Sustainable Water Development: a Global Perspective

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ABSTRACT

Major advances have been made on many aspects of water resources development and management all over the world during the period 1972-1992. Many of these development and management practices have had positive environmental impacts, and others had negative impacts. The paper provides a global perspective of sustainable water development over the past two decades.

INTRODUCTION

Freshwater has always been considered to be an essential ingredient for human survival. In Western Civilization, the eminent Greek philosopher Pindar said as early as the 5th century B.C. "water is the best of all things." According to Plato, water is one of the four elements with which all items on earth were constituted. Similarly in the South, in the great Indian epic *Mahabharata,* which can be easily compared to the Western epics of *Iliad* and *Odyssey,* Rishi Narada — probably the most well-known earliest authority on politics — greeted the great Pandava Ring Yudhistira by saying "I hope your realm has reservoirs that are large and full of water, located in different parts of the land, so that agriculture does not depend on the caprice of the Rain God" [1].

Water has continued to be considered a critical component for development in the South, but concomitant interest in the North has not been visible in recent decades, except for localized areas during periods of prolonged drought. In nearly all countries of the South, the importance of freshwater for every major aspect of development is fully recognized: clean water for drinking, and thus health; irrigation for agricultural production; for hydropower generation and cooling water for thermal and nuclear power plants; for transportation of people and goods through inland waterways; for maintenance of aquatic habitats; and for recreation. Water security, like food security, has recently often been considered to be a major concern of the South.

Interest in water in the North in recent years has been lukewarm at best. Much publicized reports like *Our Common Future* by the Brundtland Commission has been criticized severely for its view of the world from a dominant northern perspective. This report does not even provide a rationale as to why all issues that are of direct interest to the North were automatically included, whereas many other critically important issues like water, which is essential for the South's survival and development, did not receive even a cursory treatment. Thus, not surprisingly the Committee on Water Strategies for the 2 1 st Century of the International Water Resources Association (IWRA) severely criticized the Brundtland Commission Report for its "water blindness" at both the VIth and VIIth World Congresses on Water in Ottawa, Canada in 1988 and Rabat, Morocco in 199 1 respectively [2].

GENERAL DEVELOPMENTS DURING 1972-1992

In the field of freshwater, the foremost major development during the past two decades was undoubtedly the convening of the United Nations Water Conference in Mar de1 Plata, Argentina, in March 1977, at a very high decision-making level. The Conference produced the Mar del Plata Action Plan [3], which not only significantly influenced water development in developing countries during the 1980s but also is highly likely to continue affecting such practices in the 1990s through renewed and intensified efforts of the concerned international organizations [4,5]

It would, however, be a serious error to view the

Water Conference as a single, unique event of the period in question. This Conference was influenced by the World Food Conference (Rome, 1974) which discussed the importance of water for both irrigated and rain-fed agriculture, and the United Nations Conference on Human Settlements (Vancouver, 1975), which firmly put the issue of domestic water supply and sanitation on the international agenda. The Water Conference, in turn influenced the outcomes of the UN Conference on Desertification (Nairobi, 1977), World Conference on Agrarian Reform and Rural Development (Rome, 1979), and UN Conference on New and Renewable Sources of Energy (Nairobi, 198 1). In fact, an objective review of all the major UN World Conferences held during the 1972- 198 1 period would clearly indicate that water was one of the very few common threads that linked all these important events.

WATER DEVELOPMENT 1972-1992

On a global scale, it is estimated that 1,386 x 10^6 km^3 of water is available, of which only 2.665 per cent is fresh, the rest being seawater or brackish. This amount of freshwater (37 x 10^6 km^3), if distributed evenly over the world's land surface, would cover it to a depth of nearly 250 m. Seventy-six and one-half per cent of freshwater is stored in icecaps and glaciers, and another 22.9 per cent is available as groundwater. Only 0.004 per cent of freshwater, or 0.001 per cent of total water (1,500 km^3) is available at any instant in rivers. This is shown in Table 1. The total global annual river runoff has been estimated at 38,820 km^3.

From a water use viewpoint, two factors need to be considered. First, water is not uniformly distributed throughout the world. For example, nearly 1/6th of the total river flow of the world is in the Amazon Basin, and 55 per cent of the mean annual discharge of sub-Saharan Africa is accounted for by the Congo River Basin [6]. Thus, there is a considerable mismatch of freshwater and population distribution in the world.

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Second, the right quantity and quality of water is not generally available wherever required and whenever needed throughout the year. Often there is either too much water (floods) or too little (droughts). Hence, proper water management is essential to control the ravages of floods and droughts. This need has resulted in the significant increase in the number of dams that were constructed during the 20th century in most parts of the world. The reservoirs behind dams store floodwaters that can later be released as and when needed.

During the past three decades, the multipurpose role of dams has been clearly established. Thus, dams not only can release desired quantities of water for domestic, industrial, and agricultural uses but also generate hydroelectric power, provide storage for excess floodwaters, facilitate development of inland waterways, and enhance fisheries and recreational potential in the resulting manmade lakes.

While dams have been built for some 5,000 years [7], major changes have taken place during the past two decades in their planning, design, construction, and operation due to significant advances in our scientific and technological knowledge-base, and the introduction of more and more powerful computers. Ever increasing water demands, and advances in construction and operational technologies have meant that the number of large dams (more than 15 m in height) all over the world has increased remarkably during the era past 1950. Nearly 7/8ths of all the large dams in human history were constructed during the past four decades!

Table 2 shows the number of large dams constructed during the 1950-1986 period [8,9]. It should be noted that one country alone — China — accounted for nearly half of these dams. More than 78 per cent of these dams were between 15 m and 30 m high, and only about 0.1 per cent, or 26 dams, were higher than 200 m. Figure 1 shows the distribution of these dams

Table 1. Global sources of freshwater (Encyclopaedia Britannica, 1987).

