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

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ABBREVIATIONS

a.s.l.	above sea level
G.D.P.	Gross Demostic product
G.N.P.	Gross National Product
G.P.C.D.	Gallons per capita per day
gpm	gallons per minute
l/c	litre per capita
l/c/d	litre per capita per day
MCM	Million cubic metre
MCM/year	Million cubic metre per year
mgpd	million gallon per day
MIGD	million imperial gallon per day
mg/l	milligram per litre
mm/d	millimetre per day
n.a.	not available
ppm	parts per million
TDS	Total Dissolved Solids
WHO	World Health Organization

Measures of volume and capacity and their equivalence

One cubic metre	= 1000 litres
One cubic metre	= 264 gallons (U.S.)
One cubic metre	= 6.25 barrels (approx.)
One cubic metre	= 35.3 cubic feet
One gallon (U.S.)	= 3.8 litres (approx).
One gallon (imperial)	= 4.5 litres (").
One cubic foot	= 28.3 litres
One barrel	= 160 litres (approx.)

Monetary data on ECWA member countries

Country	Monetary Unit	Symbol	Exchange Rate	Population in millions	GNP in millions $US	GNP Per capita
Bahrain	Bahraini dinar	BD	BD1=$2.653	0.558570 (1981)	1,654	$3,000
Kuwait	Kuwaiti dinar	KD	KD1=$3.60	1.355827 (1981)	23,300	$17,000
Qatar	Qatari rial	QR	QR1=$0.27	0.262 (1980)	4,442	$17,000
United Arab Emirates	UAE dirham	Dh	Dh1=$0.27	1.000 (1980)	30,240	$30,240 (1980) hig in the worl
Oman	Omani rial	OR	OR1=$2.898	1.50 (1980)	5,426	$3,675
Saudi Arabia	Saudi Arabia rial	SRI	SRI 1=$0.29	8.6 (1981)	74,060	$8,610
Democratic Yemen	Yemeni dinar	YD	YD1=$2.9	1.90 (1980)	520	$240
Yemen	Yemeni rial	YRI	YRI1=$0.22	5.70 (1981)	2,394 GDP $2,910	$420
Jordan	Jordanian dinar	JD	JD1=$3.02	3,10 (1979)	n.a	$1,180
Lebanon	Lebanese pound	LL	LL1=$0.22	3.70 (1977)	n..a GNP (1977) $2,733	n.a
Syria	Syrian pound	PS	PS1=0.156	8.6 (1980)	6,974.6	$811
Egypt	Egyptian pound	LE	LE1=$1.23	38.9	n.a GDP (1979) &17,050	$480
Iraq	Iraqi dinar	ID	ID1=$3.33	12.6 (1979)	30,366	$2,410

Source: United Nations/Economic Commission for Western Asia (UN/ECWA), "The International Drinking Water Supply and Sanitation Decade Activities in the ECWA Region" (Baghdad, 1983).

INTRODUCTION

A. General

For centuries mankind throughout the world has spoiled and wasted water, one of his most precious birthrights.

It may be that there is as such water today as when man first appeared on the earth, yet water is considered short in supply and unsafe to drink in far too many cases.

The global water supply as a whole may never be increased but the existing amount can be developed and managed to supply man's need for a long time to come.

Developing countries are just now learning the importance of water for industrial development. Industries themselves, as well as the cities which spring up around them, require vast volumes of water.

It should be emphasized, however, that in arid and semi-arid region of the world the greatest percentage of water goes to fulfil the requirements of irrigation and agriculture.

The arid and semi-arid zones are roughly estimated to include half of the area of our globe and encompass portions of every continent of the world. The arid belt is roughly divided into two parts:

The northern belt extends across the western part of the United States and Mexico, across Spain, southern France, Italy and Greece into the Asia Minor Area, thence over most of India and into China.

The southern arid belt encompasses the portion of South America on the west side of the Andes mountains, the Great sahara and most of South America, joins with the upper belt through the Arabian Peninsula and India, and then extends south encompassing largely all of Australia.

The member countries of the ECWA region are all situated in either the arid zone or semi-arid zone[1/] of the world. They are the following countries:

1/ The semi-arid zone includes regions that possess fairly significant surface and groundwater resources but do not enjoy adequate precipitation either in terms of quantity, frequency or intensity.

To be of greatest benefit, precipitation should have the following characteristics:

(a) Amounts should be sufficient to replace moisture depleted from the root zone;

(b) Frequency should be often enough to replenish the soil moisture before plants suffer from lacking moisture;

(c) Intensity should be low enough so that water can be absorbed by the soil.

The drought or no-precipitation period in the semi-arid countries lasts from 5 to 7 months each year. Furthermore dry and wet cycles alternate in such regions. Dry cycles could occur for several consecutive years.

1. Bahrain.
2. Kuwait.
3. Qatar.
4. The United Arab Emirates.
5. Saudi Arabia.
6. Oman.
7. Democratic Yemen.
8. Yemen.
9. Jordan.
10. Iraq.
11. Syrian Arab Republic.
12. Lebanon.
13. Egypt.

For the purpose of the present study, it would be convenient to arbitrarily group the ECWA member Countries into three categories:

1. The Arid Zone group which includes Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates;

2. The Relatively Arid Zone group which includes Democratic Yemen, Jordan and Yemen;

3. The Semi-Arid Zone group which includes Egypt, Iraq, Lebanon and Syria.

In most parts of the arid zone the average annual rainfall does not exceed 50 mm. Real rivers or permanent water-courses are non-existent.

Geological and mineralogical surveys revealed that vast areas of the arid ECWA regions contain huge mineral wealth and underlying oil fields. Such wealth remains untapped until means are found to provide sufficient quantities of suitable drinking water and adequate amounts of water to most household and domestic requirements for urban settlements engaged in the mining and oil production industries as well as sufficient water to meet industrial water requirements.

The main obstacle hindering the development of the arid zone of ECWA member countries is the scarcity, and sometimes non-availability of water resources.

In Saudi Arabia which, incidentally is one of the few countries without either real rivers or permanent water-courses, rains rarely occur and usually only last a few hours.

The intense heat of the sun causes rapid evaporation although most of the water seeps quickly down through the sandy soil where it joins the saturated layers of the earth as groundwater. Most of the arid zone group of the ECWA countries experience this situation. The choices open for these countries to provide sufficient quantities of water necessary for their urban, industrial and limited agriculutral development may be summarized as follows:

(a) Exploration, identification and economic use of their groundwater resources;

(b) Desalination of seawater or brackish water by following the most economic technology gained from past experiences;

(c) Investigating and experimenting the possibility of using the solar energy for desalting samll amounts of sea or barckish water to satisfy the needs of small seaside areas or inland settlements where brackish water is available;

(d) Making agreements with neighbouring countries to import limited quantities of water if possible;

(e) Following such unconventional methods as artificial rain, re-use of drainage water, and re-use of sewage water effluent partially or fully treated;

(f) Re-investigating the possibility and practicability of importing icebergs from polar zones (this practice has so far been found to be uneconomical), and tankering water from other countries;

(g) Allocating funds for research activities including employing solar energy, for desalination of worthwhile quantities of seawater.

Group II of the ECWA member Countries (Democratic Yemen, Jordan and Yemen) enjoy more annual average precipitation than Group I, contain some intermittent rivers or protions of perennial rivers and water-courses, and have better potential groundwater development possibilities. Their main problem is water shortage rather than water scarcity or non-availability. Despite the fact that there are no major oil fields, they possess other possible income sources including greater agricultural development possibilities.

The water resources shortage in the semi-arid member countries of the ECWA region, Group III comprising (Egypt, Iraq, Lebanon and Syria) is of a different nature. It is attributed mainly to unfavorable annual and seasonal distribution of precipitation. The long draught cycles in some periods covering several consecutive dry years are responsible for the death of thousands of cattle and the loss of valuable agricultural crops of vast cultivated areas.

On the other hand, these countries are at an advantage over the drier areas since most of the water shortage situation can be remedied by employing a number of structural and management measures.

B. Objectives of the study

A programme element entitled "Development of Guidelines for the Economic Use of Water in the ESCWA Region", has been initiated as a component of the Water Resources Development and Management Programme included in the ECWA programme of work and priorities for the biennium 1982-1983. This report is prepared as the final output of the said programme element.

The water resources in the ECWA region, as a whole are limited. Suitable water in the arid ECWA member countries (group 1) is extremely scarce or non-available in some areas of that group. In the relatively arid ECWA member countries (group 2) there exist a serious water shortage in meeting demand in both urban and rural areas. The semi-arid ECWA member Countries (group 3) need to invest vast sums of money to conserve their water resources and regulate its distribution and allocation for various uses.

The main objective of this study is to develop general guidelines for the economic, efficient and equitable use of water in the ECWA region including a cost analysis of water use in selected fields. Recommendations are made to member countries concerning the various economic, efficient and equitable uses, limits and measures to be taken by the governments concerned.

C. Methodology

The seven following chapters are designed to help planners of water projects in the ECWA region to economically and efficiently develop and allocate the water resources of the region to various uses. Such uses are for the following: (a) drinking, household and municipal purposes; (b) agriculture and irrigation; (c) industry; (d) hydro-electric power generation; (e) animal husbandry and fish breeding; (f) navigation; (g) recreation; and (h) salinity control.

The first three uses are the major ones in the region while all or some of the other five uses are to be considered in the semi-arid member Countries, namely, Egypt, Iraq, Lebanon and Syria.

Chapter I, deals with water requirements and standards for (a), (b) and (c) above, while chapter II is concerned with the basic economic considerations, to be taken into account, to achieve physical and economic efficiency in the use and allocation of water throughout the region with sufficient attention to be paid to the matter of equity and redistribution of income among different sectors of the community.

Since desalination has been and will remain for many years to come a "must" for the prosperity and well-being of the oil-producing Gulf countries including Saudi Arabia, chapter III or the study was devoted to the subject of desalination of saline and brackish waters.

Chapters IV,V and VI give a general picture of the water situation and strategies in the ECWA region including pricing and tariffs and the unit cost of water produced by different methods. In addition chapter VI contains a general cost-benefit discussion of three major projects in the region, namely the High Dam of Egypt, the Euphrates Project of Syria and the Mosul Dam Project on the Tigris in Iraq.

Recommendations to member Countries are presented in chapter VII.

I. WATER REQUIREMENTS AND STANDARDS FOR VARIOUS USES IN THE ECWA REGION

The major water uses could be calssifed into three main categories:

(a) Municipal, and domestic uses in urban and rural areas;

(b) Industrial requirements;

(c) Agricultural demands.

A. Municipal and domestic uses

The development of urabn and rural communities in any country has been closely associated with the provision of adequate water supply and sewage systems. In fact, these systems not only consititute the basis for the promotion of public health and the conservation of manpower, but they also play a significant role in economic development.

The rapid increase in population, the growth of urban areas and the steady rise in living standards have dramatically increased the per capita consumption of water.

Only 77 per cent of the urban population and 22 per cent of the rural population in the developing countries have access to reasonable water supplies. Most of them lack satisfactory sewage disposal facilities[1/].

The main issue, from an economic view point is to know the effects of the accessibility, quality and quantity of water on health.

Many human enteric parasites are transmitted though fecal contamination of water[2/]. This perpetuates many of the problems so prevalent in the developing world. Safe drinking water and safe waste disposal are necessary prerequisites for the eradication of water-borne diseases.

The international WHO standards for drinking water are listed in the following table:

1/ Saunders and Warford: "Village Water Supply: Economics and Policy", 1976.

2/ H. Dietrich and M. Handerson, WHO, Urban Water Supply Conditions and Needs in Seventy-five Developing Countries, 1963.

Table 1: Standards for Drinking Water

Maximum	Mean	Material or Characteristics
750 mg/1	250 mg/1	Suspended sediment
25 mg/1	5 mg/1	Turbidity
-	Tasteless	Taste
-	Colourless	Colour
1 mg/1	Less than	Br - Bromium
0.5 mg/1		
1 mg/1	0.3 mg/1	Fe - Iron
0.5 mg/1	0.1 mg/1	Mn - Manganese
15 mg/1	1 mg/1	Cu - Copper
200 mg/1	75 mg/1	Ca - Calcium
200 mg/1	50 mg/1	Mg - Magnesium
400 mg/1	200 mg/1	SO_4-Sulphate
650 mg/1	200 mg/1	Cl - Chlorine
Not less than 6.5, not more than 9.2	8.5-7.6	Ph*-Acidity or alkalinity measure
4 mg/1	3 mg/1	BOD-Biochemical oxygen
	demand	
0.05mg/1	-	As - Arsenic
0.01mg/1	-	Cd - Cadium
0.05mg/1	-	CN
0.10mg/1	-	Pb - Lead
0001mg/1	-	Hg - Mercury
0.01mg/1	-	Se

Source: World Health Organization (WHO) International Standards for Drinking Water (Geneva, 1963-1971).

* Ph is the logarithm of the reciprocal of the hydrogen ion concentration.

Sedimentation, filtration and chlorination of surface water used for drinking and domestic purposes in the ECWA region are sufficient measures to render it in conformity with the WHO standards while drinkable groundwater needs only to be cholorinated. Periodic analysis of samples of water from water-supply schemes is a recommended routine.

Bicarbonate is common in groundwater. It is likely to contain more iron (Fe) than surface water. Concentrations as low as 0.3 ppm parts per million iron leaves reddish brown stains on porcelain and cloths discounting its value for household use, although it has no ill effect on the human body. Iron is removed by filtering.

Hardness of water is due to the presence of calcium, and magnesium salts in appreciable parts per million (ppm) is another source of complaint for household water consumers. In soft water they are practically absent. The degree of hardness is reported as follows:

Parts per million (ppm)	Classification
0-60	Soft
61-120	Moderately soft
121-180	Hard
more than 180	Very hard

Moderately hard water is suitable for all purposes. Hard water may be softened by a lime-soda process and zeolite or cation-exchange. The lime-soda process is employed for public and industrial supplies, while a cation-exchange is utilized for personal or domestic uses. Softening water reduces soap consumption, fuel consumption due to reduced boiler scale and plumbing maintenance expenses.

The average daily world consumption of water per capita is 80 liters according to WHO statistics. This average increases with the rise of living standards and the development of the town. Cities with over (100) thousand population in the U.S.A., for example, are designed on the basis of a daily consumption of (600) liters of water per capita including industrial uses.

B. Industrial uses

Industries consumes huge quantities of water which could be classifed into three interreleted general calsses as follows:

1. Water entering into the formation of the final industrial product forming an important part of it;

2. Water used in industries for cooling, removal of impurities and preparation of solutions;

3. Water used to dilute and remove industrial debris.

Industry consumes most of the water supply in advanced industrialized countries with agriculture a close second. Some wastewater can be treated and reused but with the present rate of growth, reduction in the total water required for industry is not a possibility. Industrialization increases urbanization thus increasing the demand on water supplies for domestic and municipal use.

In group 1 member Countries of the ECWA region, the extensive development of oil fields during the last twenty five years, with the essential urbanization associated with it created a high demand on water for industrialization and urbanization. For this reasons, desalination was resorted to as a valuable supplemental source.

Some industries require more water than others. Table 2 below lists water requirements for a large number of industries.

Table 2: Water Requirements for a Large Number of Various Industries

Inudstry	Water Usage in Cubic Meters
One ton of Petroleum	10
" ton of Canned vegetable	0.04
" ton of Paper	199.0
" " " Wool textile	600.0
" " " Cement	4.50
" " " Steel	150.0
" " " Nitrogen fertilizers	600.0
" " " Sulpher mining	11.0
" " " Artificial rubber	2,100.0
One ton of Aluminium	200.0
" " " Artificial silk	2,660.0
" " " Fibber threads	5,600.0
" " " Cotton textile	260.0
" " " Sugar	200--400

Source: Al-Sahhaf, Mehdi, "Water Resources in Iraq, and Their Protection From Pollution", Baghdad, Ministry of Guidance, 1976, p.156.

Steel production and synthetic rubber use water mainly for cooling. If the purpose is cooling it is relatively easy to retrieve most of the water used for this purpose but not without the expense of investment in cooling tanks, towers and pumping.

Water and waste treatment is freeing increasing amounts of water for use and reuse as more is learned about water quality and how to adjust fresh water of low quality (having a high mineral or organic content) for different uses. New and better treatment methods are evolving every year. Demineralization is likely to carry the burden of water improvement for some time.

Sample standard specifications of water used for different industries are presented in Table 3 below:

Table 3: Sample Standard Specifications for Water for Various Industries

Industry	Material	Percentage
Textile	Fe	Not more than 0.3 mg/1
	Mn	" " " 1.0 mg/1
	Cu	" " " 0.5 mg/1
	Dissolved solids	" " " 150 mg/1
	Suspended solids	" " " 1000 mg/1
	$CaCO_3$	" " " 120 mg/1
	Ph	Not less than 6, not more than 8

Table 3: (Cont'd)

Industry	Material	Percentage	
Chemical industries	Fe	Not more than 5	mg/1
	Mn	" " " 2	mg/1
	Ca	" " " 200	mg/1
	Mg	" " " 100	mg/1
	HCO_3	" " " 600	mg/1
	SO_4	" " " 850	mg/1
	Dissolved solids	" " " 2500	mg/1
	Chlorides	" " " 500	mg/1
	Suspended sediments	" " " 10,000	mg/1
	$CaCO_3$	" " " 1000	mg/1
	Alkali	" " " 500	mg/1
	Ph	Not less than 5.5, not more than 9	
Petrochemical industries	Ca	Not more than 220	mg/1
	SiO_3	" " " 50	mg/1
	Fe	" " " 15	mg/1
	Mg	" " " 85	mg/1
	K+Na	" " " 230	mg/1
	HCO_3(Bicarbonates)	" " " 480	mg/1
	SO_4	" " " 570	mg/1
	Chlorides	" " " 1600	mg/1
	NO_3	" " " 8	mg/1
	F	" " " 1.2	mg/1
	Deissolved salts	" " " 3500	mg/1
	Suspended sediments	" " " 500	mg/1
	$CaCO_3$	" " " 900	mg/1
	Ph	Not less than 6, not more than 9	
Food and canning industries	$CaCO_3$	Not more than 300	mg/1
	Ph	" " " 8.5	
	Ca	" " " 120	mg/1
	Chlorides	" " " 300	mg/1
	SO_4	" " " 250	mg/1
	Fe	" " " 0.4	mg/1
	Mg	" " " 0.2	mg/1
	SiO_4	" " " 50	mg/1
	NO_3	" " " 45	mg/1
	Dissolved salts	" " " 550	mg/1
	Suspended sediments	" " " 12	mg/1
Paper industry	Suspended sediments	Not more than 500	mg/1
	Fe	" " " 0.5	mg/1
	Chlorides	" " " 1000	mg/1
	Dissolved salte	" " " 1080	mg/1
	$CaCO_3$	" " " 475	mg/1
	Ph	Between 4.6 - 9.4	

Table 3: (Cont'd)

Industry	Material	Percentage	
Cement industry	$CaCO_3$	Not more than 240	mg/1
	Hardness	" " " 500	mg/1
	Fe	" " " 1.8	mg/1
	Mn	" " " 5	
	Ph	Not less than 6.9, not more than 8.8	
	Dissolved salts	1120	mg/1
	Suspended sediments	200	mg/1
	SO_4	235	mg/1
	Chlorides	100	mg/1

Source: National Technical Advisory Committee, report on "water quality criteria" submitted to the Secretary of Interior, Washington D.C., 1968.

See Also: Al-Sahhaf, Mehdi, "Water Resources in Iraq, and Their Protection From Pollution", Baghdad, Ministry of Guidance, 1976, pp. 170-172.

C. Agricultural uses

Water requirements for irrigation and agriculture form the largest portion of water used in arid and semi-arid regions of the ECWA Countries, (Group II and III).

The water requirements for agricultural crops in Iraq, which are about the same all over the two groups of the ECWA regions, are as follows:

Winter crops: One cubic metre per second for every (1,500) hactars all through the winter season.

Summer crops: One cubic metre per second for every (750) hactars all through the summer season.

Gardens: One cubic metre per second for every (1,000) hactars all through the year.

Cotton and Rice: One cubic metre per second for every (500) hacter all through the growing season.

The above-mentioned water requirements represent the average present agricultural water use in Iraq, covering the consumptive use of plants, conveyance losses through irrigation systems, unavoidable field water losses, including deep percolation, (depending on the employed field irrigation method, soil characteristics, depth of water table and climatic conditions), plus the leaching requirements.

In the ECWA member Countries belonging to Group I, the agricultural water needs are about twice as much due to intense heat, low precipitation, higher evaporation rates and unfavourable soil conditions. Expressed in terms of depths of water per unit area, the total water requirement per unit area for winter cultivation in Iraq is considered as 1.2 metre for the entire winter season, while it is estimated to amount from between 2.4 metres to 2.5 metres of water depth per unit area in Kuwait, Qatar, and Saudi Arabia.1/.

No accurate statistics regarding water consumption by cattle and other animals in the ECWA region is available. Rough estimates of the water consumption by camels, sheep and goats are as follows:

One sheep average daily consumption of water 5 - 6 liters
One goat " " " " " 5 - 6 liters
One camel " " " " " 25 - 30 liters

Table 4 presents some established standards for irrigation water quality.

Table 4: Standards for Irrigation Water

Water class	Electrical conductivity EC X 10^6	Salt content total ppm	Sodium percentage of total salt	Boron ppm
1	0-1000	0-700	60	0.0-0.5
2	1000-3000	700-2000	60-75	0.5-2.0
3	over 3000	over 2000	75	over 2.0

Source: Israelson and Hansen, Irrigation Principles and Practices, New York, John Wiley, 1962. p.226

Class (1): is considered excellent to good, suitable for most plants under most conditions.

Class (2): waters are mentioned as good to injurious for more sensitive plants.

Class (3): considered by the laboratory unsatisfactory for most crops and unsuitable under most conditions.

If the salts present are largely sulphates, the values for salt content in each class can be raised 50 percent.

