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WATER RESOURCES: PROBLEMS AND ISSUES FOR THE WATER SUPPLY AND SANITATION SECTOR

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INTRODUCTION

The FY88 Water Supply and Sanitation Annual Sector Review indicates that the total population with access to satisfactory water sources in developing countries had increased from about 1.4 billions to some 1.8 billions in the period 1980-85. Despite the enormous efforts to widen coverage, almost half of the population still lacks safe drinking water, and with an expected population growth to about 4.8 billions by the end of the century, the provision of services for these people is a major challenge for the sector. Recent estimates indicate that the additional water required to raise urban coverage from 66% to 75% and rural coverage from 40% to 50% as well as industrial demand between 1985 and 2000 is about 325 billion cubic meters per year by 2000. The additional cost of the modest projected increases in domestic coverage is estimated to be about $125 billion (1985 U.S. dollars) in new investments. If total irrigated land in the world continues to expand at a rate of 4 million hectares per year, an additional withdrawal of about 840 billion cubic meters would be required for agriculture purposes. This total increase represents almost one third of total water used in 1980.

The sector in developing countries is poorly prepared to cope with the population growth and with the ever-increasing water demand for domestic purposes and for other uses such as agriculture and industry. This dramatically increasing demand for water supply service is one, but not the only, issue that need to be addressed within the sector, as stated in the Sector Review. The others are: constraints on water availability and increased supply costs, serious constraints in financial resources needed to meet these demands; and the adequacy of sectoral policies and institutions to meet these challenges. It should be noted that these four issues are not discrete, rather they are often closely interrelated.

The present paper is a preliminary review of the profound effects of water resources and their management in providing safe water to those lacking it. Water resources problems are not completely new concerns, however they have not been sufficiently stressed within the sector in the past. The costs of supplying and distributing water depend on the availability and usability of water. Therefore, in order to reduce the risk of a future without adequate water supply service for many people, the sector must understand the nature, magnitude and urgency of the water resource issues that lead to increased scarcity, reduced quality and local availability and cost increases. The paper concludes with the identification of policy and research work needed in the water supply and sanitation sector to define appropriate responses to increasingly adverse situation.

OVERVIEW

The two first sections of the paper describe water resources availability and demand at the global level and at the country level as well. It can be concluded that taken as a whole there is enough fresh water in the world, even in many cases, there is enough water at national level to meet social demands, yet conflicts over water are growing. The key issue is not solely the physical scarcity of the resource, the main constraint is the cost of bringing usable water where it is needed. The fact of taking water for granted and the results of its mismanagement, as will be discussed in section five, have placed severe strains on existing supplies, which now are inadequate to meet the increased water demand resulting from the growth of population and industry together with the expansion of irrigated agriculture.

The following section describes the decline of quantity and quality of water. As a result of uncontrolled pollution from agricultural runoff, industrial waste and domestic sewage, the availability of usable water without extensive treatment is becoming scarce. Also, the effects which follow from man's intervention on natural resources (such as deforestation, overexploited aquifers, desiccation) can cause irreversible damages to the volume of the physically available sources.

Section four presents recent examples where supply costs are increasing due to water resources problems. These cases demonstrate, on the one hand, that intensive water competition creates the necessity to transmit water over longer distance and make more extensive use of high-cost energy-using pumping. On the other hand, environmental consequences of water uses creates the necessity for additional treatment since lower quality sources are employed. The cases also show that when the quality of the source has been irreversibly damaged, especially nearby sources, it has had to be rejected for domestic use.

The next section shows that there are few incentives to protect and conserve the resource. Especial attention is given to current pricing practices that bear little relation to scarcity of the resource which in turn encourage use beyond economically efficient levels. The findings of this review are presented in section six, while section seven presents possible actions to improve water resource management to meet these challenges. The final section presents an agenda for future research and analysis within the water and sanitation sector in order to assist borrowing countries in meeting the demands for water services.

I. WATER RESOURCE AVAILABILITY

A) At the Global Level

The main source of fresh water for human use is that received on world's land areas as a consequence of precipitation. Part of the rainfall evaporates right away, or after being used to sustain vegetation returns to the atmosphere by transpiration. The rest, called runoff, recharges streams, lakes and aquifers as it flows to the sea. The total global water available is composed of stable runoff and usable groundwater. Stable runoff amounts to about 14,000 cubic kilometers in total, but only 9,000 cubic kilometers is readily available for human use.1/ The total amount of water stored in the ground is unknown, however a 1985 estimate indicates that there are between 8 and 10 million cubic kilometers of freshwater above a depth of 4,000 meters, but only a very small proportion is economically exploitable (water table may be too deep for groundwater to be exploited). Furthermore, only about 90 thousand cubic kilometers is in rechargeable aquifers, and the remainder is fossil water.2/

In 1980, total water use was about 3,600 cubic kilometers, almost 26 percent of total stable runoff.3/ On a global basis, at recent rates of increase, water use would equal total stable runoff in about 150 years. However, the global amount of water physically available conceals significant variations in relative availability among and within countries. This global figure shows that water resources constraints are not exclusively physical constraints. An increasingly significant constraint is the cost of gaining access, transporting, pumping and treating water to get it where it is needed.

B) At the Country Level

There are many ways to assess the level of water scarcity at the country level. One physical measure of water surplus or deficit is the difference between annual precipitation and evapotranspiration. When the annual precipitation exceeds the amount of water required for crops not to suffer deficiency, the area has water surplus. If the opposite occurs, the area has water deficit. The areas of severe water deficit, where annual evapotranspiration exceeding precipitation by over 1000 mm, in developing countries are: northwestern Mexico, Northeast Brazil, parts of Chile and Argentina, the Northern Region of Africa, and most of the Middle East (the Arabian peninsula, Iran, Afghanistan, Pakistan, Northern India, and Northern China).4/ A related measure is the interannual variability of rainfall, which reflects the reliability of precipitation and the likelihood of periodic drought. The areas in developing countries with high variability, more than 40 percent, are: North and Sub-Saharan Africa, the Arabian peninsula,

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1/ World Resources Institute, World Resources 1987, p. 112.

2/ Ibid, pp. 119-20.

3/ Ibid, p. 113.

4/ Carl Widstrand, "Water Conflicts and Research Priorities", Water and Society: Conflicts in Development Part 2, 1980, Pergamon Press, Oxford, pp. 15-18.

southern Iran, Pakistan, western India, northwestern Mexico, southwest Africa, eastern Brazil, and part of Chile.

Another measure of water scarcity is the number of individuals that are dependent on one flow unit (one million cubic meters of water per year) for food security and cash crops, and for domestic purposes and industrial use. This approach is used by Malin Falkenmark.1/ She contends that when more than 2000 people compete for one flow unit, there is an inherent vulnerability to water scarcity. This level of water competition is identified as the "Water Barrier". When a country is approaching this limit, there is a need for adjustments through adequate strategies either technological or administrative or both. Falkenmark defines that above a level of competition of 1000 people the condition is "Absolute Water Scarcity".

For purpose of assessing the level of water scarcity among countries, Table 1 shows per capita water availability for the actual population in the year 1989 and when population is expected to be stationary for those countries for which consistent data is available. The basic assumption in these projections is that water available will remain equal to the present average annual flow of rivers and aquifers (generated from endogenous precipitation), based on the concept that water is a renewable resource. However the quantity may change through uneven distribution of precipitation within a country and within and across years, and also through man-made actions.

As Falkenmark discusses in her publication "Macro-Scale Water Scarcity Requires Micro-Scale Approaches"2/, experiences from the industrialized countries indicate that when the water scarcity levels are beyond 500 persons per flow unit, those countries confront considerable problems of adaptation. S.I Freidmann in his report "World Water Availability and Demand"3/, states that countries with a level of competition beyond 750 people have to make large investments in developing their water supplies and for limiting their water used. Also, they face high and growing water-related costs (operation and maintenance of facilities for withdrawing, transporting, recycling, treating and disposing of water).

In Table 2 the 35 countries for which data used in this report are available are classified by the level of water competition. In 1989, only 8 countries have a condition of "absolute water scarcity", but these number is expected to grow to 18 when the population is expected to be stationary.

1/ Malin Falkenmark, "The Massive Water Scarcity Now Threatening Africa-Why Isn't it Being Addressed?," Ambio, February 1989, pp. 112-18.

2/ Malin Falkenmark, Jan Lundqvist, and Carl Widstrand, "Macro-Scale Water Scarcity Requires Micro-Scale Approaches: Aspects of Vulnerability in Semi-Arid Development," April 1989.

3/ S.I. Freidmann, "World Water Availability and Demand,", The World Bank, 1979.

TABLE 1: FRESHWATER AVAILABILITY

Country	1989 Availability 1/				Persons/Flow Unit 2/		
	(1)	(2)	(3)	Total	(1989)	(2000)	(SP3/)
Algeria	18.9	0.2	0.7	18.4	1320	1818	4402
Argentina	694.0	x	x	694.0	47	54	76
Botswana	1.0	17.0	x	18.0	71	107	278
Cape Verde	0.2	0.0	0.0	0.2	1786	2350	2350
China	2800.0	0.0	x	2800.0	397	449	571
Colombia	1070.0	x	x	1070.0	29	36	55
Costa Rica	95.0	x	x	95.0	30	38	53
Cuba	34.5	0.0	0.0	34.5	302	339	406
Cyprus	0.9	0.0	0.0	0.9	775	844	844
Egypt	1.8	56.5	0.0	58.3	882	1097	2161
El Salvador	19.0	x	x	19.0	332	459	844
Ghana	53.0	x	x	53.0	293	427	1019
Guatemala	116.0	x	x	116.0	77	105	233
Honduras	102.0	x	x	102.0	49	69	147
India	1850.0	x	x	1850.0	441	521	919
Iran	117.5	x	x	117.5	426	555	1379
Iraq	34.0	66.0	x	100.0	188	254	710
Israel	1.7	0.5	0.0	2.2	2056	2465	3721
Jordan	0.7	0.4	x	1.1	3500	5818	15455
Madagascar	40.0	0.0	0.0	40.0	281	389	1200
Mauritania	0.4	7.0	x	7.4	284	405	1081
Mexico	357.4	x	x	357.4	243	305	548
Morocco	30.0	0.0	0.3	29.7	808	993	2222
Oman	2.0	0.0	x	2.0	704	985	2500
Peru	40.0	x	x	40.0	543	700	1150
Saudi Arabia	2.2	0.0	x	2.2	6250	9000	27727
South Africa	50.0	x	x	50.0	714	938	1880
Sri Lanka	43.2	0.0	0.0	43.2	398	454	741
Sudan	30.0	100.0	x	130.0	191	253	777
Syria	7.6	27.9	30.0	5.5	2293	3238	7091
Thailand	110.0	0.0	0.0	110.0	498	595	918
Togo	11.5	x	x	11.5	291	410	1391
Tunisia	3.8	0.6	0.0	4.4	1713	2168	4138
Turkey	196.0	7.0	69.0	134.0	386	488	813
Yemen	1.5	0.0	x	1.5	5267	7253	26000

Sources: World Resources 1988-89, World Development Report 1988.