Sources	Volume (km^3)	Percentage of Freshwater	Total Water
Polar Icecaps and Glaciers	28,200,000	76.5	2.04
Ground Water			
— within 800 m depth	3,740,000	10.1	0.27
— 800-4,000 m depth	4,7 10,000	12.8	0.34
Lakes	125,000	0.34	0.009
Soil Moisture	69,000	0.19	0.005
Atmospheric Vapour	13,500	0.037	0.001
Rivers	1,500	0.004	0.0001
TOTAL	36,859,000	99.971	2.665

Table 2. Number of large dams constructed, 1950-1986.

Continent	1950	1982	1986	Under Construction 31/12/86
Africa	133	665	763	58
Asia	1,562	22,189	23,389	613
Australia/Oceania	151	448	492	25
Europe	1,323	3,961	4,114	222
N. & C. America	2,099	7,303	6,595	39
South America			884	69
Total	5,268	35,166	36,327	1,026
of which in China	8	18,595	18,820	183

by height. Collectively these 36,327 dams stored some 5,500 km^3 of water, of which nearly 2/3rds can be used, the rest being dead storage.

During the past two decades, the number of large dams completed each year has shown a steady decline. This is shown in Table 3. It should be noted that more than 200 dams were completed in 1989, of which 80 per cent were up to 30 m high. During 1989, 45 very large dams (more than 150 m high, or contained a volume of more than 15 x 10^6 m^3, or reservoir capacity of more than 25 km^3) were under construction, of which 20 were in Latin America and 15 in Asia [l0].

Global Water Use

Since the dawn of human history global water use has continued to increase, and the trend during the past two decades has been no exception. The steady increase in water use has occurred due to two important factors:

i) Population — as the world population increases, more and more water is required for domestic, industrial, agricultural, and other purposes.

ii) Standard of living — as the standard of living increases, so does the per capita water demand.

Total water use during the 20th century is expected to increase nearly IO-fold as shown in Fig. 2 (adopted from [11]) This, however, does not mean that all different types of water uses are likely to increase by the same amount. As new sources of water become increasingly more scarce and more expensive to develop, continuing tradeoffs have occurred between the various uses. For example, in 1900, agriculture accounted for 90 per cent of all water used globally: the corresponding figure in the year 2000 is likely to be 62 per cent. In contrast, because the value-added

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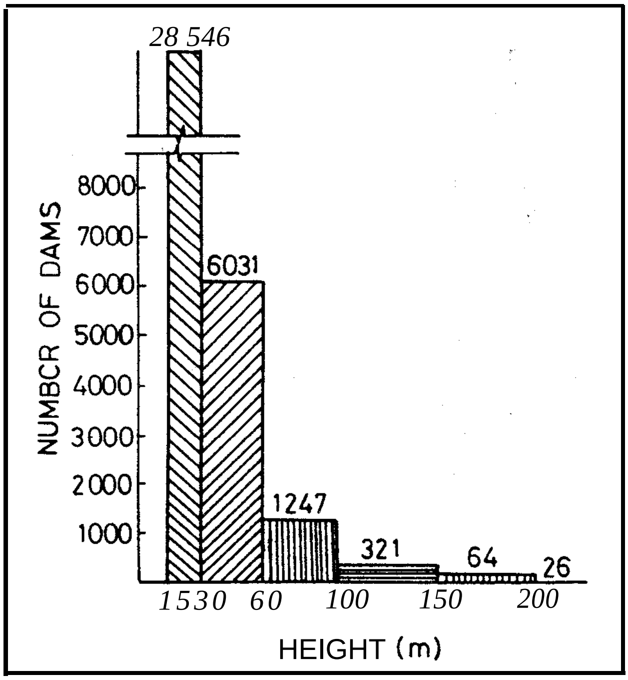

Figure 1. Distribution of dams globally by height [9,10].

aspect of water is much higher for industry than in agriculture, industrial waster use is expected to increase 4-fold, from 6 to 24 per cent, during the same period. There could, of course, be considerable variation in water use patterns in different countries, depending upon their levels of development, relevant physical factors, and other considerations.

Analysis of the present trends, however, indicates that the share of industrial water use in all probability will continue to increase during the next few decades, which means that the total agricultural water use, as a percentage of total water used, will continue to decline steadily in the future.

Domestic Water Use — Following the recommendations of the Water Conference, the UN General Assembly, on November 10, 1980, proclaimed the period 198 1- 1990 as the International Drinking Water Supply and Sanitation Decade (IDWSSD), and called upon Governments to implement the provisions of the Mar de1 Plata Action Plan and the external support agencies to provide the necessary financial assistance.

Even though a series of surveys have been carried out by WHO on the status of community water supply and sanitation conditions in both urban and rural areas during 1970, 1980, 1983, and 1989, unfortunately the data are not intercomparable for many

Table 3. Average number of large dams completed annually, 1951-1986.