The following standards are established for fisheries and fish breeding:

1/ Kashif Alghita, Bakir, Ahmad, "Hydrology and its Applictions" Mosul University Publishing House, 1982, pp. 368-372.

Table 5: Standards of Suitable Waters for Fish Breeding

Material	Percentage
PH	Not less than 6.5 and not more than 9.0
Temperature	Does not exceed the water in the hotest summer months by more than 3 degrees centigrades
Disolved oxygen	Not more than 6 mg/litre
Turbidity	Not more than 25 mg/litre
Petroleum	zero
Radio activity	zero

Source: Al-Sahhaf, Mehdi, Pollution Control and Water Resources in Iraq, Al-Hurriyah Printing House, Baghdad, 1976, p. 168.

The FAO standards for waters suitable for agriculture which seems to be very strict and waters suitable for domestic animals are presented in Tables 6 to 8.

Table 6: Water Standards for Agriculture (FAO)

Matter or characteristic	Percentage
Color	Colorless
Taste and Oder	Tasteless and Odorless
PH	Not less than 6 or more than 8.5
Total soluble inorganic matter	500 mg per litre
Total organic soluble matter	
$<$ 1 mg/l	Andrine
$<$ 17 mg/l	Eldrine
$<$ 17 mg/l	Di-eldrine
$<$ 42 mg/l	DDT
Turbidity	Free
Toxic Matter As	Not more than 0.05 mg/l
Br	Not more than 1.0 mg/l
Pb	Not more than 0.05 mg/l
Ag	Not more than 0.05 mg/l
Fe	Not more than 0.30 mg/l
Zn	Not more than 5.00 mg/l

Source: Al-Sahhaf, Mehdi, Pollution Control and Water Resources in Iraq, Al-Hurriyah Printing House, Baghdad, 1976, p. 169.

Table 7 shows somewhat detailed standards for surface waters suitable for agriculture.

Table 7: Classes of Surface Water According to Their Suitability to Agriculture

Class	Total soluble salts (mg/l)	Electrical conductivity EC in Micromhos/cm	Agriculture use
1. Suitalbe for all crops under all soil conditions	0-500	0.75	All crops(Beans, radish, peas, apples, oranges, etc.)
2. Crops relatively tolerable to salinity with good drainage	500-1000	0.75-1.5	(Wheat, barley, rice, maize, tomato, vegetable, Olive, Cabbage, etc.)
3. Crops tolerable to salinity with adequate drainage and soil care	1000-2000	1.5-3	(Cotton, Palm trees, Beet, etc.)
4. Some crops with adequate soil drainage	2000-5000	3-7.5	(Palm trees, alfalfa, salt grasses, etc.)
5. Not suitable for any crop	Over 5000	Over 7.	
Ph	5.5-8.5	temperature 12.8° 29.3°	

Source: National Technical Advisory Committee, Report on Water Quality Criteria submitted to the Secretary of Interior. Washington D.C., 1968. p. 170.

See also: Al-Sahhaf, Mehdi, Pollution control and Water Resources in Iraq, Baghdad, Al-Hurriyah Printing House, 1976, p. 173.

Almost all surface water in rivers and streams and most of the mined groundwater and springwater throughout the ESCWA region are suitable for agriculture and up to standard.

Re-use of agricultural drainage water and groundwater containing more than 3000 ppm soluble salts is feasible after mixing it with fresh water of higher quality.

Disposal of wastewater due to the previously discussed water uses-urban, industrial and agricultural necessitates the construction of adequate sewage disposal systems, terminated with sewage treatment plants. The treatment and removal of industrial debris; and the construction of appropriate drainage systems and outfalls in agricultural areas, when necessary, are essential.

Negligence of adopting such proper measures would lead to serious health hazards, pollution and quality degradation of water sources and the ruin of cultivable areas due to waterlogging and salt accumulation problems.

The wastewater disposal and treatment projects are extremely costly. A substantial portion of the capital investment and operation and maintenance costs could be recovered, however, through a carefully planned pricing and tarrif policy, the resale of treated sewage waste sludge as fertilizers and the re-use of drainage water after mixing it with appropriate amounts of fresh water.

It may be concluded that the growing population and steady development of the ESCWA region place higher demands on suitable water supplies year after year.

Desalination and domestic and/or public effluents re-use projects have to carry the burden, for many years to come, in Group 1 and 2 member Countries, the Sinai Peninsula and Matruh and Red-Sea Provinces in Egypt.

Engineering and agronomic measures in Group 3 ESCWA member Countries, can meet the required water demands through careful planning.

II. ECONOMIC CONCEPTS AND GENERAL ECONOMIC CONSIDERATIONS FOR VARIOUS WATER USES

A. Introduction

This chapter is mainly concerned with the discussion of some general socio-economic considerations, the definition of certain basic economic concepts and terminology and the explanation of the role of prices, regulations and tariff structures related to the efficient and equitable use, treatment and allocation of water for various uses.

Water is a public good used collectively by the community. The use of water resources involves withdrawal uses for agriculture, industry, commerce, municipal and residential needs, and non-withdrawal uses for navigation, waste disposal and recreation.

The simultaneous solution regarding the conflicting goals of equity and efficiency involves compromises on equity grounds. A reasonably optimal combination of regulations and prices that will lead to efficient use of water and redistribution of income, as well as to recovery of capital from investment projects, is to be sought.

"Users pay cost of service" has been the principle traditionally applied to the municipal and industrial water supplies, with greater possibility of inducing economic efficiency.

Metering policy with effective pricing has proved effective as a way to conserve water and improve efficiency in use in case of water scarcity. It was found through studies made in different countries that metering with appropriate pricing structures reduces the average maximum day or peak-hour demands by 50 per cent or more.

Increasing block rates for domestic water use provide a way for redistributing income among different sectors of the community in conformity with equity. Dual prices for water sold to households and industry is another way of redistributing income in favour of certain groups.

Waste treatment costs of industries are usually paid for by the concerned industries. They are ultimately reflected in the selling unit price of the final industrial product.

Domestic, municipal and industrial water demands form the largest portion of water use in the ECWA member countries of group 1.

Partial or total subsidies are common for water consumed by agriculture. The justification is the provision of jobs for the rural people and reduction of food imports, thus improving the foreign trade payment balance.

B. Certain useful concepts and economic terminology[1/]

1. Demand: There is an inverse relationship between the price of a product and the quantity demanded. Demand is termed final when it is purchased for final consumption such as water use for household consumption and derived when it is required as an intermediate input in the production of anohter marketable product as in the case of irrigation and industrial water requirements;

2. Opportunity cost: This indicates the cost of water when a society uses resources for one purpose rather than for another guided by more profit accured from the chosen use;

3. Social cost: reflects the full opportunity cost imposed on a society in the production process. For example, industrial wastes discharged into streams impose a cost on society;

4. Total cost: this is the sum of variable and fixed costs. Average cost is obtained by dividing the total cost by the output;

5. Marginal cost: this is the change in total cost per unit change in quantity of output. The cost of water may be regarded as the amount per unit volume that would have to be paid to make it available. It may include capital cost, operation and maintenance costs, etc;

6. The value of water: this is the maximum amount per unit volume of water that society would be able and willing to pay to obtain a given volume.

Water can have a value even when a government does not charge for it. If the quantity of water is fixed, then the value of additional water will equal its opportunity cost.

Agricultural water is more variable in value than is potable water in cities owing to sharp variations in seasonal demand and supply and to variations in quality.

It is only worthwhile building storage reservoirs to eliminate differences in seasonal values if the present value of the long-range expected marginal benefits exceed the marginal cost.

Different water values based on differences in quality can some-time be encountered;

7. Efficiency and distributional equity[2/]

1/ O.C. Herfindal, and A.V. Kneese, Economic Theory of National Resources (Columbus, Ohio, Charles E. Merrill, 1974).

2/ United Nations. Efficiency and Distributional Equity in the Use and Treatment of Water, Natural Resources/ Water Series No.8 (New York, 1980), p.44.

(a) Economic efficiency: The allocation of water is considered efficient when the marginal value is equal to the marginal cost. For a fixed water quantity, water should be re-allocated among uses until it has the same opportunity cost in each use;

If the possibility of obtaining additional water at some marginal social cost less than its opportunity value exists, then new units of water should be added until the marginal social cost equals the marginal social benefit;

(b) Equity and income redistribution: the United Nations Conference on Human Settlements (Habitat) has stressed the concept of potable water as a right, meaning that a certain minimum amount of clean water should be available to everyone everywhere to meet basic human needs.

Water rates to paying customers should be used to subsidize the cost of water from public standpipes for the poor. This is achieved by both regulations and prices;

8. "Requirements" versus "Demand" as guides to investment: the "Requirements" approach is often used for making decisions regarding the size and timing of water resources investments.

Water requirement forecasts assume that the demanded quantity of water will increase proportionally with increases in population and economic activity. It is assumed that prices will remain constant and forcasts therefore calculate the amount of water to be supplied of constant prices.

The demand-supply approach assumes that higher prices will induce customers to use less water.

Estimating the demand function and determining the optimal size of investments are complex and costly processes. In addition, adjustments to market prices are needed although they do not represent the real value to society.

"Shadow prices" sometimes called "accounting prices" are a more correct measure of the intrinsic values of the project;

9. Classification of water resources situation: the following factors should be considered in classifying water resources situation: (i) value of water; (ii) seasonal pattern of values and cost of storage; (iii) feasibility of water transfer among regions or countries; (iv) importance of water quality; (v) flooding and drainage problems; and (vi) interrelation between surface and groundwater.

Building surface or underground storage reservoirs might be less expensive for governments than enforcing different systems of measuring, rationing and pricing for each season.

If the value or availability of water differs greatly between two adjacent valleys or1/ countries, every effort must be made to reach agreement and implement the water transfer scheme;

10. The importance of water quality: problems related to water quality include the following: (i) the water must be re-used by persons downstream; (ii) fish may be killed or contaminated; and (iii) the water may be unsafe for bathing and water sports. These problems are serious in humid regions where pollutants must be controlled;

11. Flooding and drainage problems: excessive irrigation should cause drainage problems that will ruin good soil.

Flood control measures will encourage people to encroach on flood plains.

Flood will be less frequent but if they occur they will be most costly and the net effect on national income could be negative;

12. Interrelation between surface and groundwater: if the surface water is scarce, groundwater usage could be encouraged if the level of groundwater remains constant. In some cases, surface and groundwater can be treated as one, and similar pricing systems developed for both.

C. Efficiency in the use of water for irrigation and the role of prices and regulations

Water for agriculture is often wasted through exessive irrigation, thus lowering the physical efficiency in the use of water. Efficient use of irrigation water is an obligation of each user. No man has the right to waste water which another man needs. Irrigation efficiency is a general term which can be applied to irrigation practice in a qualitative manner. To describe the overall efficiency of an irrigation system quantitatively, evaluation of segments of that efficiency can be made. The product of multiplication of such segment efficiencies would give the overall efficiency.

There concepts of irrigation efficiencies will be discussed, namely, water conveyance efficiency, water application efficiency and water use efficiency.

The water conveyance efficiency concept evaluates water losses while conveying water from the point of diversion (streams or reservoirs) to the farm. In an earth canal system, the conveyance losses, due to absorption and percolation, range from 25 to 40 per cent of the water delivered at the point of diversion. Conveyance of water by lined canals or pipes would reduce the conveyance losses to only 1 or 2 per cent of the total volume of water delivered at the diversion point. The choice is, however, subject to water abundance and economic considerations. Water conveyance efficiency can be formulated as follows:

$$Ec = 100 \frac{W_f}{W_d} \quad \text{where:}$$

Ec = Water conveyance efficiency in per cent.
W_f = Water delivered to the farm.
W_d = Water diverted from diversion point.

1/ Equity in Use of Water, p.16

Water application efficiency is concerned with determining how much of the water delivered to the farm is being stored in the root-zone where it could be used. The concept can be applied to a farm or a field.

Common sources of water loss from a farm are surface-run off and deep percolation losses depending on topography and soil characteristics among other factors. Irregular land surface and excessive single water application increase losses. In normal irrigation practice, efficiencies of application are in the range of 60 per cent, whereas well-designed sprinkler irrigation systems are generally considered 75 per cent efficient.

Having conveyed water to the point of use and having applied the water, the next efficiency concept is the efficiency of water use or what proportion of the water delivered to the field was beneficially used by crops. Sources of loss of water in the field are exessive surface evaporation and deep penetration of water beyond the root zone.

Field and farm irrigation efficiences for three general soil types are presented in table 8.

Table 8: Typical water--application losses and irrigation efficiences for different soil conditions

Item	General Soil Type Porous sandy soil	Medium loam	Heavy clay
Farm lateral loss (per cent)	15	10	5
Surface run-off loss (per cent)	5	10	25
Deep percolation loss (per cent)	35	15	10
Field irrigation efficiency (per cent)	60	75	65
Farm irrigation efficiency (per cent)	45	65	60

Source: Davis-Sorensen, Handbook of Applied Hydraulics, third edition (New York, McGraw-Hill, 1969), Section 33, p.36

Properly formulated policy of prices and regulations, among several other factors, can lead to improving both physical and economic efficiencies.

High values of water are incentive to farmers to abandon water-wasting irrigation methods such as flooding and furrows and, possibly, follow instead water saving methods such as centre-pivot sprinklers and drip irrigation when feasible.

Even when the value of water is low, farmers should guard against over-irrigation to avoid drainage and salinity problems.

1. Government recovery of capital investment and subsidy[1/]: Irrigation projects are generally highly subsidized. The justification for the subsidy is based on grounds of increasing exports of agricultural products and providing employment opportunities for the rural communities.

Below is a table showing the level of subsidy of irrigation water in some countries:

Table 9: Level of subsidy of irrigation water in some countries/regions

Country/Region	Nature and level of subsidy	Reference
Afghanistan	No interest charged on repayment of capital costs (50-years period) O&M* are fully subsidized but farmers pay a fixed tax per hectare.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
Australia	All capital construction costs and part of operation and management costs.	Bhagirath (1969)
China	50 to 70 per cent of capital construction costs.	Asian Development Bank (1973)
Democtatic Kampuchea	100 per cent of capital and O and M costs.	Asian Development Bank (1973)
Democratic People's Republic of Korea	70 per cent of capital construction costs.	Asian Development Bank (1973)
Democratic Yemen	100 per cent for large and small works.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
Europe	Generally 40 per cent of costs of irrigation.	ECE Committee on Water Problems (1976)

* O & M: Operation and maintenance.

1/ Paul Duane, A Policy Framework for Irrigation Water Charges (Washington D.C.: World Bank Staff Working Paper No.218, 1975).

Table 9: Level of subsidy of irrigation water in some countries/regions (cont'd.)

Country/Region	Nature and level of subsidy	Reference
Eastern Europe	100 per cent of capital construction and O M costs. A tax on the land is paid.	F.A.O. Irrigation and Drainage Paper 40, Rome 1980.
Indonesia	100 per cent of irrigation works.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
Japan	40 to 80 per cent of capital construction, improvement and reclamation costs.	Asian Development Bank (1973)
Lao People's Democratic Republic	100 per cent of capital and O&M costs.	Asian Development Bank (1973)
Malaysia	100 per cent capital construction and over 50 per cent to O&M costs.	Taylor (1975)
Pakistan	In lower Indus region, cost of irrigation is only 10 per cent of the returns.	Caruthers (1968)
Peru	All capital costs of major irrigation projects.	Seagraves (1978)
Philippines	40 per cent of operation and management costs in the Santa Cruz system.	Torres (1972)
Saudi Arabia	100 per cent for large irrigation works. 50 per cent of irrigation pumps and farm equipment.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
South Africa	100 per cent of capital construction works and an average of 69 per cent of annual O & M costs.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
Spain	Up to 50 per cent of major works including main and primary canals. Secondary canals are paid for by farmers.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.

Table 9: Level of subsidy of irrigation water in some countries/regions (cont'd)

Country/Region	Nature and level of subsidy	Reference
Sudan	100 per cent of irrigation works. However, interest (6 per cent) is paid on capital cost. Government receives part of the farm income through fixed shares in the capital cost.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
Tunisia	30 to 60 per cent of main construction works and farm development costs.	F.A.O. Irrigation and Drainage Paper 40, Rome, 1982.
United Republic of Tanzania	100 per cent of capital and O&M costs.	United Nations questionnaire.
United States	Up to 60 per cent in Bureau of Reclamation projects; mostly by other uses, mainly power.	Water Resources Council (1968)
USSR	100 per cent irrigation infrastructure and operation	Bhagirath (1969)
Viet Nam	100 per cent of capital and O&M costs.	Asian Development Bank (1973)

Sources: United Nations, Efficiency and Distributional Equity in the Use and Treatment of Water, Natural Resources/Water, series No.8, (New York, 1980), pp.39-40.

When flows are variable, it is common to distribute water among farmers according to shares. Each farmer receives a proportion of the flow of a canal for a certain period of time;

2. Alternative systems of delivery to the farmer and pricing: There are two general types of pricing structures for irrigation water:

(a) Flat rate or fixed charges based on area or a fixed percentage of the crop;

(b) Graduated charges related to volume;

3. Systems of delivery: there are four common methods of delivery, namely continuous flow, rotation, demand and closed pipe.

The continuous system involves a continuous flow of water through a canal on certain days. Each farmer is allowed to receive the water he needs. Farmers either pay annual fees for the water or contribute labour towards maintaining the canal and removing the accumulated yearly silt.

The rotation system involves delivering water to users by turn in accordance with a preassigned schedule. Farmers receive shares of an annual flow and are charged according to the number of shares, or by hectares served.

In both cases of delivery of the demand system or the closed pipe system charges are based on volume of delivered water;

4. The relation between system of delivery and efficiency: Table 11 shows the effect of system of delivery on component and overall irrigation efficiencies.

Table 10: Effect of system of delivery on component and overall irrigation efficiences

System of delivery	Application efficiency	Conveyance efficiency	Overall efficiency
Continuous flow	0.27	0.91	0.25
Rotation	0.41	0.70	0.29
Demand	0.53	0.53	0.28
Closed pipe	0.70	0.84	0.59

Source: United Nations. Efficiency and Distributional Equity in the Use and Treatment of Water, Natural Resources/Water Series No.8, (New York, 1980), p.44.

D. Brief review on actual practices in the ECWA region and India

In Egypt, Syria, Iraq and Lebanon and, to some extent in Jordan, the prevailing irrigation methods are as follows: flooding (mainly basin) and furrow irrigation. In the vicinity of Kirkuk, 25,000 hectares are to be irrigated by centre-pivot sprinklers from the main Kirkuk project canal in Iraq1/.

Drip irrigation have been used to irrigate the planted trees along the two sides of the highway from Dubai to Abu Dhabi. Both protable sprinklers and centre-pivot sprinklers have been known in the ECWA region especially for irrigating house gardens.

The continuous and the rotation systems of delivery are the prevailing systems in Egypt, Syria, Iraq, Lebanon and Jordan. Closed pipe and demand systems of delivery are not known in the ECWA region.

Charges for water are indirect in the form of a fixed land tax per unit area or a small percentage of the crop in case they do exist. Irrigation water is fully subsidized as in the case of the Gulf countries, or highly

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1/ Alghita Kashif, Kirkuk Irrigation Project, a treatise submitted to the Federation of Arab Engineers' Conference, January 1964, (Baghdad: Civilization Press, January 1964), p.3. Text in Arabic.

subsidized as is the case in the other parts of the region. In Iraq, farmers are only responsible for desilting their field ditches. The Government of Iraq provides cultivators with loans on easy terms to help them hire government agricultural machinery and buy fertilizers etc. Extension services are offered free of charge. No government recovery of capital investment exists.

India: the total gross area irrigated in India amounts to 33 million hectares which represents 20 per cent of the world's total irrigated area1/. Twenty six million hectares of the above-mentioned area is utilized in the production of food grain.

The predominant crop is rice, followed by wheat and barely.

For irrigation water charges the Irrigation Commission in India adopted some guidelines, some of which are as follows:

1. Water rates should be levied on a "crop basis" except in the case of irrigation from tube-wells;

2. The rate should be related to the gross income from the crop and not to the cost of the project; it should range between 5 to 12 per cent of gross income, the limit being applied to cash crops; and,

3. The rate should be within the paying capacity of the irrigators and should aim at ensuring efficient utilization of available supplies.

Two general pricing structures -- fixed and volumetric rates -- are in common practice in India.

It may be desirable to use a system of shares, such as a certain proportion of the flow for given time periods as an alternative to the volumetric measure to allocate irrigation water. It is possible to design water charges to include the cost of drainage.

E. Water and waste charges to households

Water-supply and sewer services in urban centres are usually run under the direction of municipalities. The water supply and sewage schemes are non-profit enterprises planned and executed for the welfare of the citizenry. Their charges for services offered should, however, cover the operation, maintenance and replacement expenses of the water supply and sewerage projects and recover the capital investment during a period consistent with the paying ability of the people served. The structure of charges and tariffs should be designed so as to achieve the goal of income redistribution by letting the richer sector of the society which consumes more water volume per capita pay for the fully subsidized public standpipes in favour of the poor. Water and sewage disposal charges are usually combined in one monthly bill for the sake of simplicity and economy in minimizing the administrative cost.

1/ J.S. Kenwar, Water Management and Crop Planning in India (Manila: Asian Development Bank, 1973).

Efficiency, equity and cost recovery from the main objectives of the authorities.

Where metres exist, average cost pricing by equating prices to relevant marginal costs is the recommended and most prevalent practice. The policy of offering unmetered water service at a flat rate should be dismissed. Metering has proven effective in making customers avoid wasting water.

Higher prices are another incentive against wasteful water usage. Regulation can serve the dual goals of economy and equity.

Some administrators and economists are interested in taking all the factore into account when designing the tariffs for water supply and sewage disposals ending up with complicated tariffs that are difficult to understand and possibly quite costly to enforce. Such points as interruptable service contracts, peak demand pricing, waste strength charges, acreage and distance fees are not usually considered in most of the developing countries of the world.

Most countries adopt a more simple system of tariffs using the increasing block charging system, based on metering, a fixed connection fee and a fixed monthly billing fee per household.

Developing countries have been receptive to the use of increasing block rates.