1/ Total availability includes internal renewable water resources (1), as well as river flows from other countries (2), and excludes river flows to other countries (3). (x means data not available).

2/ Flow unit is equal to one million cubic meters per year.

3/ SP-Stationary Population. When population is expected to be stationary (the birth rate is constant and equal to the death rate, the age structure is constant, and the growth rate is zero). These estimates are from the World Development Report 1988.

TABLE 2: LEVEL OF WATER COMPETITION 1/

Persons Dependent on One Flow Unit 2/			
Less than 500	500-1000	1000-2000	Above 2000
At year 1989			
Argentina Botswana China Colombia Costa Rica Cuba El Salvador Ghana Guatemala Honduras India Iran Iraq Madagascar Mauritania Mexico Sri Lanka Sudan Thailand Togo Turkey	Cyprus Egypt Morocco Oman Peru South Africa	Algeria Cape Verde Tunisia	Israel Jordan Saudi Arabia Syria Yemen
When Population is expected to be stationary			
Argentina Botswana Colombia Costa Rica Cuba Guatemala Honduras	China Cyprus El Salvador India Iraq Mexico Sri Lanka Sudan Thailand Turkey	Ghana Iran Madagascar Mauritania Peru South Africa Togo	Algeria Cape Verde Egypt Israel Jordan Morocco Oman Saudi Arabia Syria Tunisia Yemen

1/ Levels of Water Competition:

Water Barrier: 2000 persons compete for one flow unit.
Absolute Scarcity: More than 1000 persons compete for one flow unit.
Adaptation Problems: More than 500 persons compete for one flow unit.

2/ One flow unit equals one million cubic meters per year.

TABLE 3: FRESHWATER WITHDRAWAL

Country	Year of Data	Withdrawal 1/			
		Total	As % Available 2/	Percent Used For:	
				P&I3/	Agriculture
Algeria	1980	3.00	16	28	72
Argentina	1976	27.60	4	27	73
Botswana	1980	0.09	1	25	75
Cape Verde	1972	0.04	20	8	92
China	1980	460.00	16	13	87
Colombia	1960	x	x	14	86
Costa Rica	1970	1.35	1	8	92
Cuba	1975	8.10	23	17	83
Cyprus	1985	0.54	60	9	91
Egypt	1985	56.40	97	12	88
El Salvador	1975	1.00	5	17	83
Ghana	1970	0.30	1	46	54
Guatemala	1970	0.73	1	18	82
Honduras	1970	1.34	1	4	96
India	1975	380.00	21	7	93
Iran	1975	45.40	39	3	97
Iraq	1970	42.80	43	5	95
Israel	1986	1.90	88	21	79
Jordan	1975	0.45	41	3	97
Madagascar	1984	16.30	41	1	99
Mauritania	1978	0.73	10	2	98
Mexico	1975	54.20	15	12	88
Morocco	1985	11.00	37	9	91
Oman	1975	0.43	22	2	98
Peru	1975	x	x	7	93
Saudi Arabia	1975	2.33	106	42	58
South Africa	1970	9.20	18	17	83
Sri Lanka	1970	6.30	15	2	98
Sudan	1977	18.60	14	1	99
Syrian	1976	3.34	9	6	94
Thailand	1975	x	x	1	99
Togo	x	0.05	1	90	10
Tunisia	1985	2.30	53	10	90
Turkey	1985	15.60	8	42	58
Yemen	1975	1.93	129	1	99

Source: World Resources 1987 & 1988-89.

1/ This includes water taken from surface and groundwater sources at the year shown in column "Year of Data" expressed in billion cubic meters per year.

2/ It refers to total water withdrawal at the stated year as a percent of total available in 1989 (see column 5 of Table 1).

3/ P&I=Public and Industry.

Water scarcity is reaching alarming dimensions in response to the rapid population growth. For all developing countries, according to the U.N.,1/ at least 19 countries are reported to fall in a competition level of more than 2000 people in 1975. By the years 2000 and 2025, they estimate that there will be 29 and 37 countries, respectively, in the same situation.

The water scarcity problem can be approached from another perspective, which is the level of water utilization expressed as percent of the total water availability. According to experience from the industrialized countries, as Szesztay reports2/, when the level of utilization is beyond 20 percent large investments have been needed in order to regulate the natural flows and to transport water to the places where it is needed. To have a picture of the level of water utilization, Table 3 has been prepared showing the total amount of water withdrawn by each of the listed 35 countries for the stated years (column "Year of Data"). Table 4 shows that 11 countries out of 35 exceed the 20 percent limit beyond which large management problems are expected.

TABLE 4: WATER WITHDRAWAL AS PERCENT OF WATER AVAILABLE 3/

< 10%	10% - 20%	> 20%
Argentina	Algeria	Cuba
Botswana	Cape Verde	Cyprus
Colombia	China	Egypt
Costa Rica	Mexico	India
El Salvador	South Africa	Iran
Ghana	Sri Lanka	Iraq
Guatemala	Sudan	Israel
Honduras		Jordan
Mauritania		Madagascar
Peru		Morocco
Syrian		Oman
Thailand		Saudi Arabia
Togo		Tunisia
Turkey		Yemen

1/ United Nation, "Water: The Fundamental Resource," Report of Working Group II on Water Resources Management, December 1988, Geneva.

2/ Malin Falkenmark, op.cit., April 1989.

3/ This table shows three ranges of water withdrawal, and the 35 countries have been listed under the categories into which they fall. (See column 4 "As % Available" of Table 3).

In order to provide a summary picture of the water situation of these 35 countries, Table 5 has been prepared showing the countries in the worst situation according to each of the criteria described above. The first column lists the countries with water deficits exceeding 1000 mm/year in combination with those whose variability of rainfall is more than 40 percent. The next column shows these countries that will face absolute water scarcity when population become stationary (more than 1000 persons compete for one flow unit). And in the last column are the countries whose withdrawals are 20 percent or more of their water available. As a conclusion, 27 countries out of the 35 are facing physical water scarcity on the basis of one or more of these criteria.

TABLE 5: WATER SCARCITY

COUNTRY	CRITERION 1	CRITERION 2	CRITERION 3
Algeria	X	X	
Argentina	X		
Botswana	X		
Cape Verde		X	
China	X		
Colombia			
Costa Rica			
Cuba			X
Cyprus			X
Egypt	X	X	X
El Salvador			
Ghana		X	
Guatemala			
Honduras			
India	X		X
Iran	X	X	X
Iraq	X		X
Israel		X	X
Jordan		X	X
Madagascar		X	X
Mauritania	X	X	
Mexico	X		
Morocco		X	X
Oman	X	X	X
Peru		X	
Saudi Arabia	X	X	X
South Africa	X	X	
Sri Lanka			
Sudan	X		
Syria		X	X
Thailand			
Togo		X	
Tunisia	X	X	X
Turkey			
Yemen	X	X	X

II. WATER RESOURCES DEMANDS 1/

A) Current Demands for Water

On the basis of an assessment prepared by the USSR in the early seventies, worldwide water use for the three major users (irrigated agriculture, industry and domestic activities) doubled from 400 billion to some 800 billion cubic meters per year during the 40-year period from 1900 to 1940, while the per capita level of usage rose from 292 cubic meter to 466 cubic meters.2/ By 1970 annual per capita water use had climbed to some 700 cubic meters, which was 60 percent higher than in 1950. At 1980, the total water use amounted to about 3600 billion cubic meters or about 800 cubic meters per person per year. It is estimated that the rapid increase in water demand, which started in 1950, was due to the growth of demand for agricultural and industrial usage. Both sectors together increased their water demands during 1950 to 1970 at a rate of about 4.2 percent a year, while the annual rate of growth was only about 2 percent in the 1900-50 period.

One major factor influencing water demand is growth in population, however water demand rate of growth is affected by other factors such as changes in rates of economic development, in urbanization and in the proportion of the population supplied with piped water. Table 6 suggests growth in water withdrawal for those countries for which data is available. Even though the sample includes only 17 countries, they clearly show that water withdrawal tends to grow faster than population. There are exceptions, however. Two countries have reduced withdrawal, Mexico since 1975 and the USA since 1980. In the case of Mexico the reduction of withdrawal was due to an increase efficiency in irrigation from 25% to 50%.3/ The USA case shows that after continual increases in the water withdrawal from 1950 to 1980, total water use was less in 1985 than in 1980.4/ One of the major reasons for this decline has been the more extensive use of pricing policies which force users to be more selective and conservative. In three countries, withdrawals grew more slowly than population (Israel, Morocco, and Turkey). Levels of water use in Israel, for example, have been influenced by legislative, administrative, and technological innovations, which have allowed conservation and efficient use of the scarce water resources of this country.5/

1/ In this section we adopt the engineering convention of defining demand as water withdrawn for use (or "water produced"). Consequently, the figures include wasted water and unaccounted-for water and are not generally adjusted for possible price and income effects on use.

2/ Sandra Postel, "Water:Rethinking Management in a Age of Scarcity," Worldwatch Paper 62, September 1984, pp. 11-12.

3/ Economic Commission for Latin America, "Water Management and Environmental in Latin America," 1979, pp. 34-45.

4/ Wayne B. Solley, Charles F. Merk, and Robert R. Pierce, "Estimated Use of Water in the United States in 1985," U.S.Geological Survey Circular 1004, 1988.

5/ Saul Arlosoroff, "Israel-A Model of Efficient Utilization of a Country's Water Resources," January 1977.

On a global basis, agriculture is the largest user of water, accounting for about 73% of total withdrawal; Industry and urban usage account for 21% and 6%, respectively.1/ The corresponding figures for all developing countries is difficult to obtain, however the sample of 35 countries listed in Table 3 have a higher level of use in agriculture of about 85% on average. In 1975 total world irrigated area amounted to 223 million hectares of which 92 millions hectares were in developing countries.2/ For this total land, the amount of water needed to irrigate crops was almost 1,300 billion cubic meters, but in order to provide this amount withdrawal had to be almost 3,000 million cubic meter. In other words, 57% of the water was lost through evaporation and transpiration. The efficiency of water use in agriculture will be discussed further in Section V.