Period	Number
1951-1974	313
1975-1982	258
1983-1986	211

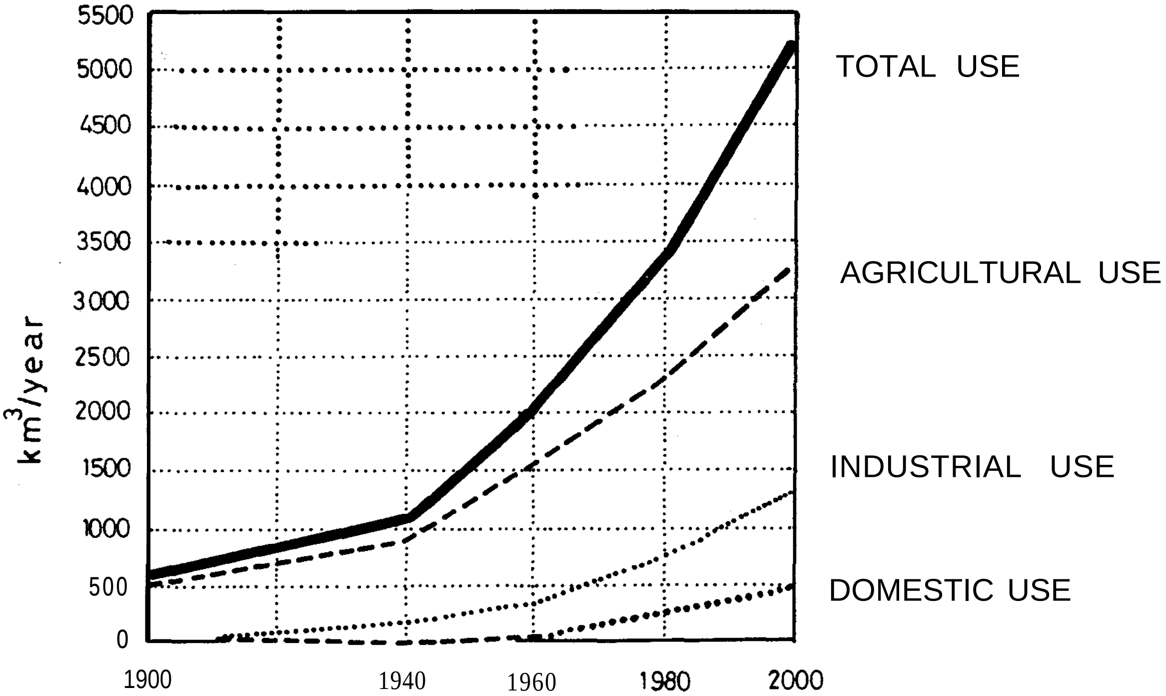

Figure 2. Global water consumption, 1900-2000.

reasons [12]. Among the main problems are that the countries reporting have not been the same, and individual countries decided what constitutes an "adequate" level of services [13] For example, it is not unusual to find that a village of 1,000 people is considered to be 100 per cent covered on completion of a single tubewell, and it continues to be considered to be 100 per cent covered, even when this tubewell has broken down completely. Nor have the reporting countries followed a consistent pattern of definition of rural and urban areas.

In spite of the above and other serious shortcomings of the WHO surveys, they do nevertheless indicate certain trends. Overall some 1,348 million additional people (980 million in rural areas and 368 million in urban areas) had access to clean water during the Decade. Progress on sanitary services was somewhat limited, since 748 million more people (434 million in rural and 3 14 million in urban areas) were covered. Accordingly, the number of people without clean water declined from 1,825 million to 1,325 million, while the number of people without sanitation facilities remained virtually unchanged [14]. The percentage of population served during 1980 and 1990, and the projections to the year 2000 by various regions are shown in Fig. 3.

It can be concluded that during the Decade, the percentage of people having adequate water supply and sanitation services in urban areas has either increased or at worst has remained the same. There are, however, significant regional variations (Table 4). For example, full or nearly full coverage, was reached in Western Asia. In other areas, percentages of people not covered have more often than not remained the same or even increased.

The worst progress was in sub-Saharan Africa, where due to high population growths, the percentage of people in urban areas not having access to clean water increased by about 29 per cent, in spite of the fact that the actual number of people receiving services doubled. Similarly the percentage of people in urban areas not having sanitation facilities increased by 31 per cent, even though the number of people having such facilities more than doubled (an increase of 119 per cent). Globally, the number of urban residents without access to clean water and sanitation facilities increased by 31 million and 85 million respectively during the Decade.

The progress in rural areas was much better. Globally, the number of rural people not having access to clean water and sanitation facilities declined by 624 million and 79 million respectively.

By the year 2000, if the present trends continue, the total number of people not having access to clean water worldwide would decrease to 767 million due to a continuing significant increase in coverage in rural areas. However, the number of people not having sanitation facilities would increase to 1,880 million, which would create attendant environmental health problems.

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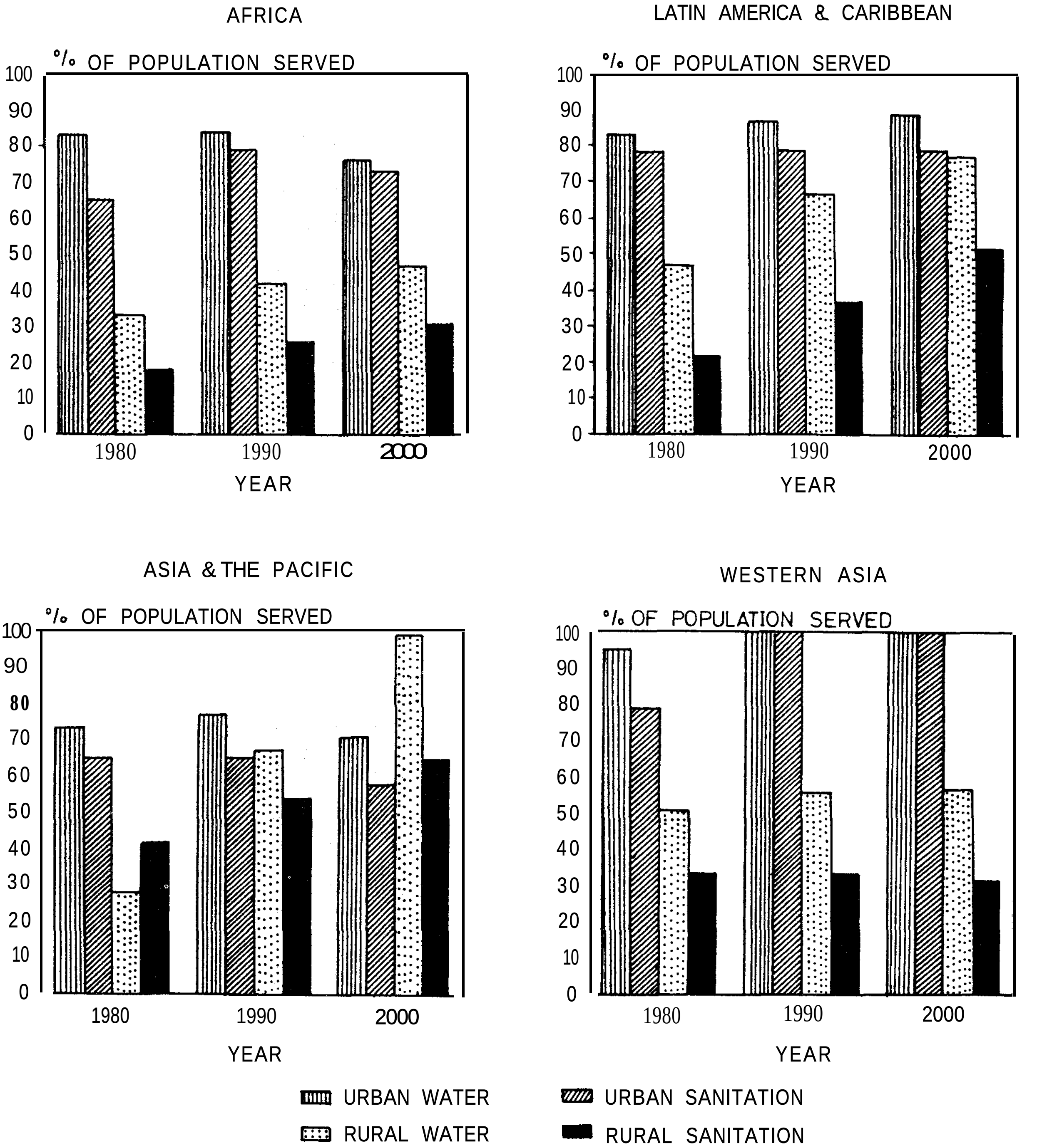

