Sustainable Water Resources Management in Arid Countries

Gestion durable des ressources en eau dans les régions arides

1992

International Water Resources Association

Association internationale des ressources en eau

Canadian Journal of Development Studies

Revue canadienne d'études du développement

Numéro spécial

Editorial Office / Rédaction

CJDS / RCED
Institute for International Development and Co-operation
University of Ottawa
25 University
Ottawa, Ontario
CANADA K1N 6N5

Subscriptions / Abonnements*	**Canada**	**USA**	**Overseas / Outremer**
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ISSN 0225-5189

Special issue / Numéro spécial

Guest Editor / Rédacteur invité: Eric J. Schiller

Sustainable Water Resources Management in Arid Countries:
Middle East and Northern Africa

Gestion durable des ressources en eau dans les régions arides:
Moyen Orient et Nord de l'Afrique

International Water Resources Association / Association internationale des ressources en eau

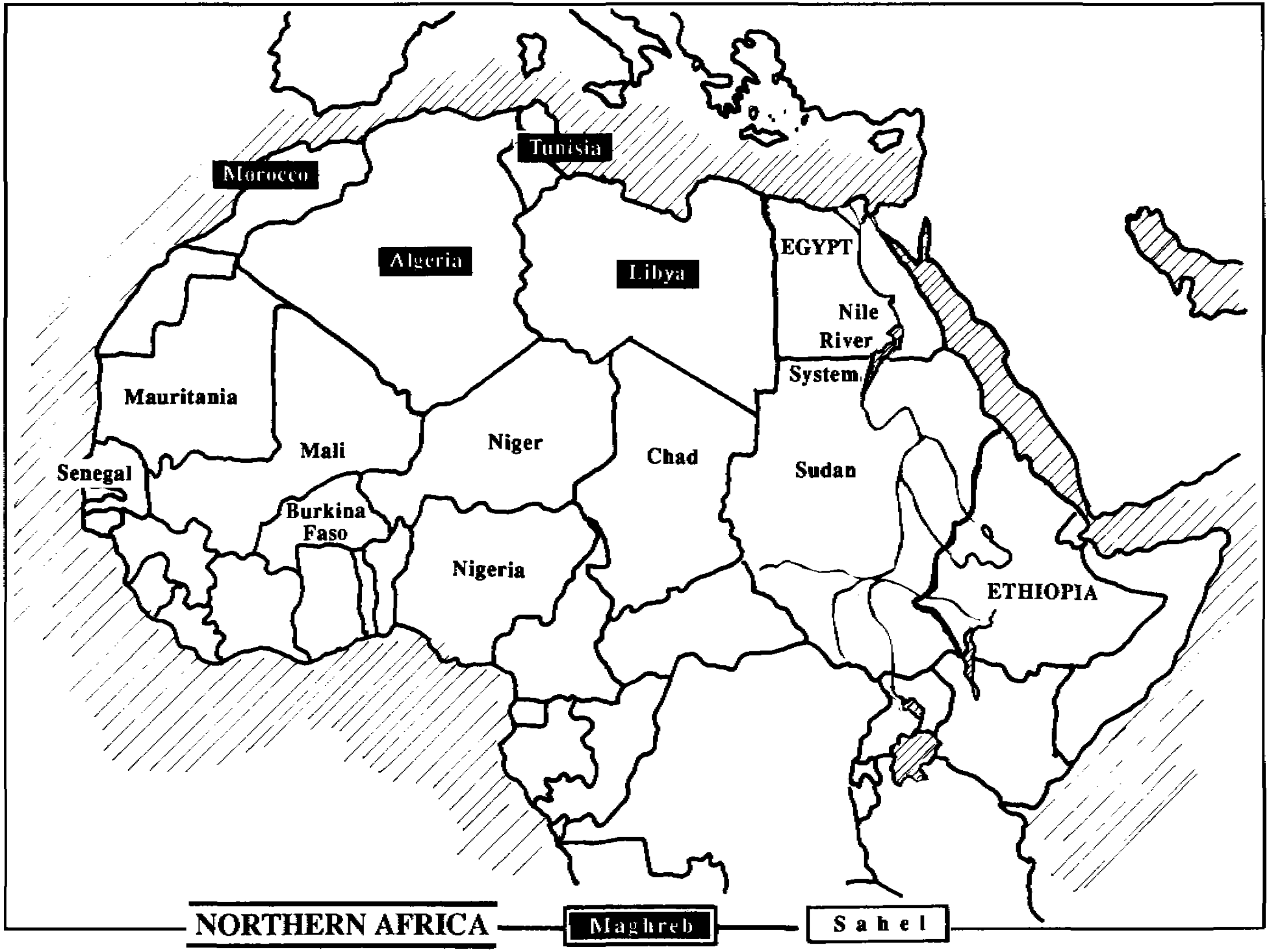
Canadian Journal of Development Studies / Revue canadienne d'études du développement

