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NATURAL RESOURCES, SCIENCE AND TECHNOLOGY DIVISION

DEVELOPMENT OF GUIDELINES FOR THE ECONOMIC USE OF WATER IN THE ESCWA REGION

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IV. WATER SITUATION IN ARID ECWA COUNTRIES (GROUP 1)

A. Introduction

The member countries of this group include Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates.

Precipitation and groundwater represent the only natural water resources in this group. There is evidence of shared underground water resources between the Gulf States and the eastern part of Saudi Arabia.

The rapid urban and industrial development in these countries and the huge increase in oil production, particularly in recent years, made it imperative to augment the limited natural water resources supplies by resorting to desalination of seawater and brackish groundwater.

Common characteristics of Group 1 member countries are mainly as follows:

1. They are all arid oil-producing countries whose development depends mainly on oil revenue. Taking the present production and transportation cost, including water cost, as $7 per barrel of crude oil and the present selling price of $29 per barrel of oil (referred to Noterdam, Holland), would leave a net profit of $22 for every barrel sold. A substantial portion of the revenue thus accrued has been and is being wisely spent by the Gulf States on such items as urbanization, including water-supply and sewage schemes, light industries and education;

2. They all lack adequate natural water resources, fertile arable soils on any reasonable scale and suffer from adverse climatic conditions, such as very low precipitation (zero in some inland deserts), erratic intense rain showers of short duration, high relative humidity in the coastal areas approaching 100 per cent and low relative humidity approaching zero in the interior desert regions, very high temperatures, in summers, high annual evaporation rates, ranging from 2 to 2.5 per annum, moving sand dunes etc;

3. They all had to resort to augment their limited water resources by unconventional methods, mainly desalination of seawater and sewage effluent recycling schemes to meet the growing water demands imposed upon them by their continuing development and their population rate of growth;

4. Due to their shared underground aquifers, any overpumping in Saudi Arabia has resulted in the decline of ground water quality and levels in the other Gulf countries and visa versa;

5. Seawater intrusion into aquifers is experienced mainly due to overpumping of groundwater near the coast.

B. Country studies

A country by country study of the situation is presented below:

Bahrain

1. General: Bahrain comprises 33 islands in the Gulf, located about 32 km, from the eastern coast of Saudi Arabia and slightly further away from the Qatar Peninsula. The total area of the country is 670 km^2. The area of Bahrain island alone is about 564 km^2. According the April 1981 census, the total population is 358,570, including 116,000 non-Bahrainis.

The climate is hot and humid, with summer temperatures rising to 45° and 50°C. Winter months are milder, with temperatures around 10° to 20°C. Rainfall is irregular, occuring generally during the winter months of December and January. The annual rainfall varies from 50 to 120 mm, with an average value of 75 mm. Bahrain experiences a high relative humidity which often approaches 100 per cent. Evaporation averages from 1.8-2.0 metres per annum.

Topographically, there is little pronounced variation in the elevation of the land surface above mean sea level.

2. Water resources: There are no appreciable surface waters and the groundwater is the major water resource available in Bahrain. The aquifer system composed of carbonate rocks are the following ones:

(a) System A: The Alat Limestone. Thickness of aquifer is ± 80 m. Depth to aquifer is less than 50 m Quality of water is fair. Soluble salts content is about 2000 ppm with low yielding wells;

(b) System B: The Khobar Limestone whose thickness is from 40 to 55 m with a water quality of 2000 to 5000 ppm. The depth to aquifer is from 20 to 110 m, with high yielding wells;

(c) System C: Consists of the UMM or Badhuma formation with permeable sections of the Rus formation. The aquifer thickness is 350 to 400 m. The depth of the aquifer ranges between 100 to 300 m, and the water quality in this aquifer is poor with soluble salts amounting from between 10,000 to 33,000 ppm 1/;

(d) System D: Wasia Aquifer. A fourth aquifer occurs at depths ranging from 400 to 700 m below ground level which is not yet developed. The total dissolved salts are less than 6,000 ppm. Water bearing characteristics of this aquifer are not yet identified but it is known to contain high temperature water in Saudi Arabia 2/.

It is genrally reported that the aquifer systems in Bahrain are recharged indirectly in Saudi Arabian territory. They are of the depleting type as the annual recharge is essentially lower than the natural and artificial discharge.

1/ Italconsult, Water and Agriculture Studies in Bahrain, Final Report, (Rome, September 1971), vol 1., pp.1-8.

2/ Government of Bahrain, Water Resources Situation, Memorandum No.6 (Ministry of Works, Power and Water, 1979), pp.1-12.

The three main aquifers, Alat, Khobar and Umm or Radhuma are hydraulically connected and often from one aquifer system.

There are three major factors affecting the groundwater quality in Bahrain: Seawater intrusion due to the prevailing overdraft conditions and resulting decline in head, upward leakage from the aquifer and the return of irrigation water to the shallow aquifer system.

Some surveys indicate that the main aquifer has lost one to two metres of head in the last 25 years, with a corresponding increase in the salinity of the water. Bahrain is situated on the outer fringe of this main aquifer, the centre of which is in Saudi Arabia. The increased withdrawal on the continent in the past has also had negative effects on the Bahrain groundwater potential.

3. Water development strategies: Bahrain's development of groundwater dates from the remotest ages of antiquity when local inhabitants used the flow from springs to distribute the water either by surface canals or by underground aqueducts. Most of these springs and canals are now dry.

Well-drilling began in the mid 1920s and accelerated during the 1940s. Drilling was generally continued through both the Khobar and Alat aquifers. In 1971, more than 900 drilled wells existed. The Umm er Radhuma aquifer is developed to any extent in Bahrain since the water is quite saline

In Bahrain about 70 per cent pumped groundwater is used for agriculture and 30 per cent for domestic purposes.

The Directorate of the Ministry of Works, Power and Water is running the Sitra Power/Water Station where there are two distillation units with rated capacity of 2.5 mgpd each. During May-September 1978 the average water production was 1.6 mgpd. Plans were approved to install three other distillation units at the Sitra Station each having a rated capacity of 4 mgpd giving rise to a maximum distillate capacity of 17 mgpd with an average output over any year of 11.5 mgpd.

Distilled water is blended with brackish or saline water to produce water supply having a Total Disolved Solids (T.D.S.) content not exceeding 1000 ppm1/.

The central areas are served with blended water (T.D.S. 2350 mg/1) with a blending ratio of 2:1 comprised of 2 parts groundwater and 1 part distillate.

A distribution system exists for the whole area. A tanker service is still partly in use but because of the poor water quality no charges are collected for the distributed water, although water metres are installed in most of the houses. A uniform monthly charge of 800 fils for each household is the only water tariff collected.

1/ Government of Bahrain, "Policy on Water Distribution Blended Supplies and Capital Investment Requirements" (Ministy of Works, Power and Water, January 1979), pp.1-8.

The Water Supply Department estimated the consumption in litres/ capita per day in 1980 for different areas as follows:

Manama	413
Muharraq	403
Rifa'ar	482
Isa town	422
Greater Manama	367

Over the period 1977-1979 new distribution systems including house connections have been installed in sixteen villages.

With the exception of Isa town, waste-water has been generally discharged to septic tanks in Bahrain. The construction of a sewerage project started in 1976. The treatment plant will serve, in the first phase, 200,000 inhabitants.

In the rural areas "packaged" treatment plants have been constructed.

The water demand projections in U.S. gallons per capita per day for the year 2000 for Bahrain were estimated as follows1/:

Water demand in gallons per capita per day (GCPD)

Municipal	Industrial	Agricultural	Total
116	214	108	438

The projected expected population of Bahrain in the year 2000 was estimated at 470,000 persons.

Kuwait

1. General: the State of Kuwait lies at the northwest corner of the Arabian Gulf. The total area of the country is 17,818 km^2, including off-shore. The population of Kuwait was over 1,350,000 in 1981 2/. The country may be classified as urban only. The relief of this country is low to moderate with the highest elevation about 300 m above sea level.

The climate is characterized by extremely hot dry dusty summers with an average maximum daily temperature of 45°C, and mild to cool winters with temperatures of 1°C. Mean rainfall is about 110 mm, and usually June to September is the dry period. Evaporation greatly dominates the whole climatic year, the highest rate occuring in June and July, (approx. 15 mm per day). Relative humidity reaches a minimum of 12 per cent and a maximum of 100 per cent.

The frequent winds from the northwest are cool in winter and spring and hot in summer. Southeasterly winds, usually hot and damp occur between July and October; hot and dry south winds prevail in spring and early summer.

1/ United Nations Economic Commission for Western Asia (ECWA), The projection of water demands for ECWA countries by the year 2000 (E/ECWA/NR/CONF.3/8) (Beirut, 1 December 1978), pp.44-46

2/ World Bank, Statistical Year book, 1981, p.141.