Figure 3. Percentages of population served by water supply and sanitation by regions.

Agricultural Water Use — Water is an essential component for agricultural production. In arid and semi-arid countries, irrigation is generally the main option to increase significantly food and fibre productions. Even in humid and sub-humid regions, irrigation is often necessary to counteract fluctuations in rainfall and thus assure multiple cropping. By the mid- 1980s nearly 36 per cent of the total global crop production was accounted for by less than 15 per cent of the arable land that was irrigated.

The total gross area of irrigated land globally has been estimated at about 270 million ha [4]. Gross area includes land that has not been irrigated due to various reasons, including rehabilitation and reclamation. The total area being irrigated at present is estimated at 235 million ha. The extent of land areas irrigated, globally and by regions, during 1973-1988, is shown in Table 5. During this entire period, Asia continued to dominate irrigation development in developing countries. Only two countries, India and China, accounted for nearly 28 per cent of global irrigation in 1988.

The FAO projections of expansion of irrigated areas to the year 2000, based on earlier trends but modified

Table 4. Percentage changes in coverage and number of people not served, 1980-1990.

	Percentage changes in:	
	Coverage	Number not served
Africa		
Water, Urban	77	29
Rural	57	7
Sanitation, Urban	106	2
Rural	78	11
Latin America and Caribbean		
Water, Urban	45	−1
Rural	31	−29
Sanitation, Urban	39	31
Rural	67	-20
Asia and Pacific		
Water, Urban	45	18
Rural	175	-47
Sanitation, Urban	39	39
Rural	48	-9
Western Asia		
Water, Urban	69	-88
Rural	28	5
Sanitation, Urban	104	-100
Rural	17	17
Total, Global		
Water, Urban	[illegible]	15
Rural	[illegible]	−39
Sanitation, Urban	49	29
Rural	51	-6

Table 5. Irrigated areas in million ha (compiled from various FAO data sources [1])

	1973	1978	1983	1988
World	181.58	**206.00**	219.09	228.61
Africa	**9.22**	**9.74**	10.43	11.15
N.C. America	**22.20**	**21.36**	27.00	25.81
South America	**6.24**	**7.13**	7.96	8.76
Asia	**117.28**	**129.52**	137.30	142.76
China	**40.85**	**45.40**	45.06	44.94
India	**31.84**	**36.55**	40.72	41.79
Europe	**12.29**	**13.99**	15.39	17.30
Oceania	**1.60**	**1.64**	1.87	2.13
USSR	**12.75**	**16.60**	19.15	20.18

by land, capital and inputs required to meet future needs, was 2.25 per cent annually for the period 1982/84 to 2000. However, by 1990, it was clear that this rate of expansion was not possible. Land use practices by different water regions and for different regions are shown in Fig. 4 [4].

Globally, the annual average rate of expansion of irrigated areas was about one per cent during the early 1960s. This rate increased to a peak of 2.3 per cent during 1972-1975, and then started to decline.

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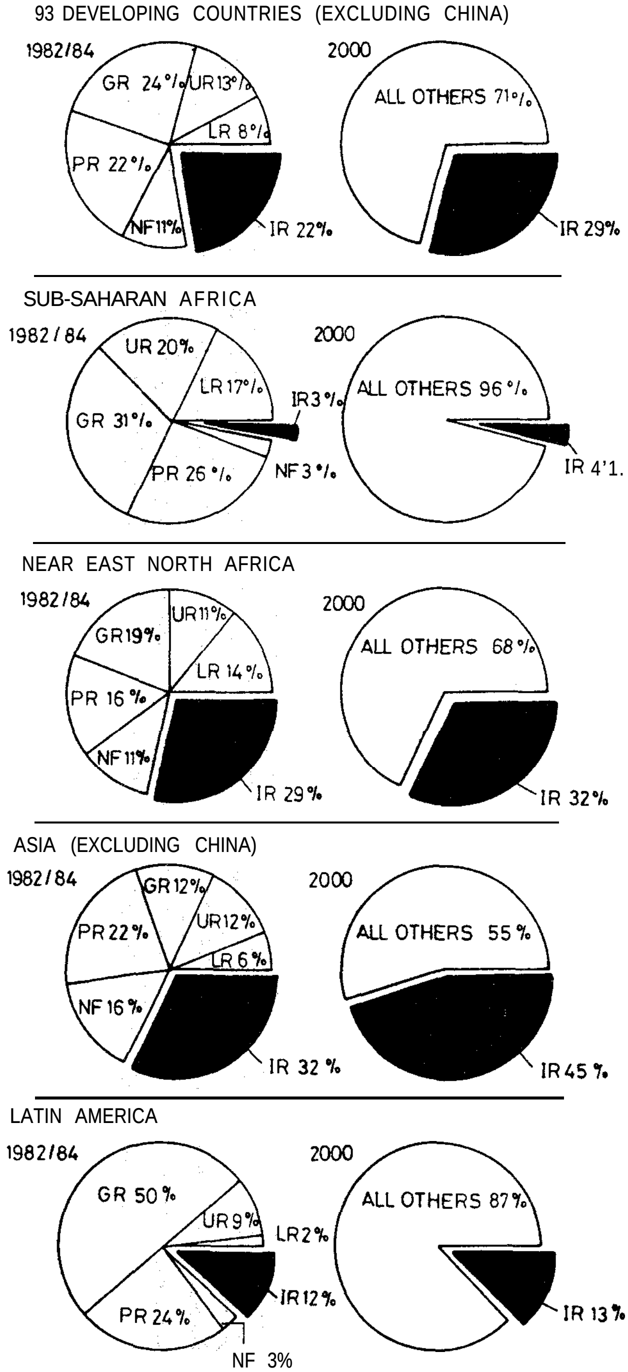