Raw water for irrigating house gardens and brackish water for some domestic uses are usually supplied by a separate system other than the drinking water supply system and could have a different charging system based on a fixed monthly charge per unit area of garden or fixed fee per cubic metre of brackish water.

"Benefits from metering and charging what water is worth are approximately equal to one half of the value of the water saved by instituting volumetric charges"1/.

Benefits of metering could be summarized as reduction in water consumption, rapid detection of leaks and fairness to all customers.

The sewage service charges are usually billed in the form of a percentage of the entire water bill being less, equal or more than the water charges according to the specific circumstances of each sewerage scheme.

F. Water quality management in streams and the role of effluent charges

Water pollution is a process by which the availability of suitable water for various uses is reduced.

The concentration of nutrients, toxics, biochemical oxygen demand, coliform bacteria, sediment, turbidity and temperature determine the water quality. Increases in most of these are undesirable, casuing pollution.

1/ Equity is Use of Water, Natural Resources/ Water Series No.8 (New York, 1980) p.44.

Fish are killed as a result of toxic materials or lack of dissolved oxygen. Toxic materials such as mercury make water unsafe for drinking, bathing or other domestic uses.

A downstream community will suffer by having to re-use polluted water discharged by an upstream community.

Physical solutions of the pollution problem in streams is concerned with such methods as waste treatment technologies, new production techniques, reduction of wastes at sources, increased flows of fresh water in the streams, storage of wastewater and in stream aeration.

Economists are concerned with incentives such as regulations, taxes and subsidies.

Insistance that industries should use particular types of waste treatment is often accompanied by government equipment subsidies.

Effluent permits are widely used to regulate waste discharges into streams and other bodies of water.

Maximum waste discharges allowed may be defined in terms of kilos per day or concentration (million gallons per litre of waste effluents).

It is possible for governments to specify the minimum biological oxygen demand (BOD) level at the most critical point on a stream during a critical level of flow. This method will not work for toxic substances that are hard to detect. A combination of regulations, subsidies and charges may be used.

The cost of monitoring should be considered when framing the regulations and setting the charges.

An acceptable level of pollution must be defined taking into account the waste-assimilating capacity of the stream, and the public interest.

<u>Summary</u>

The water-supply and sewage schemes are non-profit enterprises executed for the welfare of the population. Their charges for services offered should cover the operation, maintenance and replacements expenses and could aim at capital investment recovery, in certain situations, within a period consistent with the paying ability of the people served.

Tariffs of an increasing-block nature are designed to recover the above-mentioned expenses and achieve the goal of income redistribution and equity. Metering and pricing have resulted in reduction of domestic water use, reducing the design capacity of the system thus lessening the capital investment cost and making easier the detection of leaks. Sewage disposal charges are calculated as a percentage of the water bill and combined in one monthly bill to reduce adminsitrative costs. Dual prices, one for domestic water and a second monthly flat-rate charge for water used to irrigate house gardens with untreated water through a separate network, are usually employed.

The cost of water supplied to industries plus the cost of industrial waste treatment is charged to the concerned industries, including capital investment costs.

Irrigation water is totally subsidized in the ECWA region. Reasons are provision of jobs for the rural people, decreasing food imports and increasing agricultural exports of certain ECWA countries, thus improving the foreign trade payment balance. Some form of indirect charges for irrigation water is levied in the form of a flat annual rate per unit area or the more common method of crop yield percentage as in Syria and Egypt. Efficiency of water use in irrigation is urged through decreasing conveyance, water application and water use losses. Modern engineering and agronomic measures are adopted to achieve this goal depending on abundance of water and economic considerations. Information on unit price water production costs, tariff schedules for various uses in each ECWA member country is included in chapters (IV, V) and (VI). Such tariff schedules must be revised periodically to cope with rising costs of labour and materials.

III. DESALINATION AND REMOVAL OF MINERALS

A. Introduction

It is estimated that half of the earth's land surface is semi-arid or completely desert and that not less than 150 million people live in these areas. Man has always dreamed of desalting seawater to make deserts bloom. It is only within the past two decades that it has appeared possible to desalt a sufficient quantity of seawater to supply the needs of a city.

On January 22, 1966, Secretary-General U. Thant's report to the economic and Social of the U.N. emphasized that "the year 1965 witnessed a strong advance in applied desalination". The world capacity in 1964, an estimated 45 million gallons (170 million litres) of fresh converted water, had been doubted in 1965. Since then, the figure has steadily risen to about 7,600 million litres per day at the beginning of the 1980's1/. The most spectacular operation was the southern California desalination plant which provided over 570 million litres per day and 1,800 megawatts of electric power for southern California. It is fueled by nuclear energy.

The nuclear powered desalination project in southern California produce fresh water at the cost of $0.3 per one cubic metre of fresh water making it fairly acceptable when compared with other fresh water sources. This project is not aimed to satisfy more than 15 per cent of the water needs of the region. The desalination operation there is a supplementary source which in an emergency could prove essential.

Desalination can provide a supplementary source which could be considered in a larger programme of water quality improvement. The larger programme would include all possible sources of fresh water, Dr. Di Luzio, Director of Saline Water Office in Washington D.C., indicated in August 1965 in an address to the Water Quality Symposium that water management would include control over "Stream flows to insure sufficient dilution to preserve the self regeneration of streams, sewage treatment, control of pumping from underground aquifers, knowledge of aquifer recharging rates, control of salt water intrusion by such means as fresh water injection and planned programme of irrigational water re-use". If these measures fail to provide sufficient quantity and quality, desalination should then be considered as a supplementary source of water supply.

Desalinated water has so far not proven economic for irrigation which requires large quantities of cheap water. Arbitrary limits were set on the distance within which it may be considered economically feasible to transport desalinated water - these limits were 80 kilometres horizontally or 500 metres vertically.

Desalinated water is uneconomical for irrigation except in a few cases for fruit trees and vegetables which require little water.

1/ Nabil A. El-Ramly, Nabil A. and Chas F. congdon, Desalting Plants (Hawaii, Honolulu: Techno Economic Services, Report No.7, May 1981), pp.1-5.

Most fresh water has less than 500 ppm of dissolved solids. Water containing several thousand parts per million of dissolved solids is not desirable for drinking purposes but it is sometimes used successfully for irrigation. Water of high quality or water free of most minerals is required for human consumption but it need not be of as high a quality for agriculture and for many industrial uses. The dissolved material in most rivers is less than 500 ppm although some contain as much as 2000 ppm. Some groundwater carries soluble salts that it turns so brackish that it is unpalatable as drinking water. Some groundwater carries soluble iron which may give it colour. It corrodes water pipes and household fixtures. Other groundwaters may either contain sulfates which give off foul odours or so much calcium that they leave a deposit of lime in water pipes and cause difficulty with steam boilers.

(a) Desalination processes: much natural water contains dissolved solids, but if the concentration exceeds 1000 ppm it is classed as saline. The U.S. Geological Survey classifies salinity in this type of water as follows1/:

Dissolved solids in ppm	Salinity
1000 - 3000	Slightly saline
3000 - 10,000	Moderately saline
10,000 - 35,000	Very saline
over 35,000	Brine

"Slightly saline" water includes many surface and groundwater supplies that are potentially usable although water containing more than 500 ppm of dissolved solids are not considered desirable for domestic uses. Nevertheless, highly mineralized water in commonly used where purer water is not available.

Saline water is converted into fresh water either by 1. removing the water from the salt; or 2. by removing the salt from the water. The processes fall into five general catagories and according to these two objectives water is removed from salt by either of the following methods: (a) distillation; or (b) by freezing. Salt is taken out of water by electrodialysis with either of the following processes: (a) osmosis; (b) reverse osmosis; or (c) chemicals.

B. Fresh water from saline water

1. Distillation: the most extensively successful form of desalination is distillation which consists of heating brine - or boiling off water, leaving the salt residue. Heat is supplied by fuel oil, natural gas or nuclear reaction. In this process, the heated brine is passed into a low pressure chamber where it flashes into steam with the force of an explosion. It is then cooled, condenses into clear water and channelled off leaving the salt behind.

1/ Lashely G. Harvey, Water-Modern Methods of Use and Conservation, (Staford, Connecticuts: International Publications, Inc., 1966), p.34.

A varitation on distillation with applied heat is the more simple method of using solar energy. Water evaporates readily under the sun rays. The problem is to capture the vapour and a solar has been devised for that function. The sun rays pass through a glass or plastic cover in a basin of brine. Vapour arises and condenses on cooler materials where it condenses on the underside of the cover and drains down into a glass tube and into a vessel. The salt water becomes so warm that the process continues even after sunset. The method requires no other fuel than the sun but it is incapable of producing many litres of water per day, thus limiting its usefulness. There are, however, some small plants operating on Greek islands in the Mediterranean where impounded rainwater proved insufficient and it was formerly necessary to import fresh water to augment the supply. Importation has been reduced, thanks to the solar stills. Even though it is not capable of producing large quantities of water for cities, the process is so economical that it could be a valuable source of fresh water for desert hamlets, seaport villages, small settlements along salt lakes, hospitals, hotels and resorts;

2. <u>Freezing</u>: the relatively new freezing method is attractive because it is less expensive than distillation which requires a great deal of fuel. Saline water is sprayed into a chamber under vacuum. Rapid vaporization of some of the water lowers the temperature causing ice to form. Through rotation and scraping the sides of the chamber a slushy mixture of ice and brine accumulates which is then poured into a "separator". There the ice crystals, being lighter, float on top and the brine is drained from the bottom. The cool waste brine passes through an "exchange" where it helps to cool the incoming salt water. The ice crystals are washed with refrigerated water. The ice melts at room temperature into fresh water. Freezing is not only more economical in terms of energy requirement, but is relatively free from corrosion.

Both distillation and freezing requires water to pass from its liquid form to another phase, referred to as "phase change". Distillation is a process which forces a change from liquid to vapour and the freezing method forces water to change to a solid - or ice. Heat or electric power or both are necessary to accomplish either of these results which accounts for the high cost of these methods. Solar energy as a substitute for fuel or electric energy is cost-free, but its use is limited;

C. <u>Salt removal from saline water</u>

Methods for removal of salt from brine or brackish water are numerous:

1. Osomis: salt is removed from brine or brackish water by electrolysis or with the aid of electric current. Chemicals have positive and negative electric charges. When brine is placed in a vat and electricity is applied, for example, the positively charged sodium ions move through a membrane which is negatively charged, at the same time the negatively charged ions of chloride pass through a positvely charged membrane, deserting the water and freeing it from dissolved salts. The salt-free water is then captured and drained;

2. <u>Reverse osmosis</u>: for reverse osmosis, brine is placed under pressure which forces it through a membrane that is capable of rejecting disolved salts - a sort of straining process which separates the salt from the brine when it is forced through the membrane;

3. <u>Chemicals</u>: methods are being conducted to separate water molecules from salt. These methods involve solvent extraction and gas hydrate separation techniques. Application of chemicals to water must result in dissolving appreciable quantities of water from saline solutions, leaving highly concentrate brine behind, or with a temperature increase water must vaporize, releasing water molecules previously dissolved.

The gas hydrate separation process requires contact of gas with salt water, e.g. such gases as light hydrocarbons or halogenated methanes cause crystalline hydrates (ice) to form. The remaining liquor is separated from the crystals, leaving mineral-free water when melted;

4. <u>Measurement of success</u>: the price of obtaining fresh water from seawater depends largely upon the cost of energy. For this reason the greatest immediate future for desalination lies in the large dual-purpose plants fueled by atomic energy to convert saline water and also produce electric power. They will be used to provide a supplementary source of fresh water and electric power principally for cities and urban complexes. Some of the large commercial electric power equipment manufacturers have desalination equipment available. Several companies have developed smaller units for desalination. The equipment is used to provide fresh water for two new luxury hotels on the islands of Djerba off the coast of Tunis. These are only two of many such installations. There is also a portable water converter which can be flown in by helicopter to areas where fresh water requirements are critical. In the wake of hurricances, floods or earthquakes, this unit can save the lives of many people who might otherwise be compelled to drink contaminated water;

5. <u>The future of desalination</u>: desalination is moving at a rapid pace. Both large and small-scale equipment is being improved and more economical methods employed. So far, removal of water from salt is more successful for great volume production. Dual purpose plants promise to be the most economical in this category if powered by atomic energy and if they produce both fresh water and electric power. A process which does not require a phase change - from liquid to vapour or liquid to ice, should ultimately be more practical and economical.

Distillation and freezing were the most obvious processes to be appplied. Osmosis and reverse osmosis, or the straining of liquids through membranes thereby removing undesirable minerals and other substances requires pressure and electric energy, but not as much as distillation and freezing. Its failure to gain wide adoption has been its inability to desalinate large quantities of salt water. Perfection of techniques for large-scale operations has progressed in recent years.

Experiments with desalination have two important by-products. It is already learned that many valuable minerals other than the usual salts can be extracted from seawater. It is also learned that perfected techniques can lead to improved methods for demineralization of groundwater. Groundwater is presently subjected to various forms of treatment to make it palatable. These may not be abandoned, but new methods for removal of minerals from water will supplement existing treatment methods.

D. Desalination plant operation survey

There were more than 2,200 land-based desalting plants of capacity 95m^3 per day or more at the beginning of 1980's.

As mentioned earlier, these plants were capable of producing close to 7,600,000 cubic metres of water daily.

The above-mentioned capacity was divided as follows[1/]:

USA	15.0%
Middle East and North Africa (mostly OPEC)	65.0%
Europe and South-east Asia	12.0%
USSR	3.5%
Carribean, Mexico and South America	3.5%
Scattered throughout the world	1.0%
Total	100%

Distillation accounted for 76 per cent of the total plant capacity. More than 67 per cent of which are multi-stage flash. Membrane process, mostly reverse osmosis, accounted for 23.9 per cent. Freezing accounted for less than 0.1 per cent of the total capacity.

Surveys in the Middle East indicated that the water costs show large variations, particularly in the smaller capacities. Cost per unit volume of produced fresh water decreased with increase in plant capacity up to 5000 m^3/day after which no charge in unit cost was observed.

Charges are made for water in about half of the systems reported, the highest being roughly $11 per cubic metre.

Desalted water provided from 19 per cent to 100 per cent of the total water supply in the systems surveyed.

The reported costs of seawater desalination varied between $1.00 - 1.45 per m^3 in the United Arab Emirates in 1982[2/], and the cost of destilled seawater in Qatar varied between $1.14 - 1.16 per m^3 at zero energy cost, and $1.45 - 1.64 per m^3 with energy at world market prices in 1980[3/].

1/ El-Ramly and Congdon, op.cit., pp. 1-5.

2/ GWE Consulting Engineers, New Dubai Sewage Treatment Plant Feasibility Study, (Dubai Municipality, May 1982).

3/ Balfour-Halcrow Consulting Engineers, Master Water Resources and Agricultural Developmetn Plan (Qatar, Ministry of Industry and Agriculture, 1981).

The average maximum economic distance for the transport of desalted water is slightly less than 11 km.

The economic analysis shows wide variations in the specific investment per unit volume of desalted water even for plants of the same capacity. This is due to inflation and different industrial practices.

Fixed charges on capital investment include depreciation, interest, taxes and insurance.

The expected lifetime of all the distillation plants surveyed by the Second U.N. Desalination Plant Operation Survey in 1973 and those included in the Desalting Plants Inventory (Report No. 7, 1981) of Techno-Economic-Services, Honolulu, Hawaii, ranges from 10 to 20 years with an average of about 16 years.

The average distribution of component cost expressed as percentage of the total cost is as follows: 38 per cent for fixed charges, 21.3 per cent for labour, 20.5 per cent for fuel plus electricity, 16.2 per cent for maintenance and 4 per cent for chemicals.

E. Solar distillation

The following is extracted from a research study on "Systems for Solar Distillation" at Brace Research Institute of McGill University, Quebec, Canada.

Components and specifications for solar stills.

The main components of solar stills are as follows[1/]:

1. Transparent cover (glass or plastic);
2. Evaporator liner;
3. Solar still frame;
4. Sealants;
5. Insulation;
6. Auxiliaries - piping, pumping and reservoirs.

General specifications of solar stills

There are certain basic requirements which must be met. In general, the unit should meet the following ones:

1. It must be easily assembled in the field;

2. Imported materials should be packageable to reduce transportation costs;

1/ T.A. Lawand, Systems for Solar Distillation, (Canada, Quebic: Brace Research Institute, McGill University, 1978), pp. 1-8.

3. Materials should be lightweight for ease of handling and shipping;

4. Solar still must have an effective life, with normal maintenance of 10 to 20 years;

5. Solar still must have access parts for ease of maintenance;

6. The solar still should not require or depend upon external power sources;

7. The solar still should serve as a rainfall catchment surface.

In the reference, the most important solar distillation plants are listed as follows:

Australia (6 solar plants), Cape Verde (2 plants), Chile (2 plants), Greece (11 plants), India (one plant), Mexico (one plant), Pakistan (2 plants), Spain (one plant), Tunisia (2 plants), USA (4 plants), USSR (one plant) and West Indies (2 plants).

F. Extent of desalination in the ECWA region1/

Desalination water produced by different methods in the ECWA region, (group 1 member countries), amounts to about 50 per cent of the total present world desalted water production. Saudi Arabia's plants' capacity is about 2,010,946 m^3/d (1981). They are erected on the east and west coast, and inland. Kuwait desalination plants' total capacity is about 530,000 m^3/d (1981) situated in Shuwaikh, Shuaiba and Doha. More plants are under construction, planning or study that would add another 300,000 m^3/d at an estimated cost of $350 million. The total capacity of the Emirates desalination plants in Abu Dhabi, Ruwais, Dubai, Shyah and Ras-Al-Khaimah amounts to 218,000 m^3/d (1981). Qatar's desalination plants capacity at Ras Fontas and Ras Abu Aboud is about 123,000 m^3/day. Bahrain's Sitra desalination plant capacity is about 70,000 m^3/d. In Oman, the city of Muskat plant produces about 18,000 m^3/d for drinking purposes2/.

In chapters IV, V and VI of the present study more information concerning costs of desalinated water in the ECWA region, costs of water production by other methods and further details related to the subject will be presented.

1/ Arab Water World, March-April 1982, pp. 83, 86, 95, 99, 101, 103 and 104.

2/ All figures regarding capacities of desalination plants above refer to the year 1981.

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/l) 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: <u>Development of total domestic and commercial water consumption (in million cubic metres) between 1975 and 1980</u>.

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) <u>The Batinah Coastal Plain Aquifer</u>: 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) <u>The Deep Carbonate Aquifer System</u>: 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 waterering 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.

V. WATER SITUATION IN ECWA COUNTRIES (GROUP 2)

A. Introduction

The group consists of Democratic Yemen, Jordan and Yemen. Group 2 member countries enjoy better water resources potenalities than group 1 countries ; then have good harbour facilities, (Aden, Aqaba and Hudeida); and the possibilities of expanding tourism are better. They are not oil producing countries and depend for their development partly on foreign aid from other countries. some oil has recently been discovered in the two Yemens.

Common characteristics of Group 2 member Countries are as follows:

(a) The arable land in a member Countries in this group is very fertile with high yield per unit area, although it is usually found in he form of relatively small lots of land. They are all relatively arid and arid in climate.

(b) Agricutlure forms the major source of national income for all the countries of this group and is the occupation of a large number of the population.

(c) Rainfed agriculture is prevalent in Yemen and partially practiced in parts of Democratic Yemen and Jordan where irrigation is essential for a prosperous cultivation.

(d) All member Countries of Group 2 have suitable sites for constructing relatively small surface-water reservoirs; nevertheless groundwater and precipitation remain as their main natural water resources.

(e) Bedouins engaged in herding and cattle breading from an active sector of the population for whom the concerned governments are providing settlement projects.

B. Country studies

A country-by-country study of the situation in this group is presented below:

Democratic Yemen

1. General: Democratic Yemen has an area of 337,000 km^2 and in 1980 had a population of 1.9 million of which 33 per cent, 57 per cent and 10 per cent were urban, rural and nomad in populations respectively.

Democratic Yemen occupies the southern portion of the Arabian Peninsula. The main physiographical units are a narrow coastal plain where most of the population is concentrated, a mountain ridge reaching heights of 3,700 m parallel to the coast and a vast desert plateau inland, deeply incised by the Hadramwat valleys which are also densely populated. The deltas of the coastal wadis are the arable lands. They receive flood waters from the catchment areas in the interior, which are mostly diverted to the fields before they reach the sea.

In the interior, there are several agricultural areas which wholly or partially depend on groundwater. These plateau lands vary in height between 650 and 1,200 m. In the far north and north-east the desert extends through the Rub al Khali to the borders of Saudi Arabia, where only nomads live.

The climate is strongly influenced by the asian monsoon winds. Average annual rainfall is about 300 mm on the high plateau lands and 40 mm in coastal areas. Mean daily temparture varies between 15°C and 38°C. Minimum and maximum temperatures recorded 4°C to 48°C. The difference between night and day temperatures might be as much as 20°C to 30°C in the interior which has a desertic climate. Evaporation rates may vary from 2.5 - 4.0 m/year.

2. Water resources

(a) Surface waters: Democratic Yemen has no perennial rivers. The dry river beds of wadis convey floods of short duration (two to four hours) towards the sea or towards the desert during rainy seasons. Wadi Hadramawt has the longest and widest catchment area with interconnections with other Sub-wadis. Wadis of major importance for their agricultural possibilities, can be tabulated as follows:

Wadi	Catchment area Km^2	Yield MCM/year
Tiban	3,500	60-140
Bana	10,000	160-360
Ahwar	6,000	75
Mainfa's	5,500	30
Hajr	9,300	280
Hadramawt	114,000	144

Other wadis of less importance flow to the interior;

(b) Groundwater: in Democratic Yemen, as in most arid regions, groundwater is generally the only source of water for domestic, agricultural and other uses. Traditionally, agriculture depends on seasonal rains mostly the short intensive summer monsoons. The rains fall in the cathment areas, mainly the interior highlands, and flow as floods through the wadis and lowlands, eventually reaching the sea. A limited amount of these flood waters percolate into the subsurface aquifers, depending on hydrological, hydrogeological and geomorphological conditions, such as higher inclinations of lands towards the sea or desert; shorter or barren highlands from which floods reach the sea before staying long enough to recharge the aquifers; and in some cases, the aquifers themselves are impervious. To increase recharge, diversion walls have been built across the wadis. The building of surface and subsurface dams and local wadi-training measures have been proposed to increase the areas under irrigation by both surface and subsurface means.