2. Water resources: There are no pernnial surface waters, and groundwater is the main source of supply.

The main geological formation known to contain usable groundwater in Kuwait are the Kuwait and Hasa groups. The Kuwait group which is the upper clastic unit is subdivided into three formations: (a) the Dibdibba formation; (b) Faks formation; and (c) Ghar formation.

The Hasa group which is the lower carbonate unit is also subdivided into three main formations: (a) the Dammam formation; (b) Rus formation; and (c) Umm er Radhuma formation.

The most important of the above are the Kuwait group and the Dammam formation of the Hasa group. Silt and clay occurs in different percentages in the Kuwait which is unconsolidated, while Dammam consists of fissured limestone. The Kuwait group ranges in thickness from 60 to 300 m and overlies 120-200 m of the Dammam formation which, in turn, overlies the relatively impermeable Rus formation. In general, the aquifers system can be considered as a multi-layered leaky aquifer system with variable boundary conditions. Based on the quality of water, there are two main groundwater resources in Kuwait: fresh groundwater in the Rawdatain field and the UMM Al-Aish Field and brackish groundwater in Sulaibiyah.

Fresh groundwater from the Rawdatain and Umm Al-Aish well fields is being utilized after chlorination as drinking water for the nearby town of Jahrah and surrounding areas. Fresh water is being produced at the rate of 10,000 m^3/d from both fields.

Brackish groundwater from the Sulaibiyah and Shagaya fields is used for mixing with distilled water to be used for drinking in Kuwait city and other parts of the country. The mixing rate is at a percentage of 120. During the summer, the production of the Sulaibiyah field is increased to as high as 55,000 m^3/d owing to higher demand.

Sulaibiyah water is used for municipal needs not requiring a low dissolved mineral content.

The magnitude of natural recharge of the aquifers have not yet been determined. Part of it comes from infiltration locally received through wadis and depressions scattered over the country. Another portion is made up by the underflow from Saudi Arabia under natural conditions through the Dammam formation. Total recharge is thought to be less than the level of present withdrawal.

The water in the Rawdatain basin ranges from fresh (about 200 ppm of TDS) to brackish (about 8,000 ppm of TDS). The freshwater body overlies and is surrounded by more brackish water with the freshwater surface in the upper aquifer. Groundwater moves through the upper aquifer under water table conditions and through the middle and lower aquifers under artesian conditions. Pumpage of the field at the high rate showed a deterioration in quality, especially when demands for water from Rawdatain reach the maximum in the summer.

3. Water development strategies: If the quantity is adequate and the quality is satisfactory, groundwater is utilized for irrigation as is practiced in the Sulaibiyah and Shagaya fields.

The potable water supply relies mainly on desalinated seawater blended by brackish groundwater and on limited quantities of potable groundwater of suitable quality which does not exceed on average 6,800 m^3/d. Table 11 lists the existing and planned desalination plants in Kuwait.

Table 11: Existing and planned desalination plants of Kuwiat

Plant desalination	Year of commission	Number of units	Output of each unit (MIGD)	Total output (MIGD)
Shuwaikh				
E1 E2	1960	2	1.0	2.0
F1 F2	1965-66	2	1.0	2.0
G1 G2	1968	2	2.0	4.0
New B1 B2	1968	2	2.0	4.0
New A	1970	1	4.0	4.0
Shuaiba North				
A1 A2 A3	1965-66	3	1.0	3.0
B	1968	1	2.0	2.0
C1 C2	1968	2	2.0	4.0
D	1971	1	5.0	5.0
Shuaiba South				
A1 A2 A3 A4	1971-72	4	5.0	20.0
A5 A6	1975	2	5.0	10.0
Doha East				
A1 A2 A3	1978	3	6.0	18.0
A4 A5 A6 A7	1979	4	6.0	24.0
Shuaikh	1983-84	-	-	72.0
Doha West	1985	-	-	96.0

Source: Al-Nasir Al-Saoud, Water (Saudi Arabia, Ministry of Energy and Water, Water Resources Development Centre, 1978), p.11

Note: Shuwaikh E1 E2 and Fi F2 will soon be scrapped to make way for the new Shuwaikh units.

At present, the total production capacity of public well fields (i.e. new water well fields) amounts to about 341,000 m^3/d of brackish groundwater. The total installed capacity of 27 operating desalination plants is about 523,000 m^3/d. The average and maximum estimated demand in 1981 were calculated to be 311,000 and 385,000 m^3/d of potable water, and 130,000 and 221,000 m^3/d of brackish groundwater.

The water supply system consists of two distribution networks, one for drinking water and the other for brackish water, which is used for irrigating public and private gardens as well as for some agricultural and municipal uses.

From 14 pumping stations the fresh and brackish waters are distributed from main underground reservoirs to several main water towers in groups, filling stations for tankers and house connections. The amount of water losses have not been estimated.

About 75 per cent of the people are supplied through house connections and the rest by tanker service. This means that the total population is already being supplied with safe water. The consumption rate in 1980 was estimated at 222 l/c/d and in 1981 at 225 l/c/d for fresh water and 92 l/c/d and 93 l/c/d for brackish water.

The water tariff for piped water is as follows:

(a) for drinking water (about 500 mg/l TDS: 800 fils per 1,000 gallons = 4.45 m^3;

(b) for brackish water (about 3,500 mg/l TDS): 750 fils per month.

Information about the present water production cost was not available.

In 1972, the first sewage treatment plant, with a capacity of 100,000 m^3/d began operating. It operates now 90 per cent capacity.

At present, 70 per cent of the population is served by house connections and the rest by septic tanks. The users of the system are not charged for waste water disposal.

About 65 per cent of the secondary-treated effluents are used for irrigation.

According to some estimates, the maximum water demand will amount to 776,000 m^3/d in 1985 and 1,210,000 m^3/d in 1990. The water demand projections in U.S. gallons per capita per day for the year 2000 for Kuwait were estimated as follows 1/:

Municipal	Industrial	Agricultural	Total
68	540	123	731

The projected population of Kuwait in the year 2000 was estimated at 2.2 million persons.

The total amount of fresh water that will be available by 1985 is estimated to be 1,026,000 m^3/d, including 10 per cent blending.

The water demand in 1990 is estimated as follows:

Maximum	1,534,000 m^3/d
Average	1,226,000 m^3/d
Consumption rate	590 l/c/d

Studies are underway on an additional desalination plant, with a projected capacity of about 750,000 m^3/d, to help meet the demand in 1990. The second stage of the distribution system is already under construction. Once this stage is completed, the total population will have access to piped fresh water. Phases 2 and 3 of the Kuwait Sewerage System are also under construction. Two treatment plants with a total capacity of 250,000 m^3 are about to be completed. The total quantity of effluents will be re-used for agriculture. This will mainly serve the agriculutral areas of Sulaibiyah, the research station and the areas earmarked for forestry plantation. A modified project for this purpose, costing over KD 60 million is expected to be completed within the next few years.

Qatar

1. General: The State of Qatar is an arid peninsula about 180 km long and with a maximum width of about 85 km, protruding into the Gulf as an appendix to the Arabian Peninsula. Qatar has a surface area of 11,610 km^2.

The population is about 262,000 (1980). Qatar lies wholly within the northern desert belt. The relief is low to moderate with the highest elevation of 103 metres above mean sea level.

Annual average rainfall is 50 mm in southern Qatar and 80 mm in the central region. Maximum temperatures exceed 42°C (July/August), minimum of 7°C (February-May). Evaporation ranges from 2.5 mm/day in winter to 11.5 mm/day during summer.

2. Water resources

(a) Surface water: rainfall water is the primary surface water reosource all over the peninsula, occurring as winter storms covering the whole country during December-February.

1/ UN/ECWA The Projection of Water Demands for ECWA Countries by the Year 2000, E/ECWA/NR/CONF.3/8 (Beirut 1 December 1978), pp.44-46.

(b) Groundwater 1/: limestones and dolomites of the Rue and Dammam Formations from the principal aquifer system in Qatar. They outcrop over the entric peninsula and over the older rock units which contain highly saline groundwater.

Depth to water level generally varies from close to ground surface along the coastal areas to about 80 metres below ground level at some locations in south Qatar. Free water table conditions generally prevail in the peninsula except in southwestern Qatar where confining beds occur and provide artesian conditions.

Seawater intrusion along the coastal margin and upward leakage from the underlying connate saline water control the groundwater quality in Qatar. In northern Qatar fresh groundwater with TDS from 400 to 2000 ppm is known to occur in floating lenses over brackish and saline groundwater often occuring in the Umm er Radhuma formation.

