Irrigation efficiency is lower than for the drip irrigation system. Evaporation losses from the spray are small, generally below 2%. Losses due to wind draft may be considered at higher wind speeds and can reach 15% at 5 m/sec. Also, strong winds result in a poor water distribution pattern. Some salt sensitive crops suffer leaf burns when high salinity water is applied under a hot and dry climate. In order to avoid leaf burns to Alfalfa, night sprinkler irrigation can be applied.

(4) Greenhouse Cultivation of Vegetables

There are many farms in the Study Area which have introduced greenhouse cultivation. Greenhouses are made of galvanized steel piping covered by plastic sheets. Most of them have installed the drip irrigation system. Only three farms have installed the pad and fan cooling system.

It is impossible to use the rainfall for leaching the salt accumulation in a greenhouse. Consequently, the most effective irrigation method, that is, the drip irrigation system, must be properly operated to avoid salt accumulation.

2.4.3. Irrigation Water Requirements

The amount of irrigation water needed to obtain a normal yield of crops is mainly determined by evapotranspiration, which varies according to climate conditions and the crop coefficient, which varies according the growth stage of the crops.

(1) Evapotranspiration

a) Climate Condition in the Study Area

For this Study evapotranspiration is estimated based on climatological data from Falaj Al Mualla and Mileiha and its value is used as the crop water requirement. There is no observation data for sunshine within the Study Area. Instead, the sunshine duration data from Ras Al Khaimah Airport has been used.

The Study Area has the following climate classification:

Temperature:	hot (mean temperature > 30 °C)
Min. relative humidity:	for crop coefficient dry (< 20%) in Mar. to Nov.
Wind:	light (< 2 m/sec or < 175 km/day)

b) Evapotranspiration

Evapotranspiration, or reference crop evapotranspiration, is defined as "the rate of evapotranspiration from an extensive surface of 8 to 15 cm tall, green grass coverage of

uniform height, actively growing, completely shading the ground and not short of water".

There are many methods for estimating potential evapotranspiration. As shown in Figure 2.4.1, mean monthly evapotranspiration estimated by the Thornthwaite method, which mainly depends on the air temperature, is highest in summer and lowest in winter. Values estimated by the Penman method are located between the pan-evaporation method and Blaney Criddle method. To formulate an irrigation development plan under the climate conditions of the Study Area, wide application of the Penman method is recommended, if the recovery data is available in the Area. Hereinafter, the Penman method described is the one in FAO Irrigation and Drainage Paper No. 24, revised in 1977.

The estimated mean monthly evapotranspiration at Falaj Al Mualla and Mileiha is summarized as follows:

(unit: mm/day)

	Jan	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total(mm)
Falaj Al Mualla	3.00	3.74	4.96	6.60	8.13	8.51	8.62	8.23	7.24	5.69	4.02	2.92	2,183.87
Mileiha	3.10	3.85	5.22	7.05	8.67	9.12	8.89	8.46	7.44	5.84	4.14	3.03	2,279.81
Study Area	3.05	3.80	5.09	6.83	8.40	8.82	8.76	8.35	7.34	5.77	4.08	2.98	2,231.84

Note : Calculation sheet for Falaj Al Mualla station is shown in Table 2.4.1.

(2) Crop Coefficients

According to FAO guidelines (Irrigation and Drainage Paper No. 24, revised in 1977), the crop coefficient is set by 4 crop growing stages:

Initial stage :	Germination and early growth when soil surface is either not or is hardly covered by crops (ground coverage < 10%)
Crop development stage:	From end of initial stage to attainment of effective full ground cover (ground cover between 70 and 80%)
Mid-season stage:	From attainment of effective full ground coverage to time of start of maturing as indicated by discoloring of leaves or leaves falling
Late season stage:	From end of mid season stage until full maturity or harvest.

The crop coefficient (Kc) is determined based on the following data in each stage:

Initial stage :	Predict irrigation and/or rainfall frequency
Crop development stage:	Transition lined between the initial and mid-season stages
Mid-season stage:	As shown in Table 2.4.2.
Late season stage:	Transition lined between mid season and figured in Table 2.4.2.

Lysimetric studies were made at MAF Hamraniyah, Dhaid and Dibba Research Stations by UNDP/FAO/MAF between 1980 and 1983. Their results are shown in Figure 2.4.3. for crop coefficients and Figure 2.4.4. for ground coverage.

(3) Net Water Requirements

Net water requirement is estimated by evapotranspiration multiplied by the crop coefficient. For the Study, monthly evapotranspiration and net water requirements are calculated on a monthly basis.

In the Study Area, the land affected by salt shall be considered to be such land as where the amount of leaching water for the net water requirements is added to the estimated net water requirement caused by evapotranspiration and to the crop coefficient. In the Study, the effective rainfall was neglected because of its negligible amount and uncertain occurrence.

(4) Net Irrigated Area

Considering the emitter interval and drip outlet interval, the actual irrigated area of drip irrigation for vegetables is considered to be 50% of the cultivation area, which is wet zone area. Considering the area for access farm roads, the actual area of sprinkler irrigation for dates is estimated at 90% of the total cultivation area. Considering the number of trees and the area of basin irrigation, the actual area of bubbler irrigation for pasture is regarded as 30% of the total cultivation area.

(5) Irrigation Efficiency

The irrigation water application efficiency is composed of the conveyancing efficiency and field application efficiency. Irrigation water application efficiency for each irrigation method is considered to be as follows:

Irrigation Method	Conveyance Efficiency	Field Application Efficiency	Total Application Efficiency
Drip	0.9	0.95	0.85
Sprinkler	0.9	0.85	0.75
Bubbler/Micro Sprinkler	0.9	0.85	0.75
Improved Basin	0.9	0.70	0.65

(6) Gross Water Requirement

Gross water requirements for each crop shall be estimated by multiplying the net irrigation water requirement by irrigation efficiency. The amount of this value can be

reduced by effective rainfall. Because rainfall is erratic in the Study Area, effective rainfall is not considered in this Study. It means the amount estimated in this Study is somewhat overestimated compared against the actual gross water requirement.

(7) Irrigation Water Requirement Plans

The monthly net irrigation water requirement is calculated based on the crop water requirement and actual irrigated area. The monthly gross irrigation water requirement is calculated based on the monthly net irrigation water requirement and irrigation efficiency considering the actual irrigated area.

a) Gross Irrigation Water Requirement Option 1

The gross irrigation water requirement is estimated to be 6.2 million m^3/year (208% of present conditions) for vegetables, 2.0 million m^3/year (9%) for Dates, 13.3 m^3/year (40%) for Alfalfa and 21.5 m^3/year (37%) as the total gross irrigation water requirement (Figure 2.4.4.). This total irrigation water volume is equivalent to that of the sustainable irrigation water volume in the Study Area after the groundwater strengthening measures have been put into operation.

b) Gross Irrigation Water Requirement Option 2

4.19 million m^3/year (141% of present conditions) for vegetables, 13.4 million m^3/year (63%) for Dates, 37.8 m^3/year (112%) for Alfalfa and 55.4 m^3/year (95%) as the total of gross irrigation water requirement (Figure 2.4.5.). This total irrigation water volume is 2.6 times larger than the annual sustainable irrigation water volume in the study area and it is necessary to purchase 33.9 million m^3/year (average 1.08 m^3/sec, monthly maximum 1.58 m^3/sec, monthly minimum 0.46 m^3/sec as shown in Table 2.4.5.) of desalinated seawater.

2.4.4. Irrigation System Operation Plan

Basically irrigation practice in the Study Area is implemented on an individual farm basis. Each farm has its own water sources and irrigation distribution system. The present irrigation system can be applied only if the groundwater resources are available within their farms. When the groundwater in a farm is insufficient, the farmers have to get water through a system of collaborative irrigation, if they intend to continue to cultivate their farm.

In this Study, a group irrigation system of supplying water obtained from transported desalinated water or underground dam via pipeline, was also studied. Before the

introduction of a tubewell irrigation system, a falaj was the major irrigation water source in UAE. The falaj was operated and maintained by a small group of farmers which was composed mostly of relatives. The group could be deemed a water user's association. Nowadays, most falaj have been abandoned because they have dried up, and there are no farmers' groups operating a single irrigation water system.

As mentioned previously, the owners of the existing farms in the Study Area are from quite different origins within UAE and many foreigners are employed to operate the farms.

No autonomous group of farmers who have banded together for the purposes of irrigation water, nor any producer's cooperative, can be found in the Study Area.

Table 2.1.1. Results of Soil Chemical Laboratory Analysis

No.	Sample SSLRC	Test Pit Sample No.	Preliminary Classification	Depth (cm)	Moisture (105 C) %	Sand (63 μm - 2mm) %	Silt (2μm - 63μm) %	Clay (<2μm) %	Soil Texture	pH (1:5) in water	pH (1:5) in 1M KCl	Na meq/100g	Cation exchange capacity (CEC) meq/100g	Exchangeable sodium percentage (ESP) %	Sodium Absorption Ratio (SAR) %	Organic Carbon %	Nitrogen mg/Kg	Phosphorus mg/kg	Conductivity μS/cm	Ca mg/kg	Mg mg/kg	Na mg/kg	Salinity
1	122059/1	64-A	GP-CS	0 - 28	0.80	84.46	10.98	4.56	LS	8.00	8.70	0.10	9.80	1.02	0.68	< 0.05	0.1	0.80	127.6	77.50	9.30	30.50	Saline Soil
2	122059/2	64-B	GP-CS	28 - 85	4.90	62.79	20.22	16.99	SL	8.30	8.60	5.20	7.70	67.53	45.02	0.30	0.1	< 0.05	3,660	1,260.00	98.00	4,540.00	Saline-Sodic Soil
3	122059/3	64-C	GP-CS	85 - 95	3.60					8.20	8.60	5.60	7.10	78.87	52.58	0.20	0.1	< 0.05	3,880	15,454.00	101.50	1,605.00	Saline-Sodic Soil
4	122059/4	69-A	SD-I	0 - 15	0.40	96.02	2.27	1.71	S	9.1	8.80	0.10	5.20	3.13	2.08	0.1	< 0.05	< 0.05	100	72.50	6.30	12.60	
5	122059/5	69-B	SD-I	15 - 50	0.50					9.00	8.80	0.30	3.10	3.23	2.15	0.20	0.1	< 0.05	98	67.50	8.00	13.70	
6	122059/6	70-A	SD-G	0 - 45	0.80	91.34	4.99	3.67	S	9.00	8.30	0.01	7.10	0.14	0.09	0.20	< 0.05	< 0.05	69	41.50	6.40	9.10	
7	122059/7	70-B	SD-G	50 - 65	1.00					9.10	8.90	0.40	6.10	6.56	4.37	0.20	< 0.05	< 0.05	79	74.50	10.60	11.00	
8	122059/8	71-A	GP-CG	0 - 10	0.50					9.30	8.70	0.10	6.00	1.67	1.11	0.20	< 0.05	0.30	109	64.00	5.60	31.00	
9	122059/9	71-B	GP-CG	10 - 40	2.00	68.18	21.87	9.95	SL	9.00	8.70	0.30	13.10	2.29	1.53	0.30	0.10	< 0.05	130	43.00	9.20	70.50	
10	122059/10	72-A	SD-WG	0 - 55	0.60	94.20	3.38	2.42	S	9.20	9.00	0.10	4.90	2.04	1.36	0.20	0.10	< 0.05	111	69.50	9.20	13.80	
11	122059/11	72-B	SD-WG	55 - 65	2.40					8.90	9.60	0.80	5.70	14.04	9.36	0.30	0.10	< 0.05	400	37.50	27.00	207.00	
12	122059/12	74	SD-G	15 - 30	0.70	91.12	4.54	4.34	S	9.00	8.70	0.10	3.40	2.94	1.96	0.20	0.10	< 0.05	92	62.00	5.20	16.50	
13	122059/13	75	SD-G	15 - 30	0.60					9.20	8.90	0.10	5.40	1.85	1.23	0.30	0.10	< 0.05	131	82.50	9.00	29.50	
14	122059/14	77-A	SD-WG	20 - 30	0.60	88.80	6.42	4.78	LS	9.30	8.80	0.10	5.80	1.72	1.15	0.30	0.20	< 0.05	112	91.00	11.30	46.10	
15	122059/15	77-B	SD-WG	70 - 80	0.50					9.20	9.10	0.10	7.50	1.33	0.89	0.10	0.10	< 0.05	85	63.50	9.10	28.50	
16	122059/16	80-A	GP-G	10 - 20	0.80					9.10	8.70	0.10	5.80	1.72	1.15	0.10	0.10	< 0.05	89	60.50	7.00	10.70	
17	122059/17	80-B	GP-G	60 - 70	0.80					9.10	9.00	0.10	4.80	2.08	1.39	0.10	0.10	0.20	106	61.50	10.50	33.50	
18	122059/18	81-A	GP-G	5 - 15	0.90	86.53	8.57	4.90	LS	9.30	8.80	2.50	6.20	40.32	26.88	0.30	0.30	22.10	577	58.00	10.00	375.00	Sodic Soil
19	122059/19	81-B	GP-G	20 - 30	1.70					9.50	8.80	1.30	6.30	20.63	13.76	0.10	0.10	2.30	332	51.50	2.50	210.00	Sodic Soil
20	122059/20	84-A	GP-G	10 - 20	0.90					9.30	8.40	0.10	6.10	1.64	1.09	0.20	0.10	< 0.05	112	47.00	6.30	25.50	
21	122059/21	84-B	GP-G	30 - 90	1.90					8.20	8.00	0.50	5.50	9.09	6.06	0.10	< 0.05	< 0.05	2,480	1,665.00	99.50	162.00	Saline Soil
22	122059/22	85-A	GP-CG	5 - 15	0.50	92.13	5.51	2.36	S	9.40	8.40	0.10	7.20	1.39	0.93	0.10	0.10	< 0.05	106	63.00	7.00	27.00	
23	122059/23	85-B	GP-CG	25 - 30	0.80					8.10	8.50	0.10	4.70	2.13	1.42	0.20	0.10	0.80	160	58.50	8.10	34.00	
24	122059/24	86-A	GP-G	5 - 15	0.50					8.10	8.30	0.01	8.10	0.12	0.08	0.20	0.20	1.00	96	68.00	7.00	12.40	
25	122059/25	86-B	GP-G	20 - 25	0.80					8.10	8.40	0.10	5.80	1.72	1.15	0.10	0.10	< 0.05	72	53.00	5.60	7.60	
26	122059/26	88-A	SD-WG	10 - 15	0.40					7.80	8.40	0.10	5.00	2.00	1.33	0.20	0.30	1.10	156	103.00	9.90	35.60	
27	122059/27	89-A	GP-G	10 - 15	0.80	88.66	7.64	3.70	S	9.70	8.90	2.00	4.00	50.00	33.33	1.00	0.10	4.70	350	38.00	65.50	265.00	Sodic Soil
28	122059/28	89-B	GP-G	30 - 40	1.10	88.60	7.68	3.72	S	9.70	8.80	2.30	9.20	25.00	16.67	0.20	0.10	2.10	368	40.50	9.70	280.00	Sodic Soil
29	122059/29	91-A	GP-CG	0 - 10	0.80					7.80	8.10	0.30	7.80	3.85	2.56	0.90	0.70	7.00	145	67.00	9.60	60.50	
30	122059/30	91-B	GP-CG	10 - 30	1.00					8.00	8.90	0.20	2.30	9.09	6.06	0.80	0.10	1.00	110	38.50	15.00	49.50	
31	122059/31	94-A	SD-WG	20 - 30	0.70	86.91	8.99	4.10	LS	8.20	8.50	0.10	4.10	2.44	1.63	0.30	0.20	6.30	125	53.00	11.50	40.00	
32	122059/32	94-B	SD-WG	70 - 80	3.60					8.40	8.50	1.50	2.40	62.50	41.67	0.10	0.30	0.50	567	69.00	48.50	330.00	Sodic Soil
33	122059/33	95-A	SD-WG	20 - 30	0.70	90.85	6.49	2.66	S	8.30	8.40	0.10	5.80	1.72	1.15	0.10	0.10	2.50	128	65.50	11.50	49.50	
34	122059/34	96-A	SD-WG	10 - 15	1.30	82.65	12.90	4.45	LS	8.80	8.50	1.20	7.10	16.90	11.27	0.30	0.20	12.30	216	34.00	13.00	190.50	Sodic Soil
35	122059/35	96-B	SD-WG	40 - 50	4.40					8.20	8.60	1.00	6.90	14.49	9.66	0.10	< 0.05	1.80	325	89.00	38.00	204.00	
36	122059/36	97	GP-CG	10 - 20	0.50					8.30	8.40	0.20	9.90	2.02	1.35	0.50	0.40	17.60	105	32.50	9.30	44.00	
37	122059/37	98-A	GP-G	10 - 15	0.20	97.02	1.76	1.22	S	8.80	8.30	0.10	2.10	4.76	3.17	0.20	0.30	< 0.05	108	59.00	9.00	27.00	
38	122059/38	98-B	GP-G	30 - 40	0.80					8.90	8.50	0.20	3.70	5.41	3.60	0.10	< 0.05	< 0.05	172	51.00	24.00	50.00	
39	122059/39	100-A	SD-I	10 - 15	0.40	94.40	3.83	1.77	S	8.40	8.20	0.60	7.60	7.89	5.26	0.60	< 0.05	25.60	187	91.50	14.00	139.50	
40	122059/40	100-B	GP-CG	5 - 15	0.60	86.92	8.33	4.76	LS	8.00	8.20	1.40	4.70	29.79	19.86	1.00	0.30	10.20	603	101.50	26.50	530.00	Saline-Sodic Soil
41	122059/41	103-A	GP-CN-S	0 - 15	1.10	80.97	11.09	7.94	LS	8.10	8.00	2.80	7.60	36.84	24.56	< 0.05	0.30	6.50	4,420	760.00	82.50	3,280.00	Saline-Sodic Soil
42	122059/42	103-B	GP-CN-S	20 - 30	14.00	74.78	11.60	13.62	SL	8.30	8.20	2.40	8.90	26.97	17.98	0.10	0.20	2.50	2,970	155.00	93.00	2,410.00	Saline-Sodic Soil
43	122059/43	105-A	GP-CG	0 - 15	0.30	88.04	8.51	3.44	S	8.70	8.50	0.10	4.30	2.33	1.55	0.20	0.20	0.50	95	72.50	16.50	12.00	
44	122059/44	105-B	GP-CG	20 - 40	0.60					8.90	8.80	0.10	8.90	1.12	0.75	< 0.05	0.10	< 0.05	91	48.50	8.50	13.50	
45	122059/45	107-A	GP-G	5 - 15	0.40	91.35	6.63	2.02	S	8.40	8.00	1.00	6.40	15.63	10.42	0.50	0.30	5.60	344	26.50	11.70	221.50	Sodic Soil
46	122059/46	109	SD-WG	10 - 20	0.40	93.90	4.30	1.80	S	8.50	8.70	0.90	4.50	20.00	13.33	< 0.05	0.20	3.00	126	29.00	13.60	82.50	Sodic Soil
47	122059/47	111	SD-I	20 - 30	0.20	97.08	2.19	0.73	S	8.60	8.70	0.30	6.50	4.62	3.08	0.10	0.20	1.20	120	37.00	13.50	82.00	
48	122059/48	115-A	GP-CN	5 - 10	1.10					7.60	8.10	4.20	7.40	56.76	37.84	1.30	1.30	111.80	1,751	560.00	101.50	1,045.00	Saline-Sodic Soil
49	122059/49	115-C	GP-CN	30 - 40	9.00					7.30	7.80	0.90	4.80	18.75	12.50	0.10	0.10	3.60	2,620	1,460.00	29.00	218.00	Saline-Sodic Soil
50	122059/50	116	GP-CN	0 - 10	0.90					8.40	8.40	1.10	7.80	14.10	9.40	0.40	0.40	46.00	502	70.50	11.00	169.50	
51	122059/51	118-A	SD-WG	5 - 15	0.10	88.21	7.69	4.10	LS	8.40	8.40	0.01	5.00	0.20	0.13	0.10	0.30	2.80	117	89.50	11.20	18.20	
52	122059/52	118-B	SD-WG	25 - 35	0.40					8.40	8.50	0.01	8.10	0.12	0.08	0.30	0.30	0.50	106	67.30	11.10	23.50	
53	122059/53	119	GP-CN	20 - 30	0.70					7.90	8.60	1.00	6.80	14.71	9.80	0.10	0.30	1.20	670	184.00	29.50	285.00	Saline Soil
54	122059/54	122	GP-G	15 - 25	0.80	81.04	14.25	4.71	LS	7.90	8.50	1.30	7.60	17.11	11.40	0.20	0.10	1.30	659	175.50	33.50	285.00	Saline-Sodic Soil
55	122059/55	123-A	GP-CG	10 - 20	0.60	79.90	13.80	6.30	LS	8.00	8.30	0.10	4.60	2.17	1.45	0.20	0.30	3.50	711	490.00	8.70	33.50	Saline Soil
56	122059/56	123-B	GP-CG	30 - 35	1.50					7.80	8.00	0.10	6.00	1.67	1.11	< 0.05	0.20	1.20	2,430	1,640.00	58.50	41.50	Saline Soil
57	122059/57	123-C	GP-CG	40 - 45	5.30					7.60	7.80	0.30	8.70	3.45	2.30	0.10	0.10	1.20	2,500	1,635.00	76.50	90.50	Saline Soil
58	122059/58	125-A	GP-G	5 - 15	0.80	91.77	5.88	2.35	S	8.50	8.60	1.30	3.20	40.63	27.08	0.10	0.20	6.30	589	87.50	10.00	250.00	Sodic Soil
59	122059/59	126-A	GP-CS	10 - 20	0.40					7.90	8.30	0.30	5.10	5.88	3.92	< 0.05	0.10	4.40	374	137.50	9.00	91.50	
60	122059/60	126-B	GP-CS	35 - 45	2.60					8.20	8.60	0.30	3.70	8.11	5.41	< 0.05	0.10	0.30	527	87.50	31.50	245.00	
61	122059/61	127-A	GP-CN	5 - 15	0.50	78.39	16.51	5.10	LS	8.20	8.50	1.00	7.40	13.51	9.01	0.40	< 0.05	1.30	173	59.50	8.70	74.50	
62	122059/62	127-B	GP-CN	50 - 55	2.40					7.90	8.50	4.70	9.80	47.96	31.97	0.50	0.10	1.00	2,720	1,005.00	111.50	1,304.00	Saline-Sodic Soil
63	122059/63	128	GP-CG	5 - 15	0.30					8.50	8.50	0.10	5.30	1.89	1.26	0.30	0.20	2.60	117	82.00	6.00	29.50	
64	122059/64	130-A	GP-CN	0 - 15	0.20	92.83	4.49	2.68	S	8.80	8.50	0.01	6.30	0.16	0.11	0.30	0.10	2.50	88	85.50	7.50	13.40	
65	122059/65	130-B	GP-CS	30 - 40	2.00					8.50	8.40	0.40	4.20	9.52	6.35	0.40	0.10	4.00	214	138.00	15.00	97.00	