Figure 4. Land use (percentage) by different water regimes [4].

The current annual rate is less than one per cent. The annual rates of expansion of irrigated land by region for the period 1962-1987 are shown in Fig. 5.

There are many reasons for this decline in the rate of increase of irrigation [6]. Among the primary causes for this decline are the increasingly high cost of irrigation development — much of the favourable land areas have already been developed leaving more complex sites for future development, and increasing concern with environmental and social costs.

During the past three decades, large-scale irrigation projects have received priority attention: small-scale

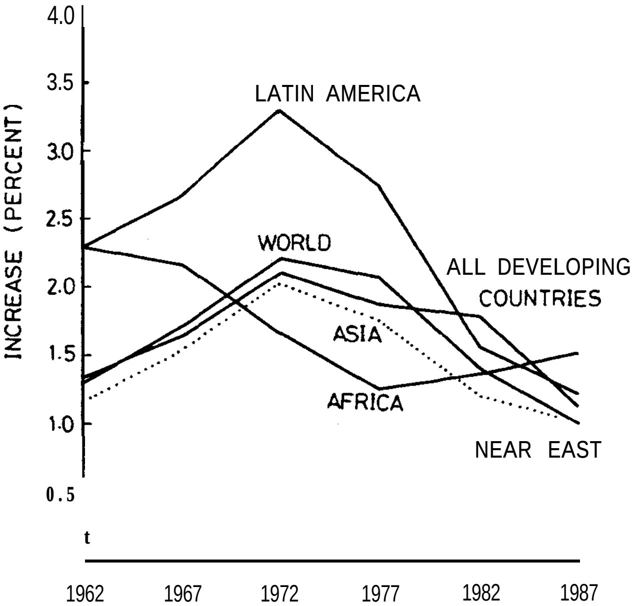

Figure 5. Rate of increase in irrigated land [4].

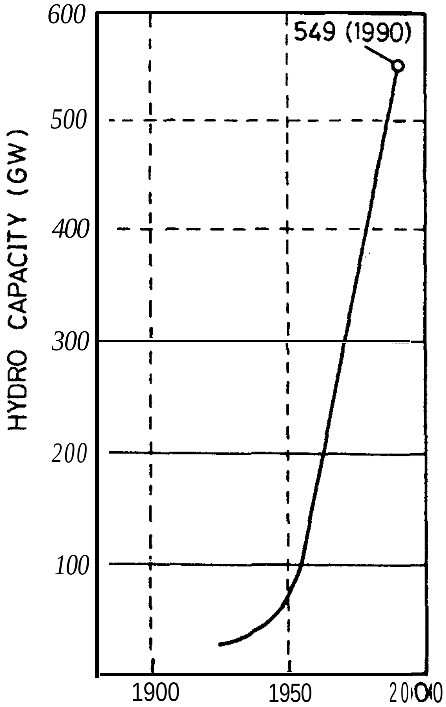

Figure 6. Global installed capacity, 19251990.

projects have generally been neglected. Current analyses indicate that small-scale programmes, including use of supplementary irrigation for rainfed agriculture, and a variety of water harvesting and water spreading techniques, have considerable potential [15]. It has been estimated by FAO [4] that in the semiarid and humid regions of Africa, water harvesting can increase agricultural production in a million hectares in the short-term and 10 million hectares in the long-term.

Reliable estimates of irrigated areas that have been affected by salinity and waterlogging are simply not available at present. However, consensus estimates are that 20-30 million hectares have been severely affected and an additional 60-80 million hectares may have been affected to some extent. It should, however, be noted that the techniques for preventing the development of waterlogging and salinity are well-known, but for a variety of reasons they have not been applied.

Hydroelectric Generation — In 1986, global hydroelectric power generation amounted to 2000 TWh, which was nearly 20 per cent of the world's total electricity production. The global installed capacity increased more than 7-fold to 549 GW by 1988 (Fig. 6). In 1988, an additional capacity of more than 100 GW was under construction in 7 1 countries, [10].

Small-scale hydro generation (less than 15 MW) amounted to nearly 10 GW in 1953, and is estimated to reach 29 GW by 199 1 [10]. It is likely that small-scale hydro development will receive increasingly more attention in developing countries during the 1990s and beyond.

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WATER RESOURCES ASSESSMENT

Water resources assessment was explicitly recognized in the Mar del Plata Action Plan as one of the essential components for scientific water management. The Plan specifically stressed the need for intensifying proper assessment practices in developing countries.

An analysis of the progress of implementation of the Mar del Plata Action Plan after one decade, carried out for the United Nations [16]. clearly indicated the unsatisfactory nature of progress in developing countries.