Except for small isolated lenses of groundwater of 2,000-3,000 ppm, the groundwater quality in the southern area range from 3,000 to 6,000 ppm.

Based on groundwater occurrence, quality and aquifer characteristics, two distinct groundwater provinces have been recognized:

(i) The Northern Groundwater Province: It comprises the northern half of the peninsula starting from just south of the Doha-Dukhan road. Groundwater occurs as freshwater floating lenses within the limestone-dolomite succession of the Dammam Rus formation overlying the brackish and saline water in the older rock units. The estimated freshwater stored in this province is about 2,500 MCM. The estimated real extent of the groundwater body having TDS of less than 2,000 ppm is about 2,180 km^2 which is 20 per cent of the Qatar area.

The fresh groundwater body in northern Qatar is currently undergoing a water level decline and shrinking in its real extent due to overtapping since 1966;

(ii) The southern groundwater province: this province encompasses slightly more than half of the land area of Qatar and its hydrogeological conditions are complex. Groundwater occurs at deeper levels, recharge is less and if poor quality. Brackish water occurs throughout southern Qatar. The water well field of Rawdat Rashid is the only major source of groundwater extraction.

In the southwest of Qatar near Abu Samra post, fresh groundwater of artesian has been encountered with TDS values of 3,000 ppm. The source of recharge in this area is believed to be from Saudi Arabia.

1/ United Nations Development Programme/Food and Agriculture Organization of United Nations (UNDP/FAO), The Water Resources of Qatar and Their Development, Preliminary Report No.1 1979.

The average recharge in northern Qatar is about 16 per cent and in southern Qatar it is about 14 per cent of the accumulated effective rainfall in excess of 10 mm/d. Table 12 shows the annual variations of recharge in different regions of Qatar;

Table 12: Recharge data in Qatar

Area	Mean annual recharge (MCM)	Minimum annual recharge (MCM)	Maximum annual recharge (MCM)	Equivalent percentage of effective rainfall in excess of 10 mm per day
Northern Qatar	17.6	5.5	26.3	16%
Southern Qatar	14.2	3.3	30.1	14%
Over the peninsula	31.8	8.8	56.4	9%
Over the peninsula for long-term 18 years 1958-1976	30.0	7.0	44	-

Source: UN/ECWA Assessment of Water Resources in the ECWA Region (E/ECWA/NR/L/1/Rev.1), (Beirut, January 1981), p.174.

3. Water development strategies: historically, groundwater was obtained from shallow wells, springs and caverns (dahl). Prior to the early 1960s all municipal water supplies were derived from pumped groundwater. The exploitation of groundwater has paralled oil production. There has been a steady increase in groundwater withdrawal for both municipal and agricultural use, rising from about 6 million m^3 in 1958 to about 80 million m^3 in 1980. Extraction was then reduced when the full extent of overwithdrawal of the northern aquifer was determined as a direct measure taken towards groundwater conservation in Qatar.

Desalination of seawater has provided an increasing proportion of domestic and industrial water needs, and by 1980 accounted for 44.4 million m^3, of which 33.4 million m^3 were produced from Ras Abu Fontas and 11 million m^3 from the Central Desalination Plant at Ras Abu Aboud. Brackish groundwater from Doha (TDS about 10,000 mg/1) is utilized as blending water with distilled water. Other desalination plants operate as separate, closed supply and distribution networks. One of the largest of such plants is the one operated by the Qatar Fertilizer Company, which has a total installed capacity of 2.9 million m^3. Another source of water is brackish groundwater derived from the Alat aquifer in southwestern Qatar. This water is used on a limited scale for agriculture and, after treatment by reverse osmosis, provides the domestic supply to Abu Samra.

Effluent water is used principally for the irrigation of trees and public gardens in Doha.

In 1974 the estimated cost of desalinated seawater was QR 1.15 per m^3; for pumped groundwater for domestic uses it was QR 1.62; and for pumped groundwater for agricultural uses it stood at QR 0.10 per m^3. However, the main difficulties in assessing the cost of desalinated water arise from the fact that the government has not assigned a value to energy, mainly natural gas. On the basis of energy at equivalent oil prices, the cost was estimated to be QR 4.00 ($1.10) per m^3 for the same year.

At present, almost every person in Qatar, including nomadic Bedau, have access to and are supplied with safe drinking water conforming to all World Health Organization (WHO) specifications. This is provided either free of charge, or at a nominal tariff compared with the economic cost of distillate production.

The bulk of the population of Doha is served by piped water. Only the outskirts are served by tankers, which use central filling points. 85 per cent of the total population live within greater Doha, whilst a further 8 per cent live in three large other towns, Wakrah, Khor and Umm Said. Work on both water distribution and sewerage schemes is already well underway in all three places.

Work is also underway to provide all 7 settlements of over 100 houses with either piped or locally distributed water and an adequate sewerage system. This accounts for a further 4 per cent of the population, leaving only the remaining 3 per cent piped systems, but with adequate supplies of tankered water from local well fields maintained and managed by the water Department.

The following table shows the development of the total domestic and commercial water consumption (in million m^3) between 1975 and 1980:

Table 13: Development of total domestic and commercial water consumption (in million cubic metres) between 1975 and 1980.

Year	Groundwater	Desalinated seawater	Total
1975	6.2	10.4	16.6
1976	6.1	10.2	16.3
1977	6.0	14.8	20.8
1978	5.4	23.1	28.5
1979	4.6	31.9	36.5
1980	3.7	44.3	48.0
1981	2.8	50.4	53.2

Source: Food and Agriculture Organization (FAO), The Water Resources of Qatar and Their Development (Rome, FAO, 1981), and UN/ECWA, The International Drinking Water Supply and Sanitation Decade Activities in the ECWA Region (Baghdad, 1983), p.108.

House connections are equipped with metres and a tariff system exists for piped water. On the other hand, tanker delivered water is cheap and is stored in ground tanks installed in many houses. The daily consumption of villa with a garden is estimated to be 4500 L. Garden watering is estimated to account for 35 per cent of the potable supplies used for domestic purposes. A rough estimation of the per capita daily water consumption is 480 l/c/d (including the part for garden watering). This figure is calculated on the basis of a population of 262,000 and a total water consumption of 48 million m^3 in 1980, with 2 MCM/year for industrial use.

Work on a piped sewerage system in Doha was commenced over 25 years ago. This system was extended by 1976 to provide capacity to treat the sewage flow from a population of 90,000. There are now more than 20 operational pumping stations in Doha.

Increasing amounts of secondary treated and chlorinated effluent have been made available for the irrigation of trees and public gardens in Doha since 1974. By 1980, this amounted to 0.7 million m^3 with a salinity concentration of 2800 mg/l, much of it accuring from leaking sewers along the city foreshore below high tide level. Over 60 km of pipelines have been laid under Doha's main roads to enable disinfected effluent to be returned to tanker filling gantries from where the effluent is used for roadside tree watering. Currently, less than 5000 m^3/d of effluent is used in this way. The surplus effluent is presently discharged to a wadi. Main sewerage services are now being extended to areas outside Doha. At Umm Said, a sewerage treatment plant is already functioning and a similar plant, which has been built at Al-Khor, will be commissioned shortly. In smaller areas "Packaged" treatment plants have been constructed to serve isolated developments. Isolated villages are served by septic tanks. The number of people served by adequate sanitation is roughly estimated to be 75 per cent.

Estimates by the Water Department indicate that an average per capita water demand of 0.61 m^3/d in 1979, will increase to 0.91 m^3/d by 1990 and remain constant thereafter. This figure seems to be too high and may be reduced by conservation measures. The resulting projection is shown in the following table:

Table 14: Per capita and total water demands in Qatar for the years 1980, 1990 and 2000

	Year		
	1980	1990	2000
Total population	262,000	345,000	437,000
Population served	249,000	334,000	428,000
Demand per capita:			
Average (l/c/d)	610	610	610
Peak (l/c/d)	910	910	910
Average total demand (m^3/d)	151,890	210,350	266,570
Peak total demand (m^3/d)	226,000	305,000	390,000

Source: Government of Qatar, Projection of Per Capita and Total Water Demands in Qatar for the years 1980, 1990 and 2000 (Doha, Water Department, 1979).

Here it is assumed that 5 per cent of the population in 1980 had no access to main water and that this proportion would decline to 2 per cent by 2000.

United Arab Emirates

1. General: The United Arab Emirates lies in the southeastern corner of the Arabian Peninsula to the north of Oman and the Rub-Al-Khali Desert.