Source : JICA Study Team 1998

Table 2.1.2. Weight Portion of Clay Mineralogy by Bulk Sample

Soil Sample	Weight % < 2um	Chlorite		Kolinite		Palygorskite		Sepiolite		Illite		Smectite		Quartz	Calcite
		weight % relevant size friction	Crystallized	weight % relevant size friction	Crystallized	weight % relevant size friction	Crystallized	weight % relevant size friction	Crystallized	weight % relevant size friction	Crystallized	weight % relevant size friction	Crystallized	weight % relevant size friction	weight % relevant size friction
64-B	20.04	0.5	P	0.4	P	12.6	W	5.7	M	0.0		0.0		0.8	0.0
69-A	8.69	0.6	P	0.7	P	6.5	M	0.8	P	0.0		0.0		0.1	0.0
70-A	10.35	0.6	P	0.6	P	8.4	M	0.6	VP	0.0		0.0		0.1	0.0
71-B	14.31	0.9	P	1.3	P	12.1	M	0.0		0.0		0.0		0.1	0.0
72-A	9.34	0.6	P	0.5	P	7.4	M	0.5	VP	0.0		0.0		0.1	0.3
74	10.80	0.6	P	0.5	P	9.5	M	0.0		0.0		0.0		0.1	0.2
77-A	10.70	1.3	P	1.2	P	6.8	P	0.0		0.8	P	0.0		0.1	0.5
81-A	10.46	1.3	P	1.1	P	4.5	P	0.0		3.3	P	0.0		0.1	0.1
85-A	8.09	1.0	VP	0.9	VP	5.2	P	0.0		0.8	P	0.0		0.1	0.0
89-A	9.88	1.5	P	2.1	P	3.8	P	0.0		2.3	P	0.0		0.1	0.0
94-A	9.80	0.0		1.7	P	6.9	P	0.0		0.9	P	0.0		0.1	0.2
95-A	9.20	0.0		1.8	P	3.9	P	0.0		2.9	P	0.5	P	0.0	0.2
96-A	9.61	0.0		2.2	P	3.2	P	0.0		2.9	M	1.0	P	0.1	0.1
98-A	7.74	0.7	P	1.0	P	3.6	VP	0.0		2.4	VP	0.0		0.1	0.0
100-A	8.55	1.1	P	1.2	P	3.6	P	0.0		2.2	P	0.3	P	0.1	0.0
103-A	13.08	0.0		1.9	P	4.6	P	0.0		3.1	P	3.4	M	0.1	0.0
105-A	9.48	1.6	P	1.8	P	3.5	VP	0.0		1.8	VP	0.6	P	0.1	0.1
107-A	8.65	1.5	P	1.2	P	3.4	P	0.0		2.0	VP	0.4	P	0.1	0.0
109-A	8.63	1.4	P	1.6	P	2.8	P	0.0		2.6	P	0.0		0.2	0.0
111	8.26	1.3	P	1.0	P	2.9	P	0.0		2.6	P	0.4	P	0.1	0.0
118-A	9.51	1.3	P	1.7	P	3.2	VP	0.0		2.6	VP	0.5	P	0.2	0.0
123-A	11.26	0.7	P	0.5	P	6.3	M	3.1	M	0.0		0.0		0.3	0.3
125-A	9.24	0.4	VP	0.8	P	7.8	M	0.0		0.0		0.0		0.1	0.1
127-A	10.94	0.4	P	0.7	P	9.7	M	0.0		0.0		0.0		0.1	0.1
130-A	8.85	0.8	P	0.7	P	4.7	P	0.0		2.3	P	0.0		0.2	0.3

Notes : crystallized condition : VW = very well crystallized W : well crystallized M : moderately crystallized
P : poorly crystallized VP : very poorly crystallized RI : randomly interstratified

Source : JICA Study Team, 1995

Table 2.1.3. Soil Water Tension, Soil Densities and Water Contents

Sample No.	Field Moisture Contents	bar	0	0.05	0.1	0.4	2	15	Field Capacity	Initial Wilting Point	Permanent Wilting Point	Plant Available Water	Bulk Density	Specific Density
		water height cm	0	51	102	408	2.040	15.300						
	%	pF	0	1.7	2.0	2.6	3.3	4.2	pF = 2.5	pF = 3.0	pF = 4.2	Capacity (%)	(g/cm³)	(g/cm³)
64A	0.8	LS	47.80	40.37	19.54	11.94	4.82	2.99	13.34	7.97	2.99	10.35	1.65	2.67
64B	4.9	SL	45.68	35.35	27.93	22.79	13.28	8.71	23.73	17.49	8.71	15.02	1.33	2.67
69A	0.4	S	39.32	28.33	11.63	7.48	3.81	1.67	8.24	5.44	1.67	6.57	1.59	2.80
70A	0.8	S	37.89	25.81	11.85	8.57	3.97	3.66	9.17	6.01	3.66	5.51	1.60	2.97
71A	0.5		44.01	24.17	20.60	14.74	6.76	4.28	15.82	10.29	4.28	11.54	1.41	2.85
72A	0.6	S	44.92	37.66	27.80	17.86	2.75	1.94	19.69	9.44	1.94	17.75	1.57	2.83
74	0.7	S	38.53	24.89	9.51	6.11	2.74	1.95	6.73	4.23	1.95	4.78	1.58	2.70
77A	0.6	LS	39.66	32.84	16.70	8.70	4.23	3.21	10.17	6.21	3.21	6.96	1.58	2.76
81A	0.8	LS	38.40	27.11	13.47	10.06	4.41	3.34	10.69	6.91	3.34	7.35	1.54	2.65
85A	0.5	S	49.13	43.97	17.83	7.35	2.67	2.20	9.28	4.74	2.20	7.08	1.79	2.62
89A	0.8	S	36.43	24.19	13.43	9.49	4.64	3.62	10.21	6.79	3.62	6.59	1.60	2.69
89B	1.1	S	36.25	27.27	16.59	9.19	4.10	3.62	10.55	6.35	3.62	6.93	1.53	2.78
94A	3.6	LS	43.01	36.97	20.98	11.61	5.75	3.77	13.33	8.35	3.77	9.56	1.47	2.83
95A	0.7	S	40.90	35.44	16.46	8.16	4.15	2.53	9.69	5.93	2.53	7.16	1.55	2.61
96A	1.3	LS	37.06	27.50	18.46	14.12	5.97	4.92	14.92	9.58	4.92	10.00	1.58	2.79
98A	0.2	S	36.10	27.78	9.87	6.17	1.98	1.92	6.85	3.84	1.92	4.93	1.64	2.75
100A	0.4	S	36.11	28.56	11.30	8.41	2.87	2.39	8.94	5.32	2.39	6.55	1.62	2.71
102A	0.6		40.34	36.01	19.50	12.91	6.78	5.37	14.12	9.50	5.37	8.75	1.51	2.69
103A	1.1	LS	41.24	37.91	20.82	13.18	6.07	5.03	14.58	9.22	5.03	9.55	1.56	2.75
103B	1.4	SL	49.71	48.24	29.78	17.10	8.40	5.72	19.43	12.25	5.72	13.71	1.52	2.81
105A	0.3	S	34.46	29.63	14.76	8.46	6.54	2.40	9.62	7.39	2.40	7.22	1.68	2.84
107A	0.4	S	41.55	27.99	14.12	10.59	4.76	4.11	11.24	7.34	4.11	7.13	1.54	2.76
109	0.4	S	37.21	30.72	14.08	7.14	3.23	2.58	8.42	4.96	2.58	5.84	1.63	2.85
111	0.2	S	35.14	27.78	8.69	5.26	1.98	1.23	5.89	3.43	1.23	4.66	1.70	2.94
118A	0.1	LS	36.26	29.54	14.18	9.81	3.92	2.65	10.61	6.53	2.65	7.96	1.64	2.69
122	0.4	LS	42.23	38.33	22.53	12.65	6.00	3.42	14.47	8.95	3.42	11.05	1.50	2.74
123A	0.6	LS	37.07	30.90	18.38	12.77	6.44	4.83	13.80	9.24	4.83	8.97	1.58	2.79
125A	0.8	S	34.50	27.41	17.06	13.90	5.65	5.60	14.48	9.30	5.60	8.88	1.64	2.74
127A	0.3	LS	46.15	39.97	21.50	11.47	5.49	4.83	13.31	8.14	4.83	8.48	1.35	2.67
130A	0.2	S	40.92	32.62	14.45	8.21	6.50	2.27	9.36	7.26	2.27	7.09	1.53	2.85

Source: JICA Study Team, 1995

Table 2.3.1. Numbers and Area under Modern Irrigation System by Regions, 1993

Region	Number of Farms	Area by Type of Irrigation				Share among Regions			Share in Region		
		Sprinkler	Bubbler	Drip	Total	Sprinkler	Bubbler	Drip	Sprinkler	Bubbler	Drip
Abu Dhabi	4,206	5,837	235	26,960	33,032	63%	10%	93%	18%	1%	82%
Central	787	874	939	866	2,679	9%	41%	3%	33%	35%	32%
Northern	448	2,152	241	1,001	3,394	23%	10%	3%	63%	7%	29%
Eastern	267	374	881	93	1,348	4%	38%	0%	28%	65%	7%
Total	5,708	9,237	2,296	28,920	40,453	100%	100%	100%	23%	6%	71%

Source : Ministry of Agriculture and Fisheries

Table 2.3.2. Productive and Poor Wells by Regions, 1993

Region	Quantity			Share among Regions		Share in Region	
	Poor	Productive	Total	Poor	Productive	Poor	Productive
Abu Dhabi	2,486	12,309	14,795	64%	43%	17%	83%
Central	843	8,187	9,030	22%	29%	9%	91%
Northern	201	3,122	3,323	5%	11%	6%	94%
Eastern	357	4,871	5,228	9%	17%	7%	93%
Total	3,887	28,489	32,376	100%	100%	12%	88%

Source : Ministry of Agriculture and Fisheries

Table 2.3.3. Groundwater Quality by Existing Well Inventory Survey, 1995

Item		Extension Unit					Survey Total
		Kadrah	Dhaid-1	Dhaid-2	Falaj Al Mualla	Meleiha	
Electric Conductivity (µS/cm)	Sample No.	33	104	100	72	152	461
	Average	2,620	3,494	1,919	2,535	2,886	2,739
	Maximum	7,860	37,700	6,480	15,370	9,170	37,700
	Minimum	1,220	200	619	933	414	200
Water Temperature (°C)	Sample No.	34	112	100	79	190	515
	Average	33.5	37.0	36.6	35.1	33.1	35.0
	Maximum	36.3	56.0	43.5	42.5	45.4	56.0
	Minimum	30.5	29.5	31.2	30.6	27.6	27.6
pH	Sample No.	32	112	84	71	185	484
	Average	7.7	7.8	8.2	7.7	7.4	7.7
	Maximum	9.8	8.8	8.9	8.2	8.0	9.8
	Minimum	6.6	6.3	6.6	7.2	4.0	4.0
Irrigation Water Salinity Class No.	Class 1	0	1	0	0	0	1
	Class 2	0	2	7	0	1	10
	Class 3	22	81	77	61	94	335
	Class 4	7	3	6	4	42	62
	Class 5	4	17	10	7	15	53
Irrigation Water Salinity Class in %	Class 1	0.00%	0.96%	0.00%	0.00%	0.00%	0.22%
	Class 2	0.00%	1.92%	7.00%	0.00%	0.66%	2.17%
	Class 3	66.67%	77.88%	77.00%	84.72%	61.84%	72.67%
	Class 4	21.21%	2.88%	6.00%	5.56%	27.63%	13.45%
	Class 5	12.12%	16.35%	10.00%	9.72%	9.87%	11.50%

Source : Farm and Exisitng Wells Inventory Survey, JICA Study Team, 1995

Notes: irrigation salinity class is estimated by electric conductivity by following criteria:

Class 1: EC < 250 µS/cm Class 2: 250 < EC < 750 µS/cm

Class 3: 750 < EC < 2,250 µS/cm Class 4: 2,250 < EC < 5,000 µS/cm

Table 2.3.4. Groundwater Quality in Northern Emirates in 1977-1981

Water Sampling		Cation Contents (meq/lit.)					Anion Contents (meq/lit.)						SAR	EC	pH
Location	Date	Ca	Mg	Na	K	Total	CO_3	HCO_3	Cl	SO_4	NO_3	Total		µS/cm	
Dhaid E/S	Apr-78	0.90	1.80	3.40	0.20	6.30	0.70	2.60	2.30	0.90	0.00	6.50	2.9	700	8.70
Dhaid E/S	Apr-78	0.70	1.80	3.50	0.20	6.20	0.70	2.20	2.25	1.00	0.00	6.15	3.1	650	8.90
Hamdah 4WRH410	Dec-76	1.96	3.70	2.35	0.10	8.11	0.00	2.51	3.38	2.18	0.02	8.09	1.4	840	7.40
Meleiha 4WRH425	Dec-76	1.44	4.93	12.82	0.38	19.57	0.00	4.26	9.30	6.02	0.03	19.61	7.2	2,000	7.60
Meleiha 4WRH425	Oct-77	0.50	4.30	13.00	0.70	18.50	1.80	3.20	8.10	5.60	0.29	18.99	8.4	1,900	8.30
Fili 4WH413	Dec-76	1.20	2.66	1.61	0.05	5.52	0.00	2.46	1.69	1.35	0.02	5.52	1.2	600	7.30
Fili 4WH413	Oct-77	1.50	2.80	3.00	0.30	7.60	1.50	1.80	2.10	1.20	0.23	6.83	2.0		7.60
Fujaira	Mar-79	1.05	3.46	4.35	0.15	9.01	tr	2.05	4.25	2.98	0.00	9.28	2.9	907	8.90
Bidya Fujaira	Jul-78	0.40	2.00	5.20	0.20	7.80	0.40	1.80	5.50	0.10	0.00	7.80	4.7	900	8.34
Siji East Coast	Mar-79	3.20	4.00	37.40	0.60	45.20	4.60	0.80	38.50	1.30	0.00	45.20	19.7	4,900	12.20
Kalab W-1	Dec-77	1.30	4.13	3.70	0.10	9.23	0.00	4.60	3.16	1.75	0.00	9.51	2.2	1,000	7.80
Kalab W-2	Dec-77	1.30	4.13	3.70	0.10	9.23	0.00	4.20	3.20	1.76	0.00	9.16	2.2	1,000	7.90
Hamraniya E/S-BA	Dec-77	16.80	16.20	39.10	1.70	73.80	0.00	2.10	12.90	58.00	0.00	73.00	9.6	7,700	8.10
Hamraniya E/S-BB	Dec-77	16.80	17.20	39.10	2.70	75.80	0.00	1.00	61.00	11.60	0.00	73.60	9.5	7,700	8.00
Hamraniya E/S-WA	Dec-77	26.20	17.80	55.40	2.10	101.50	0.00	2.10	79.50	24.60	0.00	106.20	11.8	10,200	8.20
Hamraniya E/S-WB	Dec-77	54.60	28.40	77.40	2.60	163.00	0.00	1.00	141.00	26.50	0.00	168.50	12.0	17,900	7.60
Hamraniya E/S-WA	Jan-78	8.40	9.40	23.30	1.70	42.80	1.00	1.80	31.00	11.00	0.05	44.85	7.8	4,600	8.30
Hamraniya E/S-WB	Jan-78	2.50	3.50	13.90	0.40	20.30	0.30	2.40	13.10	4.80	0.02	20.62	8.0	2,200	8.40
Hamraniya E/S-WC	Jan-78	12.90	7.90	31.70	1.20	53.70	0.50	1.50	38.40	16.00	0.07	56.47	9.8	5,400	8.10
Hamraniya E/S-ED	Jan-78	6.10	3.40	27.80	0.80	38.10	1.70	3.20	22.80	10.40	0.00	38.10	12.8	3,800	8.50
Hamraniya E/S-W-1	Feb-79	2.90	5.00	14.10	0.40	22.40	0.00	3.20	15.00	4.20	0.00	22.40	7.1	2,100	8.76
Hamraniya E/S-W-2	Feb-79	2.40	4.80	15.00	0.40	22.60	0.00	3.80	14.80	4.00	0.00	22.60	7.9	2,170	8.68
Hamraniya E/S-W-3	Feb-79	1.80	4.40	9.00	0.30	15.50	0.00	3.20	8.90	3.40	0.00	15.50	5.1	1,470	8.70
Hamraniya E/S-W-4	Feb-79	2.60	4.60	10.80	0.30	18.30	0.00	3.00	11.40	3.90	0.00	18.30	5.7	1,700	8.60
Hamraniya E/S-W-6	Feb-79	2.10	3.00	9.10	0.30	14.50	0.00	3.20	9.30	2.00	0.00	14.50	5.7	1,500	8.64
Hamraniya E/S-W-1	Jan-78	2.20	4.10	10.90	0.40	17.60	0.40	2.50	10.70	4.20	0.02	17.82	6.1	1,800	8.10
Hamraniya E/S-W-2	Jan-78	2.00	3.80	8.70	0.30	14.80	0.20	3.10	8.20	3.80	0.03	15.33	5.1	1,500	7.80
Hamraniya E/S-W-3	Jan-78	2.10	3.70	8.70	0.30	14.80	0.40	2.70	8.20	3.50	0.02	14.82	5.1	1,500	8.00
Khatt A/S W-1		3.60	3.10	16.30	0.30	23.30	0.50	2.80	4.30	15.60		23.20	8.9	1,660	8.00
Khatt A/S W-2		4.80	3.60	17.40	0.30	26.10	0.30	3.20	5.30	18.80		27.60	8.5	1,880	8.00
Khatt A/S Lemon-A	Jun-79											0.00		3,000	8.10
Khatt A/S Lemon-B	Jun-79											0.00		2,500	8.20
Khatt -1		5.80	6.60	23.50	1.00	36.90	0.00	1.00	26.30	7.99	0.00	35.29	9.4	3,800	7.60
Khatt -2		4.70	5.00	20.90	1.00	31.60	0.00	0.70	24.30	4.20	0.00	29.20	9.5	3,200	7.90
Khatt -3		3.80	3.70	15.70	0.50	23.70	0.00	0.70	18.80	2.90	0.00	22.40	8.1	2,600	7.80
Khatt W-1	Dec-77	4.20	5.80	19.10	0.50	29.60	0.00	3.10	18.00	7.30	0.00	28.40	8.5	2,900	
Khatt W-2	Dec-77	1.60	6.40	15.90	0.30	24.20	0.00	4.60	14.00	5.20	0.00	23.80	8.0	2,400	7.90
Khatt W-3	Dec-77	8.40	11.60	30.00	0.80	50.80	0.00	3.10	33.00	13.90	0.00	50.00	9.5	3,300	8.30

Source : "Water and Soil Yearbook No.2 1977-1981", MAF

Table 2.3.5. Crop Salt Tolerance

Crop	Yield Potential								
	100%		90%		75%		50%		Max.
	ECw	ECe	ECw	ECe	ECw	ECe	ECw	ECe	ECe
Orchards									
Strawberry	0.7	1.0	0.9	1.3	1.2	1.8	1.7	2.5	4.0
Grapes	1.0	1.5	1.7	2.5	2.7	4.1	4.5	6.7	12.0
Citrus	1.1	1.7	1.6	2.3	2.2	3.3	3.2	4.8	8.0
Lemon	1.1	1.7	1.6	2.3	2.2	3.3	3.2	4.8	8.0
Figs/Pomegranate	1.8	2.7	2.6	3.8	3.7	5.5	5.6	8.4	14.0
Date palm	2.7	4.0	4.5	6.8	7.3	10.9	12.0	17.9	32.0
Vegetables									
Carrots	0.7	1.0	1.1	1.7	1.9	2.8	3.1	4.6	8.0
Onion	0.8	1.2	1.2	1.8	1.8	2.8	2.9	4.3	8.0
Radish	0.8	1.2	1.3	2.0	2.1	3.1	3.4	5.0	9.0
Lettuce	0.9	1.3	1.4	2.1	2.1	3.2	3.4	5.2	9.0
Pepper	1.0	1.5	1.5	2.2	2.2	3.3	3.4	5.1	9.0
Potato	1.1	1.7	1.7	2.5	2.5	3.8	3.9	5.9	10.0
Cabbage	1.2	1.8	1.7	2.8	2.9	4.4	4.6	7.0	12.0
Sweet Melon	1.5	2.2	2.4	3.6	3.8	5.7	6.1	9.1	16.0
Cucumber	1.7	2.5	2.2	3.3	2.9	4.4	4.2	6.3	10.0
Tomato	1.7	2.5	2.3	3.5	3.4	5.0	5.0	7.6	13.0
Spinach	1.3	2.0	2.2	3.3	3.5	5.3	5.7	8.6	15.0
Beets	2.7	4.0	3.4	5.1	4.5	6.8	6.4	9.6	15.0
Forage Crop									
Alfalfa	1.3	2.0	2.2	3.4	3.6	5.4	5.9	8.8	16.0
Sudan grass	1.9	2.8	3.4	5.1	5.7	8.6	9.6	14.4	26.0
Bermuda grass	4.6	6.9	5.7	8.5	7.2	10.8	9.8	14.7	23.0
Barley	5.3	8.0	6.7	10.0	8.7	13.0	12.0	18.0	28.0

Source : FAO Irrigation and Drainage Paper No.24, Guidelines for predicting crop water requirments, 1977

Notes: ECw : Electric conductivity of irrigation water (mS/cm)

ECe : Electric conductivity of soil in the saturation extract(mS/cm)

Max. ECe : Maximum tolerable electric conductivity of soil in the saturation extract (mS/cm)

Table 2.3.6. Groundwater Extraction Survey Results in 1978

Farm No.	Gross Area	Irrigated Area	Total Groundwater Extraction	Extracted Water per ha		Ratio Eto (= 2,200 mm)	Remarks
	ha	ha	m³/annum	m³/ha/annum	mm/ha		
1	2.52	1.51	82,026	54,322	5,432	247%	
2	2.18	1.53	89,435	58,454	5,845	266%	
3	2.23	1.78	106,141	59,630	5,963	271%	
4	3.31	2.58	156,600	60,698	6,070	276%	
5	2.27	1.82	107,730	59,192	5,919	269%	
6	9.05	3.62	76,006	20,996	2,100	95%	Drp Irrigation applied (70% area)
7	8.68	3.47	178,360	51,401	5,140	234%	
8	8.76	3.50	147,911	42,260	4,226	192%	
9	9.13	4.70	155,740	33,136	3,314	151%	G.I. pipe distribution
10	4.00	2.08	106,054	50,988	5,099	232%	
11	2.86	2.00	110,185	55,093	5,509	250%	
12	8.92	3.57	122,271	34,250	3,425	156%	G.I. pipe distribution
13	2.23	1.34	79,757	59,520	5,952	271%	
14	6.41	2.56	108,113	42,232	4,223	192%	
15	2.16	1.44	81,613	56,676	5,668	258%	
Avaerage	4.98	2.50	113,863	49,256	4,926	224%	

Source :UNDP/FAO/MAF. "Cropping Pattern and Irrigation Requirements. Central Region, UAE", Technical Report 3, May 1978

Table 2.3.7. Groundwater Extraction Survey Results in 1995

Farm	Location	Falaj Al Mualla	Dhaid West	Dhaid East	Mileiha East	Wisha	Khuderah	Jabal Mileiha	Mileiha	Ikedir	Filli	Average
	Total Farm Area	2.65	3.39	2.06	2.23	4.15	6.20	7.00	4.67	6.20	3.36	4.19
Cultivation Area in ha	Date Palm	0.60	0.88	0.92	0.08	2.82	2.24	1.90	0.78	1.17	0.56	1.20
	Forage Crops	0.32	0.00	0.00	1.11	0.34	1.94	0.30	1.30	2.52	1.57	0.94
	Others	0.00	0.48	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08
	Total	0.92	1.36	1.23	1.19	3.16	4.18	2.20	2.08	3.69	2.16	2.22
Extraction	Avg. m³/day	289	104	15	160	157	250	100	298	825	498	269.60
	Unit Water m³/ha	314	76	12	134	50	60	45	143	224	231	128.96
	Unit Water m³/ha	109	31	7	72	38	40	14	64	133	148	65.63
	Est. Annual (m³/ha)	114,658	27,912	4,451	49,076	18,134	21,830	16,591	52,293	81,606	84,153	47,070
Net Irrigation Requirement	ETo in July (mm/day)	8.80	8.80	8.80	8.80	8.80	8.80	8.80	8.80	8.80	8.80	
	Kc Date Palm	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
	Kc Fodder	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	
	Date Palm (mm/day)	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	
	Forage Crop (mm/day)	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	7.92	
	Total Net Requirement (m³)*	32			63	86	161	62	91	168	100	
	Irrigation Efficiency	10%			47%	173%	269%	136%	63%	75%	44%	102%
Annual Water Requirement	Date Palm (m³)	3,726			497	17,512	13,910	11,799	4,844	7,266	3,478	
	Forage Crops (m³)	4,637			16,084	4,927	28,111	4,347	18,837	36,515	22,749	
	Total (m³)**	4,364			11,408	8,702	23,851	6,583	14,639	27,740	16,968	
	Irrigation Efficiency	4%			23%	48%	109%	40%	28%	34%	20%	38%