In Africa, the number of precipitation stations actually declined significantly from a total of 4,047 in 1977 to 3,596 in 1989 (Table 6). The Latin American and the Caribbean regions in contrast shared remarkable improvements [5].

Significantly better progress can be noted in the number of discharge measurement stations between 1977 and 1989. During this period, the number of such stations nearly doubled, from 20,698 to 39,809.

Table 6. Stations for monitoring precipitation, discharge and water quality parameters, 1977 and 1989.

	Number of Stations for Measuring:					
	Precipitation		Discharge		Water Quality	
Regions	1977	1989	1977	1989	1977	1989
ECA	4,047	3,596	918	1,695	123	361
ECE	49,240	48,507	9,549	23,946	15,509	42,327
ECLAC	12,409	19,531	3,086	5,762	218	1,439
ESCAP	20,980	20,422	5,923	7,023	3,533	2,889
ESCWA	4,018	4,240	1,222	1,383	801	821
Total	90,694	96,296	20,698	39,809	20,184	47,837

Even then, however, the situation continued to remain unfavourable in Africa, a continent that undoubtedly requires accelerated water resources development, if the aspirations of its inhabitants have to be successfully met.

In the area of water quality assessment, the progress in developing countries during the past two decades has been indeed dismal. Even as late as 1989, developing countries as a whole accounted for only about 20 per cent of the total global water quality measurement stations, (Table 5). In a large continent like Africa, at the end of 1989, only 36 1 water quality measurement stations were reported, and this number did not change materially from about 1985. During the period 1977-1989, the number of such stations in the Asian developing countries actually declined by about 1/6th.

Furthermore water quality measurements involve more complex and difficult processes, and the instruments required are significantly more sophisticated, expensive, and difficult to maintain and operate, when compared with water quantity measurements. .This means that water quality data in developing countries are often less reliable than water quantity data [17]. Accordingly, when the two facts of the very limited number of water quality stations and the data reliability are combined, it becomes evident that priority progress must be made on reliable water quality assessment in developing countries during the present decade. Otherwise effective water resource management will simply not be possible.

GLOBAL STATUS OF WATER QUALITY

At our present state of knowledge, it is simply not possible to give a reasonably reliable picture of the status of water quality for the world as a whole. For reasons mentioned in the previous section, significantly better information is available for developed countries, as compared to developing countries, but even for the former group of countries data are available only for a select group of contamitiants and for certain specific areas. The Global Environmental Monitoring Systems of UNEP and WHO has published its First Assessment [18] on global freshwater quality. While this is a useful beginning, this assessment, as UNEP's high-level Water Advisory Group observed unanimously in November 1990, was seriously flawed because of its poor methodological approach and general nonconsideration of water quality data that are currently available in developing countries. The Assessment was primarily a survey of a limited number of water quality literature, mainly from the West, without any scientific scrutiny of the reliability of information considered. Accordingly, this assessment contains numerous serious factual errors [19].

Water quality is affected primarily by domestic and industrial (including mining) effluents, human activities like deforestation and land use practices, leaching of agricultural chemicals and natural causes. In addition, in recent years, at least in the Western countries, depositing of airborne pollutants and the resulting acidification of lakes, has become an increasing concern.

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Impacts due to Wastewater — While considerable progress has been made in treating domestic discharges during the past two decades, much work still remains to be done. Even in the OECD countries, the percentage of population served by domestic wastewater treatment increased from 33 per cent in 1970 to 60 per cent in 1989 [20]. This means that some 330 million people in the OECD countries are still not served by wastewater treatment plants.

Considerable variations exist among the OECD countries. Total population served with wastewater treatment increased during 1970 to 1989 as follows: Denmark, — 54% to 98%; France — 19% to 52%; Germany (former West only) — 62% to 90%; Italy — 14% to 60%; Japan — 16% to 39%; and North America 42% to 7390.

Information on treatment of domestic wastewater in developing countries is sparse, but the situation unquestionably is significantly worse than in the OECD countries. One WHO-UNEP study [2 1] points out that the situation in Latin America is critical, since little, if any, of urban domestic waste is treated. This means that rivers of this region generally have very high coliform contents, sometimes more than 100,000 per 100 ml [22].

The International Water Supply and Sanitation Decade has had an appreciable impact on river water quality. With the construction of numerous centralized sewer systems in the urban centres, it became possible to treat wastewater. This was simply not feasible in many locations earlier. This practice has had two distinct advantages. First, because of the new treatment plants, untreated wastewater is no longer being discharged to rivers, which means levels of river water quality in some areas have already started to improve. A good example is the Ganga Action Plan in India. Because of a determined effort to clean up this important river by constructing treatment plants in urban centres, water quality improvements in many locations can already be observed. Second, many arid and semiarid countries, where water scarcity is already a serious problem, have suddenly realized that treated wastewater is a "new" source of water that could be used for productive purposes.

By 1990, most arid countries of the Middle East and North Africa had embarked upon ambitious programmes on treatment and reuse of wastewater. For all these countries, water is already a serious constraint for further economic development. Conventional sources of water have already been committed or are about to be committed, and for the most part no additional sources of water exist that can be economically used for further agricultural development.

Generally speaking, for most arid and semiarid countries, reuse of wastewater may have a greater impact on future water availability than any other technological solutions for increasing water supply such as water harvesting, desalination or weather modification. Treated wastewater can be effectively used for irrigation, industrial purposes, and groundwater discharge. In addition, as various agricultural and industrial demands are met by treated wastewater, more and more freshwater could be made available for domestic purposes [23,24]. Since wastewater has to be treated in any case for environmental and health reasons, this means that treated wastewater can be considered to be a new source of water that is available at a low marginal cost.

Impacts due to agriculture — Just as agricultural activities have numerous impacts on water quality, similarly water quality considerations have important implications for agricultural activities.