The total area is 77,700 km^2, and politically, the country is composed of the following Emirates: Abu Dhabi (67,350 km^2), Ajman (250 km^2), Dubai (3,900 km^2), Fujairah (1,150 km^2), Ras El-Khaimah (1,700 km^2), Sharjah (2,600 km^2) and Umm-el-Qaiwan (750 km^2). The population was estimated to be 1,000,000 in December 1980.

The country is largely a desert area and only the region to the north of Oman is mountainous with elevations exceeding 1000 m above sea level.

The inland areas are typical of the desert. Annual average rainfall is about 100 mm and the total varies from year to year. Rainfall usually occurs in December, January and February. The maximum temperature is about 47°C (July-August) and the minimum mean temperature is 9°C (December-January). The coastal climate is hot and humid. The average humidity throughout the year is 61 per cent, with a recorded range of 10 per cent to 100 per cent.

2. Water resources

(a) Groundwater: It is the major natural water resource within the Emirates, and the resources of good water quality are limited.

There are three main aquifer systems which constitute the groundwater resources of the country. They are as follows: (i) the shallow alluvial aquifer underlying the central gravel plain and desert foreland; (ii) the Batinah coastal plain aquifer; and (iii) the deep carbonate aquifer1/:

(i) The Alluvial Aquifer System. This is an important aquifer system in the Emirates. It is composed of deposits of boulders, cobbles, pebbles, gravel and sand. The productive zone within the aquifer is restricted almost to coarse alluvium. The saturated thickness of the productive zone rarely exceeds 10 metres in the central gravel plains. Along the coast the saturation zone extends upwards into the overlying sand sediments. Water is of good quality in the upper reaches of the main wadis, the quality deteriorates eastward towards the coast.

The reservoir capacity of the aquifer system is considerable. Surface run-off from the western slopes of the mountains is the main contributing source to the groundwater recharge, which totals about 100 MCM annually on the average.

1/ W. Barber and D.P. Carr, Preliminary Appraisal of Water Resources, Phase 1 (United Arab Emirates, 1976), p.31.

Overdraft conditions are currently occurring in the aquifer system, however, the volume of good quality water stored within the aquifer is considerable. Hence, mining of groundwater from this aquifer is possible provided that careful water abstraction is well undertaken;

(ii) The Batinah Coastal Plain Aquifer: it is another alluvial aquifer comprising deposits which from an almost continuous littoral strip extending from the Musandam Peninsula to the Omani Frontier along the Batinah.

Recharge to the aquifer is mainly from the surface run-off from the wadis adjoining the western mountains and draining eastwards towards the Batinah coast. Well yields from the alluvial fans are high. Depth to water level is shallow but water levels are only a few metres above sea level. The total renewable resources are expected to be adequate for future development. Water quality is generally fair, but deteriorates eastwards;

(iii) The Deep Carbonate Aquifer System: the aquifer system is composed of thick carbonate rock sequences underlying the region to the west of the Oman mountains extending to the area of Al-Dhabrah in southern Abu Dhabi. Groundwater movement in the aquifer is westwards away from the recharge zone over the Oman mountains. The aquifer is drained naturally at the Sabkhas in the Al-Uriq al Mutaridah region.

The aquifer is under artesian conditions with a hydraulic head at or the near the surface in Al-Ain or in the desert foreland areas, and is unconfined at other places.

Groundwater quality encountered in this aquifer is generally poor. No estimates are available for the storage capacity and the groundwater recharge.

In many areas of the Emirates water has been provided by open wells and falajs. Open wells were dug by hand and water extracted by a stick tied to a rope attached to a bucket or by an animal-powered rope-and-pulley system for irrigation and drinking purposes. Falajs, include open channels cut into the sides of hills, covered aqueducts and tunnels. In Burami they yield a continuous supply of over 340 l/sec of good quality water, but elsewhere the yields are much lower. The length of the falajs in the Emirates ranges from 1 to 6 km.

In the past twenty years or so, mechanical means for extraction of groundwater has been widespread.

The sources of water for urban use for the Emirates are the following well fields, some of which are being overpumped:

Emirate	Source of water for urban use
Abu Dhabi	Desalinated water mixed with ground water from Al-Ain
Dubai	Awir and Wahoosh well field
Sharjah	Bidaat well field
Ajman	Tawi Rashid well field
Umm Al-Qaiwain	Zarqa well field
Ras Al-Khaimah	Burirat well field
Fujairah	Fujairah well field.

Aquifers are recharged by the run-off from the mountains on rainy days. Since floods are of short duration and high intensity, the infiltration cannot compensate for the decline in water levels in some areas. The government has planned to control the water from floods and recharge the groundwater with it.

The Ministry of Agriculture and Fisheries (MAF) has plans to control and minimize the consumption of water and the pumping rate, which will result in saving more water for areas under irrigation. Drip irrigation and sprinklers together with lined channels or pipes will be used for central irrigation;

(b) Surface water resources: most of the precipitation in the Emirates falls over the mountain region, characterized by erratic, rainfall of intense but short duration, which gives rise to damage-causing floods of varying magnitudes. The table below shows the estimated peak flows and the probable flood volumes flowing in the main wadis of the Emirates.

Table 15: The Probable volume of the streamflow in some wadis in the United Arab Emirates

Flood discharge measured at	Peak flow m^3/sec	Probable duration hr.	Probable flood volume (MCM)
*Wadi Qar (near Jabal Falaj)	42.5	20	1.500
Wadi Ham (near Bithna)	29.4	2	0.105
Wadi Siji (near Siji)	50.5	4	0.360
**Wadi Lamhah (near Falaj Al-Mu'lla)	87.4	20	3.140
Wadi Lamhah (near T. Qaran)	54.7	12	1.180
Wadi Bih (near Burayeat)	190.5	54	17.440
Wadi Bih (near Al-Fulayyah)	58.4	15	1.580
Wadi Semaini (below T. Bahuth)	76.5	20	2.760

Source: Ismail M. Al-Mohaylam Water Resources, (United Arab Emirates, Abu Dhabi: Ministry of Electricity and Water, 1976), pp.1-7; see also

* Flows assessed by survey of trash marks.

**Flows measured by autographic recorders.

UN/ECWA, Assessment of the water Resources Situation in the ECWA Region. (E/ECWA/NR/2/1/Rev.1) (Baghdad, 1981) p.230 (hereinafter called Water Resources in ECWA Region).

Studies so far indicate that there are no sites suitable for major surface water storage projects. Potential reservoir sites are small, steep and would be costly. Flood waters are highly charged with suspended sediments and the useful life of storage reservoirs would be very short. However, flood retention structures, such as spreading dikes and spate breakers, for the objective of groundwater recharge have been found to be beneficial.

3. Water development strategies: the Ministry of Agriculture and Fisheries (MAF) is responsible for domestic water supplies to villages and for irrigation. Loans are available to farmers for pumps and engines. The farmer pays half the cost only in instalments. As a result the cultivated areas are expanding very rapidly. Furrow and basin-type irrigation are dominant. In recent years drip irrigation is being used in the forest development areas which are being grown along the Abu Dhabi/Al-Ain road.

The Ministry of Electricity and Water (MEW) is in charge of the urban water supply obtained from wells and by desalination.

It has been accepted as government policy that the groundwater should be reserved for irrigation. Since the quantity and recharge are limited, and that urban water should be supplied through desalination plants.

The Abu Dhabi water supply, at present, is 60 per cent desalinated seawater and 40 per cent groundwater. All cities are served by piped water. In most cases, the houses are directly connected or partly supplied by tanker service, which is also common in remote areas. According to the latest WHO/East Mediterranean Regional Office (EMRO) statement1/ 1980, 88 per cent of the urban population and 50 per cent of the rural population are served by safe water supplies. Only some remote villages still suffer shortages. All service connections are metered, but it is difficult to determine the actual consumption rates due to heavy garden watering, losses in the systems and poor maintenance of the systems. The report estimates the consumption rates 169 litre per capita per day (l/c/d) in 1975 and 259 l/c/d in 1978. An estimated country-wide consumption rate of 86 gallons/c/d (=390 l/c/d) is mentioned for the present time. Most estimates of domestic demand in the large urban communities of Abu Dhabi, Dubai, Sharjah and Al-Ain are in the range of 70 to 80 gallons/c/d. For smaller urban communities designers allow for an average domestic demand of 40 to 50 gallons/c/d. The water tariff for piped water is Dh 15 per 1,000 gallons in Abu Dhabi.

Sewerage systems exist in the cities of Abu Dhabi, Dubai, Sharjah and Al-Ain. It is estimated that the residences of approximately 60 per cent of the population in the above-mentioned cities are connected to sewerage systems. Chlorinated effluents are re-used in Abu Dhabi in the order of 4 million gallons/day, and in Dubai about 1 million gallons/d for the watercring of trees and municipal gardens.