Note : * net irrigation area assumed 0.3 and 0.8 for date palm and forage crops, respectively

Source : JICA Study Team 1995

Table 2.3.8. Drip Irrigation Efficiency Trail Results at Hamraniyah, 1983

Crop	Lateral Spacing (m)	Dripper Discharge (lit/hr)	Crop Rows per Lateral	Year 1979 * Water Applied (m³/ha)	Year 1979 * Yield kg/ha	Year 1979 * Water Use efficiency (kg/m³)	Year 1979/80 * Water Applied (m³/ha)	Year 1979/80 * Yield kg/ha	Year 1979/80 * Water Use efficiency (kg/m³)	Year 1980/81 * Water Applied (m³/ha)	Year 1980/81 * Yield kg/ha	Year 1980/81 * Water Use efficiency (kg/m³)	Irrigation at soil water tension 15 cb. * Cropping Period	Water Applied (m³/ha)	Yield kg/ha	Water Use efficiency (kg/m³)	Irrigation at soil water tension 20 cb. ** Cropping Period	Water Applied (m³/ha)	Yield kg/ha	Water Use efficiency (kg/m³)
Cabbage	1.00	2	1	3,080	23,900	7.76	3,080	23,900	7.76	3,392	39,530	11.65	Autumn '78	4,234	44,000	10.39				
	1.00	3	1	3,320	20,210	6.09	3,320	20,210	6.09	3,411	38,590	11.31	Autumn '79	4,410	43,920	9.96	Autumn '79	3,785	40,220	10.63
	1.50	2	2	3,160	31,310	9.91	3,160	31,310	9.91	2,427	39,120	16.12								
	1.50	4	2	3,290	30,030	9.13	3,290	30,030	9.13	3,172	44,840	14.14	Dhaid Station (no detailed data available)							
	2.00	2	2	2,800	25,720	9.19	2,800	25,720	9.19	2,438	32,040	13.14	Autumn '81	3,567	41,278	11.57				
	2.00	4	2	3,500	31,190	8.91	3,500	31,190	8.91	2,837	41,170	14.51	Spring '82	5,328	32,525	6.10				
	average			3,192	27,060	8.50	3,192	27,060	8.50	2,946	39,215	13.48								
Cucumber	1.50	2	1				2,971	35,748	12.03	2,386	10,455	4.38	autumn '76	2,350			autumn '76	2,120		0.00
	1.50	4	1				2,552	32,141	12.59	2,466	10,731	4.35	spring '77	4,100	31,420	7.66	spring '77	2,245	26,250	11.69
	2.25	2	2				2,874	36,015	12.53	2,138	11,184	5.23	autumn '78	2,810	22,565	8.03	autumn '78	1,870	17,610	9.42
	2.25	4	2				2,770	36,497	13.18	2,372	10,509	4.43	spring '78	2,930	24,080	8.22	spring '78	2,060	14,390	6.99
	3.00	2	2				3,176	31,959	10.06	2,321	10,211	4.40								
	3.00	4	2				2,851	35,793	12.55	2,064	10,864	5.26								
	average						2,866	34,692	12.16	2,291	10,659	4.68								
Tomato	1.25	2	1	6,959	119,630	17.19	6,959	119,630	17.19	6,142	73,935	12.04	1976-77	4,560	51,400	11.27	1976-77	4,265	44,000	10.32
	1.25	4	1	7,186	111,530	15.52	7,186	111,530	15.52	5,322	73,100	13.74	1977-78	7,603	85,415	11.23	1977-78	6,050	78,965	13.05
	1.75	2	2	6,054	109,950	18.16	6,054	109,950	18.16	5,623	69,467	12.35	1978-79	9,532	109,000	11.44	1978-79	9,024	116,000	12.85
	1.75	4	2	5,129	110,540	21.55	5,129	110,540	21.55	6,351	85,302	13.43								
	2.50	2	2	6,239	91,970	14.74	6,239	91,970	14.74	4,732	48,780	10.31								
	2.50	4	2	6,653	87,670	13.18	6,653	87,670	13.18	5,210	48,722	9.35								
	average			6,370	105,215	16.72	6,370	105,215	16.72	5,563	66,551	11.87								
Squash													Autumn '76	2,630	29,535	11.23	Autumn 1976	2,065	25,110	12.16
													Autumn '77	2,670	31,506	11.80	Autumn 1977	2,670	26,433	9.90
Cauliflower													Autumn '78	4,234	28,000	6.61				
													Autumn '79	11,490	36,120	3.14	Autumn '79	8,460	35,560	4.20
Melon													Spring '79	4,851	17,000	3.50		5,027	17,000	3.38
													Spring '90	7,064	28,290	4.00		6,520	34,320	5.26

Source : UNDP/FAO. MAF Water and Soil Investigations for Agricultural Development. Technical Report No.2. June 1979; No. 5. April 1981 & No.6. February 1984

Notes : * irrigation timing at 15 centibar of soil water tension, ** irrigation timing at 20 centibar of soil water tension

Table 2.3.9. Lemon Tree Irrigation Trail at Hamraniyah and Dibba, 1980

Irrigation Method	1.981			1.982			1.983			Dibba Station 1983		
	Water Applied (m^3/ha)	Yield kg/ha	Water Use efficiency (kg/m^3)	Water Applied (m^3/ha)	Yield kg/ha	Water Use efficiency (kg/m^3)	Water Applied (m^3/ha)	Yield kg/ha	Water Use efficiency (kg/m^3)	Water Applied (m^3/ha)	Yield kg/ha	Water Use efficiency (kg/m^3)
Bubbler	15,767	14,734	0.93	15,212	51,599	3.39	17,722	52,483	2.96	12292	3726	0.30
Drip	13,064	9,002	0.69	13,120	48,980	3.73	12,855	47,653	3.71	12014	3725	0.31
Improved Basin	22,800	14,172	0.62	18,879	59,728	3.16	17,154	59,099	3.45	36842	4853	0.13
Micro Sprinkler	18,255	8,311	0.46	12,376	50,544	4.08	12,210	41,242	3.38	13191	7451	0.56
Irrigation water with effective Rainfall												
Bubbler				17,101	51,599	3.02	17,506	52,483	3.00			
Drip				15,609	48,980	3.14	14,219	47,653	3.35			
Improved Basin				21,756	59,728	2.75	18,703	59,099	3.16			
Micro Sprinkler				14,814	50,544	3.41	13,583	41,242	3.04			

Source : UNDP/FAO, MAF Water and Soil Investigations for Agricultural Development,Tachnical Report No. 5, April 1981

Table 2.3.10. Sprinkler Irrigation Trail at Hamraniyah, 1980

Crop	1979-78			1979-80		
	Water Applied (m^3/ha)	Yield kg/ha	Water Use efficiency (kg/m^3)	Water Applied (m^3/ha)	Yield kg/ha	Water Use efficiency (kg/m^3)
Onion	5,177	82,500	15.94	5,776	43,170	7.47
Potato	4,700	28,940	6.16	4,780	25,000	5.23

Source : UNDP/FAO, MAF Water and Soil Investigations for Agricultural Development, Tachnical Report No. 5. April 1981

Table 2.3.11. Intake Rate Test Results

Sr. No.	Test No.	Date	Location	Longitude ° ' "	Latitude ° ' "	Land Use	Type of Soil	Basic Intake Rate (mm/hr.)	Time (minutes)	Remarks
1	1	3-Jun	MAF Dhaid Research Station-1	25 16 24	55 55 41	Pasture	S/S on Gravel	61.8	208.2	irrigated by sprinkler
2	2	3-Jun	MAF Dhaid Research Station-2	25 16 24	55 55 41	Date Palm	S/S on Gravel	34.3	261.8	
3	3	4-Jun	MAF Dhaid old Expr. Center	25 17 1	55 55 0	abandoned farm	S/S on Gravel	19.9	316.2	
4	4	4-Jun	Date Farm in east of Dhaid-1	25 17 12	55 56 27	Date Palm Farm	S/S on Gravel	4.4	346.6	hard impervious gravely pan by compacting at -30 cm
5	5	4-Jun	Farm on the east of sand dune of Dhaid North	25 18 33	55 54 44	near pasture	Silt Sand	74.9	232.6	Horizontal penetration(HP)=60cm VP>75cm
6	6	10-Jun	Citrus farm in An Nasim	25 20 8	55 58 25	citrus field	Sd. on Gravel	11.2	380.5	HP=45 cm, VP>65 cm
7	7	10-Jun	Abandoned center pivot in Suhelah	25 22 5	55 57 31	abandoned farm	Gravely sand	41.3	298.4	very hard to drive casing, HP=50 cm, VP>60cm
8	8	10-Jun	Bottom of the flood control dam	25 18 38	55 59 5	excavated	gravel	37.4	308.2	
9	9	11-Jun	Beside Farm of Sk. Sayid near T-18	25 20 22	55 50 3	open area	Sand	60.8	253.7	HP=75 cm, VP>70 cm
10	10	11-Jun	Farm in Ar Rashieiyysh right bank of Wadi Lamah	25 22 45	55 51 6	Date palm field	Sd. on Gravel	112.5	200.0	Sand layer thickness=55 cm, HP=60, VP>50 cm
11	11	11-Jun	Abandoned farm in Wishah near CRT	25 14 47	55 53 29	abandoned farm	Sd. on Gravel	54.6	245.8	gravely and layer thickness=58 cm, HP=45, VP=58 cm
12	12	12-Jun	Farm in Wishah near CRT diversion	25 11 33	55 54 58	Fodder farm	Silt Sand	85.7	234.0	Initially moist level at -20 cm
13	13	12-Jun	Farm in Khuderah having open wells	25 9 43	55 57 32	date & fodder	Sd. on Gravel	40.2	279.5	Sand layer thickness=55 cm, HP=60, original WL=-30 cm
14	14	12-Jun	Farm in Hamaah, on the sand dune	25 9 25	55 52 21	date & fodder	Sand	46.2	275.8	HP=50 cm, VP=55 cm
15	15-A	13-Jun	Farm in Ikhedir - 20 cm top soil	25 4 55	55 57 35	pasture	S-sand on coa	211.5	161.9	Silt sand (top soil)=20cm on coarse sand/gravel layer
16	15-B	13-Jun	Farm in Ikhedir - 60 cm top soil	25 4 55	55 57 35	pasture	S-sand on coa	64.7	253.5	Silt sand (top soil)=60cm on coarse sand/gravel layer
17	16	13-Jun	Farm in southern Meleihah	25 6 28	55 52 4	pasture	Silt Sand	48.3	256.1	compacted silt sand by CaCO3, HP=45cm, VP=65 cm
18	17	14-Jun	Farm in Fili, along the wadi	25 1 0	55 49 48	vegetable	Silt with grave	13.3	394.5	on the outcrop of rock wethered & clayed
19	18-A	14-Jun	Farm eastern edge of Bahayis	25 1 0	55 49 48	pasture	Silt on hard pa	5.3	401.9	top soil thickness = 20 cm
20	18-B	14-Jun	Farm eastern edge of Bahayis	25 1 0	55 49 48	pasture	Silt on hard pa	20.8	302.8	top soil thickness = 15 cm
21	19	26-Jun	Farm in Milehah, near Kadrah	25 13 35	55 58 40	vegetable	Sand on grave	118.1	215.3	top soil thickness = 15 cm, HP=90cm, VP>90cm

Table 2.4.1. Calculation of Evapotranspiration at Falaj Al Mualla by Penman Method

Statistics	Unit	Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temparature	C	17.9	18.6	22.1	26.3	30.9	33.4	35.5	34.7	32.4	28.6	23.6	19.7
Relative Humidity	%	60.0	60.0	54.0	46.0	44.0	45.0	48.0	51.0	49.0	48.0	52.0	60.0
Sunshine Duration	hr/day	7.5	7.8	7.6	9.5	11.0	10.9	9.9	10.0	10.1	9.8	9.2	7.6
Evapo-transpiration	mm/day	0.5	1.4	13.6	49.3	94.0	120.9	133.8	119.6	78.8	40.6	12.7	1.2
Wind Speed	km/day	60.5	69.1	77.8	77.8	86.4	86.4	103.7	103.7	86.4	69.1	51.8	51.8
Penman Method													
Vapor Pressure													
ea	mbar	20.5	21.4	26.6	34.2	44.7	51.5	57.9	55.2	48.8	39.2	29.1	23.0
ed	mbar	12.3	12.9	14.4	15.7	19.7	23.2	27.8	28.1	23.9	18.8	15.2	13.8
(ea-ed)		8.2	8.6	12.3	18.5	25.0	28.3	30.1	27.0	24.9	20.4	14.0	9.2
Wind Function													
Meas. Height Correction		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
f(u)		0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4
Weighting Factor													
W		0.661	0.671	0.713	0.755	0.791	0.815	0.829	0.824	0.806	0.775	0.728	0.688
(1-W)		0.339	0.329	0.287	0.245	0.209	0.185	0.171	0.176	0.194	0.225	0.272	0.312
Net Radiation													
Ra	mm/day	9.30	11.10	13.40	15.30	16.50	16.80	16.70	15.70	14.10	12.00	9.90	8.80
N	hr/day	10.69	11.29	12.00	12.71	13.31	13.71	13.51	13.01	12.30	11.60	10.89	10.59
n/N		0.70	0.69	0.63	0.75	0.83	0.80	0.73	0.77	0.82	0.85	0.84	0.72
Rs	mm/day	5.59	6.61	7.59	9.55	10.94	10.88	10.29	9.96	9.31	8.07	6.66	5.36
Rns	mm/day	4.19	4.96	5.70	7.16	8.21	8.16	7.72	7.47	6.98	6.05	4.99	4.02
Fml(Temp)		14.19	14.32	15.03	15.96	16.93	17.55	18.01	17.83	17.31	16.42	15.32	14.54
Fml(ed)		0.19	0.19	0.18	0.16	0.14	0.12	0.11	0.11	0.12	0.15	0.17	0.18
Fml(n/N)		0.73	0.72	0.67	0.78	0.85	0.82	0.76	0.80	0.84	0.87	0.86	0.75
Rnl		1.96	1.92	1.78	2.02	2.03	1.78	1.52	1.55	1.75	2.07	2.23	1.97
Rn	mm/day	2.23	3.03	3.91	5.14	6.18	6.38	6.20	5.92	5.23	3.98	2.76	2.05
Adjustment Factor													
c		1.12	1.11	1.11	1.09	1.08	1.08	1.09	1.09	1.10	1.11	1.12	1.12
ETo	mm/day	3.01	3.71	4.96	6.63	8.14	8.49	8.68	8.19	7.29	5.73	3.99	2.91

Table 2.4.2. Crop Coefficient (Kc) of FAO Manual

Crop	Wind speed 0 - 5 m/sec				Crop Coefficient by Lysimetric Study*		Length of Growing Stages (days)	Total days Growing (days)
	RHmin > 70%		RH min < 20%					
	Mid-season	Late	Mid-season	Late	Mid-season	Late		
Barley/Wheat	1.05	0.25	1.15	0.20			15/25/50/30	120
Green Beans	0.95	0.85	1.00	0.90			20/30/30/10	90
Dry Beans	1.05	0.30	1.15	0.25			15/25/35/20	95
Carrots	1.00	0.70	1.10	0.80			20/30/80/20	150
Corn (sweet,maize)	1.05	0.85	1.15	1.05			20/30/30/10	90
Corn (grain,maize)	1.05	0.55	1.15	0.60			20/35/40/30	125
Cabbage/Cauliflower	0.95	0.80	1.05	0.90	0.94 - 1.19	0.75 - 0.80	25/35/25/10	95
Cucumber	0.90	0.70	0.95	0.75	0.76 - 0.81	0.50 - 0.65	20/30/40/15	105
Squash	0.90	0.77	0.95	0.75			25/35/25/15	100
Eggplant	0.95	0.80	1.05	0.85			30/40/40/20	130
Melon	0.95	0.65	1.00	0.75	1.21 - 1.37	0.47 - 0.65	25/35/40/20	120
Onion(dry)	0.95	0.75	1.05	0.80			20/35/110/45	210
Onion(Green)	0.95	0.50	1.00	1.00			20/45/20/10	95
Peppers	0.95	0.80	1.05	0.85			30/40/110/30	210
Radish	0.80	0.75	0.85	0.80			10/10/15/5	40
Tomato	1.05	0.60	1.20	- 0.65	1.22	0.62	35/45/70/30	180
Potato	1.05	0.70	1.15	0.75			25/30/30/20	105
Okra								
Lettuce	0.95	0.90	1.00	0.90			20/30/15/10	75
Green Peas	1.05	0.95	1.15	1.05			20/25/35/15	95
Citrus coverage 20%	varies month by month between 0.45 and 0.55							
Citrus coverage 50%	varies month by month between 0.55 and 0.60							
Citrus coverage 70%	varies month by month between 0.65 and 0.75							
Date Palm	0.8 - 1.0							
Alfalfa	mean = .95 peak= 1.15 low= 0.40						Dry, light to moderate wind	

Source : FAO Irrigation and Drainage Paper No. 24, revised 1977

UNDP/FAO/MAF. Crop Water Requirement (Estimates and Field Measurement). Technical Report No. 7. March 1984

Table 2.4.3. Required Desalinated Water for Irrigation under Option-2 Plan

Option		Cultivation Area (ha)	Growing Period In Main Field												Total Net Irrigation Water (m^3)
			Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	
Total	Net Irrigation Requirement	2,548	2,010,561	1,764,125	2,155,795	1,953,454	1,380,905	1,252,960	1,576,701	2,166,453	3,201,844	3,500,589	2,812,264	2,852,841	26,628,491
1	Gross Irrigation Requirement	2,548	1,861,036	1,514,859	1,763,066	1,502,978	1,055,881	969,251	1,253,910	1,704,984	2,436,431	2,818,738	2,278,859	2,340,008	21,500,001
Total	Net Irrigation Requirement	4,584	7,842,223	6,271,026	5,596,420	4,213,203	2,943,719	2,853,449	3,733,794	5,211,880	7,511,404	9,191,609	8,266,855	8,572,012	72,207,596
2	Gross Irrigation Requirement	4,584	6,096,282	4,675,733	4,438,493	3,305,343	2,298,738	2,209,381	2,959,234	4,047,317	5,620,857	7,114,810	6,185,398	6,454,954	55,406,541
Desalinated	Required Amount to Import (m^3/month)		4,235,246	3,160,875	2,675,427	1,802,365	1,242,857	1,240,130	1,705,324	2,342,333	3,184,426	4,296,072	3,906,539	4,114,946	33,906,540
Water	Required Amount to Import (m^3/day)		136,621	105,362	86,304	60,079	40,092	40,004	60,904	75,559	106,148	138,583	130,218	132,740	
Requirment	Required Amount to Import (m^3/sec)		1.581	1.219	0.999	0.695	0.464	0.463	0.705	0.875	1.229	1.604	1.507	1.536	