Throughout the country the people dig wells for both domestic and agricultural use. There are about 1,800 such wells in Hadramawt alone. Only limited areas are irrigated by dug wells. Optimal discharges range from 3 to 4 l/sec twice to three times a day and are of one to three hours' duration. Such dug wells do not penetrate more than 2-3 m through aquifers. When pumped they may dry up quickly and it may be necessary to wait for some time before water levels recover. Since 1970, it has been the policy to drill wells by modern rigs, and only up to 1976 as many as 650 wells were drilled with depths of 60-70 m. The objective of drilling enough wells to irrigate 600 hectares a year has been accomplished in the past few years. Two ministries have competence in drilling: The Ministry of Agriculture (Irrigation Department) and the Ministry for Local Administration. There are about 40 rigs in the country. Drilling in the delta has been abandoned due to deteriorating conditions. The Ministry for Local Administration drills wells in rural and desert oasis areas to encourage settlement of nomads. however aquifers in these locations have not been very productive and discharges from wells of 150 m depth do not exceed 3 l/sec.

The quality of water in Democratic Yemen is in general adequate but variable in salinity and acidity.

In the interior and plateau lands, water quality is much better than in coastal areas, with the exception of Wadi Hadramawt, where it differs in all respects.

Municipal water supply is the responsibility of the Water Corporation Department organized in 1970 within the Ministry for Local Administration. Prior to that date the Ministry was incharge of the water supply of Aden only.

It has been acknowledged that in the Wadi Tiban area aquifer recharge is less than discharge. A decline in the water level and seawater encroachment have been noted in some wells notably those supplying Aden, so that an increase in water extraction is not being considered. At present, Aden consumes some 22 million m^3/year for municipal and industrial purposes.

A few measures have been taken to recharge the aquifers, among which is the building of diversion weirs across the wadis. Subsurface barrages are now being considered for that purpose and for training wadis to have longer flow periods.

3. <u>Water development strategies</u>: municipal water supply is the responsibility of the Water Corporation Department organized in 1970 within the Ministry for Local Administration. The water supply relies essentially on groundwater resources.

At present Aden consumes some 22 MCM/year for municipal and industrial purposes. The Aden water supply is a reasonably well-planned and well managed system with 24 hours service. However, it needs repair and efforts are being made to improve the supply particularly by exploiting additional groundwater resources at a distance of 60 km. In the other urban areas the supply is partly through house connections and partly by standposts but is intermittent and unsafe.

The rural water supply is very unsatisfactory; it is inadequate, unsafe, and often not easily accessible.

According to the latest statement of WHO/EMRO 68 per cent of the urban population and 23 per cent of the rural population are served by safe water supplies. If the above mentioned rural service levels are considered, the coverage is estimated to be 10 per cent only.

Water Demand Projections in U.S gallons c/d for the year 2000 were estimated as follows:

Municipal	Industrial	Agricultural	Total
93	114	79	286

The population is expected to reach 2.75 million by the year 2000. Operational targets are set to serve 98, 80 and 22 per cent of urban, rural and nomads respectively.

Tariff structures will also be set so as to allow the poorest households a satisfactory level of service.

A total of 33 urban water supply projects are planned for the 1981-1985 period, at an estimated cost of YD 21 million; 27 of these projects are already under construction. Objectives of the Country Report for 1979-1983 include increasing the abstraction rate from 22,100 m^3/d in 1979 to 89,100 m^3/d in 1983 and serving about 233,000 more people.

There are a number of United Nations projects for rural development, including rural water supply and Bedouin development.

Only 50 per cent of the Aden city area is served by a piped sewerage system. Another 25 per cent discharges through open channels into the main sewerage system. A further 25 per cent of the city is served by soakpits. There are no treatment facilities. The raw sewage is discharged by several outfalls into the inner harbour and along the sea shore.

Mukalla, the second largest city (55,000 inhabitants in 1980) has no comprehensive sanitation system. A system of drains, connected to a series of outfalls, discharges immediately onto the shore, or into the wadi. Soakpits are used. Some properties have septic tanks with outfalls to the wadi. This situation in Mukalla causes severe public health hazards and discomfort.

In other urban areas in the older parts of towns open-channel drains exist in passages or soakpits. In rural areas there are no septic tanks or soakpits. The effluent usually falls on the ground or into a tin which is to be emptied. The sanitation conditions are the worst possible.

The financial requirements for the sector development between 1981 and 1990 are estimated as follows:

For water supply	$ US 161.8 million
For sanitation	$ US 102 million

Internal sources can only provide $ US 21.2 million for water supply and $ US 15 million for sanitation; consequently $ US 128 million are required from external sources.

Yemen Arab Republic

1. General: Yemen has a surface area of approximately 200,000 km^2 a population of 5.7 million[1/], including 1.5 million Yemenis abroad. About 90 per cent of the population is in the rural areas, living in more than 30,000 settlements which constitute about 15,000 villages.

The country can be divided into five physiographical units: (a) Tihama Coastal Plain, 30-60 km wide with an average width of 45 km, extends over an area of about 440 km along the Red Sea and rises to a maximum altitude of 400m. During the rains, wadis in this region can carry enormous floods from the western mountain slopes to the Red Sea; (b) the foothills and western mountain slopes, with altitudes between 400 and 2000 m, is the only region where rainfall is abundant and good crops can be grown all year long; (c) the central highlands, with altitudes between 2000 and 3000 m, and peaks often exceeding 3500 m, and reaching to a maximum height of 3,760 m. Rainfall in the highlands is less abundant than on the western slopes; (d) the high tablelands in which the cities of Sana'a, Mobar, Dhamar and Yarim are located, with altitude between 2200 m and 2700 m above sea level. In most of the areas, agriculture exists by supplies from hand-dug wells or drilled holes; (e) the eastern mountain slopes rise gently towards the eastern deserts and constitute the largest part of the country and end at an altitude of 1000 m in Rub al Khali. Agricultural activities are possible only in a couple of very broad wadis draining the high tablelands.

Between the coastline and the desert, three basic climates may be distinguished in the country. Precipitation is scanty over most of the area. Mean annual rainfall, which occurs mostly in spring and summer, ranges from less than 100 mm up to 1000 mm; in the mountain regions it amounts to about 400 mm. In the mountain of Sana'a temperature ranges from 0°C to 20°C in winter and from 27°C to 30°C in summer. In the Tihama, winter minimum is about 20°C and summer temperatures are between 37°C and 40°C.

2. Water resources

(a) Surface waters: Surface water is available from a limited number of springs and from flash floods which occur in the wadis or dry river beds. Some main wadis in Yemen have a continuous discharge. Most of them originate on the western mountain slopes; their water infiltrates very quickly into the alluvium of the Tihama coastal plain, recharging the alluvium aquifer. The most important perennial springs are the hot and warm water springs occurring at several places throughout the country, but in some cases the salt content only permits a limited use.

1/ World Bank, Statistical Yearbook, 1981.

The nature of the discharge mechanisms of those wadis with very high peak floods and almost non-existent base flows make it difficult, if not impossible, to utilize even a small percentage for irrigation and drinking water supply. For centuries the people have built terraces, small dams and other streamflow-delaying structures to increase infiltration.

Streamflow in the wadis is emphemeral and depends on the intensity of the rainstorms on the western slopes; all these wadis discharge into the Red Sea and the Gulf of Aden in the south.

Total discharge measurements carried out in wadi Zabid at Kolah and Ma'ah indicate annual average flows of 143 MCM and 109 mcm. Differences between the two locations are caused by recharge of the alluvial aquifer in the Tihama through the stream bed and its offtakes for irrigation.

The wadis flowing through the Tihama to the Red Sea have the best potential for irrigation.

Of the four wadis discharging into the eastern desert, the wadi Jauf is the largest. The groundwater level in the flat region is about 50 m, which may open up many possibilities for development. The total annual volume reaching the wadi is estimated at about 15 MCM a year. The water quality in the area varies, the total disolved solids (TDS) content ranging from 500 to 2000 ppm;

(b) <u>Groundwater</u>: Groundwater movement within the main aquifers of Yemen is complex. Six major aquifers can be distinguished in Yemen, namely, alluvium, tertiary volcanics, recent volcanies, sandstones, limestones and basement rocks.

(i) The extended alluvial aquifer which includes the Tihama coastal plains, the montane plains and the eastern desert. The Tihama coastal plains consist of alluvial fans and flood plains composed of gravel, sand and silt, permeability in the plain is good and high yields are obtained from wells. Water quality near the mountains and the main wadis is excellent but deteriorates near the coast with the presence of salt lenses.

The alluvium in the montane plains consists of much finer components and alluvial silt mixed with gravel. Total infiltration has been estimated at 3-5 per cent of annual rainfall. Permeability is low and only moderate yields can be pumped from wells. Water levels in different plains vary from a few metres below the surface near Dhamar to more than 60 m near Sana'a.

Because low recharge figures groundwater levels go down yearly, all hand-dug wells in Sana'a have had to be deepened every month. Some have reached down to about 60 m;

(ii) Tertiary (or Yemen) volcanics: this aquifer has very heterogenous characteristics, sometimes providing small quantities of good quality water.

Wells with yields of up to 5 l/see can be drilled in areas where groundwater levels are not very deep, but drilling in these very hard volcanic rocks is difficult. They form most of the mountainous area in yemen. Deep gorge-like valleys lower the drainage base so that groundwater levels are very deep in the mountains.

(iii) Recent volcanics are not of importance.

(iv) Amran limestone of the Jurassic age provides a poor aquifer, although drilling is not difficult;

(v) Sandstone formations: Three different sandstone formations occur in Yemen.

Wajid sandstone, where many small springs may be found near the contact with the underlying basement. Development of these springs may be considered as an alternative to drilling.

Kholan series underlying the Amran limestone where only in the concentrated fracture areas reasonable yields can be expected from boreholes.

Tawilah sandstone is the best sandstone aquifer in Yemen yielding between 20 and 30 l/sec from a borehole. In the future, the drinking water supply, especially around the capital, Sana'a, will depend on this aquifer. Total thickness is between 200 and 250 m. The Tawilah sandstone overlies the Amran limestones which in some cases form an impervious layer. Springs originate near the contact between the two geological formations.

(vi) Basement rocks: in Yemen a multitude of basement rock components occur. Infiltration rates are very low. Intensive surface run-off results in a high degree of erosion. The building of small dams even underground, may store water on the impervious rock in selected steep valleys. In the eastern desert, these formations are covered by a considerable alluvial blanket;

The most exploited aquifer in Yemen is the alluvium, where the water is obtained mainly by means of hand-dug wells. In the mountain plains, drilled wells provide water in and only around Sana'a. In the Tihama, wells have been drilled with yields of up to 50 l/sec, mainly for the purpose of irrigation. Most wells drilled in the montane plains do not yield more than 10-15 l/sec.

In volcanics, yields of 1-2 l/sec may be obtained. Sandstones are productive if drilled down to a depth of 200 m. The limestones in Yemen have so far not shown goods yields.

Well drilling has been carried out by local establishments as well as foreigners.

The results of the surveys conducted in the alluvial deposits have so far given promising results. In coastal areas salt-water intrusion an salt lenses in the alluvium present a big problem.

Overdraft of groundwater is a major problem all over Yemen, especially in well fields supplying major urban areas such as Sana'a, Mobar and Dhamar, where a steady lowering of water levels has been noted over the years (1.8 m a year in Sana'a, on the average).

3. Water development strategies: eleven per cent of the total development budget has been allocated to the water supply sector. Many plans are being made for water supply schemes, drinking water supplies for the larger cities, irrigation projects in the coastal plain and in the highlands, although there is no comprehensive countrywide knowledge of water resources available. Hydrological balances and centralization of drilling activities have to be established in order to calculate exploitation possibilities.

Water supply projects in yemen can be divided into three categories:

(a) The urban water supply: it relies mainly on groundwater as the major resources and is obtained from deep wells. In five cities, modern water supply schemes are under construction or are in the planning stage.

(b) Rural water supply: most villages depend on hand-dug wells. Supplies are inadequate, water shortages are widespread and many wells are contaminated. Many village settlements located on mountain tops use cisterns and open ponds to store the rainwater harvested by small catchments and the water quality is usually bad. Other major sources are hand-dug wells and small springs. The poor accessibility of many localities is one of the major problems involved in serving the rural area. Necessary pipelines and pump stations become costly. In such cases, the price of water installations increases up to 200 YR/m^3, compared with the more common price of 50-60 YR/m^3. In some villages along the seacoast, the water has to be pumped from 20-30 km inland to ensure good quality.

Most of the water resources, specially these for rural areas are subject to seasonal fluctuation. In many places such sources become completely exhausted towards the end of the dry season, necessitating carrying of water over distances of 10 km.

(c) Irrigation Projects: there are under study at various locations to harness the flood waters in the wadis, to direct then for rapid irrigation to saturate the soil as much as possible in a short time and for increased storage of water in the substrata along the wadi beds. Wadi Surdud, Wadi Rima, Wadi Zabid, Wadi Mawr, etc., are among these projects.

Water demand projections in US gallons per capita per day for the year 2000 for an estimated population of 9.5 millions are as follows:

Muncipal	Industrial	Agricultural	Total
9.5	73	115	222

Table 18. Urban water supply projects in the Yemen Arab Republic

City	Total cost (in millions of Yemen rials)	Number of house connections	Population served (thousands)	Completion time	Present status
Sana'a City					
Phase I	129.5	6,000	48	1974-1980	Completed
Phase II (started 1980)	270	18,000	144	1977-1983	under construction
Taiz City	320	7,000	56	1975-1982	under construction
Hodeidah City	346	10,000	80	1975-1983	under construction
Ibb City	410*	8,000	64	1977-1986	under construction
Dhamar City	n.a.	9,000	72	1977-1986	planning and design stage

Source: UNECWA, The International Drinking Water Supply and Sanitation Decade Activities in the ECWA Region, (Baghdad, 1983), pp. 51-55.

* Together with sewerage.

In the five cities of the country, modern sewerage and water supply schemes are under planning or construction. As is shown in the following table.

Table 19. Present status of planning and construction of sewerage scheme in Yemen

City	Completion time	Present status
Sana'a		
Phase I	1975-1985	design completed
Phase II	-	-
Taiz	1982	under construction
Hodeidah	1975-1983	under construction
Ibb	1977-1986	under design (cost with water supply 410 million YD)
Dhamar	1977-1986	under design

In many rural areas fecal matter is accumulated and is used as fuel or manure when dry, causing a number of diseases. There are no known sanitation projects in the rural areas. The sanitary conditions are extremely bad with the absence of any kind of sewerage system or garbage collection.

Jordan

1. General: Jordan has an area of 97,400 km^2, and had a population of 3.1 million in 1979[1/]. Jordan is a land-locked country, with the exception of a narrow coastal opening in the Gulf of Aquaba, consisting of arid, rocky and sandy hills and plains with fertile uplands, west of the River Jordan.

The country may be divided into three major regions;

(a) The lowland areas, which comprise the Jordan Valley, Dead Sea and Wadi Araba Depression. It is a generally flat region with elevations up to 250 m and depressions down to 392 m below sea level (Dead Sea);

(b) The highlands, comprising the eastern and western escarpments of the Jordan Valley. The topography of this region is composed mostly of rugged reliefs and elevations are to 1,856 m above sea level; and

1/ World Bank, Statistical Yearbook, 1981 (Washington D.C., 1982).

(c) The eastern upland plateau with elevations between 600 and 1000 m above sea level.

The climate of Jordan ranges from Mediterranean (dry summers with average maximum temperature of 38.8°C, in winter average minimum temperature 0.5°C) to desert (between 28°C to 32°C for average temperature in the dry season). Annual mean rainfall varies between 50 mm (Wadi Araba and Eastern Desert) and 600 mm (Nablus-Ramalla); but about 80 per cent of the country receives less than 200 mm. Rainfall is received from late October to March, decreasing gradually from north to south and rapidly from west to east. Evaporation averages around 2 m or slightly above. Average humidity is around 55 per cent.

2. Water resources: the drainage pattern of the country is controlled by the major topographical features in Jordan. The general trend of this pattern is mainly in an east-west direction. Most of the stream flows are directed towards the Jordan Valley-Dead Sea-Wadi Araba Depression, through deeply incised wadis and rivers directing the West and the East Bank highlands. Shallow streams flow generally eastwards from the Eastern highlands towards the internal desertic basins and mudflats. In the West Bank highlands, deep wadis cut through and flow westwards to the Mediterranean Sea.

The estiamted total volume of surface water resources in Jordan is 878 MCM in an average year. It may increase to more than 1200 MCM in wet years, and decreases to about 600 MCM in dry years. Apart from the Yarmouk River, where about 80 per cent of its water originstes from the Syrian territory, most of the potential surface water resources are in the eastern wadi catchments draining into the Jordan Valley. There are about 50 MCM of annual surface run-off occurring in the desert closed basins during the rainy season. These flow volumes are hardly exploitable as most of the accumulated floods are lost through evaporation and a minor percentage percolates to the groundwater. Table 21 presents estimates of streamflows in Jordan.

In the Western Jordan Valley main wadis rainfall amounts to 147 MCM per year of which 36 MCM flows as yearly run-off.

Surface water resources of the Jordan Valley consist of the streamflow of the Jordan River and the eleven tributaries (the east bank only) with mean annual total average flows amounting to 645 MCM.

Generally the surface water quality in Jordan is very good although pollution indications are recognized in some localities. The Jordan River waters are highly saline due to return flows from irrigated areas on both banks.

Water resources areas: Jordan has been divided into fourteen areas whose boundaries coincide, in general, with natural limits of the elements of the water resources systems[1/] [2/].

1/ W. Barber, An Outline for Water Planning in East Jordan (Hashemite Kingdom of Jordan, Natural Resources Authority, 1975), pp. 1-41.

2/ Hashemite Kingdom of Jordan, Natural Resources Authroity, National Water Master Plan of Jordan, (amman, 1977), Vols I-VII, See also Water Resources in ECWA Region..., pp. 102-111.

(a) Hammad area: Hammad basin is shared by Jordan, Syria, Iraq and Saudi Arabia The area receives an annual rainfall of less than 50 mm. Several wells were drilled reaching water at a general depth of 150-200 m below ground level with poor quality (more than 2000 ppm of TDS);

(b) Azraq basin: it is a closed depression which recieves an annual rainfall of between 50-200 mm. Evaporation is high (2000-2200 mm/a). Groundwater recharge is estimated at 20-25 MCM/year and the estimated exploitable groundwater is in the order of 10-15 MCM/year. Annual flash floods of 5 MCM volume are lost by deep percolation and evaporation.

Table 20. Estimates of streamflows in Jordan (in MCM/year)*

Year	Area	Rainfall MCM	Estimated Streamflow (MCM)		
			Storm Runoff	Baseflow	Total
Dry	Eastern Jordan	3186	123	284	407
Average	Valley	4140	250	357	607
Wet	Area	5092	422	343	865
Dry	Dead	938	17	128	145
Average	Sea	1406	50	141	191
Wet	basin	1874	101	157	258
Dry	Desert	1481	4.7	18.7	18.6
Average	basins	2068	29.2	20.1	49.3
Wet		2755	78.3	21.6	99.9
Dry		5758	145.9	451.5	597
Average	Total	8065	338.6	539.7	878
Wet		10370	627.7	643.9	1272

Source: Hashemite Kingdom of Jordan, Natural resources Authority, National Water Master Plan of Jordan, (Amman, 1977), Vol III, Annex III, A-3.6, p. 1.

* Figures given do not include Jordan River Flow from lake Tiberias.

(c) Wadi Dhuleil area: annual rainfall ranges from 100-200 mm. The total mean annual surface flow including springflow is about 23 MCM. About 50 wells were drilled in the area. Overdraft conditions and water quality deterioration were experienced and a restriction on well drilling in the area was imposed since 1969;

(d) Amman-Zarqa basin: it comprises a surface catchment area of about 850 km^2 and encompasses the most populated area in Jordan where the cities of Amman and Zarqa are located. Annual rainfall varies from 200 to 500 mm. Evaporation ranges from 2,000-3,000 mm per annum. Wadi Amman is the main wadi draining the area and its total estimated annual flow into the Zarqa River ranges from 20-25 MCM. The main aquifers occur in this area where the estimated groundwater recharges are 20 MCM and 5 MCM for the upper and the lower aquifers respectively. Overdraft conditions prevail in both. A severe water shortage affects the Amman-Zarqa area and the projected water demands in the area are expected to be 85 and 165 in 1985 and 2000 respectively. To meet the increasing water demand other sources are being explored;

(e) The Irbid Governorate area: it comprises the area that extends eastwards of the Jordan Valley escarpment to the Yarmouk River and Sama Sdud area in the north. It receives annual rainfalls of between 300-400 mm. Evaporation is in the order of 2,500-3,000 mm/annum. The area is drained by a number of wadis that contribute to the baseflow of the River Yarmouk in the north, and others draining westwards into the Jordan Valley area. There are two main aquifers in the area. Depth to water level generally ranges from 150-300 mm. Water quality is fairly good (less than 1,000 ppm of TDS), and the annual recharge to groundwater is estimated at 110 MCM. However, the Sam Sdud well field is the only promising area for groundwater development. It is believed to offer annually about 10 MCM of which 6.5 MCM is already being abstracted;

(f) Jordan Valley escarpment: it comprises the eastern escarpment flanking the Jordan Valley area from Um Qais in the north to Salt in the south. The area is drained by several wadis and springs into the Jordan Valley. The mean annual rainfall ranges from 300-600 mm. Depth to groundwater level is variable. Water quality is generally good to medium. Groundwater recharge is estimated at 50-60 MCM per annum;

(g) Jordan Valley area: the area covers the Jordan Valley floor from Lake Tiberias to the Dead Sea. Surface water resources of this area were mentioned in the previous pages. The main aquifers of this area have an annual estimated recharge of 60 MCM of which only 50 MCM/year may be exploitable. Due to the overdraft conditions, water level continues to decline and water quality deteriorates. One of the major surface water projects in the Valley is the East Ghor canal which conveys about 120 MCM from Yarmouk River to irrigate 123,000 donums. Some more water is withdrawn from groundwater and from the baseflow of the side wadis for irrigation;

(h) Mujib basin: the area covers the zone east of the Dead Sea from Madaba in the north to Karak in the south. Annual rainfall ranges from 100-300 mm. Zarqa Ma'in, Majib and Karak are the main wadis in the area. They have an estimated annual baseflow of about 70 MCM. Depth to water ranges from 50-100 m below ground level. Water quality is generally good. The Swaqa, Qatrana and Sultani well fields are the main areas of promising groundwater potentials. There are projects for diverting waters from this basin to other areas of the country;

(i) Hasa Basin: the basin is drained mainly by Wadi Hasa which has an estimated annual baseflow of about 47.4 MCM. Annual rainfall ranges from 100-300 mm. Most of the Hasa baseflow is utilized for irrigation downstream.