1/ UN/ECWA, The International Drinking Water Supply and Sanitation Decade Activities in the ECWA Region (Baghdad, 1983), p.98 (hereinafter referred to as Drinking Water Activities in the ECWA Region), p.98

It is the policy of the Emirates and of the federal government to make safe water available to everybody in fully adequate quantities. The availability of modern sewerage systems is considered a basic social service. Because of the limitations of groundwater resources, subsidized drinking water in quantities required can only be achieved by increasing the production of desalinated seawater. In addition, special attention is being given to the re-use of effluents for irrigation.

The following table shows the programme of installation of desalination plants according to the estimated water demand based on data of the country report.

Table 16: The programme of installation of desalination plants according to estimated water demand
(All figures in 10^3 m^3/d)

Place	1981		1988	1998
	Available ground water	Capacity desalinated water	Projected capacity*	Projected capacity*
Abu Dhabi and Al-Ain	29	54	683	1283
Ruwais	-	(1982)32	112	144
Dubai and Jabal Ali	46	65	251	271
Sharjah	60	40	140	160
Ajman	5	-	40	40
Umm Al-Quwain	4.6	--	14.6	24.6
Ras Al-Khaimah-Galilah	18.4	27	140	221
Central region	2.8	-	15.3	15.3
Fujairah and east coast (Plant Quidfa)	23	--	58	58

Source: UN/ECWA, The International Drinking Water Supply and Sanitation Decade Activities in the ECWA Region (Baghdad, 1983), p.100

*Including groundwater as in 1981.

Oman

1. General: Oman is located in the southeastern corner of the Arabian Peninnsula and has a total area of about 300,000 km^2 of which about eighty per cent is made of wadis and deserts. The total population is about 1.5 million.

Oman may be divided into three major regions:

(a) The coastal plain stretching about 1700 km from the Strait of Hormuz to the frontier with South Yemen, which include rugged mountains in the north;

(b) The Omani Mountains in north Oman, known as the Jabal Akhdan uplands, with peaks exceeding 3,000 m and the mountaineous Dhafar region in the southern part of the country;

(c) The Interior Plains in northwest Dhahirah which is a semi-desert plain, sloping from the southern flanks of western Hajar into the Rub--Al-Khali.

There are also some islands.

In Oman, climate varies by season and region. The summer is hot and arid inland, but along the seacoasts there is high humidity. Mountainous areas have low temperatures in winter. The average annual rainfall varies between 300 and 350 mm in the northern mountaineous areas and 350 to 450 mm in the Dhofar Jabal to less than 50 mm in the central desert, if any. On the coast, the rainfall is about 100 mm, and is higher in the foothills. At Muskat the average annual rainfall for 24 years is about 99 mm.

2. Water resources: Surface water resources of Oman are negligible. Groundwater is one of the main natural resources in Oman and its availability is a limiting factor in many sectors of the economy of the country. It has received considerable development emphasis in recent years whcih is leading to an improved government role in co-ordination and establishment of a proper infrastructure. On the basis of data and reports submitted as of 1977. It appears that cautious optimism is justified with regard to the adequacy of Oman's water resources to support planned economic development.

In general, groundwater in Oman is derived either from deep fossil aquifers extending over large portions of the Arabian Peninsula or from recent wadi deposits, alluvial fans and coastal plains along the mountain ranges. In view of the high cost of production from the deep aquifers and the scarcity of the arable lands in the interior, the exploitation of this resource has had to be limited to uses related to the development of petroleum and mineral resources. Most extraction has taken place at the shallow aquifers.

Main aquifers in Oman are as follows: (a) in the northern coastal plain; (b) in the Oman mountains and interior plains; and (c) in the Dhofar-Salalah plain.

(a) Northern coastal plain (Batinah plain): the aquifer system of the Batinah Plain is contained in a wedgeshaped body of alluvial deposits which thicken from a feather edge adjacent to the mountain front towards the sea. Saturated thicknesses are as much as 100 m locally, but generally do not exceed 30 to 40 m.

The hydraulic gradient slopes towards the coast. It averages about 1 in 100 where the flow is predominantly in the clay gravels, but slackens rapidly to less than 1 in 2500 as the thickness of saturated upper gravels increases adjacent to the coast. Present extraction for irrigation is essentially concentrated in the coastal strip where waterlevel elevations are less than 2 m above sea level;

(b) Oman mountains and interior plains: the groundwater resources of the Oman mountains are developed in the narrow bottoms of deeply incised valleys which form line sinks for the groundwater discharge from the hills either naturally as springs or base flows, or is developed by means of drainage galleries, known as falajs. Land limitations prevent any important extension of the irrigated areas and available water is often in excess of requirements. Excess water moves down-gradient through valleys to the benefit of users of lower aquifers on the plains.

The groundwater of the interior plains is contained in a relatively thin cover of coarse clastic materials overlying clay deposits which in turn overlies bedrock of low permeability. Its thickness, however, is generally less than 10 m, though it may be up to 50 m in local depressions and along wadi channels. The exploitable groundwater is, therefore, erratically distributed. The irrigable land is also distributed in small areas which do not necessarily accord with the availability of water. An exception is the Wadi Qurayyat plain where 2,900 hectares of new lands have been mapped, though the water resource to supply this land has not been identified;

(c) Dhofar-Salalah plain: the Salalah Plain is about 50 km wide and a maximum of 15 km long. It is bounded to the south by the sea and to the north by mountains. Groundwater occurrence is related to carbonate rocks and conglomerates. Recharge is by underflow from the mountain range and by springs which discharge at the foot of the mountains. Flood occurences on the plain are extremely rare. The recharge appears to be very slight, although there is a fair amount of rainfall on the mountain catchment; much of this, however, occurs in the form of mist. The groundwater quality is generally poor except in the central part of the plain behind Salalah.

In carbonate aquifers, low water levels, the high cost of well construction and low yields combine to preclude the use of groundwater for irrigation. In addition, soils are patchy and thin, development for domestic use and cattle watering appears feasible.

Little is known about groundwater conditions on the interior pleteau (Nejd), where artesian flows are obtained in some areas, and the water quality is generally poor.

The main problems affecting groundwater resources and applied solutions are as follows:

(a) Saline seawater intrusion: this phenomenon is monitored in several places and countered by moving the extraction zone back from the coast;

(b) Net surface flow losses to the sea or the desert: Recharge schemes are being prepared which will not only minimize losses and recharge the alluvial fans, but will also help in the control of saltwater intrusion;

(c) Inefficient water use: to overcome this, educational effects are being directed towards the introduction of water-saving techniques and practices.

In addition to groundwater, desalination provides supplies in some areas.

3. Water development strategies: The sources for domestic water supply are groundwater or desalinated seawater. The groundwater is extracted mainly from hand-dug wells, boreholes or "falaj" systems. In mountainous regions a lot of spring discharges are used.

The water supply system for Greater Muscat has been expanded continuously since 1974. In addition to the distribution network, organized tanker services with tanker discharge points cover the suburbs, where shallow wells are generally used. Groundwater is not treated, but disinfected. Water delivered through house connection or by tanker must be paid for. The price for piped water in the capital areas is 2 Baiza per gallon. New water supply systems have also been built in some of the provincial towns. Due to the absence of sewerage systems, however, the water consumption has to be kept low. Consequently, even though public utilities are equipped with house connections, major distribution is only organized through public standposts and tanker service.

In rural areas people obtain domestic water from springs, or by means of a "falaj" system and hand-dug or drilled wells. The available water supply is often unsafe, particularly when abstracted from hand-dug, shallow wells or from downstream parts of "falaj" channels. During drought seasons serious water supply problems may arise.

According to the latest statement of WHO/EMRO 1/, 1980, 70 per cent of the urban population and 10 per cent of the rural population are served by "safe" water supplies. Water from the springs of Jabal Akhdar is bottled by a private company and avialble everywhere. The price is 150 Baiza per 1.5 l. The water production capacity for Greater Muscat is at present 4.5 million gallons per day from the desalination plant, plus about 4 million gallons per day from private and public wells.

The per capita water requirements for the capital have been estimated to vary between 80-300 l/c/d depending on income-level areas, with an average figure of 200 l/c/d.

The following criteria have been mentioned for domestic water demand for provincial towns in northern Oman in l/c/d 2/.

	1980	1985	1995
Standpipes	50	50	50
Tanker delivery	80	100	150
House connections	100	150	200

The quoted systems losses of 20 per cent are quite low.

The water supply at the capital is about fifty per cent subsdized.

1/ Drinking Water Activities in the ECWA Region, p.85.

2/ Ibid.

There is a sewerage system with a treatment plant in only one part of Greater Muscat, namely in Mutrah. All other areas of the capital and the other towns are served by individual wastewater and excrete arrangements. Septic tanks and soakaway are mainly used in the urban areas.