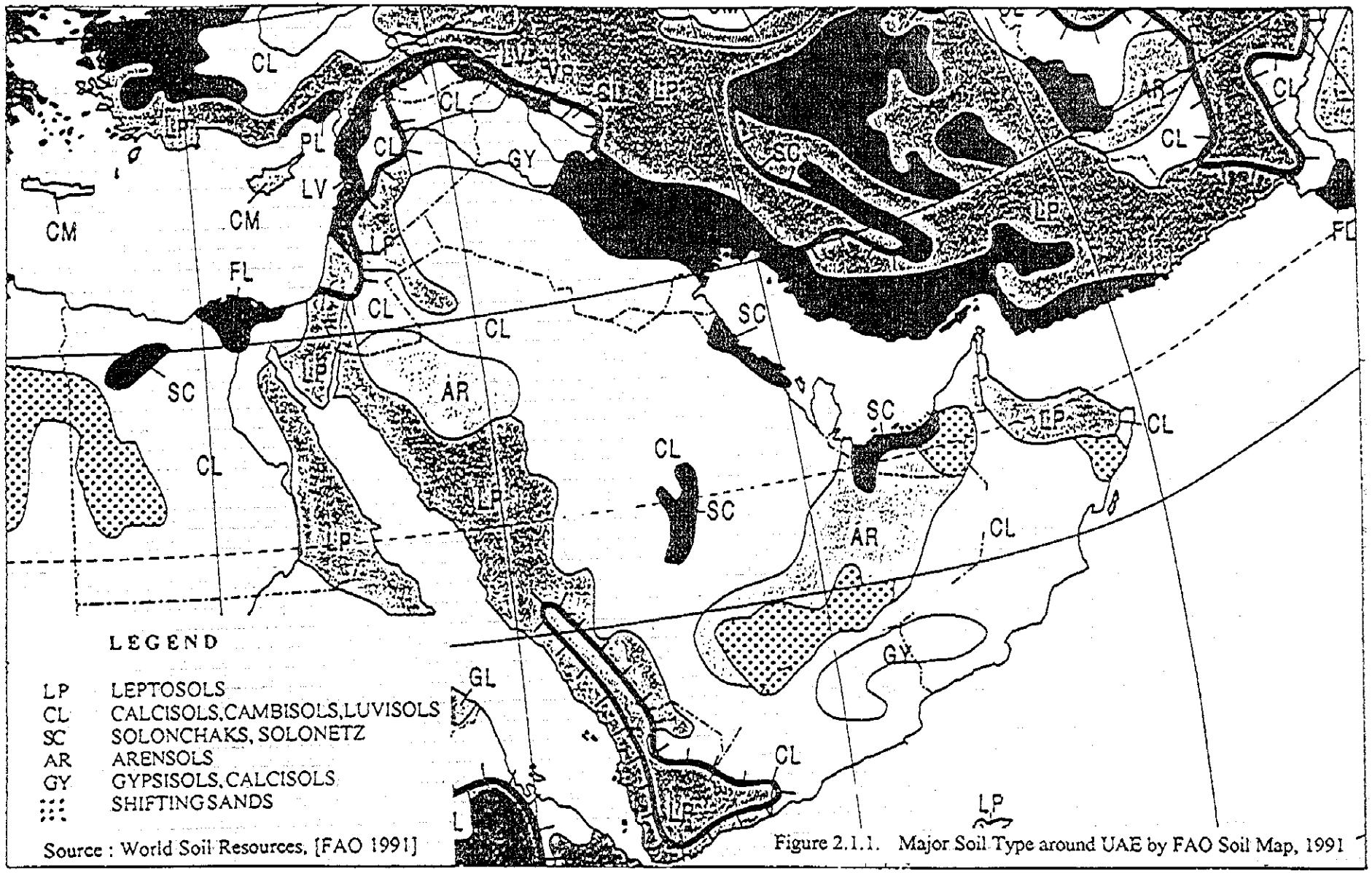


Figure 2.1.1. Major Soil Type around UAE by FAO Soil Map, 1991

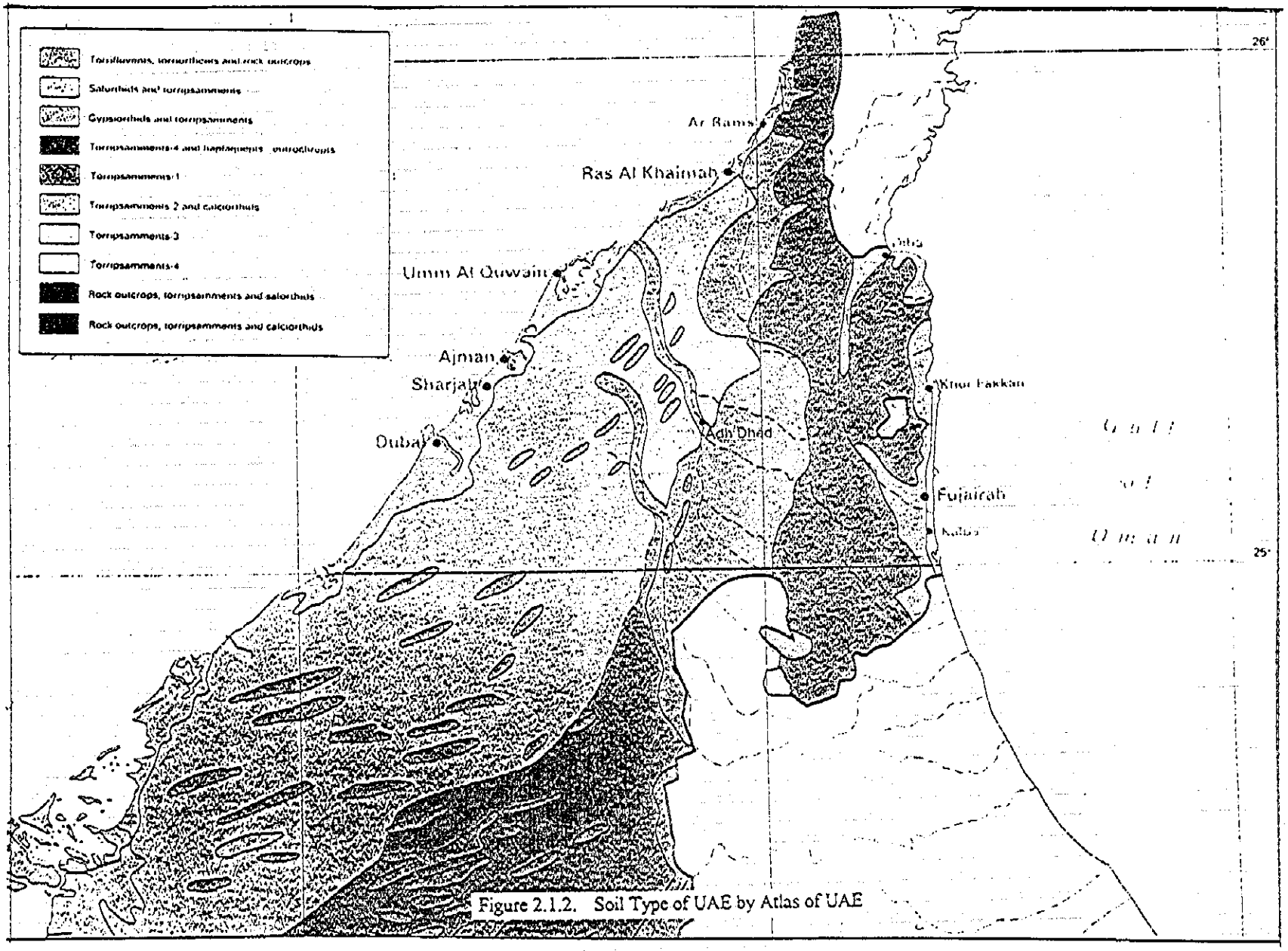


Figure 2.1.2. Soil Type of UAE by Atlas of UAE

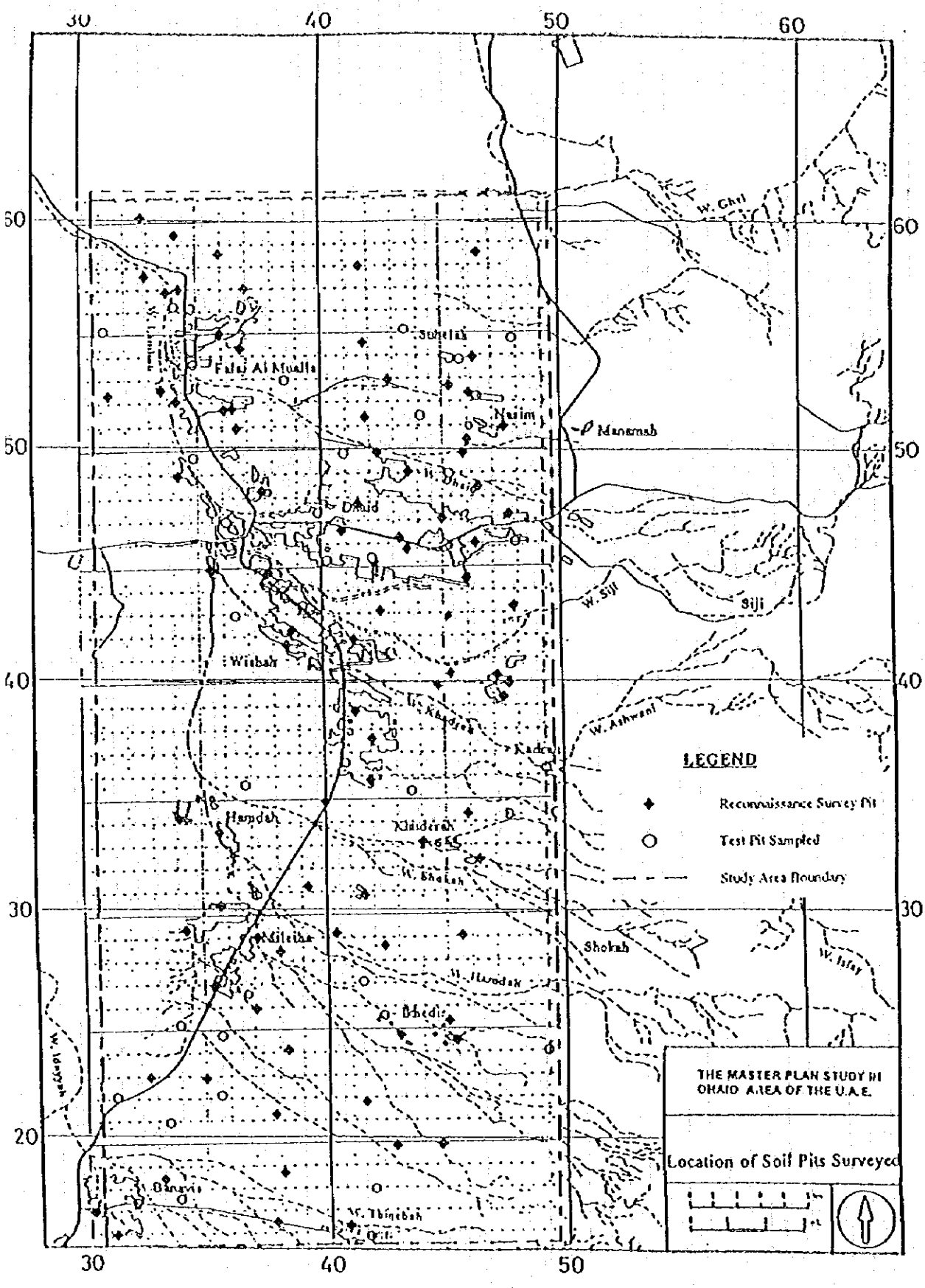


Figure 2.1.3. Location of Soil Pit Survey

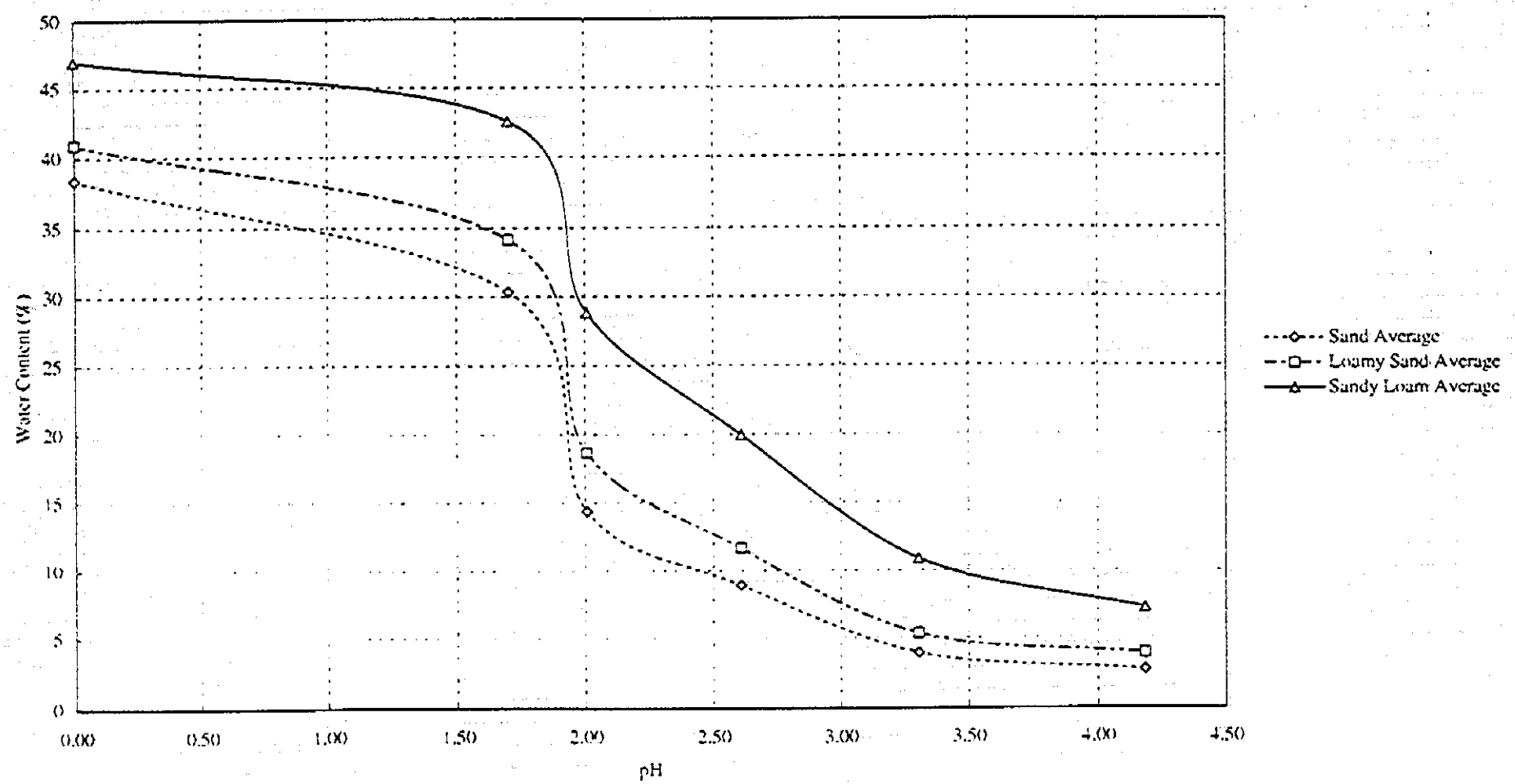


Figure 2.1.4. Soil Water Retention Curve

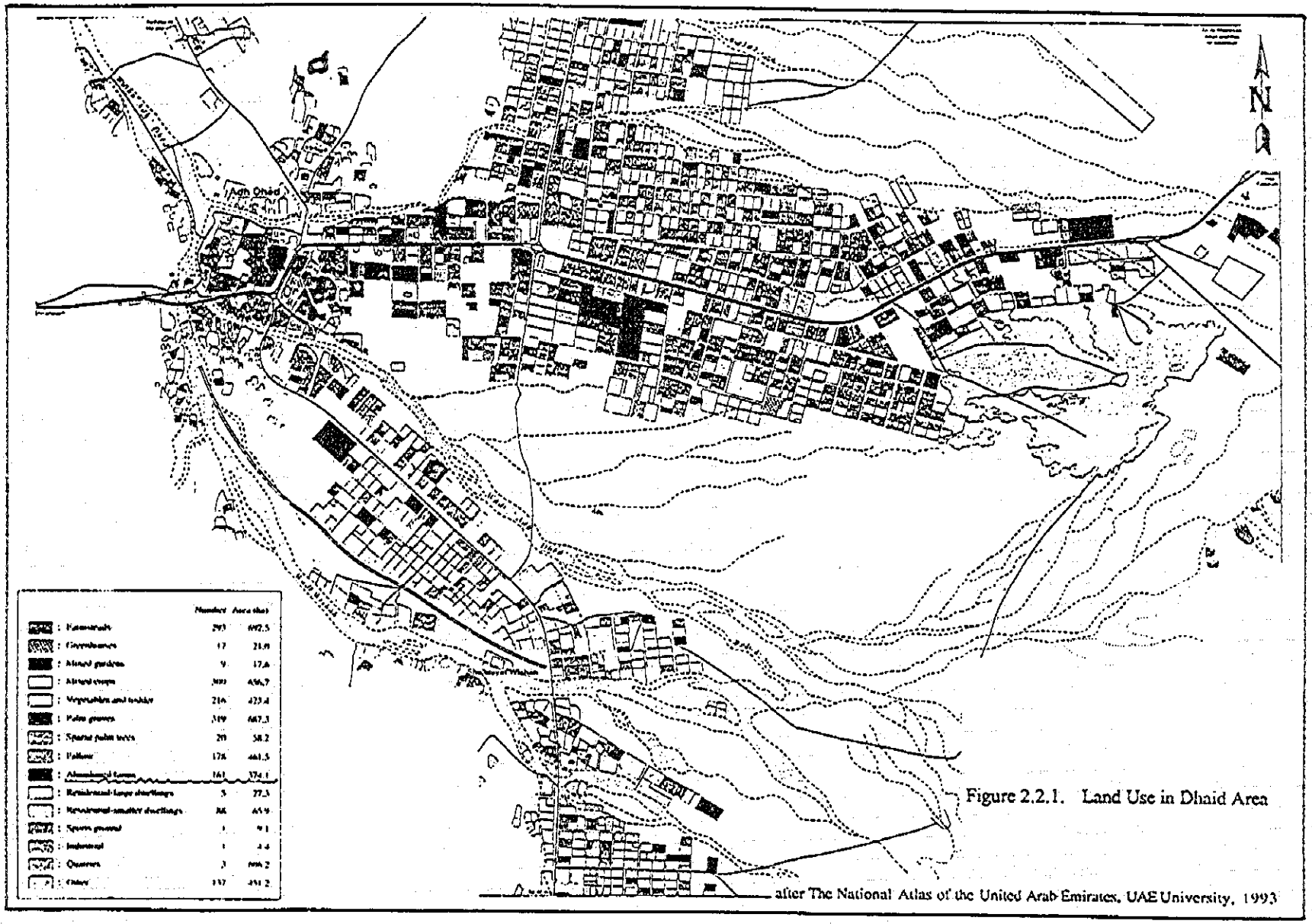


Figure 2.2.1. Land Use in Dhaid Area

after The National Atlas of the United Arab Emirates, UAE University, 1993

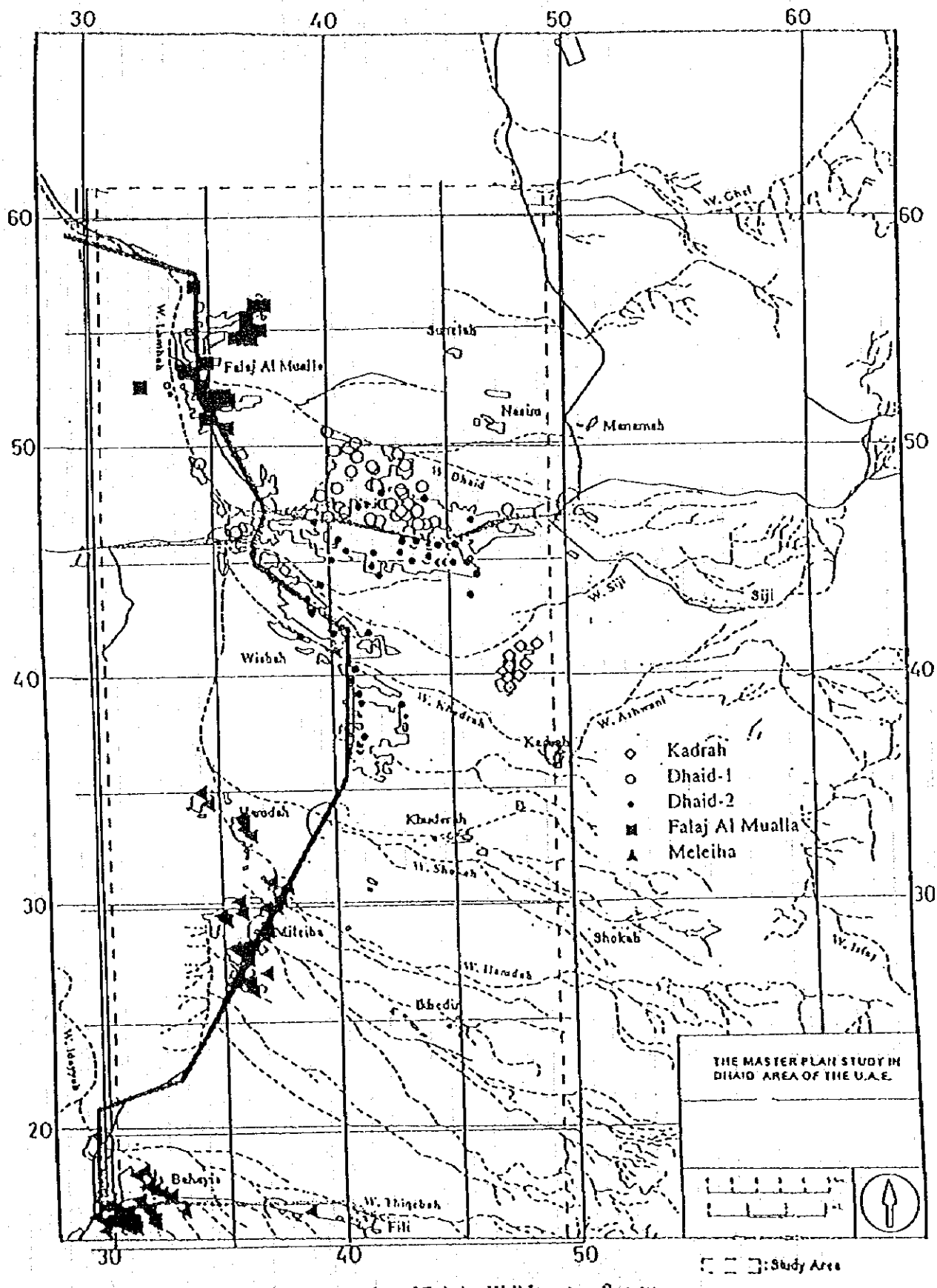


Figure 2.3.1. Location of Existing Well Inventory Survey

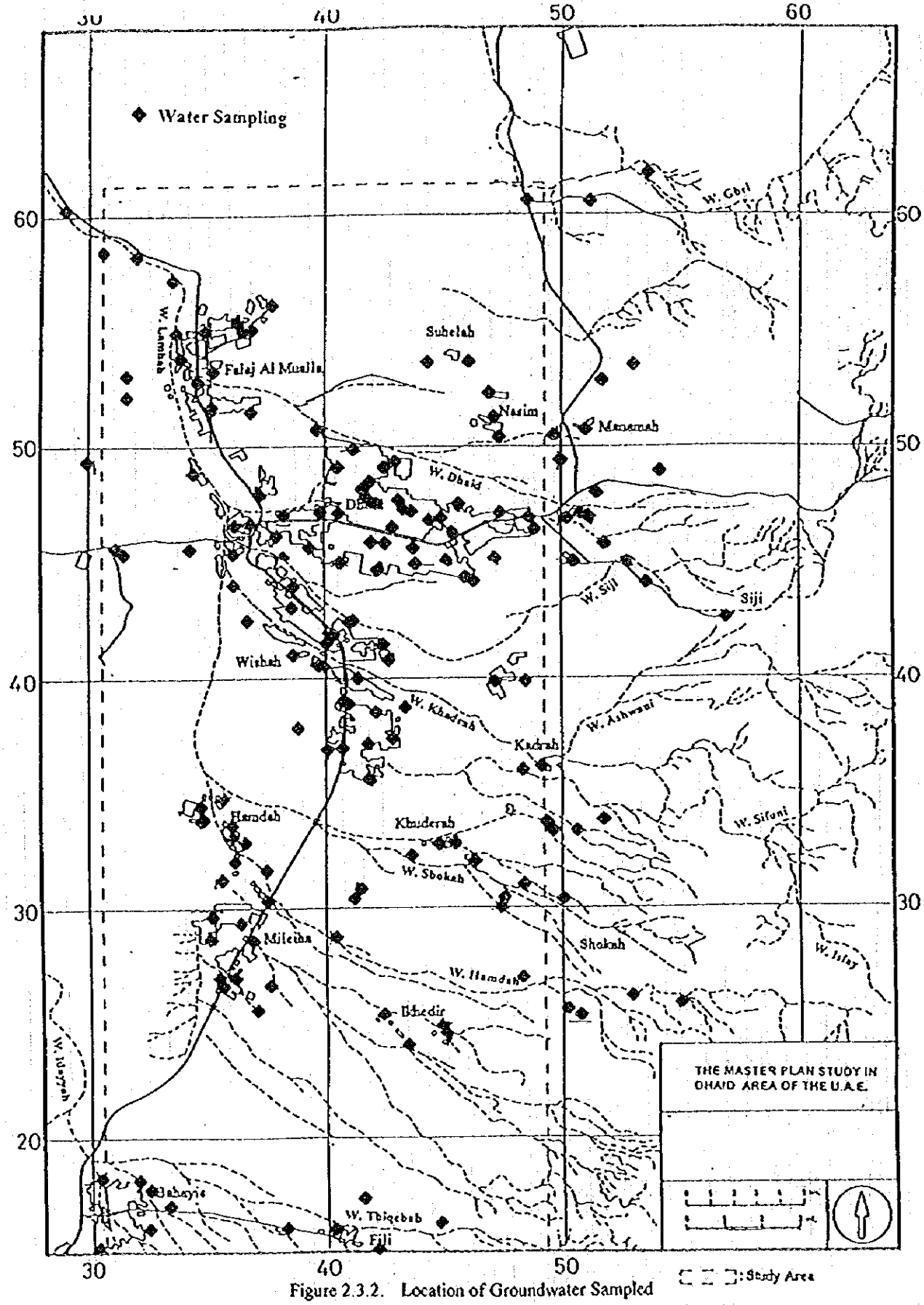


Figure 2.3.2. Location of Groundwater Sampled

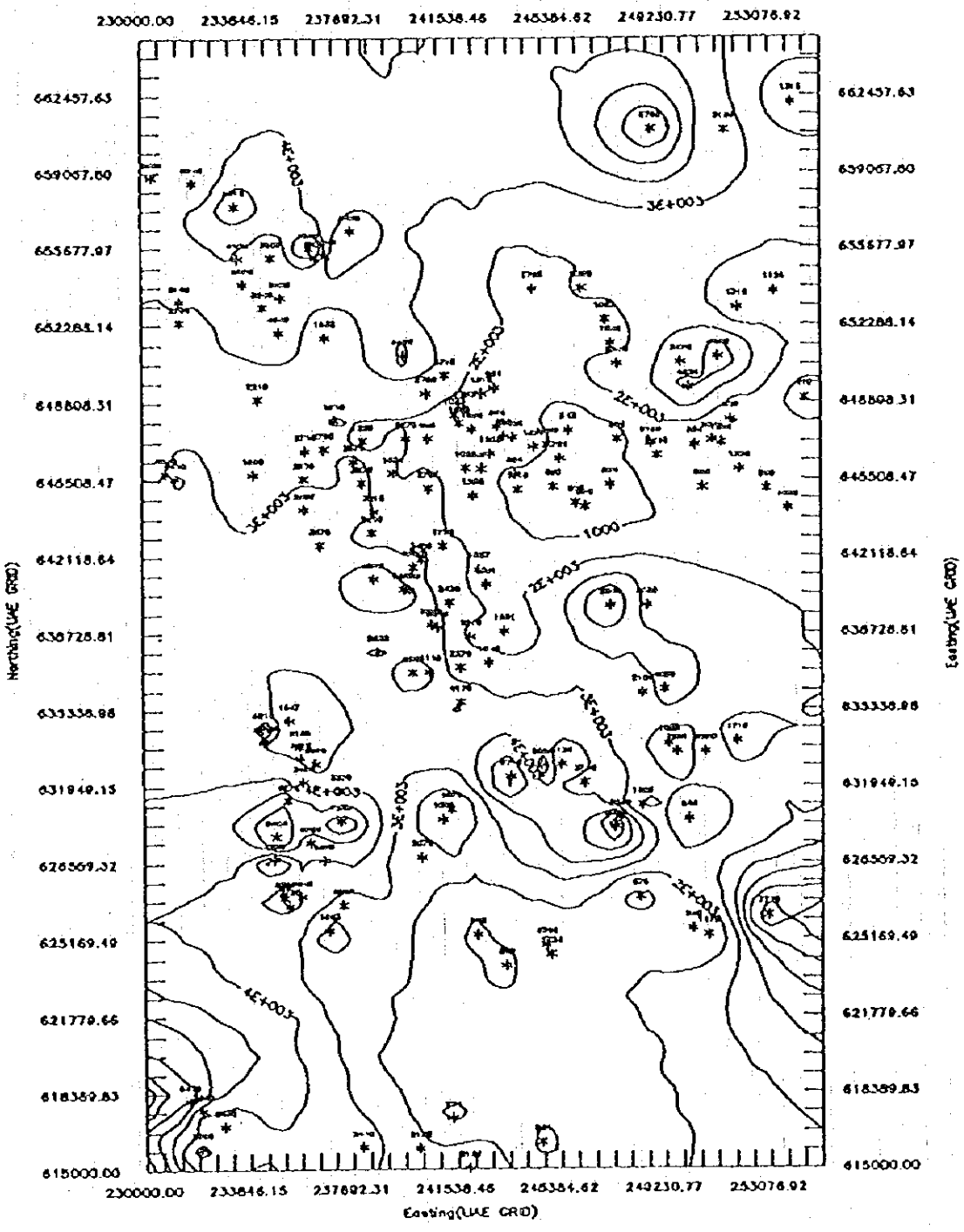
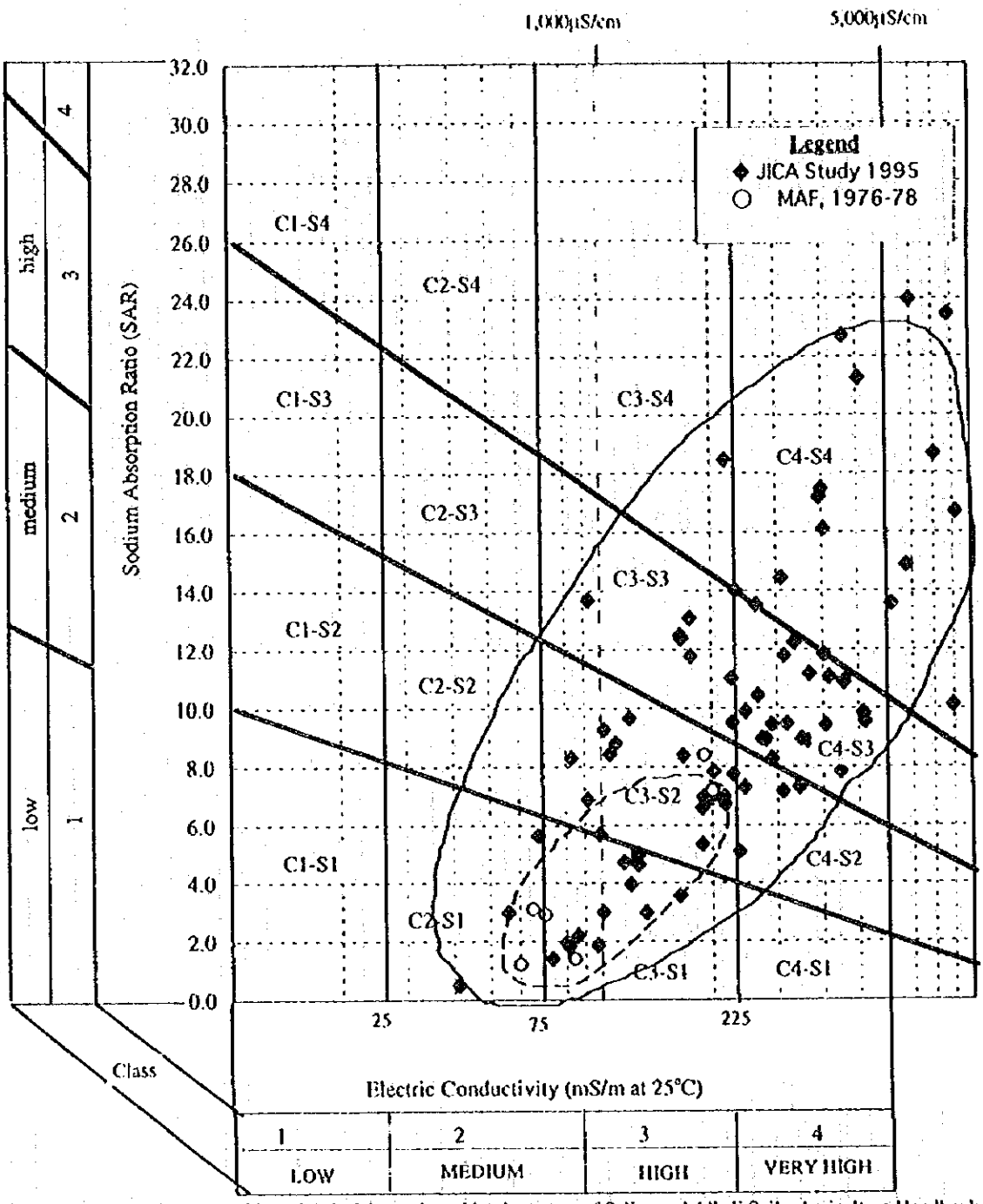


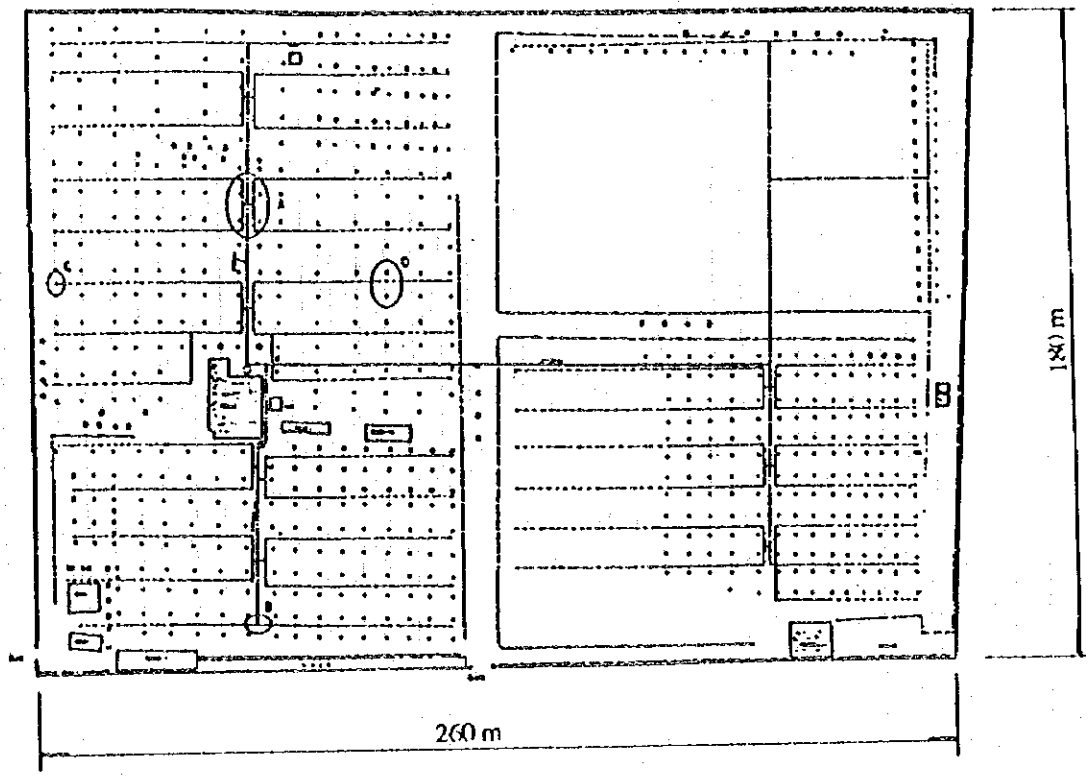
Figure 2.3.3. Distribution of Groundwater Electric Conductivity



Source : modified from L. A. Richards(ed), Diagnosis and improvement of Saline and Alkali Soils, Agriculture Handbook 60, USAD, Washington, D.C., 1954,p 80.

Figure 2.3.4. Groundwater Classification for Irrigation in the Study Area

FARM A

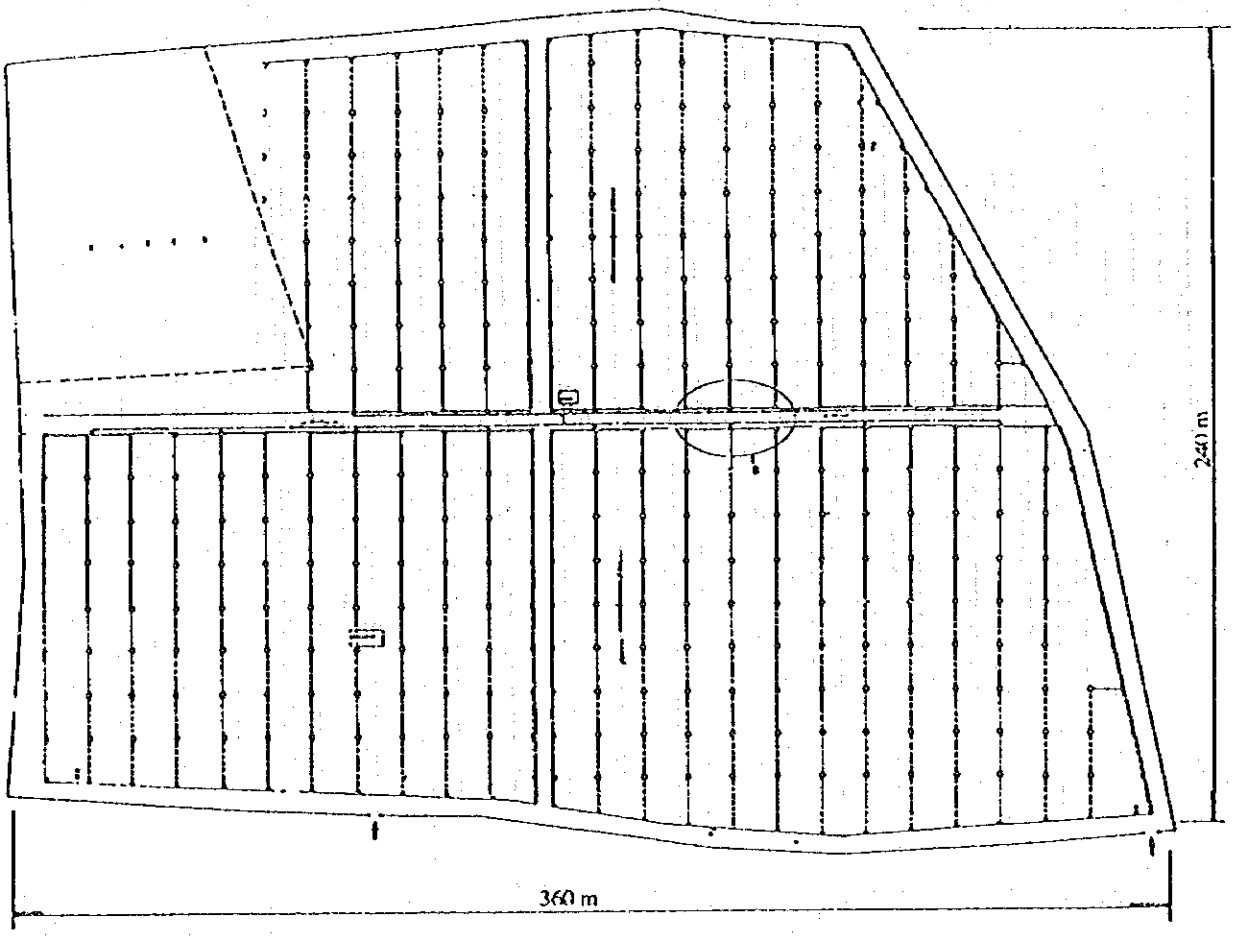


SPECIFICATION of FARM A

FARM A		
AREA	4.68	ha
SHAPE	Rectangular	260m x 180m
TANK	2	
WELL	2	
IRRIGATION TYPE	Bubbler	2.88ha; Dates and Fruits
	Basin	0.96ha; Others
PIPE LENGTH	140	m, Dia. 110mm
	340	m, Dia. 90mm
	1240	m, Dia. 63mm
	1060	m, Dia. 50mm
BUBBLER TUBE	1	roll, 400m