TABLE 6: WATER WITHDRAWAL CHANGE AND POPULATION INCREASE

Country	Period	Water Withdrawal Change	Population Increase
CHILE	1957 - 1975	99%	43%
COSTA RICA	1970 - 1980	43%	30%
EL SALVADOR	1970 - 1980	16%	15%
ISRAEL	1975 - 1986	11%	13%
JAPAN	1975 - 1980	23%	5%
KOREA	1973 - 1976	19%	5%
LEBANON	1966 - 1975	52%	25%
LIBYA	1978 - 1985	78%	38%
MALAYSIA	1970 - 1975	17%	15%
MEXICO	1960 - 1975	64%	65%
	1975 - 1980	-4%	15%
MOROCCO	1972 - 1985	38%	50%
PANAMA	1970 - 1975	31%	14%
SOUTH AFRICA	1965 - 1970	20%	15%
SPAIN	1968 - 1975	28%	6%
	1975 - 1985	25%	9%
TUNISIA	1977 - 1985	125%	22%
TURKEY	1970 - 1985	32%	41%
USA	1950 - 1960	37%	19%
	1960 - 1970	31%	14%
	1970 - 1980	20%	11%
	1980 - 1985	-10%	5%

Source: Water Resources of the World, World Resources 1988-89, Los Recursos Hidraulicos de Chile, National Systems of Water Administration U.N., The world Tables 1983.

1/ World Resources 1987, Ibid, pp. 112-113.

2/ United Nations, "Water for Agriculture," Water Development and Management: Proceeding of the United Nations Water Conference, Part 3, Pergamon Press, Oxford, pp.907-941.

Industrial water use has a major consideration in countries like Canada and the United States, where this sector accounts for 70% and 46% of the total water withdrawal, respectively.1/ However, in developing countries like India and China, industrial water use accounts for only 4% and 7% of total withdrawal, respectively.2/ A recent estimate suggests that at present, industry accounts for less than 10% of the total water demand in the developing countries.3/ Combining these estimates suggests that water for domestic purposes is about 5 percent of total withdrawal in developing countries.

B) Future Water Demands

At the present, many nations are embarking on the expansion of irrigated areas, because of population pressures and desire for local production of food. Therefore agriculture water use can be expected to grow substantially especially in developing countries. Information on the amount of land under irrigation and on its growth in selected major regions of the world in given in Table 7. This information shows that between 1950 and 1980, the area brought under irrigation worldwide nearly tripled, increasing from 94 to 261 million hectares. If irrigation continues to expand at a rate of 4 million hectares per year, and uses 10,500 cubic meters of water per year for each hectare of land irrigated4/, then an additional amount of 840 billion cubic meters of water will be needed by the year 2000. This amount represents a 32 percent increase over 1980 withdrawal levels for agriculture.

TABLE 7: GROWTH IN IRRIGATED AREA BY CONTINENT 1950-85

Region	Total Area 1985 (million Ha)	Growth in Irrigated Area		
		1950-60	1960-70 (percent)	1970-80
Africa	13	25	80	33
Asia	184	52	32	34
Europe	29	50	67	40
North America	34	42	71	17
South America	9	67	20	33
Oceanic	2	0	100	0
World	271	49	41	32

Source: Adapted from W.R. Rangeley, "Irrigation-Current Trends and a Future Perspective", in World Resources 1987, pp. 116.

1/ World Resources 1988-89, Ibid, pp. 318-319.

2/ Ibid.

3/ Sandra Postel, op.cit., September 1984, p. 15.

4/ This figure has been estimated taking into account that for 223 million hectares of irrigated land almost 3,000 million cubic meters were required in 1975, with a efficiency of 43%. If the level of efficiency rise to 55% , then each irrigated hectare will require almost 10,500 cubic meter per year.

As noted early, industry use in advanced economies is enormous; it seems inevitable that industrial development will require more water in the future, particularly in developing countries. According to target sets for the Second Development Decade of the United Nations, the industrial sector is expected to grow at an annual rate of 8 percent in developing countries, therefore it is reasonable to expect industry's share of water usage to increase from its current 10 percent share as industrialization picks up. Moreover, there is a pronounced difference between population growth and industrial growth. The growth rate of industrial output from 1965 to 1980 in developing countries was 7.2 percent a year, about three times the population growth rate of 2.3 percent a year during the same period.1/ A 1988 estimate indicates that by 2000, the industrial sector in developing countries will require an additional 250 billion cubic meter per year.2/

Population growth and increasing urbanization are expected to continue in the future in developing countries. Urban population is expected to grow from about 1,200 million in 1985 to some 2,050 million by the year 2000, while total population is expected to reach 4,800 million by 2000, which represent an increase of about 30 percent over the 1985 figure.3/ By the end of the century, almost all of the largest urban areas in the world will be in developing countries. Moreover, 75 percent of cities with 15 million people or more are expected to be in developing countries, and also over the next 25 year cities with current population of 10 to 14 million are expected to double in size.4/

About future provision of safe drinking water, according to the FY88 Annual Sector Review, if the water supply coverage of LDC urban population were to be increased from 68 percent in 1990 to 75 percent in the year 2000, and rural coverage were also to be increased from 42 percent to 50 percent over the same period, the amount of water that would be required would be of the order of about 75 billion cubic meters of water per year. This estimate has been made on the basis of the prevailing average per capita consumption levels during the early to mid-1980s. But, given the current water use levels in the developing countries, it is reasonable to expect that per capita consumption figures are likely to rise during the period under consideration at least in countries with income growth that exceeds the growth in water prices. Therefore, the actual growth in demand would be higher.

1/ The World Bank, "World Development Report 1988".

2/ The World Bank, "FY88 Water Supply and Sanitation Annual Sector Review", November 1988, p. 9.

3/ FY88 Annual Sector Review, Ibid., Annex I.

4/ S. Arlosoroff, "Issues in Water Management for Urban Centers in the Developing Countries," July 1989.

III. DECLINE IN ACCESSIBLE WATER RESOURCES

A) Man's Intervention With Natural Resources

There are many ways in which man's intervention with natural resources may affect the hydrological cycle, than in turn lead to decline in accessible water resources.1/ For example, large population can adversely affect a country's water retention capacity. This is the major effect of urbanization, since it represents the covering of the common land by roads, streets, and buildings. As a result the amounts of infiltration and transpiration are reduced, and the total surface runoff is increased. Overexploited drylands also have effects on soil permeability. It tends to seal the soil surface, either by mechanical clogging or by the formation of chemical crusting, disturbing groundwater recharge.

Deforestation, which represents the clearance of forests, has adverse effects on water resources. Forests act as buffers of rain water, but when they are removed from the surface, the water regulatory capacity of the system is lost. Soil erosion, which may be a result of the removal of forest cover, leads to the increased supply of sediment to the rivers. The major problems of this silt runoff are: increased turbidity, increased treatment costs, and increased siltation levels.

B) Over-exploitation of Groundwater Sources

As indicated earlier, the volume of groundwater potentially available is very large. Recently, groundwater sources have been extensively developed in many countries, especially for irrigation. There are clear cases of problems being created by withdrawal because of the lack of knowledge about exploitable volume or quality of groundwater. In most of the cases the rate of abstraction exceeds the rate of recharge, which results in not only a continual lowering of the water table, but also contributes to decreased pressure in aquifers, changes in rates and direction of flows, salt water intrusion and land subsidence. In Tamil Nadu in southern India, pumping for irrigation has resulted in lowering of the water table by 25-30 meters in 10 year. In Beijing, annual pumping exceeds sustainable levels by 25% and has resulted in compaction of the aquifer at the rate of 1 meter each year and land subsidence at rates of 20-30 centimeters annually. This situation is also true in Mexico City and Bangkok.2/

In countries where water supplies depend on coastal aquifers, the risk of sea water intrusion is always present; this is the case of Jakarta in Indonesia. In this city, about 2 million cubic meters of groundwater are drawn per day; this has caused such severe depletion of the aquifers below the city that saline water has intruded almost 15 km into Jakarta, and most of the shallow groundwater along the coast has become saline3/. The aquifer cannot be recharged at adequate rates; so current use lowers the water table, increasing the price of abstraction, and

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1/ Food and Agriculture Organization, "Man's Influence on the Hydrological Cycle," 1973.

2/ Sandra Postel, op.cit., September 1984, pp. 23.

3/ Gloria Davis, "Indonesia Forest, Land and Water: Issues in Sustainable Development", The World Bank, 1988, pp. 92-93.

further increasing the salinity of surface waters. Similar results are encountered in Israel and the Arabian Gulf, where salt water intrusion is contaminating fresh water supplies.1/

C) Quality Degradation

As a result of pollution, many nations are facing the decline of the availability of clean water. The main causes of degradation of water sources are: dumping untreated industrial waste and human sewage into surface sources; and seeping runoff from agricultural lands with a high content of chemicals originating from fertilizers, pesticides and herbicides into aquifers and surface waters.

In addition to their phenomenal growth in population, the urban areas in the developing countries have become centers of concentration and growth of industrial complexes. Steel and petrochemical industries as well as factories processing primary products like sugar, oil palm, coffee, hides and minerals have been causing widespread water pollution in cities which have little or no facilities for pollution control or for the collection, treatment and disposal of the large quantities of domestic and industrial wastes (toxic and non-toxic) that are being generated in them. Effluent from pharmaceutical and petrochemical industries, which are heavily loaded with toxic substances, are dangerous and very difficult to treat. The discharge of untreated domestic waste into water bodies, results in runoff seriously polluted with pathogens and organic materials. Domestic waste, in turn, is among the major sources of disease transmission. If the volume and toxicity of wastes continue increasing, and agriculture uses more pesticides and fertilizers, then about a fourth of the world's reliable supply will be unsafe for use by the year 2000.2/

In India, for example, about 70 percent of the surface water bodies are reported to be polluted; of the 78 rivers monitored in China, 54 were found to be seriously polluted with untreated sewage and industrial wastes; in Malaysia, over 40 rivers are so polluted that they are said to be devoid of fish or other aquatic life; and in the Philippines untreated sewage accounts for up to 60-70 percent of the water of the Manila's Pasing River.3/ In many parts of Latin America, municipal sewage and industrial effluent are discharge directly into the nearest water courses almost always without treatment. The cost to purify the Bogota river in Colombia is estimated in 1.4 billion dollars, a high price for this country to pay.4/ In Lima, the upstream pollution of the Rimac River has increased treatment cost (chemicals and disinfectants) by about 30 percent.5/

1/ World Resources 1986, Ibid, p. 132.

2/ Sandra Postel, op.cit., p. 19.

3/ World Resources 1987, Ibid, p. 4.

4/ Sandra Postel, op.cit., p. 19.

5/ The World Bank, "Environmental Growth, and Development," Development Committee, Number 14, August 1987, p. 5.

In many countries agriculture activities are major causes of the degradation of water resources. There is a marked increase in the concentration of phosphates and nitrates in the inland waters of many countries as a result of the runoff of pesticides, herbicide, and fertilizers from agricultural lands. High concentrations of nitrates and nitrites in potable water is considered a health hazard, especially for newborns. Moreover, excessive irrigation has caused problems such as salinization, alkalinization and water logging. In semiarid countries, salts from irrigation projects have increased the salinity of riverwater.