The main aquifer of the area is estimated to have a mean annual recharge of 20-30 MCM. The annual exploitable groundwater ranges from 10-15 MCM, of good water quality. Depth to water level in the area ranges from 30-100 m.

Most of the groundwater in the area is being utilized to meet the water demand of the phosphate mining at El-Hasa, which was 3.2 MCM in 1975 and is expected to increase to 6.5 and 10 MCM in the years of 1985 and 200 respectively.

(j) <u>The Shaubak-Ras en Naqb area</u>: surface water is non-existent in this area excepting some major springs in Wadi Araba. Annual rainfall varies between 50-350 mm. Groundwater occurs in the main aquifer where the depth to water level ranges from 50-100 m. Water quality is good (less than 1,000 ppm of TDS). Estimated annual recharge to groundwater is about 15-20 MCM and the possible exploitable groundwater is about 10 MCM per annum.

(k) <u>Araba-Disi area</u>: the area comprises the zone that extends from Aqaba-Mudawara-Ras en Naqb. Mean annual rainfall ranges from few millimetres to 100 mm. Surface water does not exist. During high rainy seasons sporodic flash floods may result in Wadi Yetum. At the major aquifers in the area, depths to water level are about 75 m in the Disi area, 150 m in upper Wadi Yetum and 20-90 m in lower Wadi Yetum and Mudawara areas. Water quality is very good (200-700 ppm of TDS). Estimated annual groundwater recharge varies from less than 35 to about 70 MCM. The safe yield of the Disi well field does not exceed 18 MCM per annum. The estimated annual exploitable groundwater in Wadi Yetum area is about 2.4 MCM. Most of the potential groundwater resources are committed for the socio-economic development of the Aqaba area and its surroundings by a water transfer project under execution;

(l) <u>Southern Ghor and Wadi Araba area</u>: surface water is limited to flash floods. The estimated mean annual flood flow of Wadi Hasa is 47.4 MCM of which baseflow is 25 MCM. Baseflows of other wadis are estimated at 5.4 MCM per annum. Groundwater occurs mainly in the valley fill deposits where quality is fair to poor. The potential groundwater in the area is not identified. It occurs in the southern Ghor with water level very close to the ground surface. The depth to water level in Wadi Araba ranges from 20-80 metres. Exploratory drilling in the area indicates low-moderate yields;

(m) <u>Jafr-Ma'an area</u>: the area receives a mean annual rainfall of less than 50 mm. Sporadic flood waters in Qa Jafer may occur in Wadi Jurdana most of which are lost by evaporation. Recharge to groundwater is estimated at 6 MCM per annum. Depth to water ranges from 15 to 30 metres. Water quality is good to fair, adversely affected by excessive irrigation;

(n) <u>The Eastern Desert area</u>: it receives scanty rainfall of less than 50 mm per year. Groundwater may occur in some localities where depth to water level is about 150 m or more increasing towards the east. Water quality is fair (1,000 ppm) and deteriorates eastwards.

3. <u>Water development strategies</u>:

The domestic and commercial water supply of the country depend mainly on groundwater resources, basically withdrawn from hand-dug or drilled wells. In addition, the water supply is supplemented by a large number of springs with discharges in the order of 40 to 70 m^3/h. Cisterns are also used in some rural areas and in the desert.

A number of storage dams have been constructed and some are under study to alleviate the overall water supply situation. The major storage dams which have been constructed are the King Talal, Ziqlab, Kufrein and Shueib dams. Studies are being undertaken to construct more dams of major importance such as the Maqrin, Wadi Arab and Mujib dams.

In the capital city of Amman, about 85 per cent of the population is served by piped water, the rest by tanker service. About 90 per cent of the blocks in the centre of the city are equipped with house connections. Individual tanks with a capacity of about 0.5 to 1.5 cubic metres are installed on the roofs of most houses because the water supply is intermittent, especially in dry seasons.

The other towns of the country and about 70 per cent of all villages are also served by piped water. Conditions in rural areas in desert regions are somtimes very poor due to lack of safe and sufficient water supplies. Presently, many people boil drinking water. In Jordan, only Amman has reached the goal of supplying water to 100 per cent of the population.

A country-wide water resources master plan provides estimates of the total water potential at 10 per cent of the average annual rainfall, or equal to 1,100 million cubic metres, consisting of 880 million cubic metres of surface water and 220 million cubic metres of groundwater.

Water demand projections in U.S. gallons c/d for the year 2000 for an estimated population of 4.7 millions are as follows:

Municipal	Industrial	Agricultural	Total
43	117	82	243

Sewerage systems with treatment plants (partly still under construction) exist in Amman and, since 1980, in the Salt area (25,000 inhabitants). In areas not connected to a sewerage system, septic tanks or cesspits are common. Systems are in the planning stage in several towns, such as Zarqa and Ruseifa (265,309 inhabitants). Treatment plants discharge mainly into wadis. Re-use of effluents is not yet planned. It has been estimated that 100 per cent of the urban population and 35 per cent of the rural population are served by adequate sanitation. Observations made in Amman indicate that the coverage is between 90 to 95 per cent.

C. Discussion on various water uses, costs, pricing and tarrifs in group 2 ECWA countries

The present total population of Group 2 ECWA countries is estimated roughly to amount to 14.5 million, while the forecasted total population for the year 2000 is estimated to amount to 17.7 million. The population in this group is not much, therefore the available water resources should, if developed methodically, be adequate well into the next century. Water use and costing practices are different in the countries of this group, therefore they are presented countrywise below.

Democratic Yemen

Present population of Democratic Yemen is estimated to be nearly 2 million and the forecasted population for the year 2000 is slightly less than 3 million.

Groundwater, as mentioned earlier, is generally the only source of water for domestic, agricultural and other uses. However, sometimes flash floods devastate the whole country and cause extensive damages.

The measures to be taken for water resources development, conservation, groundwater aquifer recharge and water quality control are as follows:

(1) Local wadis draining measures;

(2) Construction of surface and sub-surface dams and barrages to conserve water and stop salt waste intrusion to the coastal aquifers;

(3) Stopping drilling in deltas of wadis where a decline in the groundwater level is taking place;

(4) Increasing groundwater recharge by building diversion weirs across the wadis, which also assist in flood protection. From the confluence of wadi Hadramawt with wadi Masilah and downstream, along areas in wadi Masilah, variable but perennial discharges up to 10 m^3/sec are reaching the sea.

It is recommended to build a diversion dam, at a suitable site across the lower reach of wadi Masilah to command the surface discharges and divert it to the benefit of horizontal agricultural expansion, and to control and minimize floodings;

(5) Artificial recharge through injection of coastal aquifers should be considered if seawater intrusion endangers drinking water;

(6) Agricultural expansion should take place, after providing measures against flooding, in the deltas of the wadis which are the best arable lands in the country. Since 1970 till 1975 about 50,000 hectares of new arable lands was put under irrigation from drilled wells in the delta of wadi Hadramawt;

In addition to the above, the possibility of constructing a dam and reservoir of considerable capacity in a suitable site at the Hadramawt valley for flood control, agricultural development and recreational purposes should be investigated.

Water costs in democratic Yemen vary widely. They may range from \$ .02 to \$ 0.10 per m^3. Lowest costs are in wadi Bana, followed by wadi Tiban and then by wadi Hadramawt. Municipal water from wadi Tiban costs a little more than \$ 0.03 per m^3 and is sold to households at \$ 0.16 per m^3.

The country report 1/ indicates that a large number of urban and rural water supplies are to be subsidized due to an inefficient tariff system. There is no programme for the coverage of the future operation and maintenance costs of either water supply, or planned sewerage schemes, through internal fundings. The daily average per capita consumption was estimated as 59 litres in 1980, which is lower than the minimum accepted standards by WHO, however, there are plans to increase it to 111 litre by 1985.

Tariff structures for drinking water will be set so as to allow the poorest a satisfactory level of consumption.

There exists a sewage disposal system in aden but no treatment plant is available. Mukalla, the second largest city, does not have such a system.

Yemen Arab Republic

Yemen is paying great attention to the water supply and sewage disposal projects for urban centres. 11 per cent of the total development budget has been allocated to the water supply sector.

Safe drinking water is extracted from drilled wells for urban water supply.

The water supply schemes and sewerage system for the major cities of Sana'a, Taiz, Hudeidah, Ibb and Dhamar are completed. Seven other towns are expected to have their water supply and sewerage schemes completed by 1990.

The capital investment for all water supply and sewerage projects is entirely financed by loans from international, regional and bilateral funds.

1. Municipal and industrial water use: The net supply of drinking water in the capital was 9 MCM in 1982. To this amount is added 20 per cent losses. The total number of connections till the end of June 1983 was nearly sixty thousand, 94 per cent of which are house connections and the other 6 per cent are connections for schools, mosques, factories, etc. These non-domestic connections consumed 22 per cent of the total drinking water production. It is planned to double the total production rate once the energy supply problems are overcome.

A revised tariff schedule is in force at present in all the major cities of Yemen. It was designed to cover the operation, maintenance and replacement costs plus recovery of the capital investment and loans' interestes on loans. It is presented below:

1/ People's Democratic Republic of Yemen. Country Report: Submitted to the Regional Conference held in Baghdad, Iraq, from 6-11 December 1976.

Table 21: Tariff schedule No. 1 for water supply and sewerage for households in Yemen

City	Consumption m^3	water/m^3	Sewage/m^3	Total
Sana'a, Taiz,	1-10	$ 0.704	$ 0.792	$ 1.496
Ibb and Dhamar	11-20	$ 1.430	$ 1.606	$ 3.036
	over 20	$ 2.310	$ 2.618	$ 4.928
Hudeidah	1-10	$ 0.506	$ 0.704	$ 1.210
	11-20	$ 1.122	$ 1.496	$ 2.618
	over 20	$ 2.310	$ 2.618	$ 4.928

Table 22: Water supply and sewerage - tariff scheduled no. 2 (Yemen) General purpose (all cities and towns)

	water/m^3	Sewerage/m^3	Total
Mosques	$ 0.924	$ 1.056	$ 1.980
Hospitals, health centres, schools, training centres, military camps, orphanages	$ 1.056	$ 1.210	$ 2.266
Ministries and government organizations, public baths, public parks	$ 1.320	$ 1.518	$ 2.838

The price of groundwater varies from season to season and place to place. For instance the price of drinking water in Sana'a as seen from the revised tariff scedules ranges from $0.7 to $2.30 per cubic metre, but buying water from a pulled cart can sometimes cost $10 per m^3.

Prices of water in badly located villages can go up to almost $7.5 per m^3.

Spring bottled water named Shamlan is available all over Yemen at a selling price in the local markets that amounts to $55.5 per barrel which is about the price of two barrels of crude oil.

Table 23: Water supply and sewerage - tariff schedule no. 3 (for the Yemen Arab Republic) (unified tariff for all cities and towns) Industrial and Commercial Purposes

	m^3	water/m^3	Sewerage/m^3	Total
1- Restaurants	1-7	$ 0.792	$ 0.902	$ 1.694
coffee shops,	8-20	$ 1.584	$ 1.804	$ 3.388
shops	over 20	$ 2.376	$ 2.662	$ 5.038
2- Hotels, factories, and others (diametre of connection larger than 40 mm)		$ 1.760	$ 2.024	$ 3.784

In 1978 prices from $50,000 to $ 100,000 were being paid for one bore hole, however some small villages can no longer pay for even medium size bore-hole.

The following information was available from the Directorate General of Irrigation, Ministry of Agriculture, Sana'a in November 1983, on the average total well depths and discharges in various parts of the country:

Province	Total depth of well	Well discharge
Sana'a	(200-300) m	(8-16) litre per second
Baidha	(60-100) m	(4-5) litre per second
Jauf	(60-100) m	(8-10) litre per second
Ma'arib	(250-300) m	(3-4) litre per second
Tihama Plains	(80-100) m	(10-12) litre per second
Sa'adah	(200-250) m	(8-10) litre per second
Dhamar	(200-300) m	(4-16) litre per second

Cost of well drilling in Yemen:

Pumping tests (filter, analysis of water and soil, log)	$ 22 per metre
Drilling	$ 154 to $ 220 per metre
Casing and screen (supply and installation)	$ 44 to $ 55 per metre
Ordinary screens	$ 22 per metre
Johnson screens (rust-proof)	$ 100 per metre

Total cost of one metre of well (casing diametre 8 5/8"), ranges from $220-$264 for an ordinary screen and from $308-$330 per metre for a Johnson screen.

Domestic water in rural areas is supplied from the following sources: (i) rainwater collected in cisterns or surface ponds; (ii) hand-dug and some drilled wells; and (iii) springs also supply water to a number of villages in some areas. Sanitary services in rural areas of Yemen are very poor and there are no known sanitary projects.

2. Agricultural water use: At present, irrigation depends mainly on rain water. Approximately 86 per cent of the arable lands are rain-fed, about 6 per cent are irrigated from springs and 8 per cent are irrigated from wells. During the dry season cultivation ceases. The average annual rainfall volume was estimated to amount to 42 billion cubic metres based on a study conducted in Yemen in 1983.

The Directorate General of Irrigation has taken the responsibility of investigating and preparing feasibility reports on the construction of small dams all over the country. Some of the dams, of which recent information was available, are as follows:

(a) Ma'arib Dam: total capacity 600 MCM. Annual storage capacity 200 MCM. 1981 cost estimate $ 110 million. Maximum estimated cost of one cubic metre of water $0.10. Construction of this project has started in 1984.

(b) Wadi Samna Dam: storage capacity 300 000 m3, cost estimate 0.88 million.

(c) Musairita dam: capacity 300 000 m^3. Filled and emptied three times annually because of two rainy seasons, giving it capacity 900 000 m^3 cost estimates $196,000. Maximum cost of one cubic metre of water $1.10.

Many other favourable dam sites also exist throughout the country.

Jordan

The mean annual rainfall in Jordan ranges from 50 mm in the eastern desert to 600 mm in Nablus-Ramalla.

The average annual surface flow, including Jordan River and its eleven tributaries, is estimated to amount to 850 MCM per year. It is divided as follows: and (1) Eastern Jordan Valley: 607 MCM/year, (2) Dead Sea: 191 MCM/year, (3) Desert basins: 49.3 MCM/year. The surface water quality is generally very good. The Jordan Valley River's water is not usable because of high salinity due to irrigation return flows from both banks.

Storage dams already constructed in Jordan are the King Talal (completed 1978), Ziqlab, Kufrein and Shueib dams. The King Talal Dam (Rockfill) is being raised 15 m to reach a height of 108 m, increasing the storage from 56 MCM to 80 MCM. On account of pollution from upstream industries, its waters are solely used for irrigation. However, at present some restrictions are

(*) Source of information: Ministry of Agriculture, Sana'a, Yemen Arab Republic.

imposed on industries, to treat their wastewaters before discharging. The Maqarin Dam to be built on the Yarmouk river is another dam of prime importance to Jordan. Its construction awaits agreement with Syria.

The average per capita water consumption in urban centres in Jordan is estimated at 60 l/capita/day. In rural areas it is estimated at 25 l/capita/day. 85 per cent of the population in Amman are served by piped water with metered house connections. In the other part of Amman a tanker of the city service is in use. A graduated tariff system is employed in the city as a whole.

WHO/EMRO estimate that 100 per cent of urban and 35 per cent of rural population are served with adequate sanitation.

Conclusion

Group 2 ECWA member countries have limited natural water resources. There is, however, room for improving the water situation by harnessing their available surface water by the construction of small dams, the implementation of aquifer recharging projects and the consideration of making use of non-conventional water production methods. Water saving practices should also be put into action.

VI. WATER SITUATION IN SEMI-ARID ESCWA COUNTRIES (GROUP 3)

A. Introduction

The semi-arid ESCWA member Countries include Egypt, Iraq Lebanon and Syria. They all possess perennial river and enjoy annual wet periods and yearly flood seasons, and are designated as Group 3 countries in this study.

Althogh some of these countries might have ample annual precipitation in the form of snowfall or rainfall, such as in Lebanon, or ample annual runoff in their perennial rivers, a substantial percentage of which is comming from watersheds situated outside their geographical boundaries such as Egypts, Iraq and Syria, they receive no precipitation at all for a period of 5 to 7 months each year. Rainfall does not have a regular pattern. These countries experience a high degree of yearly evaporation and contain extensive desert areas.

Common characteristics of Group 3 member countries are as follows:

(a) As stated above, all members of group 3 possess perennial rivers and stream;

(b) All member countries have a varied topography, including extensive deserts, high mountains and vast plateaux and fertile plans;

(c) Agriculture forms the fundamental basis in the national economy of each member country. Providing good living and jobs for the rural people, ensuring food self-reliance and surplus agricultural products for exportation. The climate of each member Country is suitable for growing all types of crops. Both rainfed and irrigated cultivation are practiced though the latter form of cultivation occupies the larger portion of the total cultivated area in each country of the group;

(d) All member Countries suffer from occasional floods, and salt accumulation due to drainage problems in the irrigated areas;

(e) River navigation is practiced in Egypt and Iraq;

(f) The member Countries of Group 3 have a number of fairly well developed light and semi heavy industries, more skilled labourers, craftsmen and technicians than most of the other countries of the ESCWA region;

(g) Being the cradle of civilization, the member Countries of group 3 contain valuable remnants of old civilizations that attract a huge number of tourists annually.

B. Country Studies

A country by country study of the water use situation in this group is presented below:

Lebanon

1. General: Lebanon has an area of 10,400 km^2 and a population of nearly 3 million. The country, located on the eastern coast of the Mediterranean sea, is predominantly mountainous, rising steeply from the coast in the north and from narrow coastal plains in the south. Between the two ranges, Lebanon and anti-Lebanon, lies the fertile plain of the Bekaa, through whcih the Orontes (Assi) and Litani rivers flow.

In the coastal area the climate of Lebanon is characterized by warm, humid summers and mild winter. The average relative humidity is between 55 per cent and 70 per cent. Rainfall ranges from 800 to 1000 mm. Average daily temperatures in Beirut from May through September are 22°C to 29°C, occasionally reaching a high of 32°C. In winter it rarely falls below 8°C. In the inland region from December to March there is snow at altitutdes over 1,500 m. Average annual precepitation is about 800 mm, 85, per cent of which occurs during winter. In the Sannine-Laqluq highlands the annual rainfall is more than 1500 mm.

2. Water resources: According to estimates, the total annual precipitation over Lebanon in the form of rain and snowfall is about 9,700 MCM; of this total about 4,025 MCM is surface runoff, 600 MCM is groundwater recharge to aquifers and the remainder is lost by evapo-transpiration and by submarine seepage. The snow cover is the major contributing source to groundwater recharge of quifers occurring in the mountain areas of Lebanon.

Although the dry period of rainfall lasts for about five months of each year, Lebanon has a great potential of surface water resources. About 15 perennial rivers occur in the country. Twelve of them issue from the western Lebanon mountain range and flow in relatively short courses to the Mediterranean sea.

Of the above total runoff figure, 2,025 MCM flows to the Mediterranean principally through these perennial rivers and semi-perennial streams. About four-fifths of the annual surface runoff takes place between December to May, while a perennial or semi-perennial flow is maintained by springs during the dry summer and the early autumn. Considerable floods often occur after intense rainfall.

The annual surface water flow from the western slopes of the coastal mountains including the lower Litani smaller streams and spring water, is in the order of 2,570 MCM of which about 95 MCM represents El-Kabir river water in Syrain territory. In the Beka'a, the total volume of surface water flow, including the upper Litani and the major springs in the area, is about 1,305 MCM per annum, of which 140 MCM of the Hasbani river water flow into Palestine, 410 MCM of the Al-Assi river water flow towards Homs Lake in Syria and about 220 MCM is being stored in the Qaraoun Lake.

During the high flows period, it was estimated that only about 480 MCM is utilized int he country, 60 MCM for domestic purposes and industry, 200 MCM for irrigation and 220 MCM is stored in the Qaraoun Lake.

3. Water development strategy: the domestic water supply relies mainly on groundwater from springs and wells. These sources are not adequate to meet the present water consumption demands, especially in dry seasons when the spring yields decrease.

The Ministry of Electric Resources has a country-wide plan to develop the water resources through the following means:

(a) Artificial groundwater recharge in the Akkar plain, the Beirut area, the Barouk-Niha area, the Southern Coastal plain and the Beka'a;

(b) Utilization of submarine springs in the Chekka area, which have an estimated annual total volume of 80 MCM wasted into the sea;

(c) Possible dam construction at selected sites at Nahr AL-Kabir, Nahr Ostouene, Nahr Arka, Kurkuf, Qarhiya, L'al, Asfur, Jannah, Shabrouh, Nahr Awali, Nesfadon, Litani at Khardala and in the Beka'a area. The total possible stored voluem of surface water will be about 540 MCM, with 85 per cent reliability;

Groundwater development particularly in the Beka'a depression. At least 116 communities in Lebanon are served by sewer systems. More than 60 per cent of the total national population live in these 116 communities.