FERTILIZER TANK	2	
SCREEN FILTER	2	
ESTIMATED COST	122000	Dh./ha

Figure 2.3.5. Farm Facility Layout in the Study Area (Model-A)

FARM B



SPECIFICATION of FARM B

FARM B		
AREA	7.68	ha
SHAPE	Trapezoid	0.5 x (360m + 280m) x 240
TANK	1	
WELL	4	
IRRIGATION TYPE	Sprinkler	6.84ha; Feed Crop
	Basin	0.9ha; Dates
PIPE LENGTH	480	m, Dia. 110mm
	2640	m, Dia. 63mm
	2300	m, Dia. 50mm
LOW PRS. SPRINKLER	450	
FERTILIZER TANK	1	
SCREEN FILTER	1	
ESTIMATED COST	148000	Dh./ha

Figure 2.3.6. Farm Facility Layout in the Study Area (Model-B)

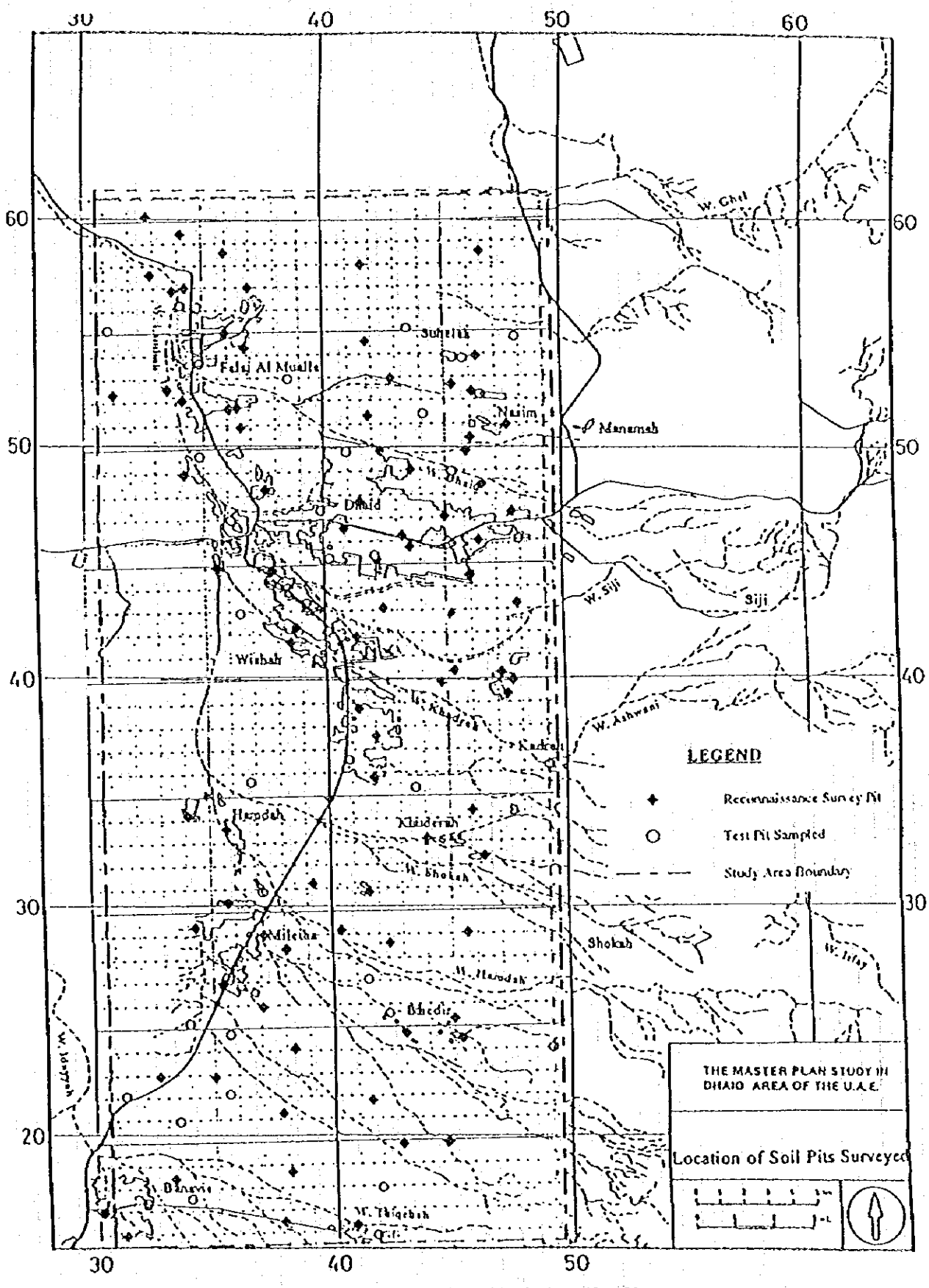


Figure 2.3.7. Location of Intake Rate Test Pits

(Unit: mm)

Item Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Remarks
Precipitation at Mileiha	1.8	3.9	11.2	19.7	37.6	30.1	13.1	3.8	0.0	3.7	7.4	1.5	133.8	Meleiha(1967-1992)
Pan Evaporation at Mileiha	310.0	219.0	158.1	145.7	154.0	220.1	321.0	434.0	447.0	452.6	434.0	375.0	3,670.5	Meleiha(1967-1992)
ETp by Penman Method	139.5	90.6	62.0	65.1	73.1	115.9	163.5	199.3	207.0	218.9	210.8	189.0	1,734.7	
ETp by Thornthwaite Method	161.2	75.0	37.2	24.8	28.0	68.2	138.0	263.5	393.0	449.5	412.3	279.0	2,329.7	
ETp by Open Pan Evaporation Method	206.2	144.0	91.1	82.2	87.9	146.9	222.9	286.1	306.0	310.9	296.1	254.1	2,434.4	C=0.6
ETp by Blaney Criddle Mehod	119.0	98.1	89.0	85.9	82.0	107.0	122.1	144.2	152.1	159.0	151.9	132.0	1,442.3	

Source : "Hydrology Vol. No. 3. 1980-1991" & "Climatorolgy Data Vol. 3, 1979-80 & 1991-92", MAF, Jan. 1993