No orgainzed excrete disposal facilities exist in rural areas.

Saudi Arabia

1. General: Saudi Arabia occupies about four-fifths of the Arabian Peninsula, and has a total area of 2,250,000 km^2, which may be divided into three regions: the narrow coastal plain running along the Red Sea; the mountain range, which is parallel to the coastal plain and has an average elevation of over 1200 m; the great sandy plateau, which is divided into the Great Nafud, the Dahna and the Rub Al-Khali, the world's largest continuous sand area.

Population is estimated to be 8.6 million in 1981 1/, of which about 25 per cent is urban, 61 per cent rural and 14 per cent are nomads (bedouins).

Saudi Arabia is a hot dry country. The absence of any significant surface water and the scarcity and irregularity of rainfall make it almost entirely dependent on groundwater.

The average annual rainfall is less than 100 mm; in the northern part rainfall is between 30 and 90 mm in the Riyadh region between 85 and 100 mm, along the Red Sea coast of Jeddah 250 mm and in the Hidjaz mountains 300 mm.

The average annual summer temprature is 33.4°C, the average annual winter temperature is 14°C. There are wide variations in inland temperatures; during the summer the maximum temperature reaches 50°C; during the night temperatures sometimes drop below 0°C.

Relative humidity is low except in coastal areas where it reaches over 90 per cent. Evaporation ranges from 1.8 m to 3.0 m per annum.

2. Water resources

(a) Surface waters: perennial streams are non-existent. In centre southern Saudi Arabia the most important run-off generating areas lie in the median rainfall belt (between 200-300 mm) away from the mountain region. In the Asir Highlands where comparatively high rainfall and steep gradients prevail a considerable volume of surface run-off takes place. Some perennial flows occurs in the higher regions, but rarely reach the Red Sea;

1/ Ibid., p. 128.

(i) Annual run-off: More than 80 per cent of the kingdom is too arid to support more than a small population of nomads. On average the 2.3 million square kilometres of the country receive only about 100 mm of rain per year and the actual precipitation can very enormously from one year to the next. Only in the southwestern agricultural province of Asir with its mountain slopes which catch the summer monsoon is there enough regular rainfall to support settlements and herding on a relatively large-scale. Elsewhere, the rain tends to fall erratically and usually in too large quantities in the wrong place. Like other desert countries Saudi Arabia is afflicted by periodic flash floods which can be as destructive as they are ill-timed.

It is estimated that all run-off of the country is about 2025 MCM per annum of which 1265 MCM/year runs in the Red Sea coastal wadis and constitutes 62 per cent of all run-off while Najran, Tathlith, Bisha, Ranya and Turaba which drain inland constitutes 24 per cent of all run-off.

In eastern Saudi Arabia, evidence of surface water run-off is almost non-existent. The existence of the Qatif and Hasa oasis and flowing springs corresponds with areas receiving seasonal high intensity rainfall.

There are no perennial streams in the Riyadh region. Records indicated a mean annual rainfall of 85 to 110 over the area. Total run off at this region is estimated as 300 MCM per annum.

Along the Red Sea coast, rainfall over the mountains is stormy and results in sudden floods of short duration. Total run-off for all wadis in this coastal area is estimated as 1610 MCM per annum;

(ii) Dams: A number of dams of various kinds were constructed wherever possible all over the country. The objectives of these dams are mainly to provide drinking water for human and livestock requirements, flood control and conservation, irrigation and artificial groundwater recharge. Up till 1979, 47 dams were constructed with a total storage capacity of 224 MCM.

(b) Groundwater: for groundwater purposes, Saudi Arabia can conveniently be divided into three principal regions: (a) the Tihama coast and Red Sea catchment; (b) the Arabian Shield; and (c) the Eastern Arabian Sedimentary basin;

(i) The Tihama coast and Red Sea catchment: aquifers in the Tihama are of two types: Wadi fill and coastal plain sediments. Water is mostly drawn from springs, underground drainage galleries and wells. In general, groundwater is not used to its maximum extent in this region although there are good aquifers in the Wadi Jizan-Tihama Ash Shaur areas;

(ii) Arabian Shield: the shield area is a vast peneplain of broad shallow wadi beds, wide gravel plains, granite, broad basalt plateaux and seolian sands. Groundwater in the region is restricted to the wadi beds or to jointed or weathered zones where crossed by wadis.

The water is used for livestock and domestic purposes, although there is always limited irrigation development along the principal wadis.

(iii) Eastern Arabian sedimentary basin: This basin is subdivided into two aquifers:

a Non-depleting aquifers: the principal aquifers in the northern non-depleting sector are the saq sandstone and the Tabuk aquifer.

The Saq sandstone covers 16,000 km^2 in the northern regions: the confined areas extends into Jordan, with an aquifer thickness varying between zero and 900 m.

Water is used in some areas for irrigation of wheat, alfalfa, vegetables and fruits. Elsewhere, the water is used for livestock. Although water is being mined from the aquifer, its high porosity and unconfined storage factor will ensure water supplies for an extremely long period of time.

The Tabuk aquifer is of less importance. It supplies domestic and irrigation water to the towns of Tabuk and Buzeidah and its quality is similar to the water of the Saq aquifer (average TDS ranging between 400-1200 mg/l, but deteriorating with depth).

In the southern sector, the Wajid sandstone lies directly on the crystalline basement. Water qualities in the Wajid aquifer are very good. The TDS content averaging between 500 and 800 mg/l.

There is little development in the Wajid aquifer. It is regarded as an excellent mining prospect. The direction of groundwater is generally from south to north. Flowing wells are widespread in the confined area, with heads up to 91.4 m above ground level.

The Minjur formation, together with adjacent parts of the Dhurma and Jilh formations and their sandstone layers, are the next major aquifer in the basin. Its thickness is from 300 to 350 m.

The Minjur-Jilh formations are not generally developed owing to their deep static water levels, which at Riyadh are about 100 m;

b Depleting aquifers: the UMM-er-Radhuma aquifer, which is a depleting type, is potentially Saudi Arabia's most important aquifer. It varies in thickness between 110 m and 450 m. It crops out over a wide area extending from the western desert in Iraq, through central Saudi Arabia into the Yemen region. It extends from the Wadi Hadramout area, through Dhofar into western Oman. Between the Umm-er-Radhuma aquifer and the Dammam aquifer is the Rus formation aquiclude.

The Umm-er-Radhuma's regional piezometric surface indicates flow to the north towards the Euphrates Valley, to the east towards the Gulf in central Saudi Arabia, and north to the Gulf from the Rub-al-Khali region.

The wasia groundwater movement, which is known in detail only in the Riyadh to Dhahran area, confirms that groundwater flows towards the Gulf;

(c) Oasis: apart from the wadis, major form another source of water. The major oasis are Al-Hasa, Qatif and Jabrin. These derive water from vertical leakage from the main basin aquifers and, as with most major springs throughout the world, there is controversy over the source of the water and the safe yield. Many wells have been drilled around the Qatif and Al-Hasa oasis and pumping has caused a reduction in artesian pressures and water levels; it is noted that the yield from the Al-Hasa spring system has decreased from 12.4 m^3/sec in 1966 to 9.7 m^3/sec in 1974. The Qatif area has similar problems. The Jabrin oasis is little developed, but studies are in progress.

3. Other sources of water: in 1985 an ambitious seawater desalination programme was embarked upon in Saudi Arabia and is rapidly becoming a well proven and developed technology for production of fresh water supplies.

Table 18 below gives a recent picture of the desalination plants in the kingdom-those either completed, under construction and planned up to 1985.

Treated sewage water in another source as there are treatment plants in some cities and plans for establishing more in the near future. The estimated treated water in 1980 was 113 MCM/year and the forecasted production in 1990 and 2000 will be 397 and 694 MCM/year respectively. In Riyadh, a project is underway to supply nearly farms with 200,000 m^3/d and 20,000 m^3/d to industry.

4. Water development strategies: groundwater represents the major source upon which the Ministry of Agriculture and Water relies for obtaining water for urban and rural regions.

The towns and cities on the east and west coasts have been and will be supplied with desalinated water. In addition, the important inland cities, like the capital and the holy cities, where groundwater is insufficient to meet rising demands, will also be supplied with desalinated water.

Water is mainly delivered through house connections and in rural areas by standpipes or tanker service. In mountainous regions "Khanat" - systems are also used.