The following examples show the cost to the economy of water pollution: In Shenyang, a Chinese city, approximately 70% of the groundwater pumped originates from the Hum river, which is subject to pollution from upstream discharges. Because of the poor quality of this source, its proximity notwithstanding, it has not been possible to consider it for domestic water supply.1/ Yingkuo, another Chinese city, is an example where, as a result of heavy pollution, the nearby Daliao river cannot be used for domestic purpose, even though it is cheaper in terms of average incremental cost (AIC) compared with water from the Bi Liu river. Water from the first source has an AIC of US$0.162/ compared to an AIC of US$0.30 for water from the second source.3/ In the city of Shanghai, pollution costs to the economy are about $300 million due to the fact that water intakes were moved about 40 Km. upstream.4/

In Jakarta the heavy pollution of raw water sources reaching the Jakarta water treatment plant has necessitated the construction of a US$40 million pipeline from the West Tarum canal to the Jakarta water treatment plant to circumvent the problem. The eventual cost of supplying this raw water to Jakarta is estimated to be $1 billion. Meanwhile, the estimated annual cost of boiling the Jakarta water to render it safe for drinking purposes is $20-30 million5/. In Algiers and Seoul, water pollution of the Isser and the Han Rivers had created the necessity to move water intakes upstream, which in turn represent increased water supply costs.6/

1/ Liaoning Province Urban Studies/River Basin Management Project. "Expansion of Water Supplies to the City of Shenyang," 1988.

2/ From now on, prices and costs are given in constant september 1988 US dollars.

3/ Liaoning Province Urban Studies/River Basin Management Project. "Expansion of Water Supplies to the City of Yingkuo," 1988.

4/ "Environmental Growth, and Development", Ibid, p. 5.

5/ Gloria Davis, op.cit., p. 9.

6/ "Environmental Growth, and Development", Ibid, p. 5.

IV. TYPICAL EXAMPLES OF INCREASING LONG-RUN MARGINAL COST

The following examples are significant in that they demonstrate that overall water availability *per se* is not the only constraint; access to the water is a critical issue. They show that water resources management problems are already being experienced in a number of countries all over the developing world. They show that water shortages are creating technical as well as economic problems. It is significant to note from these examples that the management and economic problems are caused not only by the lack of accessibility to water of adequate quantity, but also by the lack of accessibility to water of adequate quality.

Under the conditions prevailing in most developing countries each additional unit of water tends to cost more to obtain and distribute than existing supplies. Furthermore, in many countries failure in the past to invest adequately in water pollution control facilities and in water supplies has built up a backlog which must be paid for during the coming years and which will add further to the marginal cost of additional supplies.

The most dramatic examples of rising costs are in growing urban areas like Amman in Jordan where the AIC has increased sharply. When the water supply system was based on groundwater the AIC was estimated at $0.41 per cubic meter; however, chronic shortages of groundwater led to the use of surface water sources; this raised the AIC to $1.33 per cubic meter. The most recent works involve pumping water up 1,200 meters from a site about 40 kilometers from the city.1/

It will be recalled that China as a whole has enormous water resources, amounting to 2800 billion cubic meters per year for 1989. This notwithstanding, Beijing and Tianjin, two Chinese cities with a 1985 population of 17 million, have recently been experiencing severe water shortages. They have modest water resources of only 3.9% of the per capita average water availability in the United States; at present, their per capita water withdrawal is already approaching their per capita water limit of about 390 cubic meters per year; and it has been projected that by the year 2000 the water deficit for the two cities would be 4 billion cubic meters.2/ This would call for substantial development of new water sources. Already, water is being brought in from long distances - which for Tianjin is a distance of about 234 km; the next alternatives include bringing water from the Yellow River over distances exceeding 1,000 km.3/

A feasibility study for the expansion of water supply to the city of Shenyang shows that the average unit cost of water would rise from $0.04 to $0.11, almost 200 percent increase, between 1988 and 2000. The main reason is that groundwater from the Hun valley alluvium, which is the current water source, has to be rejected as an immediate means of supplying potable water for reasons

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1/ The World Bank, "Jordan Water Resources Sector Study," March 1988.

2/ Grady Timmons, "Era of Cheap Water May End for China," Water Resource Journal, June 1988, pp. 45-46.

3/ John Huang, "China Department: Water Sector Strategies.", The World Bank, April 1989.

of water quality. As a result, water will have to be conveyed to Shenyang by gravity from a surface source 51 km away from the city.1/

Tunis and Sfax in Tunisia, which are dependent on treated surface water from large impounding reservoirs and long transmission mains, are also experiencing an increases in the AIC of their water supply. While the AIC of the First Water Supply Project financed by the Bank was $0.21, the Sixth Water Supply Project had an AIC of about $0.54 per cubic meter, an increase of almost 150 percent in real terms.2/

In Nairobi, Kenya, the Second Water Supply Project built in 1982-84, with an AIC of $0.44 per cubic meter, was supposed to meet the city's requirements until near the end of 1988. However, by 1987 Nairobi started to experience serious water shortages, and the need for an expansion was clearly identified. Since extractions from present sources were approaching the upper extraction limits, the next alternative was to consider the construction of an expensive dam and storage reservoir.3/

The Lima Metropolitan Area in Peru offers another example of the increasing long-run cost caused by significant investments required to develop new and distant water sources and by the need for the development of sewage treatment and disposal facilities. In 1981, the AIC of a project to meet short-to-medium term needs was $0.25 per cubic meter. The project was based in part on a surface source from the Rimac River and partly on groundwater supplies. But the aquifer was being depleted; therefore, groundwater extraction cannot be used to satisfy needs beyond the early 1990's. A transfer of water from the Atlantic watershed which has been planned to meet the long-term urban needs, has an AIC of $0.53 per cubic meter.4/

Mexico illustrates the case of water scarcity in the midst of high overall availability of water (it has 4110 cubic meters of water per capita per year for 1989). About 85 percent of the surface water resources are found below elevation 500 meters, but at least 75 percent of the population and 80 percent of its industry are located above this level. Groundwater resources have been used extensively, particularly in areas around the metropolitan area of Mexico City, much of it for agriculture. The resultant over-exploitation of the Mexico Valley aquifer has caused great problems of land subsidence, lowering of the water table and deterioration in water quality, giving rise to the risk of irreversible damage to the available water resources, at least in some parts of the valley. Because of these problems, the use of this source is being restricted and currently water is pumped over an elevation of 1000 meters into the valley of Mexico from the Cutzamala river through a pipeline of about 180 km. The AIC of water from this source is $0.82 per cubic meter, almost 55 percent more expensive

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1/ "Expansion of the Water Supplies to the City of Shenyang", Ibid.

2/ The World Bank, "Staff Appraisal Reports of the First and Sixth Water Supply Projects".

3/ The World Bank, "Staff Appraisal Report".

4/ The World Bank, "Lima Water Supply and Sewage Project", Staff Appraisal Report, 1982.

than well water.1/ The newly designed water supply project for the city is expected to be still more costly; it has an even longer transmission line, and the water has to be pumped over an elevation of 2,000 meters to the city.2/

These examples illustrate a common experience in many countries: the least cost sources of water are always the first to be exploited; consequently, subsequent resource development becomes progressively more costly. This, coupled with the growing competitive demands raises the issues of the conservation and reallocation of water among users.

V. WATER USE EFFICIENCY

A) Efficiency in the Use of Agriculture Water

Since irrigation water has tended to be relatively more heavily subsidized than water for industrial and domestic use, the lack of appropriate pricing has resulted in very limited efforts for conservation. Farmers who pay only a small fraction of the cost (between 10-20 percent)3/ are apt to waste the resource they receive. In Indonesia, for example, farmer payments in 1985-86 amounted to less than 13% of the total cost of irrigation.4/ A review of Bank irrigation experience shows that the proportion of operation and maintenance costs recovered was frequently between 15% and 45%.5/ Moreover, in many cases charges are levied not by the unit of water applied but by the unit of land irrigated; this removes again any incentive to conserve water. Charging farmers for the water they use could provide an incentive to increase the benefits of irrigation in terms of cropping intensity and production.

With increasing water demand for agriculture, it is necessary to encourage efficiency with which the irrigation systems operate. Water is wasted as it is conveyed from the intake to the farmlands. Worldwide, the efficiency of irrigation systems is estimated to average only 37 percent.6/ Reducing withdrawals can make a given reservoir or aquifer supply last longer or serve a larger area. For example, increasing efficiency in irrigation by only 10 percent in the Indus region of Pakistan could provide enough water to irrigate

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1/ UNDP, "Study of Present Waste Management and Resource Recovery Within the Metropolitan Area of Mexico City." November 1987.

2/ Hector Garduno, "Interregional Water Transfers in Mexico," International Journal of Water Resource Development, Volume 2, Number 2, 1984, pp. 119-134.

3/ World Resources 1988-89, Ibid, p. 132.

4/ Gloria Davis, op.cit., p. 103.

5/ G.O'Mara, "A Brief Review of Cost Recovery Policy in World Bank Irrigation Lending," The World Bank, December 1988.

6/ Sandra Postel, "Conserving Water: The Untapped Alternative," Worldwatch Paper 67, September 1985, p. 11.

an additional 2 million hectares.1/ Also, improving efficiencies worldwide by only 10 percent would save water to supply all residential users.2/ Most farmers in developing countries use gravity-flow systems, which have a maximum efficiency of about 50%. With sprinkler systems it is possible to obtain efficiency in the range of 75-85 percent, and with drip systems between 60-92 percent.3/

Other ways that farmers could use water more efficiently are: scheduling irrigation according to weather conditions, soil moisture, and crop requirements. Moreover, there are other options available to reduce demand for freshwater such as the use of brackish water and treated waste water.

In the past, water policy has not taken into account the output value from competing uses. For example, Annex 1 illustrates the case of the USA where, for the same production output, industry uses only 20% of the water used for agricultural purposes. Marc Reisner in his article "The Next Water War: Cities versus Agriculture" describes the water situation of the western region of the U.S. where farmers are diverting vast quantities of water from more profitable uses while damaging the environment. In California, the share of agriculture is 85% of all water use, nearly all of it for irrigation, but it accounts for only 2.5% of the economy.