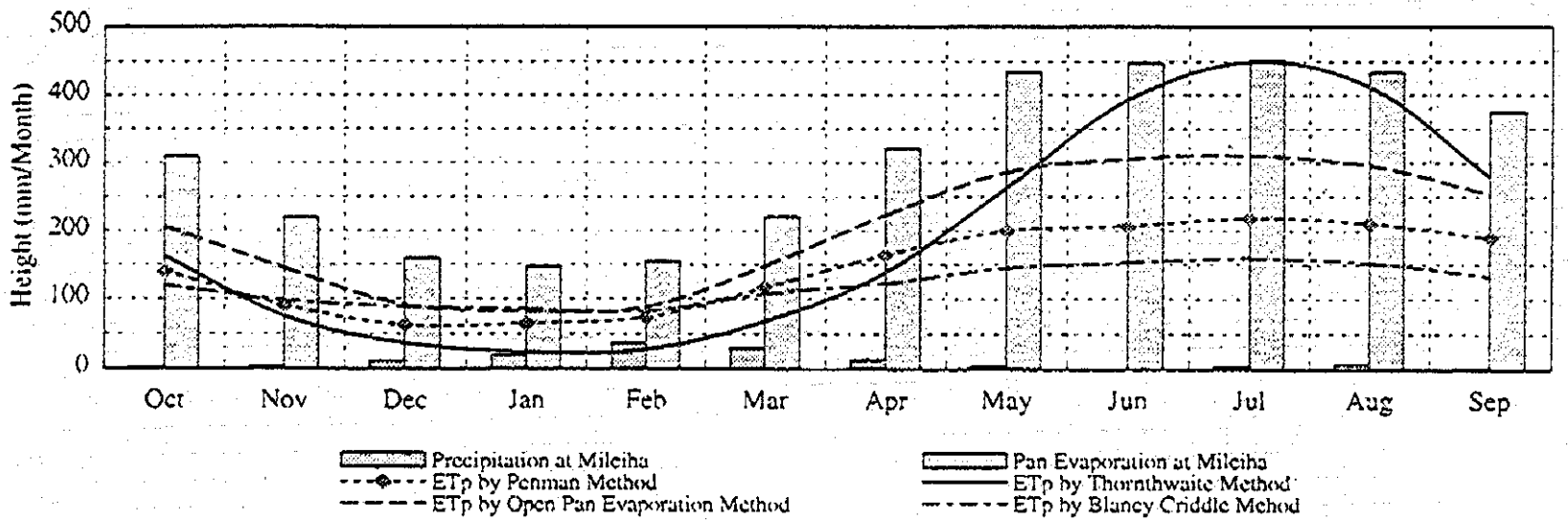


Figure 2.4.1. Evapotranspiration in the Wadi Lamaha Complex

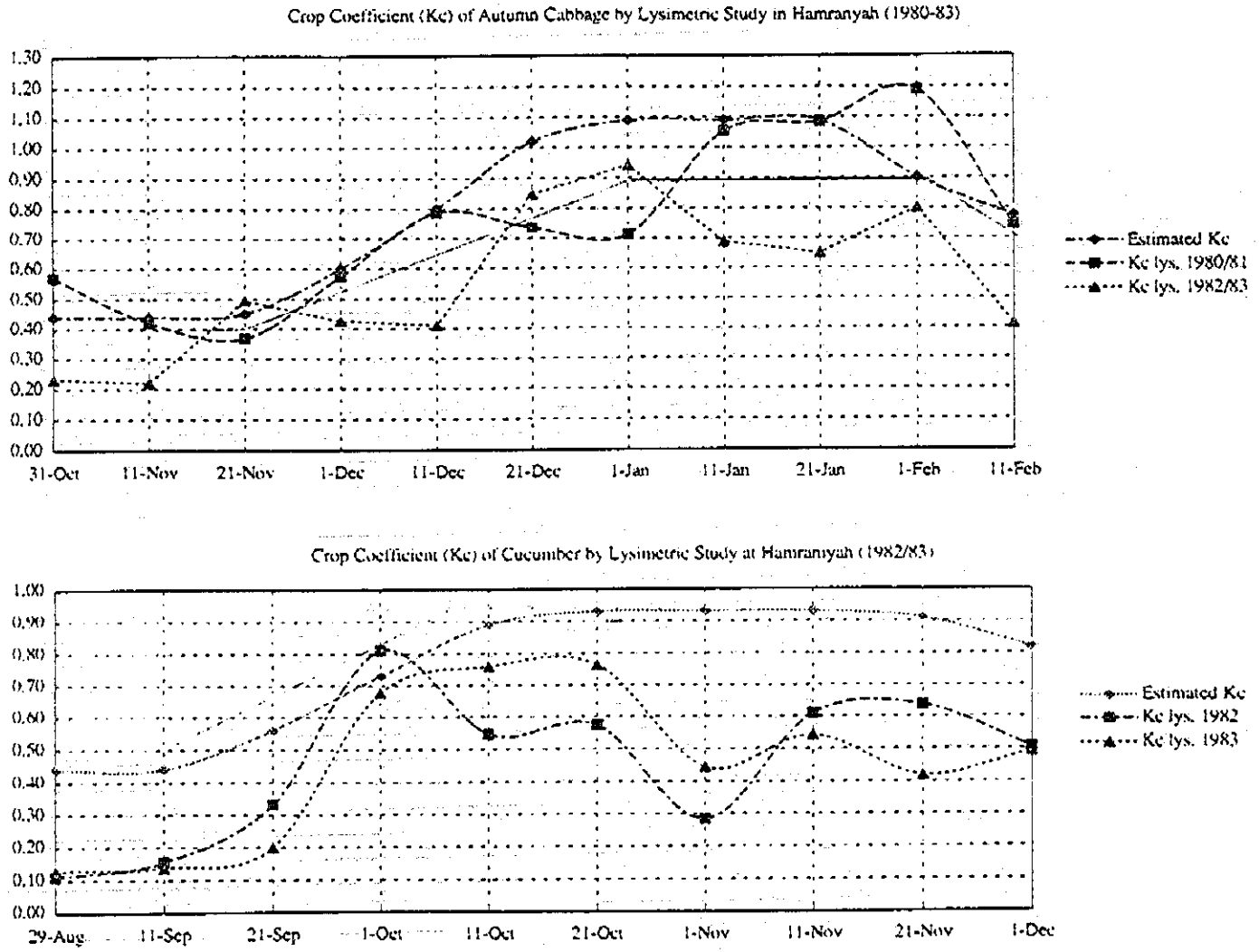


Figure 2.4.2. Crop Coefficients by Lysimetric Study in Hamraniyah, 1980-1983

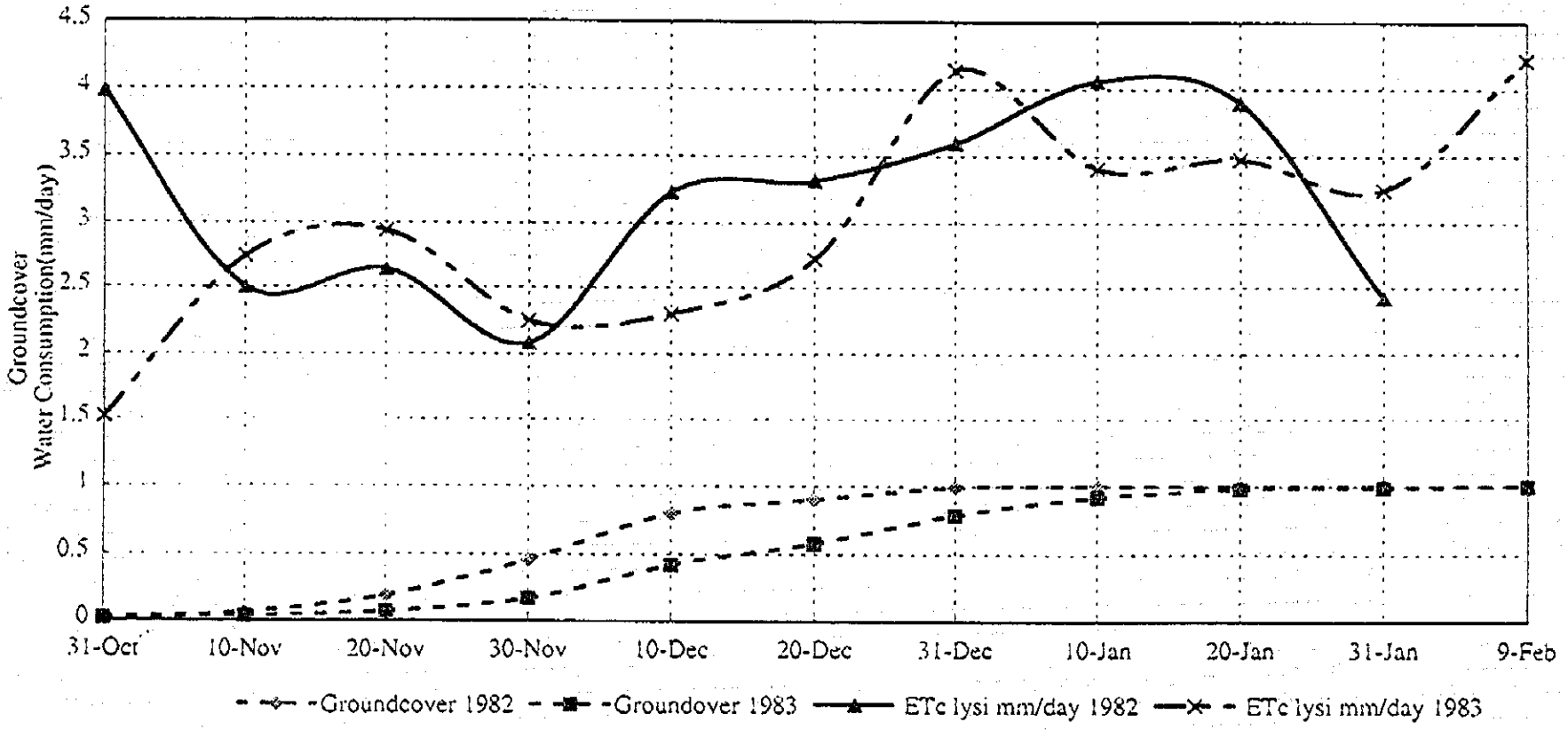


Figure 2.4.3. Ground Coverage and Crop Coefficients by Lysimetric Experiments for Tomato in Hmraniyah

Figure 2.4.4. Estimation of Irrigation Water Amount for Option-1 Plan

No.	Crop	Nursery Period (Days)	Main Field Period (Days): Before Harvest	Main Field Period (Days): Harvesting	Main Field Period (Days): Total (Date)	Cultivation Area (ha)	Growing Period in Main Field: Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total Net Irrigation Water (m3)
	(Vegetables)																		
1	Bean	0	88	15	1/Nov-11/Feb	32.7													
		Crop Water Requirement (ETc) in mm/month/ha								56	99	104	29						
		Irrigation Water Requirement in mm/month					0			34,369	52,153	54,787	15,277						156,985
2	Cabbage	41	52	30	27/Oct-26/Dec	15.4													
		Crop Water Requirement (ETc) in mm/month/ha							17	82	92								
		Irrigation Water Requirement in mm/month					0	0	1,852	12,654	14,198	0	0						28,704
3	Cabbage	31	71	17	16/Sep-16/Dec	18.4													
		Crop Water Requirement (ETc) in mm/month/ha						28	124	138	14								
		Irrigation Water Requirement in mm/month					0	5,149	22,802	25,537	2,574	0	0						56,062
4	Cauliflower	40	45	30	10/Oct-3/Dec	22.5							(Before Harvesting)						
		Crop Water Requirement (ETc) in mm/month/ha							61	127	15								
		Irrigation Water Requirement in mm/month					0	0	13,725	28,575	3,373	0	0						45,673
5	Cucumber (Greenhouse)	-27	38	73	6/Feb-28/May	33.0													
		Crop Water Requirement (ETc) in mm/month/ha											40	128	187	212			
		Irrigation Water Requirement in mm/month					0	0	0	0	0	0	13,211	42,275	61,761	70,018			187,266
6	Cucumber (Greenhouse)	-35	43	45	18/Nov-12/Feb	32.4													
		Crop Water Requirement (ETc) in mm/month/ha								21	56	83	62						
		Irrigation Water Requirement in mm/month					0	0	0	6,804	18,144	26,892	20,088						71,928
7	Dwarf Bean	(D)	60	117	16/Nov-12/May	171.1													
		Crop Water Requirement (ETc) in mm/month/ha								30	54	82	108	145	195	74			
		Irrigation Water Requirement in mm/month					0	0	0	51,316	92,368	140,263	184,737	248,026	333,553	126,579			1,176,842
8	Eggplant	45	43	40	30/Sep-23/Dec	52.7													
		Crop Water Requirement (ETc) in mm/month/ha						0	97	125	74	0	0						
		Irrigation Water Requirement in mm/month					0	0	51,090	65,838	38,976	0	0						155,903
9	Green beans	0	45	25	16/Sep-24/Nov	56.8													
		Crop Water Requirement (ETc) in mm/month/ha						42	155	97	0	0	0						
		Irrigation Water Requirement in mm/month					0	23,768	83,715	56,024	0	0	0						167,507
10	Lettuce	25	77	20	27/Oct-31/Jan	53.4													
		Crop Water Requirement (ETc) in mm/month/ha							12	71	86	92	0						
		Irrigation Water Requirement in mm/month					0	0	6,408	37,915	45,926	49,130	0						139,379
11	Musk Melon (Greenhouse)	(D)	91	21	15/Oct-5/Feb	42.7													
		Crop Water Requirement (ETc) in mm/month/ha							37	73	82	86	28						
		Irrigation Water Requirement in mm/month					0	0	15,659	34,841	39,836	31,045	13,364						146,045
12	Musk melon	D	87	110	15/Feb-6/Aug	259.7													
		Crop Water Requirement (ETc) in mm/month/ha					32						30	87	195	252	246	252	
		Irrigation Water Requirement in mm/month					83,117	0					77,922	225,974	506,494	654,545	638,961	654,545	2,841,556
13	Parsley	45	40	30	16/Sep-24/Nov	95.7													
		Crop Water Requirement (ETc) in mm/month/ha					0	43	98	103									
		Irrigation Water Requirement in mm/month					0	40,212	93,828	98,613									232,653
14	Pepper	35	56	60	5/Sep-23/Dec	200.0													
		Crop Water Requirement (ETc) in mm/month/ha					0	78	160	129	70								
		Irrigation Water Requirement in mm/month					0	156,000	320,000	258,000	140,000								874,000
15	Pepper(L.C)	35	49	182	20/Sep-9/May	173.0													
		Crop Water Requirement (ETc) in mm/month/ha						28	116	128	95	98	120	161	206	73	0	0	
		Irrigation Water Requirement in mm/month					0	48,441	200,684	221,445	164,354	169,544	207,605	278,536	356,388	126,293	0	0	1,773,289
16	Radish	D	30	1	27/Oct-27/Nov	3.4													
		Crop Water Requirement (ETc) in mm/month/ha						0	12	92									
		Irrigation Water Requirement in mm/month					0	0	414	3,172									3,586
17	Spinach	D	46	74	1/Nov-1/Mar	76.4													
		Crop Water Requirement (ETc) in mm/month/ha						0	0	67	83	93	113						
		Irrigation Water Requirement in mm/month					0	0	0	51,219	63,450	71,095	86,384						272,149
18	Squash	D	70	30	1/May-8/Aug	32.9													
		Crop Water Requirement (ETc) in mm/month/ha					68	0								101	190	252	
		Irrigation Water Requirement in mm/month					21,937	0								32,583	58,070	82,910	195,501
19	Squash	D	70	30	23/Sep-31/Dec	32.3													
		Crop Water Requirement (ETc) in mm/month/ha					0	28	83	104	81	0	0						
		Irrigation Water Requirement in mm/month					0	9,032	26,374	33,548	26,139	0	0	0	0	0	0	0	95,484
20	Sweet melon	D	70	20	16/Jan-15/Apr	48.6													
		Crop Water Requirement (ETc) in mm/month/ha					0	0	0	0	0	26	71	149	99	0	0	0	
		Irrigation Water Requirement in mm/month					0	0	0	0	0	12,624	34,474	72,347	48,069	0	0	0	167,513
21	Sweet Pepper (Greenhouse)	-35	66	139	15/Nov-11/Jun	45.1													
		Crop Water Requirement (ETc) in mm/month/ha					0	0	0	28	67	89	109	146	196	229	70	0	
		Irrigation Water Requirement in mm/month					0	0	0	12,640	30,247	40,179	49,208	65,911	88,483	103,382	31,601	0	421,650
22	Sweet Pepper (Greenhouse)	-48	37	77	4/Apr-27/Jul	49.4													
		Crop Water Requirement (ETc) in mm/month/ha					0	0	0	0	0	0	0	0	78	228	250	238	
		Irrigation Water Requirement in mm/month					0	0	0	0	0	0	0	0	38,549	112,683	123,536	117,625	392,413
23	Tomato	31	105	93	23/Oct-11/May	33.3													
		Crop Water Requirement (ETc) in mm/month/ha					0	0	24	72	83	110	137	164	215	61	0	0	
		Irrigation Water Requirement in mm/month					0	0	7,955	23,965	27,649	36,644	45,638	54,295	71,621	20,320	0	0	295,147
24	Tomato (Greenhouse)	-34	50	80	20/Mar-27/Jul	41.4													
		Crop Water Requirement (ETc) in mm/month/ha					0	0	0	0	0	0	0	22	171	302	310	185	
		Irrigation Water Requirement in mm/month					0	0	0	0	0	0	0	9,100	70,754	124,932	128,252	76,525	409,514
25	Turnip(Leaf)	D	30	20	1/Sep-20/Oct	32.8													
		Crop Water Requirement (ETc) in mm/month/ha					0	122	91	0	0	0	0	0					
		Irrigation Water Requirement in mm/month					0	40,073	29,891	0	0	0	0						69,964
26	Water Melon	D	75	16	1/Mar-31/May	33.2													
		Crop Water Requirement (ETc) in mm/month/ha					0	0	0	0	0	0	0	76	183	242	0	0	
		Irrigation Water Requirement in mm/month					0	0	0	0	0	0	0	25,328	60,747	80,332	0	0	166,407
	Vegetable Subtotal	Net Irrigation Requirement				1,712.6	105,054	322,673	890,836	1,054,898	758,679	842,203	747,907	1,028,693	1,636,400	1,451,658	980,419	931,606	10,541,028
		Gross Irrigation Requirement					61,797	489,809	518,139	620,528	446,282	377,766	439,945	605,113	962,588	853,916	576,717	548,004	6,200,605
27	Date Palm					272.0													
		Crop Water Requirement (ETc) in mm/month/ha					214	186	131	90	63	65	83	122	186	227	228	236	
		Irrigation Water Requirement in m3/month					609,210	505,862	356,279	244,772	171,340	176,780	225,734	331,802	505,862	617,370	620,069	641,847	5,006,949
		Gross Irrigation Requirement					243,684	202,345	142,512	97,909	68,536	70,712	90,294	132,721	202,345	246,948	248,036	256,739	2,002,780
28	Alfalfa					563.4													
		Crop Water Requirement (ETc) in mm/month/ha					230	166	163	116	80	73	107	143	188	254	215	227	
		Irrigation Water Requirement in m3/month					1,296,266	935,568	918,679	653,784	450,836	413,977	603,059	805,958	1,059,585	1,431,562	1,211,355	1,279,348	11,060,514
		Gross Irrigation Requirement					1,555,555	1,122,705	1,102,415	784,541	541,063	520,773	723,671	967,150	1,271,497	1,717,874	1,454,198	1,535,265	13,296,816
	Total	Net Irrigation Requirement					2,010,561	1,764,125	2,135,795	1,953,454	1,380,905	1,242,960	1,576,701	2,166,455	3,201,844	3,500,589	2,812,264	2,852,801	26,628,491
		Gross Irrigation Requirement					1,861,036	1,514,859	1,763,066	1,502,978	1,055,881	969,251	1,253,910	1,704,984	2,436,431	2,818,738	2,278,859	2,340,008	21,500,001

Figure 2.4.5. Estimation of Irrigation Water Amount for Option-2 Plan

No.	Crop	Nursery Period (Days)	Main Field Period (Days): Before Harvest	Harvesting	Total (Date)	Cultivated Area (ha)	Item	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Total Net Irrigation Water (m³)
	[Vegetables]																			
1	Bean	0	58	15	1/Nov-14/Feb	35.6														
							Crop Water Requirement (ETc) in mm/month/ha				66	99	104	29						
							Irrigation Water Requirement in mm/month	0			23,915	35,158	37,038	10,328						106,439
2	Cabbage	42	32	10	27/Oct-28/Dec	10.4														
							Crop Water Requirement (ETc) in mm/month/ha			12	82	92								
							Irrigation Water Requirement in mm/month	0	0	1,252	8,555	9,598	0	0						19,405
3	Cabbage	38	72	17	18/Sep-10/Dec	12.4														
							Crop Water Requirement (ETc) in mm/month/ha		28	124	128	14								
							Irrigation Water Requirement in mm/month	0	3,481	15,415	15,912	1,740	0	0						36,548
4	Cauliflower	40	45	10	10/Oct-3/Dec	15.2														
							Crop Water Requirement (ETc) in mm/month/ha			61	127	15								
							Irrigation Water Requirement in mm/month	0	0	9,279	19,318	2,182	0	0						30,478
5	Cucumber (Greenhouse)	-23	30	32	8/Feb-24/May	32.3														
							Crop Water Requirement (ETc) in mm/month/ha							40	128	187	212			
							Irrigation Water Requirement in mm/month	0	0	0	0	0	0	4,931	28,580	41,753	47,335			126,600
6	Cucumber (Greenhouse)	-35	42	43	18/Nov-12/Feb	21.9														
							Crop Water Requirement (ETc) in mm/month/ha				21	56	83	62						
							Irrigation Water Requirement in mm/month	0	0	0	4,600	12,266	18,180	13,580						48,627
7	Dwarf Bean	(D)	60	117	16/Nov-12/May	113.8														
							Crop Water Requirement (ETc) in mm/month/ha				30	54	83	108	145	195	74			
							Irrigation Water Requirement in mm/month	0	0	0	34,692	62,445	94,824	124,890	167,677	225,496	85,573			795,597
8	Eggplant	45	45	49	30/Sep-23/Dec	35.6														
							Crop Water Requirement (ETc) in mm/month/ha		0	97	135	74	0	0						
							Irrigation Water Requirement in mm/month	0	0	34,539	44,509	26,349	0	0						105,397
9	Green beans	0	45	25	16/Sep-24/Nov	38.3														
							Crop Water Requirement (ETc) in mm/month/ha		42	155	99	0	0	0						
							Irrigation Water Requirement in mm/month	0	16,068	59,299	37,875	0	0	0						113,242
10	Lettuce	35	77	20	12/Oct-31/Jan	36.1														
							Crop Water Requirement (ETc) in mm/month/ha			12	71	86	92	0						
							Irrigation Water Requirement in mm/month	0	0	4,332	25,612	31,048	33,214	0						94,226
11	Musk Melon (Greenhouse)	(D)	92	24	15/Oct-5/Feb	32.5														
							Crop Water Requirement (ETc) in mm/month/ha			37	73	82	86	28						
							Irrigation Water Requirement in mm/month	0	0	11,938	23,554	26,458	27,349	9,034						98,333
12	Musk melon	0	62	110	15/Feb-6/Aug	175.6														
							Crop Water Requirement (ETc) in mm/month/ha	32						30	87	195	252	246	252	
							Irrigation Water Requirement in mm/month	56,191	0					52,679	152,768	342,412	442,501	431,966	442,501	1,921,018
13	Parsley	45	40	30	16/Sep-24/Nov	64.7														
							Crop Water Requirement (ETc) in mm/month/ha	0	42	98	103									
							Irrigation Water Requirement in mm/month	0	27,185	63,432	66,668									157,285
14	Pepper	35	50	60	5/Sep-2/Dec	135.2														
							Crop Water Requirement (ETc) in mm/month/ha	0	78	160	129	70								
							Irrigation Water Requirement in mm/month	0	105,463	216,334	174,419	94,646								590,862
15	Pepper(L.C)	35	49	182	20/Sep-9/May	117.0														
							Crop Water Requirement (ETc) in mm/month/ha		28	116	128	95	98	120	161	206	73	0	0	
							Irrigation Water Requirement in mm/month	0	32,748	135,671	149,706	111,110	114,619	140,350	188,303	240,934	85,379	0	0	1,198,821
16	Radish	0	30	1	27/Oct-27/Nov	2.3														
							Crop Water Requirement (ETc) in mm/month/ha		0	12	92									
							Irrigation Water Requirement in mm/month	0	0	280	2,145									2,424
17	Spinach	0	46	74	1/Nov-1/Mar	51.7														
							Crop Water Requirement (ETc) in mm/month/ha		0	0	67	82	93	113						
							Irrigation Water Requirement in mm/month	0	0	0	34,626	42,843	48,063	58,400						183,934
18	Squash	0	70	30	1/May-8/Aug	21.8														
							Crop Water Requirement (ETc) in mm/month/ha	68	0								101	180	257	
							Irrigation Water Requirement in mm/month	14,831	0								22,028	39,250	56,051	132,167
19	Squash	0	70	30	23/Sep-31/Dec	24.8														
							Crop Water Requirement (ETc) in mm/month/ha	0	28	83	104	81	0	0						
							Irrigation Water Requirement in mm/month	0	6,106	18,101	22,680	17,664	0	0	0	0	0	0	0	64,551
20	Sweet melon	0	70	20	16/Jan-15/Apr	32.8														
							Crop Water Requirement (ETc) in mm/month/ha	0	0	0	0	0	24	71	149	99	0	0	0	
							Irrigation Water Requirement in mm/month	0	0	0	0	0	8,315	23,306	48,910	32,497	0	0	0	113,247
21	Sweet Pepper (Greenhouse)	-33	68	139	16/Nov-11/Jun	30.5														
							Crop Water Requirement (ETc) in mm/month/ha	0	0	0	24	67	89	109	146	196	229	70	0	
							Irrigation Water Requirement in mm/month	0	0	0	8,546	20,448	27,163	33,256	44,539	59,819	69,870	21,364	0	287,054
22	Sweet Pepper (Greenhouse)	-48	37	77	8/Apr-27/Jul	33.4														
							Crop Water Requirement (ETc) in mm/month/ha	0	0	0	0	0	0	0	0	78	220	250	338	
							Irrigation Water Requirement in mm/month	0	0	0	0	0	0	0	0	26,061	76,179	83,529	79,530	265,299
23	Tomato	31	105	95	13/Oct-11/May	22.5														
							Crop Water Requirement (ETc) in mm/month/ha	0	0	24	72	83	110	137	184	215	61	0	0	
							Irrigation Water Requirement in mm/month	0	0	5,405	16,219	18,692	24,773	30,855	41,438	48,419	13,738	0	0	199,552
24	Tomato (Greenhouse)	-34	50	83	20/Mar-27/Jul	28.0														
							Crop Water Requirement (ETc) in mm/month/ha	0	0	0	0	0	0	0	22	171	302	310	165	
							Irrigation Water Requirement in mm/month	0	0	0	0	0	0	0	6,152	47,819	84,453	86,590	51,334	276,349
25	Turnip(Leaf)	0	30	20	1/Sep-20/Oct	22.2														
							Crop Water Requirement (ETc) in mm/month/ha	0	122	91	0	0	0	0	0					
							Irrigation Water Requirement in mm/month	0	27,093	20,203	0	0	0	0						47,258
26	Water Melon	0	73	16	1/Mar-31/May	22.4														
							Crop Water Requirement (ETc) in mm/month/ha	0	0	0	0	0	0	0	76	183	242	0	0	
							Irrigation Water Requirement in mm/month	0	0	0	0	0	0	0	17,055	41,068	54,308	0	0	112,431
	Vegetable Subtotal					1,457.6	Net Irrigation Requirement	71,021	218,142	593,494	715,137	512,900	434,657	305,618	695,441	1,200,278	911,384	662,806	629,907	6,426,197
							Gross Irrigation Requirement	81,777	128,319	350,245	419,504	301,706	255,382	297,422	409,083	650,152	537,285	389,880	370,475	4,191,880
27	Date Palm				Area	1,825.3														
							Crop Water Requirement (ETc) in mm/month/ha	224	184	151	90	63	65	83	122	186	227	228	236	
							Irrigation Water Requirement in m³/month	4,088,672	3,393,058	2,391,143	1,642,370	1,149,939	1,165,445	1,514,999	2,226,866	3,395,058	4,143,438	4,161,684	4,307,708	33,603,333
							Gross Irrigation Requirement	1,635,469	1,358,023	956,457	657,108	459,976	474,378	606,000	890,746	1,358,023	1,657,372	1,664,674	1,723,083	13,441,339
28	Alfalfa				Area	1,641.1														
							Crop Water Requirement (ETc) in mm/month/ha	230	166	163	116	80	77	107	143	188	254	215	227	
							Irrigation Water Requirement in m³/month	3,681,530	2,657,026	2,609,393	1,857,276	1,283,860	1,232,447	1,753,117	2,289,373	3,010,064	4,066,794	3,442,365	3,634,493	31,477,636
							Gross Irrigation Requirement	4,419,036	3,189,391	3,131,752	2,224,731	1,537,056	1,479,416	2,055,813	2,747,448	3,612,082	4,880,153	4,130,838	4,361,396	37,773,153
	Total						Net Irrigation Requirement	7,842,123	6,271,026	5,596,430	4,215,301	2,943,749	2,851,449	3,733,794	5,211,880	7,511,404	9,191,609	8,266,855	8,572,011	72,207,396
							Gross Irrigation Requirement	6,096,282	4,673,733	4,438,493	3,305,343	2,298,738	2,209,361	2,959,234	4,047,317	5,620,857	7,114,810	6,185,391	6,454,954	55,406,541

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3.1. Agriculture in UAE

3.1.1. 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 such as summer temperatures exceeding 45°C and annual rainfall of than 150 mm throughout much of the country has made 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.