Grants from the following agencies to aid the publication of this special issue of the *Canadian Journal of Development Studies* are gratefully acknowledged:

— the Canadian International Development Agency,
— the International Development Research Centre,
— the United Nations Development Program,
— the Social Sciences and Humanities Research Council of Canada.

Nous remercions les organismes suivants de leur aide financière pour la publication de ce numéro spécial de la *Revue canadienne d'études du développement*:

— l'Agence canadienne de développement international,
— le Centre de recherches pour le développement international,
— le Programme des Nations Unies pour le développement,
— le Conseil de recherches en sciences humaines du Canada.


Morocco
Tunisia
Algeria
Libya
EGYPT
Nile
River
System
Mauritania
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Chad
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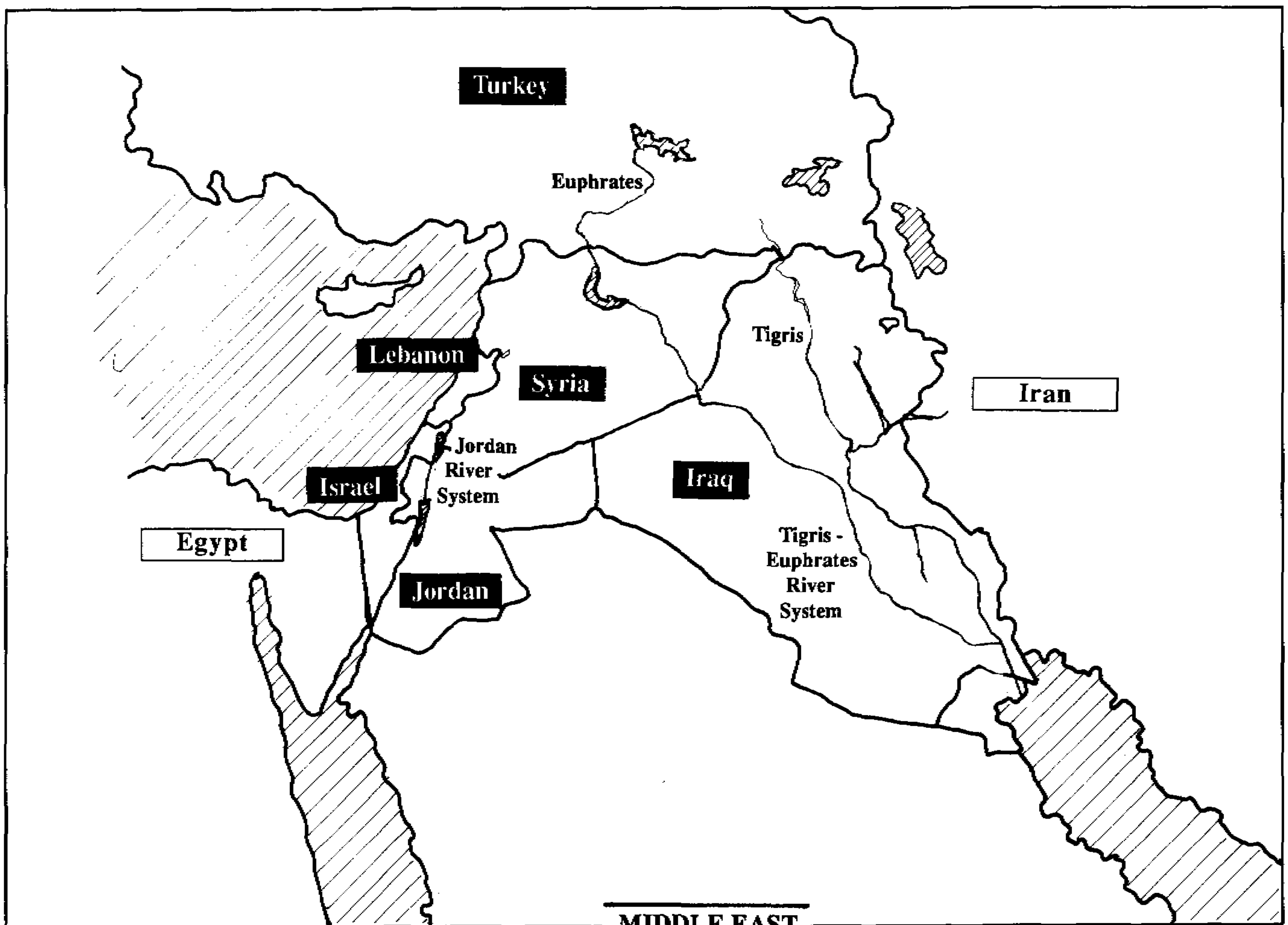
Turkey
Euphrates
Lebanon
Syria
Iran
Tigris
Jordan River System
Israel
Iraq
Egypt
Jordan
Tigris - Euphrates River System