B) Efficiency in the Use of Industrial and Domestic Water

The belief that water is a "social service" rather than an economic commodity is deeply rooted in a number of developing countries. This has been reflected in government subsidies that have effectively discouraged the application of tariffs that reflect the real cost of providing services. In the United States, studies have shown that consumers use less water in municipal systems that have meters and higher price4/; and that a 10% increase in the price of water will result in a 4-6 percent drop in water demand (estimated price elasticity -0.45/-0.61).5/

The following cases demonstrate that the lack of appropriate pricing policies only encourage the inefficient and wasteful use of water resource. The current tariff in Mexico City, for instance, generates revenue equal to only 6% of the true cost of water; and the annual cost of water supply for the Federal District alone is over 1% of the GDP of the whole country. As a result, industries in Mexico City find it cheaper to use potable water for cooling and other industrial purposes, rather than to use recycled water. In Greater Cairo where the water rate is ranked among the lowest in the world, which in turn covers only 35 percent of operation costs, the estimated water consumption in

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1/ World Resources 1988-89, Ibid, p. 132.

2/ Sandra Postel, op,cit., September 1984, p. 39.

3/ Sandra Postel, op.cit., September 1985, pp. 12-14.

4/ World Resources 1986, Ibid, p. 132.

5/ Organization for Economic Co-Operation and Development, "Pricing of Water Services," 1987, p. 51.

1984 was 310 liters per capita per day, but unaccounted-for water was between 40% and 65%. Similarly high levels of unaccounted for water are observed in Mexico City, Lima and Barranquilla for the same reasons. In Bank-supported projects the average level of unaccounted-for water is about 36 percent.1/

VI. FINDINGS

It has been the object of this paper to make an exploratory review of water resources problems in selected countries with the view to defining the scale of the problem and to pave the way for a more detailed analysis and eventual formulation of policy guidelines.

The findings of this review are as follows:

a. The amount of fresh water available, globally, is enough to provide adequate amounts to meet future needs; a major limiting factor is the increasing cost of bringing usable water to where it is needed.

b. Rapid growth in population and increasing urbanization and industrialization coupled with continuing growth in agriculture land requiring irrigation have placed severe strains on existing supplies. Therefore, the prospect is for increased competition among users for the more readily available water.

c. Water is being withdrawn at very high rates in a number of developing countries. In some cases, the rate of withdrawal is very close to the limits of the physical available resources; in others, it has been projected that the withdrawal rate will soon outstrip the available resources. Increased availability can be obtained only under conditions of increasing cost; e.g. for desalination and extensive water transfer from its sources to its users.

d. In all countries, agriculture uses the largest share of total water withdrawn. The global share is about 73%, but in developing countries this share is higher (85%). Moreover, this water is highly subsidized by governments.

e Agricultural water use for more marginal land in developing countries is expected to grow substantially because of population pressures and a desire for local production of food. Moreover, this situation will place more stress on supplies in the absence of policy and pricing changes.

f. Worldwide, the efficiency of irrigation systems is estimated to average only 37 percent. Vast quantities of water seep through unlined canals and much more water is applied to crops than is necessary for them to grow.

1/ Harvey "Mike" Garn, "Water Supply Investments in Developing Countries: Some Technical, Economic, and Financial Implications of Experience," 1987.

g. There is a marked increase in the concentration of phosphates and nitrates in the inland waters of many countries as a result of the runoff of pesticides, herbicide, and fertilizers from agricultural lands.

h. Pollution resulting from the increase in population in major urban centers, industrialization and the heavy dependence on chemical products in agriculture are reducing access to water of adequate quality. The result is the necessity of additional treatment, which is reflected in the cost of water.

i. Long-term marginal costs of water (economic and environmental) are rising sharply, particularly in and around large urban centers, even in water-rich countries.

j. The belief that water is a <u>social service</u> rather than an economic commodity is deeply embedded in the majority of developing countries. Since water tariffs bear little relation to the real cost, users do not make efforts to conserve and protect the resource. Moreover, supply institutions have experienced great difficulty in reducing water losses in their systems.

k. Prevailing cost recovery policies have discouraged efforts to improve the efficiency of operation and a rational use of water resources.

l. In most of the developing countries, tariffs and administrative regulations have not been applied intensively enough to encourage industries to pretreat liquid wastes before disposal.

VII. POSSIBLE ACTIONS TO IMPROVE THE WATER RESOURCES MANAGEMENT

Since current patterns of water use have originated or will generate serious problems, there is a need to undertake special actions for the avoidance of a water crisis or to minimize the consequences of its scarcity in relation to quantity, quality, location and timing. There is an urgent need to modify past trends of water utilization and find innovative ways of conserving the most readily available water in order to insure that this resource is adequate to meet the ever growing competition among users.

The economic and environmental costs of traditional water policies, which have been focussed on increasing the quantity of water available, are reaching levels that can longer be ignored. The time to address these issues through other alternatives than increasing supplies wherever a need is felt is now. The following are some actions that should be considered to improve the water resources management in developing countries:

a. <u>Pricing water for all uses at levels more nearly approximating its marginal cost</u>.- Water costs a certain amount to capture, deliver and distribute. Users who do not pay the real cost are apt to waste the resource. The use of a policy of pricing water at levels more nearly approximating incremental cost than is the prevailing practice could have the effect of dampening demand and reducing waste.

b. Conserving water wherever is possible.- Other water saving and conservation policies sometimes can be a more cost-effective response to imbalance between supply and demand than costly investments for increasing water supply. Current municipal and irrigation water use may be reduced by metering, increasing tariffs, leak detection and repair, water saving devices, increasing irrigation efficiency, publicity campaigns and education, and reuse of waste water.

c. Preventing the further deterioration of water sources.- Water legislation is an essential tool for optimum use and rational management of water resources and related land resources. In developing countries, legislation should be drawn to control groundwater mining, salination of fresh water bodies and the discharge of effluent to both the surface water and groundwater. Once water quality standards have been formulated, governments can employ pollution control strategies such as penalties for overpolluting (as in the United States) or taxing polluters according to how much they pollute (as in Japan).

d. Reallocating the available water among users as priorities among uses change.- There is a need for a reevaluation of current water allocations. One response to the call for more water is reallocation, either by water marketing, water rights sales or direct government regulations, giving priorities to the uses with the highest economic value. Through the development of private markets water use would tend to shift from lower to higher value uses. In the agriculture sector for example, if there is a market in which water could be bought and sold, or rented, then the farmer would bid for water in accordance with its marginal value to him. Privatization of public works and services and the introduction of cost recovery schemes where water is subsidized should be considered as a means to stretching current allocations.

e. Improving efficiency.- Reduced costs can be obtained through improvement in the operation of existing supply facilities and in the size, timing, and technical aspects of new investment schemes.

VIII. RECOMMENDATIONS FOR FUTURE WORK

This report shows that water resource problems are now substantial and are likely to increase. These problems directly affect the ability of sectoral institutions to provide services of the needed quantity and quality at costs which are affordable. Moreover, the report shows that current usage practices and disposal of waste threaten to add significantly to the problems. We conclude that is essential for the Water Supply and Sanitation Sector to now assign a high priority to water resource issues. The issues are of concern, of course, to other sectoral activities within borrowing countries and in the Bank. They obviously concern agriculture, industry, and environmental groups. Nevertheless, we conclude that initiatives are required in the sector.

INUWS, in coordination with other interested division within the Bank, should consider the following activities:

a. A major effort is needed to analyze the impacts of rapidly growing competing demands for water on the availability and quantity of water and on the supply cost implications of meeting these demands. In this connection, additional work is required on the following:

   - levels and trends of usage water levels by the major water users in the environs of several large urban areas. Possible candidates are Mexico City, Bogota, Lima, Amman, Istanbul, Calcutta, Bangkok, Shanghai, Lagos, Nairobi, and Abidjan.

   - trends in long-term marginal costs to provide water for these users.

b. INUWS should undertake a major review of the likely costs and benefits of alternatives approaches to water resources management; in particular, mechanisms used to ration, allocate, or reallocate water. These alternatives will include:

   - the use of pricing to reflect the cost of water.

   - administrative measures to control the use and reallocate it when priorities among uses change; and

   - combination of both approaches.

c. Work should done to identify aggregate water resource issues and how they vary by country depending on their water resource condition.

d. Seminars on water resource subjects using bank staff and outside experts should be organized to disseminate information on water resources, implications for the sector, and management approaches.

ANNEX 1

THE UNITED STATES: WATER WITHDRAWAL 1950-1985

Year	Water Withdrawal Total (Billion cubic meters)	Public	Agric.	Ind.	Rate of Growth Total	Public	Agric.	Ind.
1950	285.1	19.3	153.5	112.3				
1955	336.0	23.5	155.0	157.5	3.3%	4.0%	0.2%	7.0%
1960	390.1	28.2	158.9	203.0	3.0%	3.7%	0.5%	5.2%
1965	450.4	32.7	169.5	248.2	2.9%	3.0%	1.3%	4.1%
1970	512.1	37.4	179.9	294.8	2.6%	2.7%	1.2%	3.5%
1975	574.9	42.1	191.0	341.8	2.3%	2.4%	1.2%	3.0%
1980	614.3	55.3	208.9	350.1	1.3%	5.6%	1.8%	0.5%
1985	552.2 1/	56.1	230.2	265.9	-2.1%	0.3%	2.0%	-5.4%

Year	Population Total (Million)	Urban	Labor Agric.	Ind.	Share of GDP Agric (Billion $) (Constant 1975$)	Ind.	Water Withdrawal per Dollar of Value Added Agric. (Cubic meter)	Industry
1950	151.8	97.1	12.9	35.7	41.6	177.9	3.69	0.63
1955	165.9	110.9	9.9	37.3	42.7	208.6	3.63	0.76
1960	180.7	126.5	7.1	39.3	43.1	216.5	3.69	0.94
1965	194.3	139.5	5.8	41.4	44.2	296.6	3.83	0.84
1970	205.1	150.9	4.7	43.7	46.3	328.2	3.89	0.90
1975	216.0	162.6	3.8	46.2	50.2	361.0	3.80	0.95
1980	227.7	175.3	3.0	48.2	53.6	436.9	3.90	0.80
1985	239.6	184.2	4.5	49.0	57.8	488.1	3.98	0.54

Water Withdrawal Functions 2/

Alternative 1:

R(Water)=-0.070+1.67*R(Urban)+0.59*R(Agric.)+3.10*R(Industry)......R^2=0.966
(6.57) (2.82) (3.36)

Alternative 2:

r(Water)=-0.002+0.30*R(Urban)+0.11*R(Agric.)+0.58*R(Industry)......R^2=0.966
(6.53) (2.82) (3.43)

Alternative 3:

r(Water)= 0.017+1.65*r(Urban)+0.43*r(Agric.)+3.07*r(Industry)......R^2=0.966
(6.60) (2.84) (3.51)

1/ Increased use of recycled water probably lowered industrial and irrigation requirements, which contributing to the overall decline in use.

2/ The numbers in parenthesis are the associated t-values. Two of the coefficients are statistically significant because they are different from zero at the 0.05 or lower probability level. The third one (agriculture labor force) has a 0.10 level of significance.

Where: r = Growth Rate of either total water withdrawal, urban population, agriculture or industrial labor force.
R = Ratio of either total water withdrawal, urban population, agriculture or industrial labor force.