3.1.2. 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 3.1.1. Almost all emirates have their own department for agriculture and fisheries.

(2) Agricultural Region of Ministry of Agriculture and Fisheries (MAF)

For administrative purposes, MAF has divided UAE in four agricultural regions: Abu Dhabi, Central, Eastern and Northern regions as shown in Figure 3.1.2. The regions cover the following areas:

Agricul. Region	Areas Covered
Abu Dhabi	Liwa, Bida'A Zayed, Ghaithi
Central	Al Dhaid, Al Mileiha, Al Awer, Hatta, Falaj Al Mualla, Masfut, Al Muneei
Northern	Hamraniyah, Khat, Shamel, Digdaga, Shaam, Athen
Eastern	Fujairah,Kalba, Morbeh, Khorfakan, Dhadna, Dibba, Massafi

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. Even though the MAF has a small branch in Abu Dhabi city, it is the local government

which carries out the most relevant activities related to agriculture. The local government decides independent agricultural policies like the "guaranteed buying price", which means that it guarantees the farmers within the Abu Dhabi Emirate that it will purchase all agricultural products at a fixed price regardless of the market conditions. This policy is used as an incentive for the farmers and applies only in the Abu Dhabi Emirate. The rest of the emirates are under the direct jurisdiction of the MAF for agricultural and fisheries matters.

(3) Agricultural Development Policy and Budget of MAF

The federal government has no long term national development plan. Although no long term agricultural development plan exists, it is, however, understood that the MAF focuses agricultural development through the expansion of modern water saving irrigation systems and greenhouses (plastic houses), and on vegetable production, as stated in the unrealized Five Year Development Plan (1981-85).

The annual budget 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 (Table 3.1.1.).

3.1.3. Cultivation Area and Number of Farms

(1) Cultivation 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 (Table 3.1.2.). 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%) was occupied by buildings. The area under greenhouse per holding in the Abu Dhabi and Northern Regions is relatively larger than in other regions.

(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 (Table 3.1.2.). On an average, the cultivated area per holding is 3.15 ha in UAE: 4.98 ha in Abu Dhabi Region, 2.76 ha in Central Region, 3.04 ha in Northern Region, and 1.02 ha in the Eastern Region.

From total holdings, 40% belong to the range below one ha, 50% to the range between one ha to five ha. The Eastern Region has more than 75% of its holdings in the category below

one ha; in the Central Region more than 60% of holdings fall inside the category of more than two; the Northern Region has more than 50% of its holdings within the range of 0.1 ha to one ha.

3.1.4. Agricultural Production

(1) Crop Cultivation Area and Products

Fruit crops are the most important crop in the agriculture of UAE occupying 60% in 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 (Table 3.1.5.). The main fruit trees are Date Palm, which occupies 53% in total cultivated area with 34% of the total production value, followed by Citrus and Mango. The main vegetable crops are Tomato, Cabbage, Eggplant, Chard, Jew's' 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 3.1.5.).

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 (Table 3.1.6.).

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 (Table 3.1.6.).

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 Tables 3.1.7. and 3.1.8. in the last eight years, areas under cultivation of Jew's' mallow, Cabbage, Tomato and Eggplant have increased remarkably; 364% for Jew's' mallow, 341% for Cabbage, 307% for Tomato and 216% for Eggplant, while areas under cultivation of Watermelon, Cowpea and Okra decreased by 22%, 34% and 48%, respectively.

(2) Production Cost

For 1993, the total production cost of all crops in UAE was Dh.468,282,000; the breakdown of these costs are as follows: 31.5% for energy costs, 28.2% for organic fertilizers, 11.7% for chemical fertilizers, 5.5% for pesticides, and 4.5% for seeds (Table 3.2.9.). Labor costs are not included, but the reason they are not included in

official statistics is not very clear. During the same year, the total value of all agricultural production was Dh.1,885,014,000, while production costs involved were 20% of this.

3.1.5. Livestock

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 (Table 3.1.10.). 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 meat production, Camels produce the most, supplying 53% of the total meat produced followed by Goats (24%), Cows (13%) and Sheep (11%) (Table 3.1.11.). It is questionable whether Camels actually do account for most meat production in this country when they account for only 5% of the total head of livestock bred.

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

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 (Table 3.1.12.).

In poultry, 18,696 tons in weight was produced by 19 farmers in 1993 in UAE. During the 6 years from 1987 to 1993 the number of Poultry raised by farmers increased 4 times while production increased 25 times (Table 3.1.13.).

3.1.6. Agricultural Supporting Services

(1) Present Government Subsidy for Agriculture

Farm owners in the Study Area receive various kinds of subsidies from federal and local governments. In particular, the nationals who led nomadic lives before and settled in the Study Area in accordance with the national settlement policy receive more generous subsidies. It is said that the government provides an allowance for each sheep, goat, camel and Date palm, and a family is entitled to a monthly pension according to the number of persons in the household and their ages. The detailed amounts of the subsidy were not clarified, but some farm owners in the Study Area are provided with a subsidy for tap water and electricity from the local government.

In the agricultural sector, MAF provided subsidies for the following:

- Designing farm (free)

- Land preparation (leveling, eliminating gravel, etc.) (free)
- Supervision of daily work (free)
- Fertilizer distribution (50%)
- Agro-chemicals distribution (50%)
- Agricultural materials distribution (seeds, plastic covers, nets, pumps, etc.) (50%)

(2) Distribution of Agricultural Inputs

From Tables 3.1.14, 3.1.15, 2.4.16., and 3.1.17, it is possible to see the amount of seeds, pesticides, fertilizers, and seedlings distributed in UAE during 1993 by regions. If the distribution of inputs for the last four years is analyzed, it can be seen that pesticides have shown a small declining trend while chemical fertilizers have shown an increasing trend. There is no observed trend for seeds and seedlings. Concerning the amount of distributed inputs per hectare in 1993 the following was ascertained: 1.8 kg of seeds, 1 kg of powder pesticide, 1.7 liters of liquid pesticide, 573 kg of chemical fertilizers, 77 kg of organic fertilizers, 2.4 productive tree seedlings (saplings), 6,204 vegetable seedlings. Distributed amount of vegetables seedlings seems to be too high and is questionable.

(3) Agricultural Extension Services

Table 3.1.18. gives information about agricultural extension services. The total number of extension officers in the whole country is 33. On average, each consultant takes care of 629 farms, the smallest number of farms under the care of a single consultant being 243 (Northern Region), and the largest number is 1,832 farms (Abu Dhabi Region). Farms visited during one year was on average 52% of the total farms; for the region with the highest number of farms under one consultant (Abu Dhabi Region), the percentage of farms visited was 18% of all farms; for the region with the lowest number of farms under one consultant the farms visited represented 160% of all farms. Each consultant made 373 visits on average; in the northern region the highest number of visits made was 478; the lowest number of visits was 282, in the Northern Central Region. The main topics covered by the consultants were: productive trees and soils, irrigation and fertilization; pest control and vegetables and field crops. Usually a consultant covers four of the above-mentioned topics per visit.

3.1.7. Directories of Agriculture by MAF

In Crop Cultivation Directories, MAF recommends the crops to be cultivated in UAE. They are shown in Table 3.1.19. (vegetable cultivation), Table 3.1.20. (vegetable cultivation for greenhouse), Table 3.1.21 (fruit tree cultivation) and Table 3.1.22 (Date

palm cultivation). In these directories, cropping time (sowing/ transplanting/harvesting), varieties recommended, planting densities, reproduction methods (fruit trees only), and expected yields by crop are mentioned.

3.2. Agriculture in the Study Area

3.2.1. The Central Agriculture Region of MAF

Agriculture is the main activity in the Study Area. The Central Agricultural Region of MAF, which covers the Study Area, is the third most import agricultural region after the Abu Dhabi and Northern Regions. The location and boundary of the Central Agricultural Region are shown in Figure 3.1.2. The organization chart of the Region is also shown in Figure 3.2.1. As shown in Figure 3.1.2., the northeastern corner of the Study Area is under the Central Agricultural Region; also, the Eastern Agricultural Region is included near the Eastern border of the Study Area. These areas are covered by sand dunes and no cultivation area or village exists, therefore, for practical purposes the whole Study Area is considered to be under the Central Region.

3.2.2. Number of Farms and Cultivation Area

The Study Area is spread over the five emirates of Sharjah, Umm Al Quwain, Ras Al Khaimah, Fujairah and Ajman, including two towns and 14 villages belonging to five Districts (extension units); Al Dhaid-1 and -2, Al Mileiha, Khadrah and Falaj Al Mualla under the Central Agricultural Region.

The number of farm holdings and the cultivated area in five districts concerned in the Study Area were estimated from village/town data, collected by MAF for the agricultural annual statistics, and there were 2,018 farmers and 6,181 ha in 1994 with average cultivated area of 3.1 ha per farm holding (Table 3.2.1).

3.2.3. Agricultural Production

There is no available official data published so far on agricultural production in the Study Area. However, the district data collected by the MAF for the data base of agricultural annual statistics are available. The data were used for the estimation of agricultural production in the Study Area.

(1) Land Share of the Study Area in the Related Four Extension Units

In order to estimate existing agricultural conditions In the four related regions in the Study Area from relevant data, the share of the Study Area within each of the four districts regarding the number of farm holdings and the cultivated area was estimated. The Study Area was occupied by 62% of farm holders in the four districts in 1994; 87% for Dhaid, 41% for Mileiha, 16% for Khadrah and 43% for Falaj Al Mualla, and accounted for 68%

of cultivated area; 92% for Dhaid, 36% for Milciha, 31% for Khadrah and 46% for Falaj Al Mualla (Table 3.2.2).

(2) Cultivated Area, Crops, Production and Production Value

The cultivated area and the production of crops in the four districts covered by the Study Area are shown in Table 3.2.3. The cultivation area and production in the Study Area were estimated based on the above data. The Study Area's share of the cultivated areas in the five districts is as shown in Table 3.2.2.

a) Cultivated Area

The cultivated area in the Study Area was estimated as 4,584 ha in 1994; 1,158 ha (25.3%) for vegetables, 1,825 ha (39.8%) for fruit trees and 1,601 ha (34.9%) for Field crops (Table 3.2.4.).

b) Cultivated Crops

The main vegetables cultivated in 1994 were Squash (5.3% of the total cropped area), Tomato (5.0%), Onion (2.4%), Sweet pepper (1.8%), Parsley (1.7%), Eggplant (1.4%), Sweet melon (0.9%), Cauliflower (0.7%), Cabbage (0.7%), Okra (0.7%), Watermelon (0.6%) and Cucumber (0.5%).

The main fruit trees were Dates (23.9%) followed by Lemon (5.9%), Mango (2.6%), Other Citrus (2.3%), Guava (1.4%), Fig (0.9%), Lime (0.5%), etc.

The main field crops are Alfalfa (21.2%) and Green fodder (13.6%), such as Rhodes grass and what is locally called Missiblo, a species of elephant grass.

c) Crop Production

The largest crop production in the Study Area is Alfalfa of which 91,708 tons were produced (46% of the total crop production in the Area), followed by Green fodder (25%), Dates (11%), Squash (4%), Tomato (3%) and Lemon (2%).

d) Production Value

Alfalfa has the largest amount of production value in the Study Area; Dh. 128,391,000. in 1994, accounting for 40% of the total crop production value, followed by Dates (24%), Green fodder (17%), Squash (3.9%), Tomato (3.3%), and Lemon (3.2%). The yields of Alfalfa and Green fodder are 90.9 ton/ha fresh, 77.0 ton/ha fresh, respectively.

The production value per unit area is the highest for Alfalfa (Dh. 127,203/ha) followed by Cucumber (Dh. 95,873), Green fodder (Dh. 84,667), Dates (Dh. 67,293), Cowpea (Dh.

61,848), Bean (Dh. 56,541), Potato (Dh. 50,758), Squash (Dh. 48,697) etc.

(3) Cropping Pattern

In the Central Region, generally, seeds for Tomato, Onion (both for storage and green), Pepper, Cabbage, Cauliflower, Eggplant, Potato, Beans and Lettuce are sown September to October and harvested from the end of December to the end of March depending on the crop, and Watermelon, Melon, Squash, Cucumber, Okra are cropped twice a year (Figure 3.2.2.).

(4) Greenhouse Cultivation

Greenhouse cultivation is spreading in the Study Area on account of the advanced production conditions such as control of cropping season, water saving, stabilized high yield, high quality of products and so on. For this reason, the cultivated areas by crop and the yearly trends were made clear.

The total cultivated area under greenhouses in the four districts were 3.81 ha in winter and 7.51 ha in summer in 1994 (Table 3.2.5.). The crops cultivated in the greenhouses are Cucumber (3.00 ha), Squash (0.30 ha), Potato (0.3 ha) , Tomato (0.203 ha), Sweet pepper (0.005 ha) and Sweet melon (0.003 ha) in winter, and Cucumber (4.30 ha), Squash (1.40 ha), Sweet melon (1.40 ha) and Watermelon (0.40 ha) in summer. Greenhouse cultivation is most popular in Dhaid followed by Falaj Al Mualla and Mileiha, but greenhouses have not yet been introduced in Khadrah. During the last three years, the total area under greenhouses has increased by 10% on average in the four districts (Table 3.2.6.).

3.2.4. Livestock

The present conditions of livestock production in the Central Region is shown in Table 3.1.11.

3.2.5. Agricultural Extension Service

In the Central Region of MAF, there were 11 agricultural extension officers to take care of the 2,911 farms that existed in 1993. In other words, each consultant had to visit, on average, 265 farms during the year. During the same year, the consultants in the Central Region totaled 3,104 visits. The visits dealt with vegetables and field crops, fruit trees, pest control, soil, irrigation and fertilization.

3.3. Farm Survey

3.3.1. Farm and Existing Wells Inventory Survey

(1) Farm Household Survey

An understanding of the present conditions and utilization of wells is indispensable, because agriculture in the Study Area relies entirely on groundwater for irrigation all year round. The groundwater resources are not unlimited, so the farmers should utilize them carefully and effectively.

It is also very important to collect details concerning the agricultural activities and well conditions of individual farms. Each farmer has his own wells on his farm, so the Study Team conducted Farm and Well Inventory Surveys together. These surveys were conducted by a sub-contractor under the supervision of the Study Team. Interviewing methods were adopted for this Farm and Well Inventory Survey. In order to gain an initial understanding of the information likely to be provided by each respondent, an preparatory exercise was undertaken in the middle of June. After this exercise, the Study Team refined and modified the questionnaire for more efficient data collection. The modified questionnaire can be seen below.

Since there are a lot of farms in the Study Area, it would have been rather difficult to investigate all farms within the limited working period. Consequently, 200 farms were selected for these surveys by MAF Central Regional Office staff. The selected farms were from five areas according to the extension unit areas, namely Falaj Al Mualla, Dhaid I, Dhaid II, Mileiha and Khadrah. Falaj Al Mualla and Khadrah supplied 40 farms, and Dhaid I, II and Mileiha supplied 160 farms. Each area has three categories of farm classified by cultivated area, which is given in information provided by the MAF Central Regional Office. For these surveys, two survey teams were employed. One team was composed of two investigators (including at least one fluent Arabic or Urdu speaker), and usually went to survey two farms within a normal working day. One of the team members questioned the farm owner or worker, while the other recorded the information regarding farm size or type, production and well details. The team also walked around the farm to verify responses. The team also took on-site measurements of wells for temperature, conductivity and pH.

Even though the survey was conducted in the summer vacation, the fieldwork of the survey was completed by the end of July 1995.

(2) Sampling of Interview Survey

According to the existing data from MAF Central Region, about 2,000 farm holdings are

estimated to be in the Study Area (Table 3.2.1.). It is impossible to survey all the farms in the Study Area within the limited survey period of the Study. Through discussions with the staff of the Central Agricultural Region, including consultants, it was decide to sample 200 farms (equivalent to 10% of total farms estimated). They were selected from five districts (Consultation Unit of the Central Agricultural Region), Falaj Al Mualla, Khadra, Dhaid-1, Dhaid-2 and Mileiha, in accordance with the number of existing farm holdings and the farm size category of MAF. Numbers of farm scale category in each of the five district are as shown below:

District (Extension Unit)	Number of Existing Holdings	Number of Sampled Holdings by Farm Scale				
		Large	Medium	Small	No Answer	Total
Dhaid	1,485	58	41	0	1	100
Mileiha	302	42	17	0	1	60
Khadrah	67	6	5	3	1	15
Falaj Mualla	164	16	7	1	1	25
Total	2,018	122	70	4	4	200

Note : Dhaid includes Dhaid-1 and Dhaid-2

The locations are shown in Table 3.3.1. and Figure 3.3.1.

(3) Questionnaire for Farm Survey

The Study Team prepared a draft form of questionnaire for the Farm Inventory Survey. In order to modify the draft form to a final form to meet the practical conditions, a pilot survey of 20 sample farms was conducted by a joint team composed of members from the Study Team, the consultants of MAF Regional Office and the local consultant. The major items in the final form of questionnaire are:

- **respondent details** : position (owner/family/employee).
- **owner details** : name, ethnic / tribal group, full-time farmer / part-time farmer, location, address.
- **family members** : adult (number of male/female/total), children (number of male/female/total), family members engaged in agriculture (number of male/female/total), employee family status (number of persons in the family, nationality).
- **farm details** : year opened, total acreage of farm, area available for cultivation, area cultivated, area of land owned.
- **cropping; production, consumption and sale of products** : acreage and number of trees by crop, cropping season (month of seeding/harvesting) by crop, production by crop, home consumption by crop, amount of sale by crop, average unit selling price by

crop, total selling price.

- **marketing** : marketing channel of products (wholesaler, retailer, intermediary, cooperative, government marketing board, local market, others).
- **cropping input/resources** : fertilizer / pesticide / herbicide used (kind, amount, cost), labor input by crop, production cost by crop.
- **livestock details** : number of livestock breeding, livestock production, home consumption and sale of products, breeding cost of livestock.
- **financial** : total annual expenditure, total annual income.
- **farmers' opinions** : schemes, farming intentions, water source, irrigation, irrigation cost.
- **water uses** : irrigation facilities installed, irrigation practices, cost of irrigation
- **water/well inventory** : well details, pump details, static water table, water quality at the time of survey, major use of well, problem with well.

The questionnaire for the farm inventory survey is attached in Appendix 2-1.

3.3.2. Farm Household Survey Results

(1) Farm Size and Cultivation Area

The crops and the areas cultivated by the 200 farms in the Study Area in 1994 are shown in Table 3.3.2. The total cultivated area was 519 ha of which 60% was occupied by orchard, 30% by pasture crop and 10% by vegetables.

(2) Crops and Areas Cultivated

As shown in Table 3.3.3., the largest cultivated area was under Dates which occupied 36.8% of the total, followed by Alfalfa (16.4%), Rhodes Grass (9.3%), Lemon (8.3%), Mango (5.6%), Methapleon (3.9%, local name is Misiblo, a kind of pasture crop), Squash and Orange (2.9% each), Tomato (2.3%) and Lime (2.1%), while the most popular crops cultivated among the farms were Dates, which were cultivated at 73.0% of the total farms, followed by Methapleon (44.5%), Lemon (41.0%), Alfalfa (38.0), Mango (37.0%), Guava (26.0%), Rhodes Grass (25.0%), Orange (17.5%), Lime (17.0%) Chico (15.0%), Fig (11.0%), Eggplant (9.5%), Squash (8.5%), Tomato (7.5%), Citrus (7.0%), Cauliflower (4.0%), Sweet melon (3.5%), Cabbage (3.5%), Pomegranate (3.5%) and Beans (3.0%).

As mentioned above, nearly 90% of the cultivated area is occupied by perennial or semi-perennial crops such as Fruit trees and pasture crops.

(3) Consumption of Products

As shown in Table 3.3.3., 80% of the vegetables produced were sold by 70% of the farms and 22% of the pasture crops produced were sold by 7% of the farms, but of the fruit products, almost the entire amount was consumed at home. As a whole, more than half of the production amount was consumed at home. Nearly 60% of the farms do not sell any crop products.

(4) Production Costs and Labour Requirements

Based on the Farm Inventory Survey, the production costs for each crop is estimated to be as shown in Table 3.3.4. Labor and manure were the main production input costs.

The largest labor requirement was in vegetable cultivation which accounted for 9 times more than fruit cultivation and 1.5 times more than pasture cultivation (Table 3.3.5.).

Manure is one of the most important input materials for desert agriculture, especially for vegetable cultivation.

Production cost was highest for Eggplant which amounted to Dh. 39,516/ha, followed by Sweet melon (37,971 Dh./ha), Methapleon (34,863), Courgette (32,884), Alfalfa (28,634), Squash (26,483), Rhodes grass (25,071), Watermelon (23,475) and Tomato (23,312). The total production costs were highest in vegetable cultivation, where they amounted to more than double that required for fruit tree cultivation.

Looking at each crop, Jew's mallow, Sweet melon, Watermelon and Tomato required large amounts of labor, which was mainly needed for watering (Table 3.3.5.).

(5) Production and Net Incomes

Production and benefit in the 200 farms estimated from the inventory farm survey are shown in Table 3.3.6. The total crop production in the 200 farms amounted to 19,599 tons with an average of 98 tons per farm in 1994.

81% (15,830 tons) of the total production was accounted for by pasture crops and the rest was evenly shared by vegetables and fruit trees.

The total net income in the 200 farms amounted to Dh. 10,488,263, with Dh. 52,441 Dh.(71%) per farm on average being earned from pasture crops, 22% from fruit trees and the rest from vegetable crops. However, crops such as Eggplant, Sweet melon, Beans, Cabbage, Pumpkin, Watermelon, Courgette, Green beans, Orange, Chico, Pomegranate and Grapefruit showed a loss.

(6) Livestock

Goats are the most common livestock in the area, with 6,675 head being bred at 54% of

the farms in 1994, followed by Sheep (5,720 head, 45% of the farms), Chickens (2,144 head, 20%), Cattle (1,191 head, 35%), Camel (757 head, 18%) (Table 3.4.5.). The average number of head of livestock per farm is estimated at 67 Goats, 69 Sheep, 19 Cattle, 58 Chickens, and 23 Camels.

Almost all livestock are consumed at home; 33% (22 head) of the total head of goat, 49% (34 head) of sheep, 27% (16 head) of chicken, 23% (4.3 head) of cattle and 6% (1.5 head) of camel.

3.3.3. Supplemental Farm Survey

(1) Greenhouse Cultivation Survey

A detailed survey on greenhouse cultivation was carried out by the Study Team with the cooperation of MAF counterpart personnel. The results obtained are shown in Tables 3.3.7. to 3.3.10. and are summarized below.

Crop	Production (kg/ha)	Unit Price (Dh./kg)	Gross Income (Dh./ha)	Production Cost (Dh./ha)	Net Income (Dh./ha)	Water Consumption (m^3/ha)
Jew's mallow (Dhaid-1)	9,259	5.0	46,296	33,091	13,205	1,890
Cucumber (Dhaid-1)	69,444	3.0	208,332	114,807	93,525	1,900
Cucumber (Al Ain)	113,280	2.75	311,250	136,367	175,153	4,789
Sweet melon (Dhaid-1)	50,000 pcs.	3.5/pcs.	175,000	95,444	79,556	3,667

The yield and the net income from Cucumber cultivated on the Al Ain farm is quite high though it seems to be somewhat overestimated. However, attention should be paid to their consumption of large amounts of irrigation water. Such over-irrigation may cause soil salinization. In fact, damage due to soil salinity is currently the largest problem for vegetable cultivation in the area.