Water quality considerations have important implications for agricultural activities

Agricultural activities have four major impacts on water quality [25]:

i) alterations in sediment load due to changes in land use practices and cropping patterns;
ii) changes in salinity and waterlogging due to agricultural activities;
iii) water quality deterioration due to anthropogenie chemicals like fertilizers and pesticides; and
iv) water quality degradation due to effluents from agro-processing industries.

Sedimentation: land use patterns change due to introduction of irrigated agriculture. Generally cropping intensities increase, cropping patterns are changed, and fallow periods are reduced or even eliminated. These changes could directly affect the rate of soil erosion and runoff regimes from such areas. Much of the soil eroded often contributes to higher sediment load to watercourses, which could result in higher than expected sedimentation rates for reservoirs, with concomitant serious economic losses.

A major problem facing many developing countries is clearing of forests to increase the availability of agricultural land to provide food for a continually increasing population. If vegetative covers change over an area, the rates of soil losses could change as well. Similarly, livestock grazing could affect soil loss from pastures. Overgrazing significantly increases the rates of soil erosion by reducing grass cover as well as contributing to top soil deterioration by compaction and loosening of soil particles by animal activities.

While erosion of soil from land and its transportation by water and subsequent deposition elsewhere is a normal process that occurs naturally without any human activities, agricultural practices, especially improper ones, significantly accelerate this process. Even though it is often not possible to quantify erosion reliably and to differentiate between naturally occurring erosion and soil loss due to human interventions, sedimentation is already a serious problem for major

Table 7. Sediment yields of selected major rivers [17].

River	Catchment Area, $10^6 km^2$	Runoff cm	Yield ppm
Haihe	0.05	4	40,500
Huanghe	0.077	6	22.041
Chang Jiang	1.94	46	'531
Mekong	0.79	59	340
Ganges/Brahmaputra	1.48	66	1,720
Indus	0.97	25	1,849
Tigris/Euphrates	1.05	4	1,152
Amur	1.85	18	160
Niger	1.21	16	208
Nile*	2.96		3,700
Zaire	3.82	3:	34
Mississippi	3.21	18	602
Orinoco	0.99	1 11	191

* Before Aswan High Dam

rivers. Table 7 shows the sediment yields of some selected rivers [25].

The sediments carried by a river gets deposited upstream of a dam, a process that continually reduces its reservoir capacity. For example, the construction of the Hoover Dam reduced the sediment discharge of the Colorado River at Yuma, Arizona, where it enters Mexico, from 135 million tons to only 0.1 million tons per year. Similarly, the River Nile used to carry 100-l 50 million tons of suspended matter annually at Aswan before the construction of the High Aswan Dam. Nearly all of this sediment load is now deposited in the High Dam Lake or in the river before the Dam [17].

Salinity and waterlogging: one of the important reasons for the decline of agricultural productivity in irrigated areas is the development of salinity and waterlogging. Irrigation contributes to additional input of water, which if not properly drained, causes groundwater level to rise until a new equilibrium is reached. While waterlogging is not an inevitable result of irrigation, it occurs because of inadequate provision of drainage. Soil salinity increases since plants extract pure water and most of the salt contained in irrigation water is left behind.

Changes in water tables due to introduction of irrigation without adequate drainage are shown in Table 8.

Agricultural chemicals: up until the mid-seventies, the extent of water quality deterioration due to the increasing use of agricultural chemicals was considered to be minor, and their potential overall impact was underestimated. During the 1980s however, contamination of water by pesticides and wastes has become an important cause for environmental concern, especially for groundwater in Europe and North America. This is because substantial amounts of groundwater are currently used for domestic purposes: 73 per cent in the Federal Republic of Germany, 70 per cent in the Netherlands, and 30 per cent in Great Britain [26]. In the United States, groundwater is the primary source of water for over 90 per cent of the rural population and 50 per cent of the total population.

Table 8. Increase in water table due to irrigation.

Irrigation Proiect	Country	Water Table (m) Original Depth	Rise/Year
Nubariya	Egypt	15-20	2.0-3.0
Beni Amir	Morocco	15-30	1.5-3.0
Murray-Darling	Australia	30-40	OS-l.5
Amibara	Ethiopia	10-15	1.0
Xinjang Farm 29	China	5-10	0.3-0.5
Bhatinda	India	15	0.6
SCARP I	Pakistan	40-50	0.4
SCARP VI	Pakistan	10-15	0.2-0.4

Increasing contamination of groundwater by agricultural chemicals is being observed near intensively farmed areas. In addition to routine use of such chemicals, other sources of contamination include manufacturing sites, transport/transfer facilities, commercial storage, mixing, formulating, rinsing and disposal sites, and major spill sites.

Based on available data, it is not possible to provide a clear picture of pesticide contamination even in North America or Western Europe: data availability is worse in other parts of the world. Some 39 pesticide compounds have already been detected in groundwater in 34 states in the U.S.A. or Canadian provinces [27]. It is highly likely that contamination of groundwater with pesticides and their metabolites will continue to increase in the future.

In contrast to pesticides where many different types of chemicals are involved, the main concern with fertilizers so far has been nitrates. Equally nitrate contamination has been studied more intensively than pesticides. This is because presence of nitrates at higher levels than the maximum limit of 45 mg per litre in drinking water can cause methemoglobinemia in infants below the age of 6 months. There is also some concern that nitrates could be reduced to nitrites in the alimentary canals of humans, and then react with amines to form nitrosamines, which are carcinogens. This could contribute to the development of gastric cancer. There are, however, some dissenting views on this issue.

Total amounts of nitrates added to water bodies is location specific. For example, current estimates indicate that precipitation contributed to annual addition of 8-20 kg of nitrates per hectare in the Western countries. Similarly it was estimated that 15 Mt of nitrates are annually disposed of in the U.S. in wastes, 40% of which are from animals, 20% from crop residues and 20-25% from municipal wastes [25]. A number of studies in the north-central U.S. show annual losses of 20- 10 kg of NO_3N per hectare of agricultural land is common [27].

Uncontaminated groundwater generally contains less than 3 mg of nitrates per litre. If this level is exceeded, human activity can be suspected, unless there are other possible explanations [25].