There are some general patterns of water use as a function of the rate of growth of consumers-urban users, agriculture and industry labor force. Time series data of the U.S. were used in a multiple regression analysis, and the conclusions that can be drawn from this analysis are the followings:

- **Alternative 1:** We could expect an increase of 1.67 units in the ratio of water withdrawal for an increase of one unit in the ratio of urban population, an increase of 0.59 units for a one unit change in the ratio of agricultural labor force, and finally an increase of 3.1 units for a one unit change in the ratio of industrial labor force.

- **Alternative 2:** We could expect an increase of 0.30 units in the growth rate of water withdrawal for an increase of one unit in the ratio of urban population, an increase of 0.11 units for a one unit change in the ratio of agriculture labor force, and finally an increase of 0.58 units for a one unit change in the ratio of industrial labor force.

- **Alternative 3:** We could expect an increase of 1.65 units in the growth rate of water withdrawal for an increase of one unit in the growth rate of urban population, an increase of 0.59 units for a one unit change in the growth rate of agriculture labor force, and finally an increase of 3.1 units for a one unit change in the growth rate of industrial labor force.

The data also illustrates the case that industry requires an average of 20 percent of the water withdrawal for agricultural purposes in order to add the same production output expressed in constant dollars. Therefore, the value of additional agriculture production from increase water use is usually far less than the value of using the same water for other purposes.

Sources:

- World Tables, The Third Edition, Volume I and II. Trends in Water Resources Use and Development in the ECE Region, United Nations.
- World Development Report 1988.
- World Resources 1987, 1988-99.
- "Estimated Use of Water in the United States, U.S.Geological Survey.

ANNEX 2

CASE STUDIES

I. CHINA

Between 1950 and the present, the Chinese population has more than doubled and the per capita water availability has decrease from about 5,500 cu m/yr to 2,520 cu m/yr (Gustafsson, pp.63). Since 1950 the national water requirements has more than quadrupled. During 1949 and 1980 the ratio of water withdrawal to total annual runoff has increase from 4% to 16.4%. In 1980 approximately 87% of the water withdrawal was used for agricultural purposes, 7% for industrial use, and only 6% for domestic one (Water Resources 1988-89). Table 2.1 presents this information.

The figures in Annex 2 show that China, as a whole, is far away from water shortages; only 16% of its 2800 billion cubic meters of water resources were being withdrawal in 1980. But, because of the marked difference in water distribution between north and south, the water supply situation is critical for the northern districts. They all have extremely low water availability, and the difference between supply and demand of water resources has become the main restraining factor in the economic development.

Moreover, recent studies have shown that until the beginning of the 21st century, the total per capita water consumption will be increased to 530 cu m/yr, while at the same period the annual supply would be only 470 cu m/per (Proceedings of the Tenth Session of the Committee on Natural Resources, pp.202). The shortage of water is imminent if some actions are not taken.

TABLE 2.1: WATER AVAILABILITY, WITHDRAWAL AND NEEDS FOR CHINA

	1950	1980	2000
Water Availability (per capita cu m/yr)	5,500	2,600	2,100
Water Withdrawal (As % of annual runoff)	4.0	16.4	25.2
Allocation (As % of total withdrawal)			
- Domestic Use	---	6	---
- Industrial Use	---	7	---
- Agricultural Use	---	87	---

The following are the problems faced by some Chinese cities:

Beijing & Tianjin

These two cities in Northern China, with a total population 17 million in 1985, have recently been facing periodic water shortages and serious deterioration of water quality. The per capita water withdrawal is already pushing the per capita limit of about 390 cubic meters available per year. It is expected that by the year 2000 water demand will increase by about 50% in Beijing, and 120% in Tianjin (Timmons, pp.45), creating, therefore, a projected water deficit of 4 billion cubic meters by the year 2000 (World Resources 1988-89, pp.132).

The key reasons for the shortage is physical water scarcity. As a result of the semi-arid land of northern China, Beijing and Tianjin have modest water resources of only 3.9% of the per capita average water availability of the United States, 10,000 cu m/yr (Water Resources 1988-89, Table 21.1). In the last 30 years the rapid urban and industrial growth and, of greatest importance, the rapid increase in irrigated agriculture have increased the demand for water. In addition, reduced surface water inflow because of increased upstream withdrawals exacerbates the problem. Both groundwater and surface water resources are fully exploited. Groundwater is being withdrawn at a rate that exceeds natural recharges: for Beijing the ratio is four to one (World Resources 1987, pp.120). Moreover, water tables in some areas are falling by up to 1-4 meters per year (World Resources 1986, pp.132).

Another reason, and maybe the most important, is that shortages result from disparity in the allocation of this resource. Approximately 67% of the current water withdrawn in those two cities is used for agricultural purposes, industry uses 20%, and the domestic and municipal demands accounts for the rest (Timmons). Water policy has not compared water value in competing uses, since the value of additional agricultural production from increases water use is usually far less than the value of using the same water for other purposes. Agriculture uses more water and is a lower value use.

Changcun

Existing sources of water supply to this city are both groundwater and surface water. Currently, the groundwater table is experiencing reduction, and further extractions would certainly result in soil subsidence and subsequent foundation problems in many parts of the city. Today the total population is 5.8 million, and almost 38% is urban. Water supply shortage is one of the most important issues in this Chinese city. Present water demand is estimated to be about 500,000 cu m/d, however, available water resources can only meet 80% of the demand (CHINA: Changcun Water Supply Project, J. Huang). Moreover, it is expected that water requirements will grow to about 800,000 cu m/d in 1995 and 1,000,000 cu m/d in the year 2000.

Agriculture is well developed, and the major part of the farm land is irrigated by surface water. Almost 50% of the water resource available is currently drawn from a reservoir about 50 km east of the city, which was built for irrigation purposes. Because of that, the city has to pay US$0.27 per cubic meter as compensation to agriculture. In the recent years Changcun has shifted towards industrialization, and the heavy industrial growth has caused a dramatic increase in water use, which is high compared with similar industries in other cities. In order to meet the domestic needs of the urban population, and to support industrial growth, a project is being proposed to extract 800,000 cu m/d from a river about 150 km away from the city.

Shenyang

Water supply is obtained entirely from groundwater sources most of which are adjacent to the city. Almost 57% of the water withdrawal is extracted from Shenyang, which is the only exploitable aquifer in the region. The static water is about 5m below ground level near the river, but to the north it is now as low as 35 m due to overpumping by industry. . The total capacity of these wells has rose by 56% between 1975 and 1986, and they represent 25% of the total water withdrawal.

Approximately 70% of the groundwater pumped from Shenyang originates from the Hum river, which is subject to pollution from upstream discharges. Also the aquifer is contaminated by industrial discharges within the city. As a result, the quality of this water is poor, and the principal constituents causing concern are: pH, iron, manganese, phenols and nitrates. Treatment of this water to a potable standards would involve expensive and sophisticated processes. Moreover, the pH, iron and manganese problems could be solved by treatment, but it is impractical to considered water treatment as a solution for phenol and nitrate contamination.

Per capita municipal water demand is projected to increase by 24% between 1986 and 1995. To satisfy the water demand for 1995, three possible sources have been identified:

- Dahuofang reservoir, which was built for flood control purposes. It is proposed a reduction of 130 million cu m/d for irrigation use, approximately 10% of the total irrigation water. The water shows high turbidities and high algae counts, because of the use of fertilizers in the upstream catchment. The process of removal of the algae is higher than the conventional sedimentation. The AIC of this alternative at 10% is US$0.15/cu m1/.

- Liao River Alluvium, from which adequate volume of water can be abstracted, since it is possible to obtain water from the river and from irrigation water applied to the land during the summer. However, this recharge may affect local farmers, who are opposed to this plan, and are asking for compensation payments due to the fact that 25,000 ha of land will be affected. Quality of the water is really poor because of the high manganese 0.4-0.8 mg/l and the high iron 5-10 mg/l. The AIC at 10% is US$0.16/cu m, without including costs for compensation to farmers, whose initial claims are US$0.13/cu m.

- Hun River Basin Alluvium, which offers plenty of water and is close to the city. However, this source has a limitation, the quality of water. This source may be considered for a industrial supply system, after overcome the problem of wastewater upstream.

1/ All the prices are given in constant september 1988 U.S. dollars

Yingkou

Yingkou presently obtains water from three groundwater sources, with a reliable per capita yield of no more 60 cu m/yr during dry winter and 73 cu m/yr in the summer (Yingkou Water Supply - Feasibility Study Report). The quality is good (turbidities below 3 FTU), and the water receives treatment only by chlorination. However, the risk of saline intrusion exists. Presently saline water occurs at shallow levels beneath the city. Several industrial users operate their own private water supply installations. Water consumption is reported to have grown at an average annual rate of 11% between 1960 and 1979. Following this pattern, the per capita water demand is expected to grow from 73 cu m/yr to 230 cu m/yr by the year 1995. The alternative sources to satisfy future needs are only surface waters, because there is no scope for further development of groundwater in the vicinity of Yingkou.

There are three river systems that can be considered as potential sources. First, the Daliao river, where the water is heavy polluted by the industrial and domestic effluent from the major cities upstream. Currently this river cannot be used as a source of domestic drinking water because of the serious health risks, however it is the cheapest sources for industrial supply (AIC US$0.16/cu m and transmission main 24 km long). The Da Qing river is the next one, where the water is of high quality. There were identified three potential sources, and the best alternatives in terms of AIC at a discount rate of 10% is the Sandaoling & Zhou Jia reservoirs (AIC US$0.15/cu m). Those reservoirs were built for irrigation purposes, therefore a charge will be made for raw water supplies. The last one is the Bi Liu river, where water is assumed to be of good quality. This could be the next alternative with a AIC of US$0.30 per cubic meter and the transmission system will be 91 km long (pumping water system).

II. INDIA

Bangalore and Hyderabad, two Indian cities, are rapidly growing at an annual rate of 4% and 7% during 1981-86 (Bowonder, pp.385-390). In 1951, Hyderabad had a population of 1.12 million, and Bangalore 0.10 million; these have increased to 3.0 and 4.0 million respectively by 1986. To cope with water requirements, it was necessary to increase water supplies. Table 2.2 summaries the evolution of the marginal capital cost of the infrastructural facilities at a discount rate of 10%.

III. INDONESIA

Taken as a whole, Indonesia has relatively abundant water resources. Annual average rainfall is about 2,340 mm, 140 percent greater than the world mean of 970 mm, and the available resources are 8,000 cu m per person per year (1,178 billion cu m/yr). However, the water supply situation in Java is critical because of population density, intensive agriculture and above average industrialization and urbanization. Java only has 6% of the total available water resources, and the annual per capita water availability is 745 m3, which represents 9% of the national average (See Table 2.3).