Four municipal sewage treatment plants have been fully or partially constructed, out none are currenly in operation. The most common means used for private wastewater disposal in unsewered areas is soakaway pits.

Syria

1. General: Syria has an area of 186,000 km^2 and a population of about 10 million. The country may be divided into five major topographical unite 1/:

(a) The coastal strip which extends from the Turkish border with Syria in the north till the Nahr AL-Kabir mouth in the south. Tt is a narrow coastline plain running along the Mediterranean coast;

(b) The coastal mountains which are composed of two parallel ranges separated by the Ghab depression. The western range extends parallel to the Mediterranean coast. The eastern highlands which extend paralled to the western mountain range reach the maximum elevation of 2,800 m at Mount Hermon;

1/ C. Safadi, Water Resources of the Syrian Arab Republic, (Damascuss, Ministry of Public Works and Hydraulic Resources, 1979), (Text in Arabic) pp. 3,4.

(c) The dislocated plains which separate the eastern and the coastal mountain ranges and consist of Al-Ghab, Al-Rouj and AL-Qmq plains;

(d) The inland mountains, plains and plateau which occur at different localities in the rest of eastern and southern Syria.

The climate of the Syrian Arab Republic is of the Mediterranean type, characterized by a cold rainy winter and a dry hot summer with two transitional periods in spring and autumn. The precipitation pattern is influenced mainly by the two mountain belts.

The rainy season usually begins in September and ends in April with the possibility of heavy showers in May. Snowfall occurs on the western highlands, and over all altitudes exceeding 1,500 m above the level. Rainfall decreases from north to south and from west to east. High intensities are usually recorded in winter in the northern regions. Evaporation ratess range from 1,000 to 3,000 mn per annum.

Mean annual rainfall distribution in the country is as follows:

(a) South-eastern region, less than 200 mm;
(b) Northern region and Jebel El-Arab, 200-400 mm;
(c) Al-Jawlan and the extreme north-east, 400-600 mm;
(d) Coastal plains, 800-1000 mm; and
(e) Western Mountain region along the coast, 1,200-1,600 mm.

During a period of about six months, between September and April, temperatures drop below zero in most regions except in the coastal plains. The coldest part of the country is the north-eastern area where temperatures drop to between 10^{o}C and 15^{o}C below zero.

The absolute maximum temperatures rise above 40^{o}C in the interior region, starting from May. The temperature rises above 45^{o}C in the east and northeastern regions in July. It is usually below 35^{o}C in other parts of the country.

2. Water resources:

(a) Surface waters: western and northern Syria a medium to high amount of perecipitation and the main surface rivers originate and flow from these regions.

The average annual flow of rivers in Syria is estimated to be 30 billion m^3 with the following distribution:

	Average annual flow MCM
Euphrates	26,174.9
Aafrine	252.3
Queik (Quwaid)	78.8
Jagh-Jagh	94.6
Northern Kabir	94.6
Yarmouk	473.0
Sajour	94.6
Orontes	N.A.
Khabour	1,639.9
Belikh	283.8
Es-Sinn	378.4
Barada	220.8
Aawaj	78.8
Southern Kabir	N.A.

It is to be noted that the Euphrates alone constitute about 85 per cent of the total. This river, however, is of an international character with Turkey and Iraq sharing its waters;

(b) Groundwater: the average annual groundwater recharge in Syria has been estimated to be about 5 billion m^3 and the average annual groundwater discharge has been estimated as 5.7 billion m3 from various basins.

The most important groundwater regions are as follows:

	Groundwater region	Groundwater area	Average annual discharge (CMC)
1-	Northern plains		
		Radd	65
		Ras El-Ain	1,450
		Tel Abiad	----
		Halab	334
2-	Hauran vlocanic plateau		314
3-	Syrian steppe		
		Demascus	518
		Dawwa	----
		Jebel Abdul Aziz	60
		Badiet-El-Jezirah	15
		Budiet Esh Sham	---
4-	Western mountain manges		
		Ghab	800
		Edleb	66
		Coastal	373
		quaens off-shore	----
		Submarine springs	---

The groundwater quality in the area varies but is generally of good quality.

3. Water development strategies

(a) Water supply: Large springs are the main source of water for the city of Damascus and other large towns in the western part of the country. Aleppo and other large towns in the north obtain domestic water supplies from the Asad Lake, the Euphrates river and its tributaries. Small towns and rural communities depend mainly on groundwater for their domestic supplies. Of all these large towns, it is the city of Damascus which faces major problems with regard to its domestic supplies and the needs of its industrial areas.

Water demand projections for the year 2000, indicate municipal, industrial and agricultural demands as 78, 135 and 56 gallons per capita per day respectively.

The government has made great strides in developing surface water resources. Total reservoir capacity has risen to 12.6 billion m^3;

(b) Irrigation projects: the total irrigated area in Syria, from both surface and groundwater resources is in the order of 600,000 hectares. Groundwater is utilized for irrigation of about one-third of this area. The rest of the irrigated lands use surface water resources. Among these the salient one is the Euphrates Project:

(i) The Euphrates project 1/: the Euphrates Project comprises and earth dam of 60 m height and 2.5 km length, to impound a total volume of 11.7 billion m^3 of water at Tabqa. The power component comprises eight units, generating a total of 800 megawatts. The average annual discharge of the Euphrates river at Tabqa is 28.2 billion m^3 and the minimum annual flow is 14.2 billion m^3.

Egypt

1. General: Egypt has an area of 1,000,000 km^2 and a population of over 40 million. The country is located in the northeast of the African conitnent. Occupying a part of the arid belt of north Africa and western Asia, it is subdivided into the following physiographical provinces:

(a) The Mediterranean coastal area with a mean annual precipitation is 125 mm;

(b) The Red Sea-Gulf of Suez coastal areas where the average rainfall is less than 25 mm;

(c) The Nile Valley between the delta and the High Dam lake;

(d) The South-Sinai-Red Sea granitic ridges;

(e) The tabland areas in central and northern Sinai, in the area between the Nile and the Gulf of Suez and in almost all the area west of the Nile;

(f) Natural depressions, some of which are below sea level..

1/ Syria, Euphrates Project Authority, Euphrates Project (Damascus, Imprimerie de l'Armee, 1970), pp.10-14.

The climate of Egypt is characterized by scanty rainfall, except in a narrow coastal strip around Alexandria. There are high temperatures in summer and dry summer winds. The average winter temperature is about 15°C and summer temperatures range between 35°C and 45°C. In Cairo the average maximum temperature in winter is 20.4°C and in summer 36°C. The average minimum in winter is 9.3°C and in summer 21.0°C.

2. Water resources

(a) Surface waters water resources presently available in Egypt amount to about 61 billion cubic metres annually, contributed mostly by the Nile river, and on a smaller scale by the drainage water utilized for irrigation, and by groundwater

The Nile provides Egypt with all its surface water. Being the second longest river in the world, it originates from Lake Victoria and ends in the Mediterranean. Its total length is approximately 6,500 km of which 1,000 km flows from south to north in Egypt. The waters of the Nile drain to its course from two main regions:

(i) The White Nile: the tropical lakes supply the river with relatively clear water all along the year and furnish it with from 45 to 130 million m^3 daily;

(ii) The Blue Nile: The Ethiopian Plateau supplies the river with the heavily silt laden waters during three months each year, namely, July, August and September. The volume of water reaching the Nile from this source is from 600 to 1,000 million m^3 daily depending on the flood condition. It furnishes the river Nile with 72 per cent of its total yearly discharge.

The annual discharge of the Nile varies between 45-150 billion m3, with an average of 84 billion m3. Before the High Dam in Aswan was constructed, as much as 100 billion m3 was discharged to the Mediterranean during wet years;

(b) Groundwater: despite the fact that groundwater forms a small percentage of Egypt's water resources, it is the only source supporting life in the western desert oases, the Red Sea coastal region and the southern and northern parts of the Sinai Peninsula.

The main aquifers are as follows in decreasing order of productivity:

(i) The basal clastics (the Nubian Sandstone portion of the basement rocks). Water occurs generally under artesian conditions, and the salinity of the water is generally less than 500 ppm;
The Qattara-Siwa depression in north Egypt (natural outlets), where the amount of water discharged exceeds 3 million m^3/day;

The El-Kharga and El-Dakhla oases, in the southeast part of the area. The amount of water extracted exceeds 1 million m^3/day.

The El-Farafra and El-Bahariya oases, located in the central part of the vast area west of the Nile Valley where natural and artificial discharge occurs in the order of 400,000 m^3/day;

The area east of the Nile excluding the Sinai Peninsula. The basal clastics also act as an aquifer, but the capacity is rather limited;

The Sinai Peninsula. During oil-drilling operations, high pressure water was encountered in the sandstone aquifer, with quantities similar to groundwater found in areas west of the Nile;

(ii) The sand and gravel section deposited in the Nile and delta depression. This aquifer has a thickness of about 350 m, and is almost saturated with water (salinity is in the range of 500 ppm) and depends for its recharge on the surface water of the Nile as well as on the complex of irrigation canals. It has been determined that in this part of Egypt, the water table is continous and declines gradually from south to north. After the construction of the High Dam, the water table began rising, presumably as a result of the pronounced difference in head of the water in the High Dam Lake (+ 178 m) and the surface water in the river to the north (maximum level and +80 m). The amount of water stored in this aquifer as a renewable resource is probably about 600 million m^3.

At the northern edge of the delta, severe intrusions of saline water from the sea have been observed, which can be related to the overpumping of groundwater. Mounds of saline water are locally developed in the new reclaimed areas and are related to the overuse of water for irrigation and the lack of efficiency of the drainage systems;

(iii) Fissured limestone aquifers have a broad geographical distribution in Egypt and constitute good examples of karstic features;

(iv) The Mediterranean calcarenites which have developed in the coastal plain in the form of stranded ridges. The body of water, the slainity of which is about 1,000 ppm, floats on a saline water wedge resulting from the intrusion of seawater. Locally, however, sub-artesian and perched conditions occur and are attributed both to change in facies and to the geological structure. This aquifer is replenished through direct infiltration of local precipitation (winter rainfall averages 125 mm). The water is extracted from this aquifer by different types of wells;

(v) The wadi fillings act as aquifers of limited importance in Sinai and along the Read Sea coast. Hundreds of shallow hand-dug wells are known to exist. The water of the wadi fillings depends on local precipitation and on surface run-off.

Horizontal wells (galleries) excavated to less than one metre below the water table are located at Marsa Matrouh and between Al-Arish and Rafah in Sinai.

3. Water development strategy

(a) Drinking and municipal water supply: the country is divided into several service regions. Besides the five metropolitan areas of Greater Cairo, Alexandria, Port Said. Ismailia and Port Suez (the latter three are usually referred to as the "Suez Canal Cities"), there is a large area of provincial Egypt containing other big cities, districts and villages. The regions are served by different water-supply and sanitation organizations supervised by the Ministry of Housing and Reconstruction. The Ministry of Health is responsible for ensuring the hygenic safety of drinking water and sewage disposal. The Ministry of Irrigation plans, operates and maintains all national irrigation schemes in accordance with the requirements of agriculture, minimizing contamination of these canals whose water is utilized for human drinking.

The country is faced with a high population growth rate and the preference of the younger generation is to live in large cities. Approximately 95 per cent of the population lives in the Nile Valley and the Delta. A further 5 per cent lives in areas predominately supplied by large irrigation canals such as those of Faiyium and the Canal Cities. About 97 per cent of the urban population and 74 per cent of the rural population are served by safe drinking water including water from protected bore-holes, springs and sanitary wells;

(b) Irrigation: since ancient times summer agriculture in the Nile Valley was confined to the narrow strip of lowlands neighbouring its main course and its delta, directly after the recession of the flood waters. Today the cultivated area in the Nile Valley amounts to 2.35 million hectares, and the cultivation period has been extended thanks to stored water.

Since 1843 efforts have been made to make use of all the summer flow of the river by constructing regulating structures on the Nile.

Main structures that have been built are the Khairiyah Barrage, the Asyoutt Barrage, the Diroot Barrage, the Naja'a Barrage and others, together with associated irrigation systems.

In view of the loss of a substantial quantity of flood waters to the sea each year, and the availability of good level cultivable lands that need more water to sustain agriculture, especially after the introduction of cotton and rice cropping, it was decided to store some of the Nile water during periods of abundance in reservoirs by building dams at suitable sites along the Nile.

The first proper reservoir built on the Nile was the Aswan Dam started in 1898 and completed in 1902 with a capacity of one billion m^3 which was raised for the first time in 1914 to make its capacity 2.5 billion m^3 whcih was raised again for the second time in 1932 to make its capacity 5 billion m^3.

In 1925, the Snar Dam was constructed on the Blue Nile with a reservoir capacity of one billion m^3 of which the share of Egypt was 800,000 m^3. On the White Nile, the Jebel El-Awliya Reservoir was constructed in 1938 with a capacity of 2.5 billion m^3. Egypt also shared the cost of the Owen Dam on Lake Victoria to provide 1.5 billion m^3. The water thus provided was hardly sufficient for the cultivated area of 5.6 million Feddan (2.35 million hectare). Therefore planners undertook examining the economic viability of constructing a large reservoir on the Nile to accomodate all the river's discharge in order to insure the availability of sufficient water during each year and to elimnate the flood menace.

The High Dam at Aswan is a large earth-rockfill dam that closes the ccourse of the Nile completely 7 km south of the Aswan dam. It is 111 meters high and 3.6 km long.

The reservoir has a total volume of 137 billion m^3, covering a surface area of 5,000 km^2, extending into Sudan.

The High Dam will guarantee a constant annual volume of 84 billion ^{3} of which the share of Egypt is 55.5 billion m^3 and that of the Republic of Sudan is 18.5 billion m^3. 10 billion m^3 is lost annually as evaporation and seepage losses.

In the last section of this chapter more information is included on the cost and economic benefits accruable to the High Dam.

Iraq

1. General: Iraq has an area of 438,500 km^2 and a population of aout 14 million. In 1979 the Gross National Product (GNP) was $US 2410 per capita. The Gross Domestic Product (GDP) was 30,710 million 1/. Iraq, generally a flat country, may be divided into four geographical areas with the two major rivers, the Tigris and Euphrates as the basic features:

(a) The vast alluvial Mesopotamian plain which forms the central part of the country or 21 per cent of total area;

(b) The mountainous region in the north and northeast with heights ranging between 750 m and 3,600 m above mean sea level comprising 6 per cent of total area;

(c) The foothills zone that flank the mountainous region from the northwest and southeast with elevations between 200 m and 750 m above sea level form 15 per cent of total area;

(d) The northwestern desert and southwestern desert plateaux covering the remaining 58 per cent area of the country. This great western desert plateau slopes gradually upward and westwards and ranges in elevation from sea level to 700 m a.s.l.

1/ World Bank, Statistical Yearbook, 1981.

Iraq is practically a landlocked country despite the fact that it possesses a very short coastline along the Basrah Gulf in its southern part. Its climate is basically of the subtropical continental arid type with dry hot summers lasting for nearly four and a half months, mind winters of about three and a half months duration and two short transitional seasons. This general pattern varies locally according to topography.

The climate of Iraq may be subdivded into three types:

(a) The desert region, where the annual average rainfall between 150-200 mm and where large variations exist between day and night temperature all the year around;

(b) The mountain region, where the climate is Mediterranean with annual rainfall reaching 1,000 mm. Temperatures are moderate in summer, not exceeding 35°C, and in winter there is snow;

(c) The steppes region, where the annual average rainfall varies between 200-400 mm. Temperatures are not as extreme as those in the deserts. Evaporation is generally very high over the country, with yearly total values varying from 1.8 m to 2.5m. The prevailing winds in all seasons blow in a northwesterly direction.

2. <u>Water resources</u>: Water resources in Iraq consist mainly of the following: (a) precipitation (rain and snowfall); (b) surface waters; and (c) groundwater.

Distribution of precipitation has a lready been presented in the previous section.

(a) <u>Surface waters</u>: The major rivers flowing in Iraq are the Euphrates and the Tigris and its tributaries:

(i) <u>The Euphrates</u>, one of the major rivers in the region, originates in Turkey. There are some dams on the Euphrates in Turkey, including the Keban, before it crosses into Syria, and there is the Taqa dam in Syria. The Euphrates flows in a south-easterly direction until it enters Iraq.

There are some tributaries joining the Euphrates between Turkey and Iraq. The total drainage area of the river in Iraq reaches 300,000 km^3. The mean annual flow of te Euphrates near the Turkish-Syrian border is about 28 billion cubic metres a year, and this volume is not much increased by the time it joins Tigris in Iraq, although the Euphrates inside Iraq is joined by many desert wadis from the right side that flow into the river during the rainy season;

(ii) <u>The Tigris</u> is the second most important river in the area, though its flow is more important for Iraq than the of the Euphrates. The Tigris reserves its major tributaries downstream from the city of Mosul. Five tributaries join the left side of Tigris inside Iraq, the Khabour, the Greater Zab, the Lesser Zab, the El-Edhaim and the Diyala.

The two Zabs provide the river with 43 per cent to 63 per cent of its total supply

(b) Groundwater: the main source of water in the majority of the country is surface water, but groundwater also consitutes one of the most valuable water resources in Iraq, especially in foothills and desert plain areas. There are nearly 10,000 settlements in rural areas in Iraq. In the north, 70 per cent of the settlements are supplied with water from wells and springs and 23 per cent form rivers and irrigation cannals. 84 per cent of the settlement in the central part and 91 per cent of the settlements the south use surface water. Generally, the cost of groundwater is relatively high owing to the depth of wells and the cost of maintenance.

In general groundwater is acceptable for domestic use and for irrigation, but is generally mineralized. The most severe problem is salinity and sulphur intrusion, which locally may exceed 30,000 ppm. Such waters occur over the whole Mesopotamian plain up to tharthar Lake.

Groundwater with concentration of up to 2,500 ppm is considered suitable for drinking in the rural areas of Iraq. This limit may be as high as 3,000 ppm provided that the nitrate content is less than 50 ppm. Bacteriological tests are not made for groundwater in the country, therefore water considered potable in rural areas may not meet international standards.

The following six regions of groundwater in Iraq were identified with regard to depth, salinity and yield.

(i) The north and northeastern parts of Iraq where groundwater depth is from 10 to 50 m. Salinity is from 200 ppm reaching 2,000 ppm in the Kirkuk desert. Yield is from 150 to 1000 gallons per minute for each 15 cm to 25 cm diameter tube well.

In this region ains (artesian wells whose dynamic heads reach ground level only), kahreses (horizontal wells) and natural waterfalls and rapids emerge from the mountain sides or neighbouring mountain plateaux through cracks in the earth crust. They form the only sources of drinking water for the inhabitants of those areas and their cattle also providing for limited irrigation.

There is no accurate census on the number and sites of springs and no information on the flows or studies for possible development;

(ii) The Jubail Hamrine region, including the plain extending 25 km west of Tigris to Jabal Hamrine in Tikreet and Samarrah and Mandali and Badra near the Iraqi-Iranian borders. Depth of ground water in this region is from 5-55 metres below ground level. TDS is around 1000 ppm and yield of each well (diameter 15 to 25 cm) is between 100-400 gallons per minute.

(iii) The western Desert Region comprising the north western desert and the south-western desert.

The north western desert includes the Rutbah, and the Habbaniyah regions and the area neighbouring the Iraqi-Syrian and Iraqi-Jordanian borders to a distance of 35 km inside Iraq. Total dissolved salts vary from 500 ppm to 3000 ppm. Depth of groundwater in Rutbah is 50 m below ground level. The yield of a 15-25 cm diameter well is 20 gallons per minute. The depth of groundwater in Habbaniyah region is from 100 to 200 m below ground level and yield of each 15-25 cm diameter well is more than 100 gallons per minute. The groundwater in the region neighbouring the Syrian-Jordanian border with Iraq is at a depth of 150 m or more and the yield of each 15-25 cm diameter is about 30 gallons per minute.

The South western desert includes the regions of Shibcha, Salman, Baeyyah and Zubair. TDS is from 1,500 to 8,000 ppm. The depth of the water table ranges from 25 to 100 m below ground level. The yield of each 15-25 on diameter well is 50 gallons per minute;

(iv) The region extending from north of Hit to Ur near Nasiriyah, or what is known as the region of Springs. Groundwater in this region is confined or artesian. When the confined water finds a crack in the works it emerges to the ground level forming what is called the Ain or water-eye. Springs and water eyes are numerous in this region and most of dug or drilled wells are artesian. TDS varies between 1,000 to 5,000 ppm and the yield of each 15-25 cm diameter well varies from one gallon to 500 gallons per minute.

(v) The Mesopotamia plain between the Tigris and Euphrates from Basrah in the south to Baghdad City. Depth of water table varies from 0.01 to 10 m below ground level. Except for a narrow strip along the rivers and main canals, the groundwater is not suitable for any purpose due to high TDS content varying from 10,000 to 50,000 ppm;

(vi) The region of the Jazirah desert and the region extending from the northwest to the southeast connecting Jazirah desert and Iraqi-Iranian borders in Missan Province.

Jazirah desert lands is mostly gypsum and contains a lot of sodium chloride. Groundwater in Jazirah desert is unsuitable for use due to high total dissolved salt content and some petroleum pollution.

3. Water development strategies: surface water is the main source of Iraq's overall water supply. Flooding has traditionally been a major problem adversely affecting the country. To reap multi-purpose benefits, including production of energy, Iraq has constructed a number of dams and others are underway. These dams are briefly described below:

(a) Major projects

(i) Euphrates River Projects: Haditha dam and reservoir, is 50 m high and has a total capacity of 11.3 billion cubic metres. The power plant has a capacity of 345 megawatts. The dam regulates the flows of the river reducing flooding and sedimentation, ensuring navigation all the year around, storing water for irrigation during dry periods, enhancing fishing and other benefits.

To the south of Ramadi town (situated 63 km south of Hit) and on the right bank of the river lies the Habbaniyah depression.