The pattern of increasing nitrate concentrations in the Petite Traconne Spring, France, from about 1930 is shown in Fig. 7 [28]. Similar increasing trends have been noted during the past two decades in many west

If this level is exceeded, human activity can be suspected

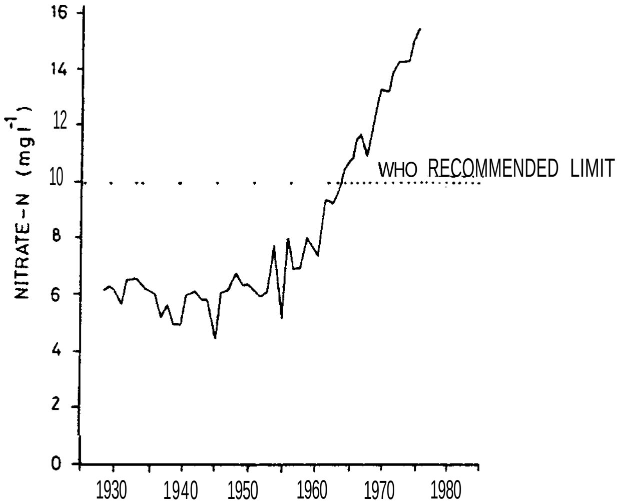

Figure 7. Nitrate concentration in Petite Traconne Spring, France, 1930-1975 [28].

European countries, and a few irrigated areas in developing countries.

Lake Acidification: during the past two decades, lake acidification has become an increasingly important concern in Europe and North America. The problem is most noticeable in the glaciate regions of the Precambrian shields of northern Europe and North America. Freshwater acidification has been observed in Scandinavia, the Netherlands, Federal Republic of Germany, Belgium, United Kingdom, Eastern Canada, northeastern United States, and some East European countries.

On the basis of observations of 6,908 Swedish lakes, carried out in 1985, Statens Naturvardsverk [29] extrapolated that 4,600 lakes, out of a total of some 83,000 lakes in Sweden, have pH values equal to or less than 4.9. Some 4,000 lakes were considered to be fishless, and another 17,000 had reduced populations of acid-sensitive species. It should be noted that the majority of acidified lakes were small, having an area of less than one km^2.

MAJOR WATER-RELATED ISSUES DURING 1972-1992

In addition to the earlier discussion, four issues can be considered to be major water related concerns of the past two decades.

Environmentally-sound Management of Inland Waters (EMZNWA) — There is no doubt that environmental quality was firmly established as a major objective of water resources management all over the world during the past two decades. Spearheaded by UNEP, the concept of EMINWA was scientifically formulated, and then widely disseminated [30,3 1]. This was also the period, when for the first time ever, a major water project in a developing country (Silent Valley Project, India) was rejected primarily due to environmental grounds.

Water pricing and cost recovery — During the 1980s water pricing and cost recovery became a major item for discussion in many national and international fora. It was felt that if right water prices could be charged, farmers and other consumers would become rational optimizers, which would substantially contribute to efficient water use. Furthermore, if the government departments could receive the extra revenue that would be generated due to water pricing, they could operate and maintain their water systems properly.

By the early 1990s it was increasingly being realized that two fundamental issues have to be considered before water pricing becomes an attractive policy instrument [32]. First, water pricing has thus far been viewed primarily as an economic instrument: its sociopolitical implications in developing countries have generally not been understood. Second, water has been traditionally subsidized to achieve very specific sociopolitical objectives of food security, provision of clean drinking water, and increasing the health and income of rural poor, especially women. If economic water pricing is to be introduced, other policy instruments have to be developed to achieve the same objectives.

Two fundamental issues have to be considered

Development of international water bodies — The extent and magnitude of this global problem have not been generally recognized thus far. Nearly 47 per cent of the land areas of the world (excluding Antarctica) falls within international water basins that are shared by two or more countries. There are 44 countries where a minimum of 80 per cent of their total areas lies within international basins [32]. Globally, there are 2 14 river and lake basins that are international in character.

As the demand for water increases, and the exclusively national sources of water are fully developed, the only major sources of water that would be available in many countries in the future are likely to be international in nature.

Unfortunately, to a great extent, international organizations have deliberately stayed away from the development of international waters, primarily because these issues have been considered to be politically sensitive. The leadership shown by President Eugene Black of the World Bank in the 1950s who was instrumental for the signing of the Indus River Treaty, has been generally missing, except for Mostafa Kamal Tolba, Executive Director of UNEP, who orchestrated the Zambezi Action Plan.

Institutional aspect of water management — A major constraint to efficient water management during the past two decades has been the weaknesses of the institutions concerned. As a general rule it can be said that most water institutions in developing countries need significant strengthening.

In addition, in order that water can be managed in its totality in a rational fashion, inter-institutional collaboration has to be substantially improved. Currently water-related policies are developed in a fragmented fashion by a host of institutions in nearly all countries. For example, irrigation is considered by the Ministry of Irrigation, water supply by municipalities, hydropower by the Ministry of Energy, navigation by the Ministry of Transport, environment by the Ministry of Environment, and health by the Ministry of Health. Lack of coordination, and often intense rivalries, have meant that water policies developed have generally been sub-optimal. The World Bank and the Regional Development Banks also suffer from the very same shortcoming. Without institutional rationalizing and strengthening, water management simply cannot become optimal in the future.

A major constraint ... has been the weaknesses of the institutions concerned

CONCLUDING REMARKS

It is clear that during the past two decades much progress has been made on different aspects of water resources development and management in different parts of the world. In spite of such progress, however, it is equally clear that much remains to be done, especially in developing countries. Furthermore, with recent major political changes in Eastern Europe, it is now becoming apparent that water quality conditions in many East European countries are much more serious than anyone had anticipated earlier. For these and also other reasons discussed earlier, it is highly likely that water, like energy in the 1970s, will become the most critical resource issue in most parts of the world by the late 1990s and early part of the 2 1 st century,

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