(2) Forage Crop Cultivation Survey

In order to confirm the yield and harvesting practices for Alfalfa, an Alfalfa yield survey and farmers' hearings were conducted at two farms in Khadra. The results are summarized as follows:

Farm-A cultivates 3.85 ha of Alfalfa; that is, net cultivation area, after subtracting farm ditches, roads and the canal area, comes to 2.64 ha (about 68.6% of cultivated area). Crops are harvested 13.59 times a year. The unit yield in green Alfalfa is 171 ton/ha for

the net cultivation area and 117 ton/ha for the gross cultivation area.

Farm-B cultivates 3.68 ha of Alfalfa, and the net cultivation area is 2.31 ha (about 62.8% of cultivated area). It harvests 13.59 times a year. The unit yield in green Alfalfa is 167 ton/ha for the net cultivation area and 105 ton/ha for the gross cultivation area.

Unit yields of Alfalfa in both farms are higher than the average yield according to MAF statistics at 90.9 ton/ha.

Annual gross income was estimated at 69,088 and 43,366 Dh/ha for net cultivation area and gross cultivation area, respectively. Because of different selling prices(A farm at Dh. 0.50/kg, B farm at Dh. 0.38/kg and MAF statistics at Dh. 1.40/kg), gross income per unit area was a quarter of MAF's statistical data. These was caused by sale contract conditions set at the pre-harvesting stage by area bases, in addition to which there is bartering for by middlemen.

3.4. Evaluation of Present Agriculture in the Study Area

3.4.1. Production and Benefit per Unit Area by Farm Inventory Survey

(1) Production and Benefit per Unit Area

Production, production value, production cost and net income per unit area of each crop cultivated in the 200 farms were made clear as shown in Table 3.4.1.

The highest production was of Methapleon with an average yield of 154,028 kg/ha, followed by Rhodes grass (100,915 kg/ha), Cucumber (99,981), Alfalfa (91,551), Tomato (48,908) and Squash (46,496).

The highest gross income was from Alfalfa (Dh. 97,113/ha), followed by Cucumber (91,061), Methapleon (74,072), Tomato (73,851), Okra (54,088), Carrot (49,440), Rhodes grass (42,846), Lime (41,184) and Cauliflower (38,422).

The highest net income was obtained by Cucumber and amounted to Dh. 68,676/ha, followed by Alfalfa (68,478), Tomato (50,539), Carrot (40,851), Methapleon (39,208), Okra (35,913), Lime (31,620), Chili (25,461), Mango (20,169), Cauliflower (19,089) and Rhodes grass (17,775). Meanwhile, Eggplant (-17,771 Dh./ha), Grape fruit (-14,858), Orange (-12,420), Watermelon (-12,345), Cabbage (-10,173), Courgette (-7,384), Chico (-72,64), Pomegranate (-5,966), Beans (-5,306) and Green beans (-3,192) all showed a loss (Table 3.4.1.).

The production and the benefit per unit area were also estimated from the Statistical Data published by MAF. According to the results shown in Table 3.4.2., the highest net income was obtained from Alfalfa (Dhs113,203/ha), followed by Green fodder such as Methapleon and Rhodes grass (73,667), Cucumber (62,373), Pomegranate (41,469), Cowpea (33,848), Dates (32,293), Squash (31,697), Eggplant (30,770), Turnip (29,644), Potato (29,066) and Tomato (28,117), while, Grapes (-29.887), Mango (-16,896), Sweet pepper (-16,077), Banana (-15,343), Parsley (-12,297), Fig (-8,619), Almond (-5,643) and Onion (-2,412) all showed a loss.

(2) Comparison of Crop Production

As shown in Table 3.4.3 and 3.4.4., the following tendency can be seen between the data estimated from the Farm Survey and from the Statistical Data published by MAF.

- The unit prices were obtained by the Farm Inventory Survey (except where the unit price has been substituted by the wholesale price), are lower than those obtained from the statistical data published by MAF.
- Both the production per unit area and production costs obtained by the Farm

Inventory Survey are higher than those in the statistical data published by MAF for vegetable crops, but lower than the statistical data published by MAF for tree crops and field crops.

It seems that these lower unit prices obtained by the Farm Inventory Survey may show present farmers' actual sale conditions in the Study Area.

(3) Livestock Balance Sheet

The cost benefit analysis on the livestock in the Study Area based on the Farm Inventory Survey was made as shown in Table 3.4.5. Benefits are estimated based on the animals, milk and eggs produced in 1994, and costs are estimated breeding costs including the cost of feed, health care and labour, but excluding the cost for home-made feed. As shown in Table 3.4.5. the livestock in the Study Area is not economical except for Antelopes and poultry. From this, it is possible to conclude that the keeping of livestock in the Study Area is intended for in-farm or in-family consumption or as a financial investment.

3.4.2. Study on Promising Crops

(1) Indicator of Crop Income per Unit Water Consumption

The objective of agricultural development in the Study Area is to establish a sustainable and high-income agriculture through the introduction of suitable crops and farming technology.

To achieve this goal, promising crops for sustainable and high-income agriculture are discussed and studied, using the data from 1) Farm Inventory Survey, 2) the statistical data published by MAF and 3) the experimental data carried out by UNDP/FAO between 1987 and 1988 in UAE, which introduced the indicator of "Crop Income/ Water Consumption" (CI/WC).

The amount of water consumption for each crop in the main field (Nursery period was excluded from this calculation) was calculated based on the Penman Method from meteorological data in the Study Area, with consideration paid to the growing period of each crop and the cropping season. The amount of water consumption was calculated based on the growing period in the main field (not including the nursery period). On the experimental data, gross crop income was used in place of net crop income as the data was not available.

(2) Selection of Suitable Crops and Cultivation

There are three sources of crop production data which were analyzed using the criteria

shown below:

- Unit price: average whole sale price during harvest period at Dubai Market in 1993 (Table 3.4.6.)
- Production cost: based on costs applied in MAF statistics with water costs added
- Crop water consumption: data estimated by Penman method for each crop growing period

The comparison of each crop based on the same assumptions are shown in Tables 3.4.7. and 3.4.8. in NI/WC value order. It is possible to say that crops with estimated higher NI/WC indicators also show high values of net income per unit area (Dh/ha).

NI/WC indicators show high on Cabbage, cauliflower, carrot, Musk melon, Watermelon, Tomato and Spinach for open field crops, and all crops intended for greenhouse cultivation such as Musk melon, Cucumber, Sweet melon, Dwarf bean, Sweet pepper, Jew's mallow. The only exception is Tomato.

However, under present conditions, the cultivation of fruit trees and field crops such as Alfalfa, Methapleon and Rhodes grass can not be recommended for the Area because the NCI/WC value of fruit tree and field crops is extremely low compared with those of vegetable crops, consequently, a large loss of farming income and an extravagant waste of water for irrigation would result.

In the case of fruit tree cultivation, the introduction of high quality varieties and processing technology is thought to be important.

3.4.3. Conclusions of Present Agriculture in the Study Area

(1) Conclusions

Based on the above mentioned analysis it is possible to conclude that the agriculture in the Study Area is a short-sighted, inefficient type of agricultural production that depends mainly on field crops and tree crops that consume much water, as shown in Figure 4.8.1. This is because absentee farm owners have more important sources of income and leave the cultivation of their farms up to foreign workers. Farm owners do not pay much attention to profitable farming but rely easily managed cultivation which can be done by foreign workers in the owner's absence, such as perennial tree cropping, and semi-perennial forage cropping. However, the recent degradation of the groundwater in the Study Area means that this type of agriculture cannot continue. A few devoted farmers in the Study Area have been considering the installation of water-saving, modern irrigation systems which would be highly beneficial for both vegetable crops and greenhouse

cultivation.

(2) Present Development Constraints

The problems and constraints to agricultural development in the Study Area are summarized as follows:

Deterioration of Groundwater. The most serious problem in the Study Area is the deterioration of groundwater in terms of productivity, quality and the lowering of the water table. The causes of this are over-extraction, over-irrigation, and the over-development of land. Because of this deterioration, farmers must re-drill existing wells deeper or drill expensive new wells. In some cases lack of finance forces them to abandon their farms. An additional burden is the problem of salinity.

Absentee Owners. Most owners of farms in the Study Area have other occupations. They do not cultivate and farm by themselves. The actual work and day-to-day management is left up to foreign laborers, while most owners live in major cities like Dubai or Sharjah, where they engage in other businesses. Most nationals use their farms as a kind of family resort. The products from their farms do not flow into the market because they are consumed at home. Some farmers have an interest in selling their crops for profit, but their agriculture is not fundamentally managed on a "profit-oriented" basis. Consequently, most owners do not necessarily work their farms efficiently, even with the assistance of the government extension officer, due to a lack of interest in modern farming methods and a lack of willingness to learn.

Poor Access to Agricultural Markets. Most farms have no opportunities to access agricultural markets, or information on prices or demand. Inevitably they sell their products to wholesalers at prices below their production costs. Due to a lack of market information, many farmers produce single crops. For example, during the harvesting period, all farmers sell the same produce to the market at the same time, the market becomes saturated with the crop, and consequently the price falls.

Low Competitiveness against Imported Agricultural Products. Due to the Government's policy of maintaining an open market in agricultural products, an abundance of high quality vegetables and fruits flow into the UAE markets from all over the world, in response to market demand. Occasionally, not only are the imported products of better quality, their prices are also lower than the production costs of the UAE

farmer. The domestic agricultural products are occasionally driven off the market or abandoned or fed to animals.

Lack of Technical Extension Services: Currently agricultural promotion activities by extension officers in the Study Area are concentrated on the distribution of the government subsidy, and providing seeds, fertilizers, seedlings and agricultural chemicals to the farmers. Many of the farmers, however, desire technical information regarding crop cultivation, post-harvest processing and access to markets, so an improvement in the technical extension services is important. Alongside inadequacies in the technical extension system, experimental research at research stations cannot be said to function efficiently in meeting the demand from farmers.

3.5. Agricultural Development Master Plan

3.5.1. Basic Strategy for Agricultural Development

As stated in the previous section, the basic strategy of agricultural development in the Study is to set up "sustainable agriculture and highly profitable agriculture". To achieve these twin targets, the following plan has been formulated:

- Assessment of the characteristics of arable land suited to irrigated agriculture and its appropriate area, taking into account, in addition to the sustainable development potential of groundwater resources, conditions such as soil, land and the state of the basic agricultural infrastructure.
- In order to introduce modern methods of irrigation and bring about effective use of water resources, there should be active introduction of irrigation-efficient, high-income yielding crops. For vegetable cultivation in particular, intensive, water-economic greenhouse cultivation should be actively introduced.
- Opportunities for market access will be increased; the development of stable markets, a switch-over to the production of goods in line with consumer needs, communication to the farmer of market information, etc.
- If agricultural development is to be a part of the national strategy to secure self-sufficiency in foodstuffs, then agriculture cannot be seen as just a means of supplementing one's livelihood, or as a leisure activity: it must be a paying enterprise in itself. To bring this about, in addition to the support now given to farm management, the government must have a general agricultural policy that includes socio-economic considerations in the form of farmer-support services, such as training and extension on cultivation method and post-harvest techniques, and easy access to market information. To institute such a policy it is essential that the UAE government and separate emirate governments work together. The necessary policies are suggested as part of the Study.

3.5.2. Land and Water Sources

It has been confirmed by the groundwater balance analysis that the deterioration to the quality and quantity of groundwater is caused by the over-development of farm land and over-extraction of the water for irrigation in the Study Area. Recently developed farm lands are located in the outskirts of the fertile lands, which have been cultivated since olden times, for example, in the Dhaid area. The land is basically gravelly, and consequently, the surface is covered to a certain depth of by transported silty sand used

for cultivation, even though it cannot improve irrigation efficiency.

(1) Option 1

In Option 1, a reduction in the cultivation area is planned to meet the irrigation water requirement up to the sustainable recharge amount after the maximization of recharge capacity. How to reduce the cultivation area or close existing farms is too difficult to define because of social background, and it is not proposed in this Study. In the case of closing farmland, those farms using inefficient irrigation procedures, such as farms in gravelly areas, would be closed first.

(2) Option 2

In Option 2, the whole cultivation area as of 1994 would be supplied with irrigation water under a water-saving irrigation system and insufficient water demand would be met by supplying desalinated seawater.

In both options, new farm development or expansion of existing cultivation is not proposed.

3.5.3. Sustainable Agricultural Development

Cropping area with consideration for sustainable agricultural development was determined in the following way:

Sustainable agriculture in the study area is defined as agriculture which can be managed using irrigation water supplied regularly from several water sources.

In the study, the following options were analyzed:

Option 1: Use of groundwater only
Agriculture is planned with a supply of 21.5 million m^3/year of irrigation water (Based on the results of the groundwater analysis, available groundwater is 19.5 million m^3/year and 2 million m^3/year is the expected potential)

Option 2: Use of groundwater and desalinated sea water
Agriculture with high profit crops and water saving irrigation methods will be introduced to the entire present cultivated area of vegetables, tree crops and pastures. The resultant water shortfall will met by supplying

desalinated seawater.

3.5.4. Option 1 Agricultural Development Plan

(1) Selection of Most Promising Crops

To achieve sustainable and highly profitable agriculture, the basic strategy of agricultural development of the Study, it is necessary to look at appropriate crops, the cropping period, cultivation method, cultivation area, irrigation water requirement and net income in order to formulate an agricultural plan.

Referring to the unit cost of desalinated water, crops which show an NI/WC indicator greater than 10Dh/m^3 are recommended as crops for the Study Area. Where there is more than one crop in the same growing period with high NI/WC, only the crop with the highest NI/WC is selected.

In Figure 3.5.1., under present cultivation techniques, irrigation and marketing conditions, it is clear that field crops seem to be the most attractive from the point of view of the net income factor, but in view of the net income per unit of water consumption, they are second best compared to vegetables. After improving the above mentioned conditions, the attractiveness of vegetables compared to field crops will become apparent from the point of view of the net income per unit water consumption.

Tree crops and forage crops show low NI/Wcs of less than 10Dh/m^3 and they are not recommended for cultivation in the Study Area based on this criteria.

However, considering the importance of Dates which is a traditional national staple food, Date palm has been selected for cultivation. For this selection, an increase in market unit price is expected to come from introducing a high quality and high yielding variety (present unit price is 3.5 Dh./kg, and expected price is 7.0 Dh./kg). It was considered that the NI/WC ratio of Dates will be able to be increased to the expected value following the intensive introduction of the variety Barhi which is a high quality and high yielding variety of Date palm, in addition to the introduction of improvement in the cultivation and post harvest techniques (Table 3.5.1.).

Alfalfa, which is one of main forage crops for the traditional livestock is considered as the next most important crop after vegetables and Dates. Therefore, Alfalfa is also selected as one of the recommended crops for the Project for the following reasons:

1) Income crop throughout the year which can be harvested thirteen times per year
2) Its high demand and stabilized market
3) Can be used as a rotation crop with vegetables

4) Its contribution land fertility improvement (nitrogen fixation)

The selected crops and their cultivation practices are shown in Figure 3.5.1. and Table 3.5.2. The most highly profitable crops, which also save water, are Musk melon grown under glass (October 15 to February 5) and Sweet melon grown in open fields (January 16 to April 15), Cucumber under glass (November 18 to February 12), Spinach in open fields (November 1 to April 15) Pimento under glass (November 16 to June 11) and Cabbage in open field (October 27 to December 28).

(2) Cultivation Area

The area to be put under the cultivation of vegetables is to be determined based on their productivity. The required production volume of each vegetable at harvest time was estimated from such conditions such as 100 million head of consumption population and 50 g/head /day of supply volume. Through this plan, a total annual production 67,600 tons of vegetable in production is expected in the study area; expected total vegetable demand is 300 g/head/day. (307 g in Japan 1980, 307 g in Europe in 1992 according to FAO). (When this Plan is implemented, self-sufficiency in vegetables in UAE will be improved to 60% from the present 30%.)

The cultivation area of Dates is determined based on the present total net profit of tree crops.

The proposed cultivation area for Alfalfa is based on balancing the irrigation water requirement with that of vegetables and Dates.

(3) Cultivation Plan

Based on the above mentioned conditions, a sustainable high profit crop production plan was projected as shown in Table 3.5.2 and Fig. 3.5.1.

a) Cultivation Area

2,548 ha of total cultivation area is planned. 1,713 ha of vegetables (67% of total cultivation area), 272 ha of Dates (11%) and 564 ha of Alfalfa (22%) are considered. Compared to the present cultivation area, these areas are equivalent to 148% for vegetables, 15% for Dates and 35% for Alfalfa and 56% of the total cultivation area (see Table 3.5.3.). The cultivation area of each vegetable, its cultivation period, cultivation method (in open field or under glass, seeding period, direct seeding or transplanting, harvesting period) are shown in Table 3.5.2. and Figure 3.5.1.

b) Expected Yield

67,800 tons (265% of present condition) of vegetable production, 5,229 tons (18%) of Dates production, 51,209 tons (37%) of Alfalfa production and 124,238 tons (65%) of total annual production is expected.

c) Expected Net Income

Dh. 187 million (841% of present condition) from vegetables, Dh. 25 million (100%) from Dates, Dh. 61 million (36%) from Alfalfa and Dh. 273 million as total net income, without giving consideration to the excess costs involved in groundwater strengthening, an increase of 26% from the present (Table 3.5.3.).

d) Gross Irrigation Water Requirement

It is estimated that the gross irrigation water requirement will be 6.2 million m^3/year (208% of present condition) for vegetables, 2.0 million m^3/year (9%) for Dates, 13.3 m^3/year (40%) for Alfalfa and a total gross requirement of 21.5 m^3/year (37%). This total irrigation water volume is equivalent to that of the sustainable irrigation water volume in the study area after the groundwater strengthening measures.

As mentioned before, as this gross irrigation water requirement is calculated based on the calculation procedures of FAO and the expected irrigated area at an assumed irrigation efficiency; there is a possibility that more water will be used than the gross irrigation water requirement. It is important to implement suitable water use methods for irrigation, such as adopting water saving irrigation systems. Compared to cultivation in open fields, effective irrigation water use is relatively easy in greenhouses. An area of 420 ha is suggested for vegetable cultivation in greenhouses, which is 0.21 ha/farmer of glass (equivalent to 6 units of a standard greenhouse). Considering the labor force of farmers, this area for greenhouses is entirely manageable.

(4) Proposed Farming at a Typical Farm in the Study Area

Proposed crop production plan for a typical farm in the Study Area is shown in Table 3.5.4. The total cultivation area is 1.26 ha (0.85 ha for open field, 0.15 ha for greenhouse, 0.13 ha for Dates, 0.28 ha for Alfalfa). A net income of Dh. 135 thousand and 11,047 m^3/year of irrigation water requirements are expected. With several kinds vegetables being cultivated, it is necessary to adjust the cultivation area of different vegetables among the farmers.

3.5.5. Option 2 Agricultural Development Plan

(1) Cultivation Area

The area is the same as the current area of vegetables under cultivation, Dates and Alfalfa are considered, applying the same factors as in Option 1. The cultivation areas of each vegetable are determined as a portion of the cultivation area in Option 1. Dates are grown tree crops and Alfalfa in the pasture areas.

(2) Proposed Farming

a) Cultivation Area

4,584 ha of total cultivation area are planned. 1,158 ha of vegetables (25% of total cultivation area), 1,825 ha of Dates (40%) and 1,601 ha of Alfalfa (35%) are considered (Table 3.5.6.). The cultivation area of each vegetable, period, method (whether open field or greenhouse, seeding period, direct or transport seeding, harvesting period) are shown in Table 3.5.5.

b) Expected Production

45,836 tons (179% of present condition) of vegetable production, 35,094 tons (118%) of Date production, 145,475 tons (107%) of Alfalfa production and 226,405 tons (118%) of total annual production is expected (Table 3.5.6).

c) Expected Net Income

Dh. 126 million (568% of present condition) from vegetables, Dh. 167 million (671%) from Dates, Dh. 174 million (103%) from Alfalfa and Dh. 467 million as total net income without considering the excess cost for groundwater strengthening and desalinization of sea water is expected. This is 217% of total net income.(Table 3.5.6.). Considering the Dh. 154 million/year which is the estimated annual cost for purchasing desalinated seawater (US$ 1.27 = Dh. 4.56) and for the construction and maintenance of water distribution facilities, a total net income of Dh. 312 million is expected, a 145% on present net income.

d) Gross Irrigation Water Requirement

4.19 million m^3/year (141% of present condition) for vegetables, 13.4 million m^3/year (63%) for Dates, 37.8 m3/year (112%) for Alfalfa and 55.4 m^3/year (95%) as total gross irrigation water requirements are anticipated (Table 3.5.6). This total irrigation water volume is 2.6 times larger than the annual sustainable irrigation water volume in the study area and it is necessary to purchase 33.9 million m^3/year (average 1.08 m^3/sec, monthly

maximum 1.58 m^3/sec, monthly minimum 0.46 m^3/sec) of desalinated sea water.

(3) Proposed Farming at a Typical Average Farm

Proposed crop production plan for a typical average farm in the Study Area is shown in Table 3.5.7. The total cultivation area is 2.27 ha (0.43 ha for open fields, 0.14 ha for greenhouse, 0.9 ha for Dates, 0.8 ha for Alfalfa). An average net income of Dh. 231 thousand is anticipated and 27,456 m^3/year of irrigation water is expected to be required.

3.5.6. Agriculture Supporting Services

It is impossible to promote agricultural development without the participation of the farmers, in whom it is necessary to foster a businesslike attitude and awareness that water resources are limited. Therefore, agricultural extension activities will certainly play an important role. Furthermore, agricultural support services need to be introduced for the smooth implementation of proposed cropping plans.

(1) Adjustment of cultivation area

Over-production of certain vegetables may be caused by concentration on high profit crop cultivation. To control such over-production, it is necessary to adjust the cultivation area among the farmers, especially with regard to vegetables. Allotment of vegetable cultivation areas for each farm are shown in Tables 3.5.3 and 3.5.6. Based on these Tables, it is necessary for the extension staff to support the adjustment of cultivation areas among the farmers.

(2) Strengthening Seeds and Seedling Supply System

It is necessary to establish a supply system for seeds and production materials which corresponds to the needs of farmers; especially, a system to supply high quality Date seedlings is necessary. Considering the 272 ha of land area proposed for the cultivation of Dates, it is necessary to propagate around 42,500 Date seedlings (156 seedlings/ ha). Date seedlings are produced at the agricultural examination center of the central area agricultural division in Al Dhaid. This center acts as one of the agencies for the production of tree crop seedlings in UAE. As there is a 419 ha area of cultivation under this center, it is necessary for the government to extend support for supplying facilities and materials.

(3) Technical support

There are five extension units in the Study Area and 1 to 2 extension officers are working in each unit. At present, the promotion of fertilizers, agricultural chemicals and seeds are their main activities. It is necessary to strengthen technical support regarding vegetable cultivation and irrigation technology. There is a serious problem of salinization caused by over-irrigation in the Al line area, and guidance regarding suitable irrigation technology is necessary for effective water use and prevention of salinization. For this purpose, it is necessary to increase the number of extension staff by another two people in each unit.

An improvement in the abilities of the extension staff is also important and a seminar for extension staff has been convened for this purpose. However, according to data gathered during the inventory survey, further technical support by extension officers is required because reliance on the extension officers has decreased. Therefore, further technical training such as study courses arranged by the agricultural examination center are suggested.

(4) Implementation of practical tests

It is necessary to suggest suitable crops, optimum farming practices and appropriate irrigation methods based on the results of practical tests. Systematic field testing on these matters was carried out by UNDP/FAO in 1982 to 1983 and it is recommended that this be continued at the agricultural examination center of the central region agriculture division. Especially, suitable crops for the present off-crop season (July to October) are required. Therefore, implementation of research and development for suitable crops and related technology is highly recommended.

(5) Training of farmers

It is suggested that the government provide training for farmers. Facilities belonging to the agricultural examination center of the agricultural division of central region should be made available. Guidance on the technology of production, post harvest and food processing, the introduction of new varieties and strains of crops, and the supply of marketing information would be the important contents of the training.

(6) Strengthening of governmental support for agricultural promotion

Several low priced vegetables are imported to UAE supported by government and on agriculture and local farmers are forced to compete with such imported foods. It is necessary to maintain the present governmental assistance system for agriculture in UAE considering that sustainable agriculture is very difficult given the limited natural