(b) The Habbaniyah scheme. In brief it consists of the following: (1) the Ramadi open dam across the river; (2) the Warrar Inlet channel regulator leading excess flood waters to the Habbaniyah lake with a storage capacity 3 billion cubic metres; (3) the Dhibban outlet regulator leading from Habbaniyah lake to the Euphrates; and (4) the Mujarrah Escape Regulator whose capacity is 2800 m^3/sec which is operated when Habbaniyah is full.

(c) Tigris/Euphrates Water Transfer Project: it is located through a canal taking off from the southern part of the Tharthar Depression situated between the two rivers. The design capacity of the canal is 1100 m^3/sec. At 20 km from the head it bifurcates into two branches: the Tharthar-Euphrates branch which is completed and the Tharthar-Tigris branch now under construction. The capacity of the Euphrates branch is 500 m^3/sec, and the Tigris branch 600 m^3/sec)more details on pp. 166-187).

(ii) Tigris River Projects

(a) Mosul dam: it is a rockfilled dam under construction is 131 m high, and has a total capacity of 12.5 billion cubic metres. When completed it is expected to produce about 2.3 billion kilowatt hours annually. It is a multi-purpose project for irrigation, flood control and hydro-electric power generation. It is designed to supplement the irrigation of the Jazirah agricultural area between the two rivers in the northern part of Iraq which supplies the country with wheat in wet years. In summer and during dry years, irrigation becomes necessary to support winter cultivation. Summer cultivation will be introduced to the area, on a large scale, for the first time after the completion of the project. The project will protect Mosul City and all the towns and villages downstream till Sammarrah from flood dangers and add to the flood protection facilities of Baghdad and the middle and southern parts of Iraq.

(b) Dokan Dam and Reservoir on Lesser Zab River: it is located on the tributary of the Tigris and is situated 60 km west of Sulaimaniyah City. It is a concrete arched dam completed in 1956 at a cost of 17 million dinars (excluding hydropower development. The dam is 116.5 m high and has a total reservoir capacity of 6.8 billion cubic metres.

One of the major purposes of Dokan Dam and Reservoir Project is to provide sufficient water for irrigating about 362,000 hectares down-stream, and 25,500 hectares of high lands by pumping. Work has started on the irrigation schemes and is expected to be completed by 1985;

(c) Derbend-i-Khan Dam on Diyala River: it is a rockfilled dam constructed in 1961 at a cost of 27 million dinars. The power units were installed later on. The dam is 128 m high and has a total reservoir capacity of 0.5 billion m^3;

(d) Hamrine Dam on Diyala River: it is a rockfilled dam completed in 1979 at a cost of 12 million dinars. It is 25 m high and has a reservoir capacity of 3.2 billion m^3;

(e) Gharraf Canal: Gharraf Canal originates from the Tigris river just upstream of the Kut open dam and flows in a southeasterly direction between Tigris and Euphrates for a distance of 168 km, from the head regulator at Gharraf to the fail regulator at Bada'a, and then continues for another 40 km. It irrigates about 700,000 hectares and is navigable.

There are several smaller canals and regulators along the Tigris further down towards its confluence with the Euphrates forming the Shatt El-Arab. There are two navigational barrages, completed in the late seventies, which made the Tigris navigable up to Baghdad.

The Shatt El-Arab River originates from the confluence of the Tigris and Euphrates rivers at Qurna in the south and discharges into the Basrah Gulf with a length of about 195 km and an average width of 500 m. The total annual water supply of all rivers exceeds 78.5 billion m^3. Iraq contributes only 25 per cent of the total water supply of the basin.

Other water bodies include shallow lakes, swamps and marshes which are shallow depressions of flat-lying lowlands adjacent to the courses of the Tigris and Euphrates rivers in the lower region of Mesopotamia;

(iii) Tigris-Euphrates connection projects

- Tharthar Project: the Tharthar depression lies at a distance of 65 km to the northwest of Baghdad between the Tigris and Euphrates. The lowest point in the depression is 3 m below mean sea level. Its length is about 100 km and its average width is 25 km at level 60 a above mean sea level. Its total capacity at that level is 72 billion m^3. By means of canals Tharthar is connected both to the Tigris and Euphrates rivers.

The project consists of the following parts:

a) The Sammarrah barrage;

b) The Tharthar inlet regulator;

c) The protection levees and the Tharthar inlet canal;

d) The Tharthar-Euphrates and Tharthar-Tigris outlet branches:

(a) Sammarrah Barrage is a concrete gated barrage opposite Sammarrah commanding the inlet regulator to the Ishaqi Project main canal from the Tigris. The Ishaqi project irrigates 125,000 hectares on the right side of the Tigris. Power generating units are also being installed at the barrage;

(b) The Tharthar inlet regulator which is built on the right bank of the Tigris just upstream of the Sammarah open dam.

(c) The protecting levees and the Tharthar inlet canal: The protecting levee is a huge earth embarkment or dyke extending in a southerly direction on the right side of River Tigris for a distance of 62 km from the left end of the Tharthar inlet regulator;

(d) The Tharthar-Euphrates and Tharthar-Tigris outlet branches: since 1956 the Tharthar Project has been employed as a diversion for excess flood waters of the Tigris river to secure the safety of Baghdad and the middle and southern regions of Iraq.

In order to make use of the stored waters in dry years a main canal from the southern region of the Tharthar depression was dug. After flowing for a distance of 27 km the main canal bifurcates into two branches - the Tharthar-Euphrates branch and the Tharthar-Tigris branch, with a regulater on the head of each branch;

(b) Water supply: surface water is the major source of the country's water supply. The high quantities of suspended sediments during the rainy seasons frequently create problems at treatment plants. Rural areas are supplied through compact filter units of different sizes. Some areas in the north-eastern and western regions are supplied by groundwater, which is drawn from deep wells, springs or kahrezes. The upper reaches of the rivers contain water of high quality. As the rivers proceed south and westward the quality of their water deteriorates. Groundwater is generally high in mineral content, however nearly 4200 wells have been drilled until recently.

The drinking water capcity has increased during the last 15 years at an annual rate of over 10 per cent. Figures on the total capacity are as follows: 1970, 300 million m^3; 1979, 500 million m^3; 1980, 750 million m^3.

The urban population is served mostly through house connections, and, in some cases, by public standposts and tanker service. Baghdad has a separate network, with house connections, for raw surface water pumped directly out of the Tigris river, which is used for irrigation of gardens. The Baghdad water supply facilities are old. The water losses are very high. Replacement of faulty or worn-out facilities is already underway. The rural population is served through house connections in cases where purification units are available; otherwise water is supplied through public standposts, wells, springs, river sources and mobile tankers.

Table 24: Estimates of rural and urban populations in Iraq for 1980-1981 and 1990 service coverage

Population	1980-1981 (millions)			1990 (millions)		
	Total	Served	Percentage	Total	Served	Percentage
Urban	8.34	8.08	97	11.30	11.30	100
Rural	4.79	1.06	22	5.80	5.50	95
Total	13.13	9.14	70	17.10	16.80	98

Source: Files of Ministry of Planning, Baghdad, Iraq

Field surveys indicate that the average consumption rate per capita is steadily increasing. According to the estimates, the per capita consumption rate ranges between 70 and 275 litres per day. Projections for the year 2000 are as follows:

Water demand projections in U.S. gallons per capita per day for the year 2000

Population	Municipal	Industrial	Agricultural	Total
19.2 million	77	124	183	384

C. Concluding discussion on various water uses, costs, pricing and tariffs in group 3 ECWA countries Egypt, Iraq, Lebanon and Syria.

The present total population of Group 3 ECWA countries is estimated roughly to amount to 67.5 million, while the forecasted total population for the year 2000 is estimated to amount to 95 million. This group has the largest population, but also possesses adequate water resources to meet projected demands.

1. Lebanon: Lebanon has ample surface and groundwater resources. Total estimated volume which can be developed is about 1,100 MCM per annum.

The domestic water supply relies mainly on groundwater, about 75 per cent of which comes from springs and 25 per cent from wells. The present selling price of bottled spring water, as sold in the local markets in Lebanon, amounts to $33.2 per cubic metre.

About 90 per cent of the urban population and about 85 per cent of the rural population used to be served by house connections (present situation unknown). Tanker service was also common. Per capita consumption rates were estimated to be 200 litres per day for the urban population and 100 litres per day for villages. Tariff systems existed for piped water but the extent of their enforcement at present is not known. The system losses were estimated to be in the order of 35 per cent. The water supply is subject to regular cutoffs and intermittent supply periods. Problem created by the war situation, such as the damages on water supply facilities the theft and destruction of equipment and tools, the lack of inspection and maintenance, and the shortage of funds arising from problems involved in collecting revenue are reported to be continuing, and many consumers have had to resort to illegal to obtain water.

Under the present political instability, normal development of water resources is not carried out on a regular basis.

2. <u>Syria</u>: the estimated average annual flow of the rivers in Syria is 30 billion cubic metres of which 26 billion m^3 are from the Euphrates river, which originates in Turkey. The average estimated groundwater discharge in Syria is 5.7 billion m^3 per year.

40 per cent of te country's area is semi-arid with average annual precipitation exceeding 250 mm. This semi arid region of Syria is inhabited by 80 per cent of the population.

In the Syrian steppe groundwater with low TDS is of paramount importance since they supply several urban and rural areas with drinking water in addition to supplying water for industry and mining.

Large springs are the main source of water for the city of Damascus and other large towns in the western part of the country. The cost for the population of groundwater from major aquifers ranges from 0.34 to 3.41 U.S. cents per cubic metre. The cost of production of groundwater from the highly productive zones of Hama, Ghouta and Jezireh ranges from 0.34 to 0.61 cents per cubic metre. The cost is high when the production of wells does not exceed 5 l/sec or the total pumping head exceeds 75 m.

Cost of drilling well including rig, moving, mounting and dismounting varies from $US 250 to 500 per well according to site distance and natural conditions.

Drilling wells 8 to 14 inches in diameter costs from 25 to 35 dollars per metre for depths ranging from 0-50 m, and from 35 to 50 dollars for depths ranging from 50-100 m depending on whether the formations are soft, medium or hard.

The cost of the casing thickness is 3 mm per metre of casing is as follows:

8"	diameter	$US 18
9"	"	$US 20
10"	"	$US 22
12"	"	$US 25

Table 25: Total costs of vertical centrifugal pumps, pipes, annexes and mounting
(in US dollars)

Dynamic water level	Discharge (litre per second)				
(metres)	6	8	10	15	20
25	715	860	960	1,530	1,845
50	1,285	1,515	1,760	2,785	3,415
75	1,860	2,260	2,560	4,045	5,800
100	2,430	3,815	4,275	6,245	7,470

Charges for water in Damascus are of an increasing block nature. They increase from $0.031 per m^3 to $0.078 m^3 if consumption is more than 45 m^3 within three months.

Large towns in the north and north eastern parts of Syria obtain drinking water from the Euphrates.

General Cost-Benefit Situation of the Euphrates Project: Agriculture contributes 40 per cent to national income in Syria and is the leading sector in national development.

Syria's Euphrates Project implemented jointly by Syrian-Soviet co-operation is estimated to have cost about $900 million. The main structure in the Project is the Tabqua Dam across the Euphrates in Syria, completed in 1971. The gross storage volume of the Assad reservoir behind the dam is 11.7 billion cubic metres.

The electric energy generated by the Tabqua dam is the best possible way of producing low cost electrical energy (800,000 kilowatt total unit capacity).

Value of production in the Project area is estimated to reach $164.13 million by the year 2000. In its ultimate phase the project will directly contribute an estimated $109.2 to the annual national economy. Foreign exchange earned by the project in its ultimate phase is estimated to amount to about $117 million per year.

The 600,000 hectars area suitable for agriculture, when fully developed, will double agricultural production in the country.

Lands irrigated by the project will enable the settlement of 60,000 families or 300,000 persons. In general the increase in employment imputable to the Project will vary between 14 to 18 per cent of present employment.

3. Egypt: water resources presentlyt available in Egypt amounting to an average of about 61 billion cubic metres annually is made up of the following components:

Egypt's share of Nile water	55.5 billion m^3
Drainage water utilized for irrigation	5.0 billion m^3
Groundwater exploitation	0.5 billion m^3

(a) Major water project: the first dam built on the Nile was the Aswan dam which was raised twice to increase its capacity to 5 billion m^3 in 1932. Snar reservoir was constructed in 1925 on the Blue Nile with a capacity of one billion m^3 of which 800,000 m^3 was Egypt's share. The Jabel-El-Awliya reservoir on the White Nile was constructed in 1938 with a capacity of 2.5 billion m^3, of which Egypt's share was 1.5 billion m^3. The total stored water for Egypt was raised to 10.3 billion m^3 after strengthening the Aswan Dam for the third time. The fluctuation of the annual discharges of the Nile from 45 billion m^3 in dry years to 150 billion m^3 in wet years led to the construction of the High Dam at Aswan with a total storage capacity of 180 billion m^3.

General cost-benefit analysis of the High Dam

The cost of the High Dam amounted to about $295.2 million (240 million Egyptian pounds). The cost of the complimentary works is estimated to be about $600 million (500 million Egyptian pounds).

The power plant has a total capacity of 2100 megawatts and an annual energy production rate of 10 billion kilowatt-hours.

The economic benefits of the High Dam can be summarized as follows:

(i) Horizontal expansion of the cultivated area by adding 1.3 million feddan to present agricultural lands (546,000 hectares);

(ii) Intensifying agriculture through vertical expansion of 700,000 feddans (294,000 hectares);

(iii) Insuring the availability of irrigation water to the entire area of cultivated lands in all years including dry periods;

(iv) Insuring complete flood protection in all years including very wet years;

(v) Crop production increases due to lower groundwater levels in most areas downstream;

(vi) Expansion in rice cultivation for export purposes;

(vii) Improvement of navigation on the Nile by making it navigable all through the year;

(viii) Generation of new electric energy that amounts to 10 billion kilowatt-hours.

The direct increment in the national income of Egypt is estimated at LE 234 million (nearly is $300 m) annually in addition to the indirect increment accrued from improvement in drainage conditions in the present agricultural areas, in navigation and flood protection in the increase of electrical energy generated from the Aswan Dam and of the fish wealth in the High Dam reservoir.

(b) Water pricing: a water tariff schedule of an increasing block nature for domestic, industrial, public places, bulk supply and a fixed rate per cubic metre for government and ports is in force in Egypt.

Table 26: General schedule of water tariff

Customer category	Price $/m3	Comments
Domestic	$ 0.0123	Up to 10 m^3 consumption Minimum charge $ 0.123
	$ 0.0187	11 m^3 and above
Industrial and public places	$ 0.0492	On water consumption billed in 1976
	$ 0.0738	For consumption of new customers and consumption in excess of 1976 usage.
Government	$ 0.0923	
Port	$ 0.6763	
Bulk supply	$ 0.1722	Up to 500 m^3 per day by Marsa Matrouh.
	$ 0.3383	For 501 m^3 per day and higher usage by Marsa Matrouh.

Extreme difficulties have been encountered in adjusting water tariffs to reflect rising costs and to achieve a balance between costs and revenues.

There is a large gap between the production cost of a cubic metre of water and the average revenue from the consumption of a cubic metre of water. For example, during a six month period, ending on 30th June 1980, the water production cost was $ 0.0375 per cubic metre compared with an average revenue charge of $ 0.0265 per cubic metre.

In Cairo, losses in the distribution networks are very high. About 80 per cent of the population is served by house connections and about 20 per cent by public standposts. Average daily domestic water consumption per capita including losses, may be in the order of 170 litres, whereas actual consumption is probably not more than 100 litres. In rural Egypt the daily per capita consumption is in the order of 50 litres.

In Egypt about 70 per cent of the urban population and 5 per cent of the rural population are served by adequate sanitation.

The strategy of Egypt regarding water for drinking and household uses is to increase the daily per capita consumption rate in Cairo to 400 litres and to 150 litres in rural areas by the year 2000. These activities require a total investment of over 2 billion Egyptian pounds in 1979 prices,

4. Iraq: the water resources of Iraq consist of the following: (a) precipitation; (b) surface water; and (c) groundwater.

The average annual rainfall varies from 50 mm in the southwestern desert to 1,000 mm in the northeastern mountains with on annual evaporation from 1.8 m to 2.5 m.

Surface water is the major source of the country's water supply and the total average annual discharge of the rivers flowing through Iraq is estimated at 80 billion m^3 at present. A number of water storage projects have been constructed on these rivers.

(a) Water services and pricing: groundwater constitutes one of the most valuable water resources, especially in foothills and desert plain areas. The development of the north and southwestern deserts which cover 58 per cent of the country's total area depends principally on proper groundwater exploitation in the future. Seventy per cent of the rural settlements in northern Iraq are supplied with water from wells and springs.

In general, groundwater is acceptable for domestic use and irrigation except in the Mesopotamian plain where its salinity is high, reaching 30,000 ppm at some localities.

presently, 97 per cent of the urban population and 22 per cent of the rural population are served by safe drinking water. In 1990 the coverage is expected to reach 100 per cent for urban and 97 per cent for rural areas.

Baghdad city has a modern sewage disposal system. All other major cities have their sewerage projects either completed or under construction. An increasing block tariff system is implemented for both water and sewage services. The water tariff in Baghdad is as follows:

Domestic consumption	0-60 m^3	\$0.04 per cubic metre
	60-90 m^3	\$0.0533 per cubic metre
	90 and over m^3	\$0.067 per cubic metre
Raw water for house-gardens		\$0.0133 per cubic metre per month or \$0.333 per m^2 of garden per year.

Sewage service charges in Baghdad are set at 50 per cent of the charges on currently consumed water.

No charge on irrigation water for agriculture is levied at present;

(b) Water projects and uses: the major surface water storage projects in the country are as follows:

Name	Capacity
Habbaniyah project (Euphrates)	3 billion m^3
Dokan reservoir (Lesser Zab)	6.8 billion m^3
Derbendi-Khan reservoir (Diyala)	3.2 billion m^3
Hamrine Dam (Diyala)	3.0 billion m^3
Mosul Dam (Tigris)	12.6 billion m^3 (Under construction)
Haditha Dam (Euphrates)	11 billion m^3m (Under construction)
Tharthar Project	
(Euphrates-Tharthar link) Tigris (Tigris - Tharthar link)	38.1 billion m^3 (Under construction)
Total storage	77.7 billion m^3

The major water supply projects in Baghdad are as follows:

(i) Kharkh side of Baghdad has three major water supply projects at Qadissiyyah, Shalchiyyah and Sarrafiyah;

(ii) Rasafa side of Baghdad has Karradah, Rashid Military Camp and 7 April water supply projects. The Baghdad sewerage system has been steadily expanded in recent years. At present the residences of about 35 per cent of the population are connected to the system. The rest use septic tanks and cesspools, which are de-sludged, more or less regularly, by tankers;

The rural sewerage system is at an early stage of development. Most of the population is served by septic tanks, seepage pits and cesspools.

(iii) Economic analysis of Mosul Dam Project is as follows:

(a) Unit cost of storage: the unit cost of a cubic metre of water in the reservoir is calculated as follows:

Top elevation of Dam (a.m.s.l.)	Max. normal operating level	Volumes of reservoir (billion m^3)
+ 336 m.	+ 329 m.	10.74

Total investment[1/] in million $	Price per m^3 of water in $
494	0.046

(in the Derbandi-Khan Dam Project, the price per cubic metre of water was $0.024 at the time of completion in 1961. Using an inflation rate of 250 per cent to bring it to 1981 prices it will be $ 0.060 per m^3).

(b) Irrigation costs Benefits comparison: cropping programmes for the three proposed areas of Jazira, shimal and the East Division, to be irrigated directly from the Mosul Reservoir, vary a great deal. This causes large variations in irrigation demands and therefore also in benefits and expenses. The irrigation benefits of these areas are discussed only generally.

(i) Jazira area: The Jazira area is at present predominantly a grain growing area. The proposed cropping programme includes grain and diversified crops. This proposed cropping programme provides for the growing of corn during summer on a part of the grain land and cover crops on a part of the sesame and sugar beet lands. The estimated benefits for this area are $232.40/hectare while costs are $132.86/hectare. This resulting benefit-expense ratio is 1.75.;

(ii) Shimal area: the proposed cropping programme for the Shimal area favours the growing of high value crops such as sugar beets and cotton during summer with no irrigation during winter due to high pumping cost. The annual benefits per hectare are $371.52 while expenses per hectare are $237.32. The resulting benefit-expense ratio is 1:5;

(iii) Eastern Division area: this area has a wide diversification of crops. The addition of a winter cover crop to follow the summer crops, together with corn and sesame on grain lands, allows for 15 per cent double cropping. The estimated benefits for the area average $346.28 per hectare while the expenses are $216.72 per hectare. This provides for an estimated benefit-expense ratio of1:60. The mean annual benefit-expense ratio for the three areas is 1:64. The calculations were in accordance with the cropping programme proposed by the Kuljian Corporation in the "Eski Mosul Irrigation Project". Values for yield, unit income, and annual

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1/ The estimated cost of the Mosul Dam Project as a whole including power generation units, transmission lines, pumping stations directly downstream from the dam, irrigation schemes, highways etc. is estimated to amount to $US 1.5 bn.

expenses are those of chapter XIX of Technical and Economic Report on "The Regulation of the Middle Course of Tigris Rivers" by Technoprom export (1962), and therefore would require updating.

The price values themselves may not be quite exact, but the benefit-expense ratio gives a clear picture of the advantage of the project concerning the areas to be irrigated directly from the reservoir.

Below the Mosul Dam, on both bank of the Tigris, there are over 2.7 million hectares of irrigable areas requiring 31 billion m^3 of water annually, of which the Mosul Dam can supply from 12 to 15 billion cubic metres of water depending on the extent of agricultural development of the three aforementioned areas of Jazira, Shimal and the Eastern Division.