TABLE 2.2: MARGINAL CAPITAL COST OF WATER SUPPLY FOR HYDERABAD AND BANGALORE (US$ per cubic meter)

Hyderabad		
Scheme-I	0.09	(Laying a pipeline from the River Manjira, completed 1965)
Scheme-II	0.17	(Reservoir and long distance pipeline, completed 1981)
Scheme-III	0.63	(Pumping system and 100-140 km pipeline, to be completed 1989-90)
Bangalore		
Scheme-I	0.07	(Pumping water from the River Kauvery river, completed 1974)
Scheme-II	0.10	(Completed 1984)
Scheme-III	0.22	(To be completed in 1988-89)

Source: Bowonder, B., "Pricing of Urban Water Supply in India: Policy Issues".

The total population of Indonesia in 1980 was about 147.5 million people, and about 62% were living in Java, which has approximately 6.8% of the land area. The population density in Java at that time was 690 person/km2. The agriculture sector is the largest sector in this country's economy, and the irrigated area in Java alone is about 59% of the total irrigated surface. In 1980, the water used for agricultural and municipal purposes were about 87% and 1.8% respectively of the total potential water resources available. In general, most of the domestic needs can be supplied from subsurface water and springs, but usually the location and reliability of such sources are not precisely known and their development requires exploration time and expense. Surface water, while more accessible, has the disadvantage of requiring more specialized treatment which is both costly to build and to operate.

For Jakarta, groundwater supplies almost 60% of municipal water. About 2 million cu m groundwater are drawn per day, which has depleted the aquifers below Jakarta so severely that saline water has intruded almost 15 kilometers into the city and most of the shallow groundwater along the coast is saline. At the present time groundwater abstraction is undertaken mainly by the private sector for residential and industrial use. The aquifers cannot recharge at adequate rates, so current use lowers the water table, increases the price of abstraction, and cause the salinity of surface water.

Industrial water is derived primarily from groundwater. In West Java detailed surveys show that almost 65% of industrial water is from private wells and another 25% is private abstractions from rivers and lakes. Only 10% of the water used comes from public supplies. However, with the increase of water pollution in the river systems and the deterioration of groundwater quantity and quality in some areas, future supplies will have to be derived from public water systems.

TABLE 2.3: WATER AVAILABILITY AND NEEDS FOR INDONESIA AND JAVA

	INDONESIA	JAVA	JAVA AS % INDONESIA
Water Availability (million cu m/yr)			
Surface (firm flow)	703,000	44,000	
Subsurface	476,000	24,000	
Total	1,178,000	68,000	5.8
Population in 1980 ('000)	147,500	91,300	61.9
Per capita (cu m/yr)	8,000	745	9.3
Projected 1990 Needs (million cu m/yr)			
Agriculture	137,000	62,000	
Industry	500	200	
Domestic	6,600	4,100	
Total	144,100	66,300	46.0
As % Water Resources	12.2	97.5	

Source: Indonesia - Forest, Land and Water: Issues in Sustainable Development, The World Bank, March 1988

The following example illustrates the cost to the economy of water pollution in Jakarta. The heavy pollution of raw water sources to the Jakarta treatment plant is necessitating the construction of a US$40 millions pipeline from the West Tarum canal to the Jakarta water treatment facility, and the eventual cost of supplying raw water to Jakarta is estimated at about US$1 billion. The cost of boiling water to make it safe for consumption is estimated at US$20-30 million per year in the Jakarta area alone.

Exploitation of the remaining feasible surface water impoundments and groundwater sources, together with improving irrigation efficiency, careful allocation of supplies and enforcement of pollution controls are needed to conserve Java's water resources to serve future growth adequately.

IV. KOREA

Korea has limited water resources. The per capita annual surface water runoff is about 1,700 m3, almost 40% and 12% of Japan and the United States respectively. Rainfall is about 1,160 mm and 2/3 of the annual precipitation is concentrated in only four months (Korea: Sewerage and Wastewater Management). As a result, Korea requires the construction of large dams to provide storage reservoirs and to regulate year-round flows in the major rivers.

TABLE 2.4: WATER DEMAND AND SUPPLY IN KOREA1/

Classification	1982	1985	Increased by %
Total Water Demand	186	217	16
Domestic	29	39	34
Industrial	11	16	45
Agricultural	115	131	14
Storage	31	31	--
Total Water Supply	199 (176)2/	246	24
River	133	141	6
Underground	15	17	13
From Dams	51 (28)	88	73
Excess or Shortages	13 (-10)	29	

Source: Korea Water Supply and Sanitation Sector Profile, pp.59, The World Bank, January 1985

Increasing water demand, at the same time, requires the construction of many multipurpose reservoirs and regional water transmission systems with long transmission pipelines and expensive pumping. The cost of such facilities is increasingly so fast because of two factors: the lack of appropriate dam sites and the elevated land costs. Most of the suitable locations for medium and large dams have been already used and the total water available would stay almost constant from now on. Korea has considerable forested and agricultural areas which are strictly protected on environmental and food-production basis. This protection has constrained the development of the cities and has resulted in extremely high land prices. Table 2.4 summarizes water demand and supply during 1982 and 1986.

Presently, the rapid urbanization and the accelerated industrialization growth have overextended all urban services, which has led to a decline in the quality of the environment. Increases in income, urbanization and industrialization have resulted in considerable growth of the per capita demand for water. For example in Seoul, water production per capita for the period 1981-86 had increased 4.2% and is projected to increase about 3.0%, 2.5% and 1.6% p.a. during the periods 1986/91, 1991/96 and 1995/2001 respectively. For the year 2001 the forecast per capita demand is about 200 cu m.

V. JORDAN

The long-term safe yield of groundwater is estimated to be about 364 million cubic meter per year, and current consumption accounts for 90%--

1/ Unit 100 million of cubic meter

2/ The figures in parentheses indicates the amount actually withdrawn irrigation 52%, municipal and industry 48%. Surface water resources, in turn, are estimated at a total of 540 million cubic meter, and presently almost 62% is being exploited (1.5% M&I, 98.5% irrigation). Over the coming years, according to the projections, it will be a great increase in the total consumption of about 40% (936 million cu m) by the year 2005. These figures mean that at that point of time the water demands will reach available resources. Presently, water demand for agricultural purposes accounts for 76% of water consumed, while the rest is for municipal and industrial consumption. Projections for 2005 water demands show that agriculture will require 64% of the total water use, and 36% will be for M&I uses (See Table 2.5).

Jordan has no sizable sources of surface water. There are only a few suitable dam sites for storage of surface water. Moreover, the construction of storage dams in Jordan is extremely costly compared with other countries with scare water resources. For comparison purposes, the unit cost for dams in Jordan, Tunisia, and Cyprus are given in Table 2.6.

Amman's water supply is based on groundwater from two aquifers. Investigation of the two aquifers has led to the conclusion that the future demands of Amman can not be meet from those sources in the Amman-Zarqa Basin. Presently, the water extraction from Amman/Zarqa is excessive, since the safe long term yield is only 133 Mm3 per year and the total production in 1986 was 173 Mm3.

Water allocation problems occur between irrigation needs and M&I water, particularly in the Jordan Valley. Water consumption in the Amman/Zarqa area is made up of municipal 39%, agricultural 55%, and industrial 6%. The King Talal Dam was originally constructed for irrigation purposes, but presently Amman depends on this resource to meet its municipal and industrial water demand.

Water resources in Jordan are scarce and expensive to exploit. Up to now the government strategy has been to use groundwater for municipal and industrial purposes as well as agriculture, and surface water for irrigation. However, because of water scarcities this approach has to be modified. It is a need to consider water resources management in an integrated perspective, that takes into consideration the growing interdependence between water uses for municipal, industrial and irrigation.

The long-run average incremental cost of water at a discount rate of 10% varies between US$1.04 per cubic meter in areas where water is locally available to US$1.38 for areas such as Amman, where part of the water has to be pumped over long distances. (Jordan Water Resource Sector Report)

Water scarcities are such, especially in Amman, that the AIC has increased so sharply. For example, for the Second Water Supply Project based on groundwater the cost was estimated as US$0.41/m3. However, the chronic shortages of groundwater led to use a surface water source, the King Talal Dam including a transmission system, where the AIC was about US$1.33/m3. Moreover, future water development investment in Jordan are expected to be extremely costly. They will have to include long conveyancing systems to bring water from northern sources, and AIC is estimated to be about US$1.50 per cubic meter.

TABLE 2.5: WATER RESOURCES AND CONSUMPTION IN JORDAN1/

	Groundwater		Surface Water		Total	
Water Available	3642/ (40%)		540 (60%)		900	
Consumption	1986	2005	1986	2005	1986	2005
Municipal & Industry	155	258	5	77	160 24%	335 36%3/
Agriculture	171	158	340	443	511 76%	601 64%
Total	326	416	345	520	671	936

Source: Jordan Water Resources Sector Study, pp. 8-18, The World bank, March 1988

TABLE 2.6: COST COMPARISON OF LARGE DAMS

Country	Dam	Unit Cost (US$/cu m)
Jordan	Unity	0.97
	Karameh	2.26
	Wadi Arab	2.40
Tunisia	Sidi Salem	0.11
Cyprus	Kouris	0.34

Source: Jordan Water Resources Sector Study, pp.20.

VI. IVORY COST

During the last two decades, Abidjan has been one of the fastest growing metropolitan cities in Africa, averaging an annual population growth rate of about 10%. In 1978 some 70 percent of all economic and commercial took place in Abidjan, which contained around 15% of the national population. The fast growing city of Abidjan depends for its water needs on a vast aquifer below the city, where groundwater is of high quality with a low pH (around 5). In 1980

1/ Values given in million of cubic meter per year, except as indicated as percentage

2/ Exclude the fossil aquifer, which account for 102 million cubic meter, but it will require expensive conveyance

3/ This percentage is high but not out of line with other arid countries, like Algeria, where M & I water currently accounts for 25% of water used it was estimated that the aquifer had a safe per capita yield of around 170 cu m/yr, and it could cope with future demand at least through the end of the century. Beyond that, more expensive surface water resources would have to be exploited.

As a least cost solution to satisfy Abidjan's 1990 water requirements, the Second Water Supply Project contemplated further exploitation of the groundwater resources. Treatment of this water to potable standard had included only pH adjustment process. The marginal cost calculated at an opportunity cost of 10% was US$0.60 per cubic meter. However,the overall AIC for new components is US$1.54 per cubic meter, including the construction of full treatment facilities.

VII. KENYA

Kenya has limited water resources relative to area and population, per capita supply is 610 cu m/yr. Nairobi is in a continuing period of rapid population growth of about 7% per annum. The city is the largest urban community in Kenya and the center of government, commerce, industry, education and tourism. In 1985 water demand increased to about 180,000 cu m/d (60 cu m/yr/per), and it is estimated that by 1995 water consumption will reach 380,000 cu m/d.