MIDDLE EAST

TABLE OF CONTENTS / TABLE DES MATIÈRES

Water Resources: An Emerging Crisis

ERIC J. SCHILLER*

This book is about an emerging crisis — in world development, in environmental degradation and in water resources management. Water scarcity is a phenomenon that spans a wide region in the Middle East and in Northern Africa. It is a common feature that binds together countries that are otherwise very different economically and culturally. This publication gives background information to decision makers and planners who want to better understand the water resources situation in this part of the world.

The problem of water shortages in the Middle East and Northern Africa is a developmental issue, since water limitations are seriously impeding the economic growth and development of countries in the region. Even countries that are quite advanced technologically are experiencing restraints on their future development. If the issues related to water in the region are not resolved, food shortages, human health problems and armed conflict could easily be the result. Given that war has devastating effects on economic development, especially in poorer countries, the developmental concern about this issue is even more pressing. It was this awareness of the developmental implications of the Middle East/Northern Africa water shortages that has motivated the three agencies, the World Bank/UNDP, the Canadian International Development Agency (CIDA) and the International Development Research Centre (IDRC) to sponsor this publication.

Water scarcity in the Middle East/Northern Africa region is rapidly becoming part of a widespread environmental concern for the region. The twin phenomena of depletion of existing water resources together with pollution of these resources is causing growing hardship in the area. Land deprived of its scarce water resources, either by natural phenomena or human activities, produces devastating consequences, as recent events in the sub-Saharan region of Africa demonstrate. At the very least, water scarcity creates an environment where sustainable development is severely limited as in the Maghreb (Libya, Tunisia, Algeria and Morocco) and in the worst case, extreme water shortages can create an environmental climate that could exacerbate serious conflicts, as evidenced by water-related tensions in the Middle Eastern region. Because of the environmental aspects of this topic, this publication is intended to serve as background material for the United Nations Conference on Environment and Development (UNCED) to be held in Rio de Janeiro in June, 1992.