(iv) Flood control: the maximum flood that can pass Mosul without causing great damage is 5000-6000 m^3/sec. During the period from January to the end of March 5.5 billion cubic metres are allocated for flood retention. The largest recorded flood at Mosul, in 1963, had a peak of 7,539 m^3/sec and a 20-day volume of 7.1 billion cubic metres. If this flood is controlled properly the maximum discharge downstream from the reservoir would not exceed 300 m^3/sec.

A flood operation study at the Mosul Dam was made for a flood peak of 15,000 m^3/sec and a 20-day volume of 8.9 billion m^3.

Throughout the study the maximum discharge downstream from the reservoir was 4,000 m^3/sec of which 600 m^3/sec through the irrigation outlets. If this same flood peak occurs concurrently with flood peaks from the tributaries above Baghdad, with the same severity, the uncontrolled maximum flow at Baghdad would be 24,200 m^3/sec. Regulation with the existing Dokan reservoir, Samarra open dam, Wadi Tharthar reservoir and Mosul dam reservoir would decrease this peak to 5,900 m^3/sec.

This regulation by the Mosul Dam provides considerable flood protection for the cities of Mosul and Baghdad;

(v) Hydro-electric power benefit: the total investment in the cost estimates for the power station amounted to $US 84 million. The mean cost of the produced electric energy will be $0.0036/KWh as compared to a cost of $US 0009/KWh and $US 0.0068/KWh for electric energy produced from oil and natural gas thermal plants respectively. Thus the cost of hydro-electric energy generated by the Mosul project is cheaper than the cost of energy generated by fuel oil or natural gas.

Additional benefits of the Project are the enhancement of the environment and the provision of a pleasant recreational resort for the population.

1/ IVO Consulting Engineers, Helsinki Mosul Dam Project (Iraq, Ministry of Agrarian Reform, Directorate General of Irrigation, 1968), Planning Report, Vol.1, pp.127-139.

Conclusion

The natural surface and groundwater resources of group 3 ECWA countries are adequate. Wise conservation and scientific management of the water resources would lead to satisfying all their present and projected future demands for development, including prosperous agriculture, developed urbanization, numerous industries, almost complete flood protection, river navigation where applicable, fish breeding, recreation and salinity control.

VII. RECOMMENDATIONS

A. Introduction

Major water projects in the ESCWA region can be classified into three main categories:

(a) Water supply and sewage disposal schemes;

(b) Irrigation and agricultural projects;

(c) Projects providing water for various industries.

(a) The water supply and sewage disposal schemes: there are non-profit enterprises planned and executed for the welfare of the citizens.

An adequate quantity of safe drinking water and basic sanitary facilities are a matter of human rights.

In the ESCWA member Countries the capital investment needed for such projects is totally paid for by Central Governments. Tariff schedules, however, are designed to cover the cost of operation, maintenance, and replacement. Only in Yemen are the tariff schedules also designed to recover the capital investment costs during a period consistent with the paying ability of the people served. Information on pricing and tariffs was presented at the end of chapters IV, V and VI. In most ESCWA Countries water and sewerage tariffs are of an increasing-block nature embodying the principles of equity and income redistribution;

(b) Irrigation and agricultural projects: with the continuing growth of the population of the ESCWA region (about 100 million at present to a forecasted figure of 135.5 million for the year 2000), agriculture is assuming a more important role in the development of the region.

Agricultural projects in the ESCWA region are economically feasible only when large quantities of water can be secured at relatively low costs.

Based on the price of water alone, desalinated water would remain uneconomical for agriculture until technological advances permit the production of abundant cheap quantities of fresh water from saline waters by solar distillation or other improved desalination technologies.

Irrigation projects are costly. They are generally highly subsidized by concerned governments. Justifications for subsidy are based on grounds of achieving an acceptable level of food self-reliance, decreasing food imports, increasing agricultural products exports and providing employment opportunities for the rural communities. A 100 per cent subsidy for irrigation and drainage projects is the common practice in the ESCWA region. Charges for operation and maintenance and other agricultural services are indirect in the form of a fixed land tax per hectare or a small percentage of the crop, usually not exceeding 10 per cent;

(c) Projects providing water for various projects: the total cost of water projects for industries together with the operation, maintenance and replacement costs, are fully recovered from the concerned industries and are reflected in the selling unit price of the final product.

B. Recommendations to ESCWA member countries

Based on the six previous chapters of the report, recommendations are presented to each ESCWA member Country as follows:

1. Bahrain

(a) Establishing a national water-resources authority responsible for water resources development, conservation and quality control is recommended. This may have been recently established;

(b) Combating water waste by reduction of water consumption through setting an adequate tariff system for drinking water, garden watering, and wastewater disposal, and the introduction of metering is urgently recommended;

(c) Since Bahrain is shaping up into a commercial centre for the Gulf region, desalinated water production must be increased to meet the demand for more drinking water of better quality. More desalination plants are recommended. Solar stills are a source of fresh water for desert hamlets, small settlements along the coasts, hospitals, hotels and resorts would be very economical and are highly recommended;

(d) To reduce water distribution losses, old networks must be renewed and conveyance water losses reduced through setting active maintenance and repair teams all around the country;

(e) Provision of some sewage disposal facilities for the rural communities and adequate sewage systems in all towns is recommended;

(f) Sewage effluents recycling projects are recommended whose water production should be allocated for agriculture and industry;

(g) Overpumping of groundwater must be avoided by setting advanced pumping programmes in co-ordination with the Gulf countries;

(h) Measures against pollution of shorelines must be enforced;

(i) Salt tolerant and moderately salt tolerant crops are to be encouraged. Date palm, sugar beet, cotton and salt grasses are among the salt tolerant crops, while pomegranate, fig, grape, olive, alfalfa, flax, tomato, asparagus, barley, rice and sudan gross are known to be moderately salt tolerant;

(j) It is recommended that agriculture be fully subsidized and that fish and sea-food be made a routine portion of the daily diet.

2. Kuwait

(a) Kuwait is urged to complete its programme of construction of seawater distillation plants. All people have access to safe water supplies and adequate sanitation services now thanks to the wise policies pursued by the government. The additional constructed plants will meet the water demands of the growing population and the different economic developing sectors in the future;

(b) Completion of sewage disposal systems and re-use of treated effluents for agricultural expansion is recommended;

(c) Metering and the introduction of an adequate tarif system for drinking water, garden watering and wastewater disposal are recommended measures to combat water waste and reduce water consumption.

(d) It is recommended that the irrigation efficiency be increased through the introduction of lined canals and pipes for water conveyance to the farms and fields and that water- saving field irrigation methods such as sprinklers and drip irrigation be adopted;

(e) Sufficient funds for research on desalination and on solar distillation, in particular, must be allocated;

(f) It is recommended that the water-transfer project from the Shatt-El-Arab to Kuwait be reconsidered since the preliminary examination of the old outdated data on the subject, when inflated by 450 per cent, to bring the cost and prices to present day levels, indicate the constructional and possible economic feasibility of such a project;

(g) Further recommendations are full subsidy of agriculture; enforcing measures against shoreline pollution, and making fish and seafood a part of the daily diet.

3. Qatar

(a) Qatar is recommended to optimize its drinking water supply by mixing distillate with brackish ground water in suitable ratios to ensure that people are ingesting an adequate quantity of mineral salts which is quite important in hot climates. It is also recommended to install small local reverse osmosis desalination plants whereever necessary and to complete and expand its sewerage systems to serve new developments;

(b) Since groundwater in Qatar has been overexploited optimization of groundwater extraction and allocation is recommended with the help of foreign technical aid. Pre-arranged pumping programmes in co-ordination with other Gulf countries are recommended to help stop decline of ground water levels, salt intrusion and quality deterioration;

(c) Solar stills all along the coasts of the Qatar Peninsula are recommended as an economic source of fresh water for small settlements along the coasts;

(d) Urban effluents recycling projects are recommended as an enhancing source for agriculture;

(e) Combating waste by the introduction of metering and setting an increasing block tariff system for drinking water, garden watering and water waste disposal and vigilent and active maintenance to detect and prevent leaks is recommended;

(f) In co-ordination with other Gulf members a project for rain-making and cloud seeding to force passing clouds over Qatar to unload their moisture cargoes is recommended;

(g) Increasing irrigation efficiency by lining canals or using pipes and irrigating fields by sprinklers or drip irrigation methods is recommended. Salt to tolerant and moderately salt tolerant crops must be given priority;

(h) Fish must be made a part of the daily diet.

4. <u>United Arab Emirates</u>

(a) It is recommended to establish a national water resources authority for water resources development, conservation and control. National design criteria and standards for water projects are also recommended;

(b) Increasing desalinated seawater plants in the Emirates to cope with the growing demand for drinking water is recommended;

(c) Solar stills should be introduced to supply small settlements, hospitals, hotels and desert hamlets near the coasts with relatively cheap fresh water;

(d) Completion of the sewerage of schemes of Abu-Dhabi, Dubai, Sharja and Al-Ain where 80 per cent of the population live is urged and speeding up the construction of sewerage schemes for the cities of the northern region is urgently recommended;

(e) It is recommended to introduce metering and to set up an increasing-block tariff system for drinking water, graden watering and waste water disposal;

(f) Making use of experiments in other countries in the field of rural water supply, sanitation and community participation is advised;

(g) Reduction of conveyance and application water losses in irrigation by conveying water through lined canals or pipes and using water-saving field irrigation methods such as sprinkling and drip irrigation are recommended;

(h) Drilling deep wells in the Khider and Nassassa regions to transfer water to Ghanassa Island and drilling deep wells to depths from 400 to 500 metres below ground level in the Saih-El-Miyah project is recommended since the water extracted would be suitable for drinking and agriculture and its cost would range between $ 0.70 and $ 0.90 per cubic metre judging by costs obtained from deep wells in the nearyby Za'ala and Bada'a Bint Suad projects. Pumping programmes should be co-ordinated with other Gulf member Countries;

(i) The Falaj systems in the central and southern coastal parts of the Emirates should be carefully looked after and reconstructed where necessary since the represent a cheap and safe method for groundwater extraction;

(j) Sewage effluents recycling projects are recommended and their yield is to be used in agriculture.

5. <u>Oman</u>

Oman is lagging behind other Gulf countries in developing its water resources and in providing adequate drinking water and sanitary facilities for the population, despite the fact that it is an oil-producing country and that is possesses relatively better water resources potentials.

(a) It is recommended to provide every township and village with reasonably accessible clean and safe water by investing heavily in water supply and sewerage schemes. A minimum of 100 litre per capita per day is recommended for urban population of 50 l/c/d for rural population;

(b) An equitable increasing-block tariff system is recommended to cover the cost of maintenance, operation and replacement;

(c) Standpipes should be fully subsidized;

(d) Allocation of sufficient funds for health education and environmental protection activities is recommended;

(e) Establishing a national water resources authority for water resources development, conservation and control and for setting standards is recommended;

(f) A comprehensive plan for rural water supply and sanitation should be prepared;

(g) Being the main source of domestic water in rural areas, falaj systems must be well maintained and protected from pollution;

(h) Measures to improve irrigation efficiencies, reduce agricultural water consumption and introduce water-saving irrigation methods including canal lining, use of sprinklers and drip irrigation should be taken;

(i) Recharge schemes should be prepared which will not only minimize lossess and recharge the coastal alluvial fans, but will also help in control of saline water intrusion;

(j) Introduction of solar stills along the Omani coasts and cloud seeding activities should find room for useful application in Oman.

6. Saudi Arabia

(a) A national water resources authority responsible for water development, conservation and quality control must be established. Such authority should include a strong hydrology section responsible for carrying out periodic hydrologic measurements at selected sites all over the country. Data thus collected should be processed and published;

(b) A comprehensive plan or rural water supply and sanitation must be prepared;

(c) A set of national standards for minimum quality requirements of water produced for various uses and for disposal of waterwater must be prepared. National design standards for water projects should also be set;

(d) The city of Taif needs additional resources to supplement its present 7,000 cubic metre per day water supply. Groundwater resources should be investigated;

(e) Villages should depend primarily on deep wells for their water supply. The poor accessibility of many small villages which are scattered all over the country enhance the importance of deep-well drilling for supplying water to such localities;

(f) Combating domestic wastewater and reduction in water consumption is recommended through the use of metering and enforcement of an increasing block tariff system for drinking water, garden watering and wastewater disposal;

(g) It is recommended to improve irrigation efficiency by conveying irrigation water through lined canals or pipes and employ water-saving field irrigation methods such as sprinkling and drip irrigation;

(h) Natural pastures should receive proper attention overgrazing should be avoided. A grazing area should be kept aside for each village cattle of other villages should be prevented from using it;

(i) Falajs on the Tihama coast and Hassa and Qatif oases deserve attention. Maintenance of falajs and regulation of irrigation from these sources are recommended;

(j) Solar distillation, cloud seeding, recharge projects, icebergs towed to Jeddah for fresh water production should all find applications in a vast country like Saudi Arabia and are worth considering;

(k) Water transfer from the Shatt-El-Arab in Iraq to Saudi Arabia is worth investigation;

(l) Urban sewage effluents recycling projects whose yield is to be used in agriculture are highly recommended.

7. Democratic Yemen

(a) Preparing and implementing a groundwater pumping programme taking into consideration the safte yield of each region;

(b) Constructing spreading dikes and spate breakers at the terminal of wadis before they meet the Arabian sea to help control seawater intrusion and provide water for recharging the coastal strip;

(c) Introduction of solar stills all along the 1,100 km long coastal strip wherever feasible to provide fresh desalted water at low cost;

(c) Construction of sub-surface and surface weirs, at suitable sites, across wadis to help recharge the deltaic aquifers;

(e) Have at hand a suitable number of small planes with pilots trained in cloud seeding, if this proves feasible;

(f) Designing and implementing a tariff schedule of an increasing block nature for water supply and sewage service charges;

(g) The feasibility of building a surface dam with reservoir capacity of 2 billion or more cubic metres annual storage in Hadramwat Valley after interconnecting with all suitable adjacent valleys to provide sufficient storage water should be considered. A similar project was executed in the case of Grande Dexence Dam in Switzerland.

8. Yemen Arab Republic

(a) Groundwater extracted from drilled wells is expensive and of excellent quality. It should be reserved for drinking, unless its extraction cost is less than $ 0.1.

(b) Solar desalination plants should be introduced for fresh water production along the Red Sea coast villages, hotels, etc;

(c) The small-dam construction programme is promising to provide relatively cheap water for agricultural expansion, recreation, fish-breeding etc;

(d) A programme for recycling urban effluent water should be initiated;

(e) Structures to prevent the spill of flood water from the western slopes to the Red Sea should be provided;

(f) A charge for water provided for agriculture should be levied on farmers representing an appropriate percentage of the value of the annual yield of the lot when irrigated from wells or from small dams.

9. Jordan

(a) Jordan is recommended to develop the groundwater potentialities in the Sama Sdud well field within the Irbid Governorate;

(b) Groundwater potentialities of the Swaqa, Qatrana and Sultani well fields in the Mujib basin, should be further developed and a water transfer project from the well fields to Amman is recommended to help solve the capital's water shortage;

(c) Both regulations and economic incentives are recommended in dealing with the treatment of waste effluents from industries, including modern equipment subsidy, to achieve pollution control of storage water of the King Talal Dam;

(d) It is recommended to investigate the economic feasibility of installing a medium-sized reverse osmosis plant in the Jordan River Valley to desalt its water for domestic use;

(e) It is recommended that schemes for re-using urban treated waste effluents from Jordan's northern cities, where 85 per cent of the country's population live, for agriculture and industry be introduced;

(f) Active maintenance teams for water supply distribution networks would minimize water losses and save water and money;

(g) A crop charge in terms of percentage is recommended in order to pay some of the expenses of the irrigation projects;

(h) Caution should be exercised before deciding to implement the Euphrates-Jordan water transfer scheme, as discussed below. All alternatives to achieve the same objective are to be thoroughly investigated from the practical and economic point of view. The transfer scheme will enable Jordan to abstract 160 MCM per year from the Euphrates in Iraq at Al-Qaim near the Iraq-Syrian border. The UK consultant Howard-Humphreys are well-qualified technically for the project. Its estimaed cost is in excess of $US 1 billion and consists of 650 km pipelines and four stages pumping stations. The project would serve all drinking water demands in North Jordan[1/]. The cost of one cubic metre of transferred water will exceed $ 0.50.

10. Lebanon

(a) The hydrology and topography of the country permit the construction of many dams to generate considerable amounts of hydroelectric energy, a substantial part of which can be readily sold to other countries. It is strongly recommended that this target should be actively pursued in all future plans for water resources development. This would enable the government to have sufficient revenue for carrying out modern water supply and sewerage schemes in the urban and rural areas, developing its industry and agriculture;

1/ "Maqarin Deadlock Forces Major Revision of Jordan's Water Plans", Arab World Water, (July 1983).

(b) Use of the 2025 MCM of water discharged, on the average, to the Mediterranean every year, must be realized in allocating it to various sectors of the economy;

(c) A non-profit tariff schedule for water supply, sewerage services and disposal of industrial waste should be prepared to cover operation and maintenance costs. It should be of an increasing block nature.

11. Syria

(a) Syria is recommended not to spend any more funds on major storage or flood-control works;

(b) Since groundwater extraction is relatively cheap in Syria, the Government is recommended to spend more on groundwater extraction to develop the desert and arid parts of the Republic;

(c) Cattle breeding is a profitable business in Syria, therefore pastures and grazing regulations should be given special attention in the water use in the various parts of the Repbulic;

(d) Water supply and sewerage projects should cover the whole country with well prepared tariffs to cover operation and maintenance expenses;

(e) Syria should conclude agreements with Turkey and Iraq in sharing the waters of the Euphrates, which will enable the Republic to plan its agricultural expansion on a sound basis;

(f) Since the cost of reclaiming the hilly gypsious land in the Euphrates project is high, Syria may confine its cultivation in areas with class 1 and 2 soils for the time being;

(g) Water saving irrigation methods are recommended to avoid drainage and salinity problems as much as possible;

(h) Socio-economic conditions give the development of groundwater in the semi-arid regions of Syria paramount importance in plans for future development;

(i) In the southwest artificial recharge of the alluvial and volcanic aquifers would be a practical and economic solution to problems that already exist and those expected to rise in the future.

12. Egypt

(a) Revision of the water supply tariff schedule on a non-profit basis is essential to cope with the increasing expenses of maintenance, replacements and operation. Public utility rates should be set at levels that would achieve a balance between cost and revenue, with only minimal subsidies to be provided by the Government. Sewerage service charges should be combined with the water bill following the same guidelines;

(b) The frontier governorates of the Red Sea, norther and southern Sinai, the Matrouh and New Valley, where only one per cent of the population lives, have a considerable resource problem. They can obtain water from the Nile only by expensive long trunk mains and pumping works. Treated urban wastewater, solar desalination and other non-conventional water development techniques are recommended measures for temporary relief of the resource problem in those frontier regions. In the long-run, dual-purpose desalination plants or water from the Nile, whichever is cheaper, are to be considered;

(c) With sufficient surface water provided by the High Dam at all seasons and the high agricultural skill acquired by the Egyptain farmers throughout the centuries, agriculture should remain the backbone of the country's economy, only to be enhanced by the following factors: (a) modern methods of cultivation, including the introduction of agricultural machinery, fertilizers, pest and plant disease control, and extension services; (b) specail consideration for cotton and rice production to help the export balance; (c) a land or a crop yield tax to be enforced to cover the operation and maintenance expenses of the irrigation and drainage systems; (d) farmers should be able to receive loans with low interest rates to be paid back on easy installments enabling them to purchase necessary equipment to increase production; and (e) due to the limited arable land in the Nile Valley, wher 99 per cent of the population live, vertical expansion of agriculture is strongly recommended;

(d) High losses in water supply distribution systems due to leakage in all Egyptian cities call for strict active operation and maintenance teams.

13. Iraq

(a) Iraq is almost 100 per cent flood-proof, therefore no more funds should be spent on other major works relating to flood-control;

(b) Drinking water and sewerage service tariffs should be revised and set to recover operation, maintenance and replacement costs through an increasing block tariff system making the first low-cost block so designed as to provide every person with 100 l/day. Standposts should be fully subsidized;

(c) The water-wasting traditional method of rice cultivation by in-undating the rice farms to a depth of 50 cm prior to seeding should be abandoned and replaced by modern methods using fertilizers, modern drainage systems, pest and plant disease control measures, weed extraction etc. This will save from 5 to 7 billion m^3 wasted annually on what is locally termed as "Tadyiab" prior to seeding;

(d) Irrigation return flows in Iraq are abundant. It is roughly estimated to amount to 10 billion m^3 in an average year with a TDS of 2000 to 3000 ppm. By mixing irrigation return flows with fresh river water, the TDS can be reduced to an acceptable level. The drainage water thus treated can be re-used for irrigation. Moderately salt resistent plants are recommended in this case. For example, pomegrenates, figs, grapes, olives, alfalfa, cantaloupes, flax, tomatos, asparagus, barley, rice, lettuce, carrots, spinach, onion, peppers, wheat, etc.;

(e) Iraq is recommended to continue land reclamation by constructing drainage systems down to field drains, land levelling and weed extraction, salt leaking and use of fertilizers, use of crop rotation, etc. Total reclamation costs are expected to range roughly from $ 6000 tO $ 7000 per hectare. It is suggested that half of the reclamation cost be subsidized by the government and the other half be recovered through a land or crop-yield tax whichever is more feasible;

(f) Maintenance of all water projects should receive prime consideration. This will save both water and money in the long run;

(g) Projects for soil stabilization and prevention of sand-dunes movement along both sides of the Gharraf Canal in the southern par to Iraq between the Tigris and Euphrates should be implemented;

(h) Well drilling in the northwestern and southwestern deserts with a limited work on building of small dams at suitable sites of the Euphrates desert wadis will be necessary for the development of the desert areas and settling the nomadic tribes;

(i) Some harnessing measures of the springs in the north and northeastern parts of Iraq are recommended to provide water for forestry and local domestic needs;

(j) A programmed and co-ordinated operation of the reservoirs in the country together with the Tharthar project would enable Iraq to employ the principle of perennial storage almost completely, thus avoiding any wastage of water in wet years and any serious water shortage in dry years;

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