Table 17: Desalination plants: completed, under construction and planned under Second (1975-1980) and Third (1980-1985) Plans

Name	Completion date	Scheduled completion date under Second Plan	Scheduled capacity under Second Plan (cubic metres per day) (2)	Actual date of completion under Second Plan	Scheduled completion date under Third Plan	Thousand cubic metres per day.
West Coast						
Jeddah I	1970		19,000			
Jeddah II		1977	38,000	1978		
Jeddah III		1980	76,000	1980		
Jeddah IV		to be carried over	190,000		1982	190,000
Jeddah V					1986	94,000
Al-Wajh I	1970		228			
Al-Wajh II		1976	455	1976		
Al-Wajh III		to be carried over	57,000		1986	3,800
Duba I	1970		228			
Duba II	1970		455	1977		
Duba III		1979	19,000		1983	19,000
Haql I		1979	455	1979		
Haql II		1979	5,700		1983	5,700
Umm Laj I	1975		445			
Umm Laj II					1983	3,800
Yunbu I		1979	19,000		1981	95,000
Yanbu II					1985	76,000
Medina I		1980	76,000			
Medina II		to be carried over	152,000			
Rabegh I		1977	910		1982	1,000
Al-Birk I					1980	1,900
Al-Lith I		1979	460		1982	460
Masturah I					1982	1,900
Tuwwal I					1982	1,900
Qunfudhah I		1979	3,800		1984	3,800
Mekka Taif I					1985	152,000
Asir (Shuqaiq)I					1987	94,000
Farasan		1977	455	1979		
East Cost						
Al-Khobar I	1974		28,500			
Al-Khobar II		1980	190,000		1982	190,000
Al-Khobar III		to be carried over	152,000			
Al-Khafji I	1974		455			
Al-Khafji II		1979	19,000		1983	19,000
Al-Khafji III		to be carried over	95,000			
Jubail I		1977	9,500		1982	114,000
Jubail II		1979	76,000		1984	665,000
Jubail III		to be carried over	114,000	1979		
Uqair I		to be carried over	95,000			
Inland						
Al-Kharj I		to be carried over	570			

Source: "Water Extraction in Saudi Arabia," Arab Water World (Beirut) March-April 1982, p.99.

The residences of the population of cities and towns are connected to networks as follows: Riyadh 75 per cent, Jeddah 60 per cent, Mecca 60 per cent, Medina 50 per cent, Taif 50 per cent, Dammam 80 per cent, Hofuf 50 per cent, Khobar/Thugbah 90 per cent and Dhahran 90 per cent 1/.

Water from Wadi Nissah, is bottled by a private company and available everywhere. The price is SR 2 per 1.5.1.

According to the latest statement of WHO/EMRO 2/, 1980, 65 per cent of the urban and 20 per cent of the rural population are served by "safe" water supplies. Consumption rates are roughly estimated as follows:

1978 (in 1/c/d)

Riyadh	300	Medina	275	Medda	163
Jeddah	353	Taif	99	Dhahran	526

The average consumption rate in 1978 from 9 towns was estimated to be 176 1/c/d.

A list of 65 municipalities with populations of between 1665 and 99,382 shows an average consumption of 130 1/c/d. This figure was calculated from well capacities and size of population in 1978. Extreme rates are as follows: minimum 16 1/c/d for Afia, maximum 73 1/c/d for Hawtat Sudair. Rural schemes deliver about 38 to 57 1/c/d. A rate of SR $0.25/m^3$ was mentioned as the Riyadh Water Tariff.

Some cities towns are served by limited sewerage systems. In others, sewerage systems are under construction or are in the planning stage. All plans involve the re-use of effluent for irrigation purposes. At Medina, an effluent irrigation system is already in operation. At Riyadh, feeder mains between treatment plants and irrigation areas are laid.

All indications point to a coverage of nearly 100 per cent of the total population with safe water and adequate sanitation by the year 2000. Water Demand Projections in U.S. gallons per capita per day for the year 2000 is as follows:3/.

Population	Municipal	Industrial	Agricultural	Total
14.5 million	91	254	121	466

(c) Discussion on various water uses, costs, pricing and tariffs in group 1 ECWA countries.

The present total population of the ECWA region is about 100 million, and the total forecasted for the year 2000 is about 135.5 million. As the population of the region continues to increase, the demand for water to satisfy

1/ Ibid., p.132.

2/ Ibid.

3/ Water Demands by the Year 2000, pp.44-46.

the urban and industrial needs as well as the water demands to produce food and fiber for the growing population will also increase.

ECWA countries in group 1 suffer from inadequate natural water resources, the lack of fertile arable soil and adverse climatic conditions. The natural water resources, consisting mainly of precipitation and groundwater, are not enough to provide the domestic and industrial water demands of the rapidly developing Gulf countries, with the exception of Oman which appears to have considerable water resources. For the rest of the Gulf countries, desalinated water is resorted to on a large scale to supply the addational water required for urbanization and industrial development.

1. Municipal and industrial uses of water: the main sources of water for municipal and industrial uses are desalinated seawater and brakish water, groundwater and treated wastewater.

(a) Desalinated water: the available data concerning the cost per cubic metre of desalinated seawater in some of the Gulf countries and other countries of the world were presented earlier.

U.S.A.	(Nuclear dual-purposes desalination project in southern California)	$0.30
Japan	(distilled sea-water)	$0.85- $0.92
Libya	(distilled sea-water)	$1.16
Qatar		$1.485 1/.
Qatar	(EW Bank Ltd.) consultants, Ministry of Electricity and Water) Qatar	$1.10
Qatar	(Shell International Co., 1980)	$1.35- $2.16
Qatar	(cost of distilled sea-water): (with energy at market price):	$1.62
	(energy at zero price):	$1.12
Qatar	(cost of distilled sea-water, average of a above prices)	$1.472
Abu Dhabi	(cost of distilled water)	$1.45
Saudi Arabia	((SWCC estimate cost of desalinated water per cubic metre)	$0.45- $0.53

1/ J.G. Pike, A Proposed Water Resources and Agricultural Development Plan, 1980-2000, Project Proposal No.3 (Qatar, Doha, 1980).

The most economical method of desalination at present lies in the large dual-purpose plants fueled by atomic energy to convert saline seawater into fresh water and produce electric power at the same time.

Desalination can also be achieved simply by employing solar energy. The Gulf countries enjoy sunny days almost all around the year at the average rate of nine sunny hours daily. The energy transmitted by the sun rays to the earth surface is in the order of two calories per square centimetre per minute1/.

A solar still for desalination has been devised for that function. The method requires no other fuel than the sun but with the present technology it cannot produce significant amounts. Nevertheless, the process appears to be economical so it could be a valuable source of fresh water for desert hamlets, seaport villages, small settlements along sea coasts, hospitals, hotels and resorts:

(b) Groundwater: Groundwater is the only and most important water source in the Gulf area in addition to precipitation. It has been overexploited in many locations in a haphazard manner resulting in steady and continuous decline in the groundwater levels and quality deterioration due to salt intrusion. This represents the prevailing groundwater situation in the Bahrain, Emirates, Qatar, and Saudi Arabia.

Groundwater in the Gulf countries is encountered and utilized in one of the following manners:

(i) Springs emerging from cracks and crevices in the earth crust under artesian pressure. They prevail in Bahrain, the Emirates, Qatar, Oman and the east and west coastal areas of Saudi Arabia. Their discharge is mainly utilized for agricultural development;

(ii) Pumping from hand-dug or drilled wells which represents the most frequently employed and expensive method for mining groundwater. The cost involves the cost of drilling, casing, pump installation, developing, fuel and operation;

In the last quarter of 1980 and during 1981, 1,100 deep wells2/ had been drilled in the Al-Ain region in the Emirates. The average yield ranges between 12 to 96 cubic metres per hour. The Za'ala Project completed during 1981 contain 37 productive deep wells, producing about 4,000 cubic metre per day. The capital cost of the project is $8.1 million. The yearly cost including 7 per cent interest is estimated to amount to $1.215 million which makes the cost of one cubic metre of groundwater from Za'ala project about $.0.87.

1/ Kashif Bakir, op.cit., chapter II, p.329. Text in Arabic.

2/ Arab Water World, September-October 1981, pp.24-26.

In the Bada'a Bint Suad Project the Emirates 46 deep wells had been drilled. The productive capacity of the Project is (16,000) m^3/d of pure drinking water. The estimated capital cost is $27 million with an estimated yearly cost of 4.05 million making the cost of one cubic metre of groundwater from the Bada'a Bint Suad project about $0.72.

In the Saih El-Miyah Project the Emirates, which is under planning, groundwater is found at depths ranging from 400 to 500 metres below ground level. Twelve deep wells whose estimated yield is 32,000 cubic metres per day are to be drilled.