A comprehensive study of groundwater shows very little potential for groundwater of suitable quality in the immediate vicinity of Nairobi. It is necessary a reevaluation of all feasible means of making a significant increase in Nairobi's water supply capacity at the least cost.

The Second Water Supply for Nairobi built in 1982-84 added about 108,000 cu m/d to the total average daily water treatment and transmission capacity, and its AIC at 10% discount rate was US$0.44 per cubic meter including transmission main 36 km long.

By 1987, the city started to experience water shortages, and the need for expansion of Nairobi's water supply was clearly identify. Since extractions from the water sources in the Chania-Thika River systems, which provided at that time almost 50% of total capacity, were approaching the upper extraction limits, to satisfy future water demand the next alternative has to consider the construction of an expensive dam and storage reservoir, representing high costs.

VIII. MAURITIUS

Surface waters contribute with the 60% of the total water supply in the island, while the underground water provides the difference. Most of the underground water demand is placed upon the Curepipe aquifer, and it is estimated that this aquifer will supply most of the future demands, whose total potential is about 120,000 m3/day. Currently, the surface water supplies about 80,000 m3/day and underground water renders about 50,000 m3/day. Even though, the quantity of water seems to be no problem, its quality is a serious issue.

Current patterns of agricultural practice, industrial discharges, and commercial/residential sewage disposal indicate that both surface and ground waters are becoming severely polluted. Moreover, much of this pollution is occurring in the Curepipe aquifer, which is one of the most heavily exploited. Looking into the future, in order to meet the drinking water standards, improvement of water treatment facilities will be required, which means the increase of associated costs.

IX. TUNISIA

The total annual exploitable water resources amounts to 3 billion cubic meters, of which 58% was under exploitation in 1981, including 7% for potable water. By the year 2000 more than 90% of the exploitable water resources will be under exploitation, of which 22% for potable water. Most groundwater resources in northern Tunisia have a limited capacity making them only suitable for potable water supply systems for small towns. The larger population centers are being more and more dependent on treated surface water. However, most of the fresh surface water resources are found in the north-west of the country, requiring large impounding reservoirs to optimize availability and long transmission mains and canals to convey the water to the consumption centers. Table 2.7 gives you an idea of how the average incremental cost to provide potable water is increasing in this country.

TABLE 2.7: AVERAGE INCREMENTAL COST (US$)

Water Supply Project	AIC	% Increase
First and Second	0.21	--
Third	0.26	24
Fifth	0.30	43
Sixth	0.54	157

SOURCE: Water Project Appraisal Reports

X. LATIN AMERICA

Available of water "per se" is not a major issue in Latin America, however, there are water supply problems in the region that have to deal with the location of the resources in relation to population and economic activity. For example, on the one hand the Amazons basin contains an enormous quantity of water, but its location makes it virtually useless for the future demands; on the other hand, the metropolis of Mexico City already has grave water supply problems. Sixty percentage of the population tends to be concentrate in 20% of the land area of Latin America that only has 5% of its water resources. As a conclusion, water problems in Latin America tend to be localized.

In many places water problems have been more serious because of the rapid economic growth, industrialization and urbanization of the region, which has lead to an increasing water requirements for domestic, industrial, agricultural, and energy generation purposes.

In order to satisfy water demands, it has become imperative to undertake increasingly costly projects, which makes the economic dimension of the water management more critical in many of the areas that are most significant to the development of the region. The increasing contamination of the rivers has imposed an extra cost on society that further tends to magnify the importance of cost and prices in water management.

The institutional agreements developed in the region are not the most appropriate to deal with water problems. In many countries water managers tend to respond to these problems by building more and larger projects, rather than by trying to obtain the most efficient use of already existing infrastructure. Legislation is usually contradictory in specifying property rights to water, which impedes the use of economic criteria in water management. Also the legislation usually considers views about the social role of water creating an obstacle to the establishment of water markets.

Mexico City

The current water consumption in the Metropolitan area of Mexico City is approximately 60 cu m/sec. The following table presents the water consumption of Mexico City (Watson, 1987).

Present schemes have reduced the per capita water consumption from 360 to 340 lcd in the last decade, with the rapidly expanding city, both in terms of industry and population (2.9% per year), this reduction is not sufficient to offset an overall increase in demand. How long existing sources of water can support this increase in demand remains to be seen.

TABLE 2.8: WATER CONSUMPTION IN THE METROPOLITAN AREA OF MEXICO CITY

Type of Use	Average per Capita	%	cu m/sec
Domestic	210	62	37
Industry	74	22	13
Commercial & Public Services	56	16	10
Total	340 (lcd)	100	60

Demands on natural water supplies are continually increasing and to minimize these demands on a diminishing resource, recycling of water should be practiced wherever technically feasible and economically viable. At present industry water consumption accounts for 20.8% of water supplied. It is therefore in this area that the greatest effort must be made to encourage wastewater recycling and minimize potable water consumption. Apart from industry, the other potentially high consumer of low grade water is irrigation.

The results of a long-run marginal cost analysis by direct comparison of specific costs and total production of three different alternatives are given in Table 2.9 From these figures it is concluded that the most appropriate alternative in terms of allocated cost is the last one, in order to satisfy demands of low grade water. The total immediate demand is the area is of about 88 l/s, 38% from an industrial zone and the rest for irrigation of the surrounding area.

TABLE 2.9: AIC OF WASTEWATER REUSE AND ALTERNATIVE WATER SUPPLY

Source	AIC (US$/cu m)
Well Water1/	0.56
Externally Supplied Water2/	0.82
Wastewater Treatment and Reuse3/	0.36

1/ Well water drawn from the Mexico Valley aquifer which is already over-exploited. However, the AIC has been assessed for the purposes of comparison

2/ Water pumped into Mexico Valley from the Cutzamala Project, 180 km pipeline

3/ This includes the treatment of 100 l/s of wastewater (2500 mg/l BOD) to a 30:20 SS:BOD standard from a nearby source, 1.5 km. (Raw water pumping station and rising mains).

ANNEX 3

WATER WITHDRAWAL FOR SOME SELECTED COUNTRIES, 1957-1986
(Billion Cubic Meters)

Country	Year Data	Water Withdrawal				Growth Rate			
		Agric.	Industry	Public	Total	Agric.	Industry	Public	Total
AFRICA									
ALGERIA	1970	1.62	0.12	0.26	2.00				
	1980	2.16	0.15	0.69	3.00	2.9%	2.3%	10.3%	4.1%
EGYPT	1976	43.20	0.90	0.90	45.00				
	1985	49.60	2.82	3.95	56.37	1.5%	13.5%	17.9%	2.5%
LYBIA	1978	1.22		0.25	1.47				
	1985	1.91		0.71	2.62	6.6%		16.1%	8.6%
MOROCCO	1972	7.50	0.20	0.30	8.00				
	1985	10.01	0.33	0.66	11.00	2.2%	3.9%	6.3%	2.5%
SOUTH AFRICA	1965	6.38		1.26	7.64				
	1970	7.64		1.56	9.20	3.7%		4.4%	3.8%
TUNISIA	1977	0.82		0.20	1.02				
	1985	2.07		0.23	2.30	12.3%		1.8%	10.7%
ASIA									
ISRAEL	1975	1.32	0.11	0.29	1.72				
	1986	1.50	0.10	0.30	1.90	1.1%	-1.0%	0.4%	0.9%
JAPAN	1975	57.00	18.30	12.30	87.60				
	1980	58.00	31.47	18.33	107.80	0.3%	11.5%	8.3%	4.2%
KOREA	1973	6.90	1.09	0.92	8.91				
	1976	8.03	1.39	1.18	10.59	5.2%	8.5%	8.6%	5.9%
LEBANON	1966	0.40		0.09	0.49				
	1975	0.65		0.10	0.75	5.5%		0.7%	4.7%
MALAYSIA	1970	7.40		0.68	8.08				
	1975	8.63		0.79	9.42	3.1%		3.0%	3.1%
TURKEY	1970	10.03	0.94	0.83	11.80				
	1985	8.89	2.96	3.74	15.60	-0.8%	7.9%	10.6%	1.9%
EUROPE									
SPAIN	1968	14.60	0.70	1.10	16.40				
	1975	18.00	1.25	1.75	21.00	3.0%	8.6%	6.9%	3.6%
	1985	21.04	2.06	3.20	26.30	1.6%	5.1%	6.2%	2.3%
AMERICA									
CHILE	1957	8.03	0.20	0.30	8.53				
	1975	15.46	0.67	0.84	16.97	3.7%	6.9%	5.9%	3.9%
COSTA RICA	1970	1.24		0.11	1.35				
	1980	1.76		0.17	1.93	3.6%		4.4%	3.6%
EL SALVADOR	1970	0.74		0.12	0.86				
	1980	0.83		0.17	1.00	1.2%		3.5%	1.5%
MEXICO	1960	30.00	2.24	0.76	33.00				
	1975	47.70	3.79	2.71	54.20	3.1%	3.6%	8.8%	3.4%
	1980	42.00	5.78	4.14	51.92	-2.5%	8.8%	8.8%	-0.9%
PANAMA	1970	0.75		0.13	0.88				
	1975	1.00		0.16	1.16	5.9%		3.7%	5.6%

PER CAPITA WITHDRAWAL FOR PUBLIC USE

Country	Year Data	Per Capita (cu m/yr)	Growth Rate
AFRICA			
ALGERIA	1970	18	
	1980	35	7.2%
EGYPT	1976	23	
	1985	82	14.9%
LYBIA	1978	92	
	1985	189	10.9%
MOROCCO	1972	19	
	1985	28	3.0%
SOUTH AFRICA	1965	64	
	1970	69	1.6%
TUNISIA	1977	34	
	1985	32	-0.7%
ASIA			
ISRAEL	1975	76	
	1986	69	-0.8%
JAPAN	1975	110	
	1980	157	7.3%
KOREA	1973	27	
	1976	33	6.8%
LEBANON	1966	43	
	1975	36	-1.8%
MALAYSIA	1970	65	
	1975	66	0.3%
TURKEY	1970	23	
	1985	75	8.1%
EUROPE			
SPAIN	1968	33	
	1975	50	5.9%
	1985	83	5.3%
AMERICA			
CHILE	1957	42	
	1975	82	3.8%
COSTA RICA	1970	64	
	1980	76	1.7%
EL SALVADOR	1970	34	
	1980	42	2.1%
MEXICO	1960	21	
	1975	45	5.3%
	1980	60	5.8%
PANAMA	1970	88	
	1975	93	1.1%

Source: Water Resources of the World, World Resources 1988-89, Los Recursos Hidraulicos de Chile, National Systems of Water Administration U.N.