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Finally the topic represents a crisis in water resources management. Humankind has always had to manage wisely its water resources and to live within its constraints. In water-scarce areas the peoples living there have evolved a lifestyle well adapted to the marginal nature of these regions. However in the Middle East/Northern Africa regions, relatively recent influences have disrupted this ancient lifestyle: the discovery of vast oil reserves, modern technology allowing large extractions of groundwater or major impoundments of existing rivers and the general influence of modern technological development throughout the region. These factors have helped to remove the restraints on population growth. The result is that rising populations and increased technological growth are again causing countries to be confronted with the region's major constraint: limited water resources.

This topic was discussed in several sessions of the Seventh World Water Congress, sponsored by the International Water Resources Association (IWRA) in Rabat, Morocco. Most, but not all, of the presentations herein originated at this Congress. Water shortages in the region will continue to be a major preoccupation of this international organization, as evidenced by the fact that the next tri-annual IWRA Congress will be held in Cairo in 1994.

Similar to the presentations at the Congress, the articles here are bilingual in nature. The editors appreciate that this may be frustrating for monolingual readers. However, translated abstracts of each article are given and readers are encouraged to seek assistance in obtaining translation services when required for those articles of interest.

Le lecteur francophone y trouvera quelques articles d'un grand intérêt écrits en français. N'ayant ni le temps ni les fonds pour faire la traduction de tous les articles, les éditeurs ont eu à présenter les articles tels que soumis par les auteurs. Les lecteurs francophones sont priés de chercher l'assistance de services de traduction pour les articles en anglais qui les intéressent.

In order to grasp the problem in its entirety, four major areas are discussed:

1. Historical and political background;
2. Water resources data of the region;
3. Technological and management strategies;
4. Country studies.

I. BACKGROUND

T. Tvedt's historical review of the water conflicts in the three main river systems in the region — the Nile, the Tigris-Euphrates and the Jordan — reminds us that the aridity of the region is a characteristic more important than its vaunted oil resources. This aspect has influenced much of its history, both ancient and recent, and its influence is destined to increase as the growing industrialized populations push existing tensions to dangerous limits.

J. Starr's article develops upon Tvedt's analysis. Recent water-based conflicts in the same three river basins are discussed. Warnings from Egypt, Jordan, Syria and Iraq show that the potential for war is there if water-based conflicts are not resolved peacefully. There are however water-rich countries in the region (Lebanon, Turkey), which could be part of a regional solution.

A. Water Resources Data

Regional water resources data are presented by maps, graphs and tables. Great detail cannot be given by means of these global data, but the regional nature of this widespread water problem can be better understood.

Dans « Perspective des besoins et des ressources en eau des pays africains riverains de la méditerranée » par J. Margat, on donne une large place à la dichotomie entre les besoins et les ressources en eau, et aux problèmes qui en découlent. Du Maroc à l'Égypte on présente des projections des besoins en eau par secteur, suivant plusieurs scénarios de développement socio-économique et de politique de l'environnement.

Following Margat's survey of the water resources of Egypt and the Maghreb, L. Oyebande and I. Balogun's article gives an overview of the semi-arid West African region which forms part of the Sahel. They discuss the widespread problems of water shortages and the uncoordinated development of the region. Discussing the main river systems in the area (Niger, Senegal, Volta, Gambia and Lake Chad Basin), massive water transfer schemes are presented that may be used to redistribute the water resources of the area.

Le deuxième article de J. Margat s'attaque aussi aux problèmes du Sahel, car « c'est dans les pays de la zone semi-aride que se cumulent le maximum de problèmes, souvent aggravés par les sécheresses ». On présente ici un aperçu global des ressources en eau de tout le continent africain qui démontre une variété extraordinaire. Cette présentation permet de quantifier les analyses de situation et de classer les pays suivant des macro-indicateurs révélateurs du type et de l'acuité des problèmes.