(iii) The Falaj System which is a fairly cheap method of tapping unconfined groundwater almost horizontally. Water flows through the underground Falaj Gallery by the force of gravity. No pumping is required. No overdraft is experienced since the amount of discharge depends on the amount of natural recharge in the supply region of the Falaj. Falajs are encountered in the central and southern coastal parts of the Emirates, in Oman and in the Tihama coast of Saudi Arabia.

The art of constructing falajes wherever hydro-geologic conditions permit should be preserved and encouraged as an economical method for tapping uncofined groundwater that does not require more than initial construction cost and relatively cheap maintenance costs.

In Saudi Arabia, a good quantity of non-renewable water exists in deep aquifers in the central and eastern regions. The entire Wasia aquifer complex (including pipelaying) is estimated to cost around $ 400 million for the supply of 200,000 cubic metres a day.

(c) Use of treated sewage effluents: treated sewage effluents are being used through recycling schemes in Qatar, United Arab Emirates, Kuwait and Saudi Arabia to supply water for irrigation, livestock feeding and industrial use.

The third plan in Saudi Arabia (1980-1985) estimates the reclaimed urban water from treated sewage effluents to be able to add 15 per cent to the Kingdom's known conventional water resources as compared to 25 per cent from desalinated water1/.

About 65 per cent of the secondary treated effluents in Kuwait are used for irrigation;

(d) Role of pricing and metering: it is universally accepted, at present, that an adequate water supply and basic sanitary facilities are a metter of human rights. With the limited water resources of the Gulf countries from which suitable drinking water and domestic water requirements can be derived and the high cost of desalinated water, the role of pricing and metering as an incentive for economy in water use for household and domestic purposes can hardly be overemphasized. It would be quite useful in this connection to have a general review of the present water-supply and sewage disposal tariffs in the Gulf countries, according to the latest available information.

1/ Arab Water World, March-April 1982, p.95.

Household water use and sewage disposal tariffs in the Gulf countries:

(a) Bahrain: A uniform monthly charge of 800 fils ($0.302) for each household is the only water tariff. No charge collected for tanker service of sewage disposal.

(b) Kuwait: Drinking water: 800 fils per 1,000 gallons equivalent to $0.64 per m^3, and brackish water: (for house-gardens irrigation and some municipal uses) $2.7 per month. No charge for sewerage.

(c) Qatar: Drinking water supplied free. No charge for sewerage.

(d) The Emirates-Abu Dhabi: the tariff for piped water is Dh 15 per 1000 gallon equivalent to about $0.9 per cubic metre. No charge for sewerage.

(e) Oman: The price for piped water in the capital is 2 baizas per gallon, equivalent to $1,288 per cubic metre. A sewage system does not exist. The income of the capital water supply is considerable, although slightly over half of the production costs are subsidized.

(f) Saudi Arabia: a rate of SR 0.25 m^3 was mentioned as the Riyadh tariff, Currently SWCC gives water free for municipalities. It is expected that the annual operating cost of $225 million will be covered by revenue from water and electricity charges. No charge for sewerage. Prices of bottled water as sold in the local markets of Oman and Saudi Arabia amount to $43 and $38 per barrel respectively, which is more than the selling price of one barrel of crude oil.

2. Agricultural use of water: in group 1 countries the main source of water for agriculture is groundwater. Use of treated sewage effluent is also becoming acceptable, however, the cost of desalinated water is too high to be considered. It would cost $24,000 per hectare in Kuwait and $25,000 per hectare in Qatar annually to provide water for irrigation from desalination. Costs would be similar elsewhere in the other countries of the group.

(a) Saudi Arabia: only in the southwestern agricultural province of Asir with its mountain slopes which catch the summer monsoon is there enough regular rainfall to support cultivation and herding on a relatively largescale. A large number of dams to reduce damage from flashy floods and provide water for future use have been built and more are planned mostly in the mountainous Asir.

Groundwater has sufficed major oasis settlements in the past, but only at the large Hasa oasis is there enough to support farming on any scale, and that, today is chiefly due to a major renovation scheme completed in 1973.

(b) Bahrain: about 70 per cent of the pumped groundwater is used for agriculture.

(c) Kuwait: limited agricultural areas in the Sulaibiyah and shagaya fields are cultivated with irrigation from groundwater if the pumped quantity is adequate. Treated effluent is also used on a limited scale.

(d) Qatar: Agriculture in Qatar is based almost entirely upon irrigation from pumped groundwater and accounts for just over half the total of all water consumed in the State. This proportion has steadily declined since 1976 (total irrigated area 3,050 hectares, maximum 3,300 hectares). A thousand hectare agricultural project feasibility report was prepared for the Government of Qatar and the estimated capital cost was $62.54 million to be mainly irrigated by treated effluent water over the development period 1982-2000 with an estimate return of 4 per cent.

For another project in northern Qatar, the initial estimated capital cost of providing water for irrigating 19,600 hectares (cereal, fodder, vegetable) together with limited summer cropping is in the order of $2,000 million. Water needed for irrigation amounts to 150 MCM of which 27 million m^3 can be safely supplied from groundwater and the rest from desalinated seawater1/.

(e) The Emirates: water extracted by pumping groundwater is used in agriculture. The cost of pumps and engines are half-subsidized, the other half of the cost is loaned on instalment payment. As a result the agricultural areas are expanding rapidly. It has been suggested to the government that groundwater be left for irrigation. Furrow and basin irrigation are dominant. Recently drip irrigation has been introduced on an experimental basis. Sprinkling is used for irrigating trees. No suitable sites for surface dams are available. Structures to control floods are being planned to recharge groundwater (flood retention structures).

(f) Oman: In the batina northern coastal plain irrigation is essentially concentrated in the coastal strip. In the Oman mountains, land limitation prevents any important expansion of the irrigation areas. In the interior plains, the land is distributed in small areas. The Wadi Qurayyat plain is an exception where 2,900 hectares of new lands have been mapped. The Dhofar-Salalah plain with springs and falajs prevalent in the region (50 km wide, maximum length 15 km) has a very poor quality water.

Irrigation water in Oman consists entirely of groundwater from springs, falajs or, in few cases, from deep drilled wells.

Conclusion concerning agriculture

It is clear from the above discussion that agriculture in the Gulf countries is extremely constrained by the following factors:

(a) The limited natural water resources and the expensive cost of desalinated water;

(b) Low Soil fertility;

(c) Small areas of arable lands due to topography; and

1/ Government of Qatar, Water Resources Development (Doha, Technical Report No.XIV, 1983), p.14/8.

(d) Adverse climatic conditions such as moving sand dunes in summer, very intensive rains of short duration in winter which cause destructive flashing floods, and high evaporation rates in summer.

The limited agriculture, though probably fully subsidized, should be adhered to as a necessary measure for enhancing the environment and for esthetic reasons and producing fodder crops. Sea-fishing fleets as provides of an important part of the daily diet could and should be given prime consideration.

Recycled secondary treated urban wastewater whose cost is estimated to be about $0.40 per m^3, including everything, in the Emirates and possibly less in the other Gulf countries, can be economically employed for industrial uses, a limited agricultural expansion and cattle feeding.

Water recycling schemes are likely to be implemented in all major cities in the Gulf countries.

3. Icebergs as a fresh water resources: Prices of towing icebergs from Anarctica to Jeddah1/ are as follows:

Unit price from large icebergs	$0.20 per cubic metre
Unit price from medium icebergs	$0.25 per cubic metre
Unit price from experimental icebergs	$0.43 per cubic metre

Weeks and Campbell 2/ in a separate study concluded that the cost would be roughly $0.05 per m^3 calculated at prices of ten years earlier.

further research is needed to be conducted into towing icebergs for use as a fresh water resource.

4. Water transfer schemes in Group 1 countries: It may be feasible to pump water from the Shatt El-Arab in Iraq to Kuwait and/or Saudi Arabia which have common borders with Iraq, according to a project proposed in 1954 by U.K. Consultant Sir Alexander Gibb and partners.

However, this scheme has not been considered since then and there is no up-to-date data available.

1/ J.M. Day, "Icebergs Used in Theory and Suggestions for the Future", Desalination, vol.29 (1979), pp. 25-40.

2/ W.F. Weeks, and W.J. Campbell, "Icebergs as a Freshwater Resources: An Appraisal", Symposium on Hydrology of Glaciers, Cambridge, England, February 1969.

Conculsion

The natural water resources of (Group 1) ECWA countries are inadquate. Untill the production of large quantities of fresh water from saline water by solar distillation becomes technically and economically feasible, the continued development and prosperity of those member countries would have to depend on supplementary water produced by conventional desalination methods, domestic effluents recycling and other unconventional fresh water production methods. However, practice of water-saving methods could result in saving considerable amounts of water. Moreover, the categorization of uses of water according to their quality requirements would make it possible to use low quality water where quality is not important, thus preseving fresh water supplies for domestic uses.