2.4.3.).

The average cultivation area in each farm is estiniated at 3.15 ha in UAE, 4.98 ha in the Abu Dhabi Region, 2.76 ha in the Central Region, 3.04 ha in the Northern Region and 1.02 ha in the Eastern Region (Figure 2.4.4.).

2.4.4. Agricultural Production

(1) Cultivation Area and Yield

Fruit crops are the most important crop in the agriculture of UAE occupying 60% of the total cultivated area and 39% in total agricultural production value in 1993/94, followed by vegetable crops, sharing 24% in area and 35% in value, and field crops, sharing 14% in area, 25% in value (Figure 2.4.5.).

The main fruit trees are Date Palm which occupies 53% of the total cultivated area with 34% of the total production value, followed by Citrus and Mango. The main vegetable crops are Tomato, Cabbage, Eggplant, Chard, Jews' mallow, Squash, Cucumber, Sweet melon, Cauliflower, Onion etc., and the main field crops are fodder crops such as Alfalfa and Rhodes grass, which rank third and fourth in production value among all the crops sharing 16% and 9% respectively (Table 2.4.1.).

The Abu Dhabi Region produces the largest amounts of vegetables and fruits, that is, 81% and 38% respectively of the total production in UAE in 1993/94 (Figure 2.4.5.). On the other hand the Central Region is the largest cultivator and producer of field crops, which occupy 38% of cultivated area and account for 54% of production in the country. The main field crops are Alfalfa and Green fodder. Fruit production in the Region is second and vegetables are third, with shares of 26% and 7%, respectively (Figure 2.4.5.). The Northern Region occupies the second position in vegetable production, with an 11% share, and occupies the third position in field crops, but fruit production is the lowest in the country. The Eastern Region occupies the third position in fruit production, but vegetables and field crops are lowest as agricultural land is limited.

According to Figure 2.4.6. in the last eight years, areas under cultivation of Jews' mallow, Cabbage, Tomato and Eggplant increased remarkably; 364% for Jews' mallow, 341% for Cabbage, 307% for Tomato and 216% for Eggplant, while areas under cultivation of Water melon, Cowpea and Okra decreased to 22%, 34% and 48%, respectively. .

(2) Cultivation Method

MAF issued the Directory of Agriculture to give guidance to farmers and recommend suitable cultivation. These directory books describe the cultivation timing (seeding transplanting and harvesting), recommended varieties, planting density or interval, grafting, irrigation application and expected yields.

(3) Crop Production Cost

According to MAF's Annual Agriculture Report 1993, crop production cost in UAE was estimated at Dh. 468 million, composed of 31.5% for fuel costs, 28.2% for manure, 11.7% for chemical fertilizer, 5.5% for chemicals and pesticides and 4.5% for seeds. The labor cost was not clarified. Considering from the gross production value in 1993 is estimated at Dh. 1,885 million, the production costs occupied about 20% of production value.

2.4.5. Livestock Production

Goats are the most common livestock in UAE, accounting for 64% of the total livestock followed by sheep (25%), Cows (5%) and Camels (5%) in 1993 (Figure 2.4.7.). The Central Region breeds 57% of the total head of livestock in UAE, of which Goats account for 53%, Sheep for 32% and Cows and Camels 7% each, followed by the Abu Dhabi (35%), the Northern (28%) and the Eastern (15%) Regions.

In the area of meat production, Camels produce most, supplying 53% of the total meat produced followed by Goats (24%), Cows (13%) and Sheep (11%) (Figure 2.4.8.).

In the area of milk production, Cows rank first with a share of 47%, followed by camels (24%), Goats (22%) and Sheep (7%) (Figure 2.4.9.).

Judging from the remarkable increase in head of livestock treated at veterinary centers during the last 15 years, it can be said that there has been a large increase in the number of livestock bred in recent years, especially cows and sheep.

In the area of poultry, 18,696 tons in weight was produced by 19 farmers in 1993 in UAE. During the six years from 1987 to 1993 the number of poultry raised by farmers increased four times while production increased 25 times (Figure 2.4.10).

2.4.6. Agricultural Supporting Services

For the agriculture sector, MAF provided subsidies for following items;

- Designing farm (free)
- Land preparation (leveling, eliminating gravel, etc.) (free)
- Supervision of daily work (free)