J. Kolars next outlines the water resources situation in the middle East region (Israel, Jordan, Lebanon, Syria and Iraq) with consideration also given to the role of Turkey and Iran. As well as giving global water balances for the countries involved, the water supply and consumption patterns in the main river basins of the area (Euphrates/Tigris, Jordan, Litani and Orontes) are described. From these data it is clear that the limited water resources of the area and the rapidly expanding population are creating troublesome scenarios that need to be addressed immediately.

B. Technological and Management Strategies

Faced with the vast problems of water scarcity in the region, some of the strategies required to tackle the problem are: (1) more efficient irrigation procedures; (2) increased reuse of wastewater; and (3) more effective human resources development.

R. Lenton writes from the perspective of irrigation as practised worldwide. He finds inefficiencies, and therefore water wastage, to be a global phenomenon. However, as populations continue to increase and arable land is limited, there is worldwide concern to do "more with less" in terms of water and land resources. Since agriculture uses more than 80% of the region's water in the Middle East/North Africa, the strategies proposed by Lenton are crucially important, (i) more efficient irrigation with less water wasted; (ii) thorough re-use of treated waste water whenever possible; and (iii) adequate human resources development (HRD) to meet the future challenges.

N. Khouri, in his article on Water Reuse Implementation, presents the scope and procedures involved, together with criteria to determine whether water-reuse is appropriate or not. The trend in the region is towards increasing waste water reuse as shown by a recent UNDP study. It is already practised extensively in some oil-rich countries (Kuwait, Saudi Arabia) as well as other less wealthy states (Tunisia). As water resources become scarcer, this technique will become more economically feasible. Properly implemented water reuse offers the possibility of increasing water availability while decreasing the impact of water pollution.

D. Robert et N. Boutayeb ont constaté que le manque de main d'œuvre qualifiée constitue l'un des freins les plus importants à la promotion du processus de développement du secteur des ressources en eau dans la région de l'Afrique du Nord et du Moyen Orient. Ils abordent la question du développement des ressources humaines autour des points suivants: le constat de la situation actuelle, les principaux obstacles, les leçons de l'expérience des années 1980 et les stratégies futures.

C. Country Studies

In order to illustrate in more detail the water shortages in the region, case histories are given for four countries taken from subregions in the area — Jordan (Middle East), Egypt (Nile River Basin), Morocco (Maghreb) and Northern Nigeria (Sahel).

Jordan faces possibly the worst water crisis in the Middle East. Al-Fataftah and Abu-Taleb discuss factors causing this situation — the arid climate, unsolved water sharing disputes, high population growth rates, acute financial constraints and lack of sustained peace in the area. Jordan's Water Action Plan presents strategies to solve Jordan's water shortage problems in both the short and long term. However, regional cooperation will be needed to effectively cope with the water resources problems of Jordan and its neighbours.

Egypt is a key country in the region, serving as a link between the Middle East and Northern Africa, as well as being the main water user of the vast Nile Basin River system. Egypt is a desertic country that is almost totally dependant on the Nile river for its water resources, with irrigated agriculture accounting for the vast majority (84%) of all the water used. Since the Nile river drains from nine countries, at great distances from Egypt, any major change in the water-use patterns in these countries would have dramatic effects upon Egypt. In addition to water quantity considerations, indicators show that the environmental degradation of the Nile waters is increasing. M. Abu-Zeid's article describes various structural and operational changes in water use which are designed to enable Egypt to cope with water quantity and quality problems.

Le Maroc comme pays maghrébin démontre à la fois les contraintes imposées par les limitations hydrologiques et les solutions susceptibles de résoudre ces problèmes. Après avoir donné un aperçu des ressources en eau du Maroc, D. Mriouah nous indique les méthodes susceptibles d'apporter des solutions à ces problèmes, y compris quelques techniques traditionnelles très intéressantes (épandages des crues et galeries souterraines destinées au captage des eaux) et des infrastructures de plus grande envergure (grands barrages et canaux de transfert d'eau).

Finally, L. Oyebande and I. Balogun describe a part of the semi-arid region south of the Sahara desert known as the Sahel. The need for surface water storage is stressed and water management strategies are proposed. Future interbasin water transfer schemes are described and the need for integrated planning is emphasized to ensure a sustainable level of water resources development.

The Struggle for Water in the Middle East

TERJE TVEDT*

ABSTRACT

This article discusses how regional population growth, a general increase in the standard of living over time, and the development of irrigated agriculture have created a gap between access to and the need for water, which might escalate the disputes over the scantiest resource of the Middle East: water. The problem is discussed in a historical perspective but also relates to the question of establishing international laws regarding the utilization and the sharing of international river basins.

RÉSUMÉ

Cet article décrit les raisons pour lesquelles la croissance démographique, l'augmentation du niveau de vie et des cultures irriguées ont créé un schisme entre l'accès à l'eau et les besoins en eau, schisme qui pourrait envenimer les disputes au Moyen Orient autour de cette ressource si rare: l'eau. Tandis que le problème est abordé dans une perspective historique, l'article suggère également que des lois internationales soient promulguées en ce qui concerne l'utilisation et le partage des eaux internationales.

INTRODUCTION

In this article on developments in the Middle East, the spotlight will be focused neither on OPEC meetings in Vienna, militant Muslims gathered for Friday prayers, nor on the Wailing Wall in Jerusalem. The focus will be on fresh water — the rivers of the Middle East. Since the beginning of the 1970s, Westerners have often tended to look upon "Arab" as a synonym for "Oil Sheik." Caricatures of Bedouins controlling the petrol pumps in Paris and Washington, together with headlines about Arab oil princes buying up enterprises in the West have captured an important facet of Arab reality. But *this* conceptualization, *this* "Arab" is the result of a particular relationship, i.e. the *evocative* perspective is "our" relationship to "them" and is

* Historian and Senior Researcher at the Centre for Development Studies, University of Bergen, Norway, Terje Tvedt has published extensively on water-related issues.

coloured by events of the 1970s and 1980s. The oil perspective inhibits the discovery of more fundamental and inherent characteristics and deep running international regional lines of conflict. The major economic resource common to Arabs is not the black gold which reportedly drips from them, but the arid regions they inhabit.

The rivers have played a fundamental role in the region's culture and history, in framing the territorial borders and in shaping the economic life of the countries. In describing the area, the water aspect will be focused on in order to uncover the contours of deep lying features and "eternal" geographical structures. The discussion will centre on modern history and divergent standpoints regarding water utilization, identified and analyzed in connection with three multinational river basins: the Nile, the Jordan and the Euphrates/Tigris. In my opinion, an understanding of the Middle East's more recent history, and its complex political scene, is dependent upon an understanding of these divergences and their development and change over time. Other examples of the water problem in the Middle East can dramatise the area's ecological features. In the 1970s, the Gulf states seriously considered the feasibility of towing an iceberg from the Antarctic to the Persian/Arabian Gulf as a source of fresh water. As a solution to the water crisis in Libya, Gaddafi initiated the construction of the longest river pipeline in the world, the Great Man-Made River of approximately 2000 kilometres.[1]

The history of large and complex individual water technology projects in river basins, where the states' history and culture are closely linked to developing irrigation and water control, may provide a magnifying glass, a political prism, for studying politics advantageously (Tvedt, 1986). However, individual projects will only be mentioned here to illustrate more fundamental development trends in inter-state relations along the same watercourse area. The object is to show that regional population growth, a general increase in the standard of living and the development of irrigation have created a gap between access to and the need for water which will escalate disputes over the region's scantiest resource. These differences will assuredly lead to new conflicts and perhaps to "water wars" in the Middle East. The relationship between society and river water is in the process of changing its character in the Middle East; the utilization limit which a watercourse can tolerate is in the process of being reached now, at the end of the 20th century.

I. IRAQ AND SYRIA

In order to understand the depth of the water problems, some hydrological data must be given. The Euphrates has its source in eastern Turkey from where it flows in a southerly direction through Syria. There it confluences with its most important tributary, the Khabur, before it traverses Iraq's most arid areas. The annual mean flow of the Euphrates, measured at Hit, Iraq, is generally given as about 31 billion m^3 with a minimum flow of about 16 billion m^3 (Ubell, 1971). The river has the second most copious flow of water in the Middle East but compared with rivers on other continents and in other regions it is modest. For example, the Amazon's flow is more than 100 times greater, the Zambezi's 50 times greater and even the Rhine

1. The Ground water in the Jefara region in Lybia sank by one meter per year in the 1960s (*Middle East*, May 1981, p. 52). The project cost more than 25 million dollars, which is more than most countries can afford (*Middle East Economic Digest*, 25 May 1990, p. 5).

has a flow which is nearly four times greater. Nearly 90% of the bulk of water has its origin in Turkey, the remaining 10% coming from Syria. South of Baghdad, the Euphrates then joins with the Tigris and flows out into the Persian/Arabian Gulf as the Shatt-al-Arab.[2] The water in the Tigris also comes primarily from Turkey. The annual mean flow at Mosul is about 23 billion m^3. Tributaries such as the Greater Zab jointly contribute about 30 billion m^3 annually. The rainfall in the Baghdad area is below 200 mm per year. Under normal conditions Iraq contributes a modest amount of water to the rivers on which the country's agriculture depends.[3]

Until the middle of the 1960s, Iraq was the only country which utilized the Euphrates on a large scale. The water history of Iraq goes back at least to the Sumerian civilization, at about 3000 BC. A number of hydraulic civilizations dependent on irrigated agriculture arose.[4] The most complex of these were found in the Sassarian period (226-637 AD), and under the Abbasid dynasty (750-1200 AD). At the end of the last century the old canal system was modernized, but it was not until the construction of the Al Hindiya Dam in 1909-1913 that the modern phase of river utilization commenced (in Egypt there was a corresponding, but more radical development in the 1880s and 1890s.) Since the middle of the 1970s, Iraq has used about 30 billion m^3 of water annually on irrigation. Saddam Hussein's government from the beginning placed great importance on irrigation, and the budget for this sector was doubled after he became president (Middle East, January 1981, p. 48). The target was to develop four million hectares of arable land during the 1980s. The result was not achieved, but several reservoirs came into operation at the beginning of the 1980s: the Lower Khalis (1981), several large projects along the Tigris in the Kurdish area at Mosul and Kirkuk, the Himrin Dam and Haditha Dam on the Euphrates. Therefore, in Mesopotamia, the Greek word for "the country between the rivers," water control has run like a red thread throughout the area's long history.

The struggle over river water has been a source of conflict but also of attempted cooperation between different states along the watercourse for a few decades. Before the construction of the Tabqa Dam in Syria, the utilization of the Euphrates was considered a predominantly Iraqi affair. But when the artificial lake was completed in 1973,[5] constructed by the Soviet Union in accordance with an agreement from 1966,[6] it immediately became apparent that the struggle for the water from the

2. This article will focus on the scarcity of water as a resource for irrigation, food production and energy. In many parts of the world rivers are still important communications arteries. The war betwen Iran and Iraq, which broke out in 1979, was connected to a long-standing conflict between England and Teheran over the use of the Shat al-Arab as a traffic artery.

3. One indication of the Arab power's extreme dependence on rivers is that there are clear parallels between Egypt's situation and Iraq's. The Nile receives no new sources in the north after it confluences with the tributary Atbara in the Sudan. This is the longest unfed stretch of river in the world. In Upper Egypt several years may pass between rainfalls. In Cairo the mean annual rainfall is 18 mm. The difference between Egypt and Iraq in this connection is that Egypt is even more dependent on the Nile than Iraq is on the Euphrates and Tigris.

4. For a definition of the term "hydraulic society" and a discussion of the ancient river civilizations and their importance for the development of states and the character of societies, see Wittfogel (1956 and 1957).

5. For a description of the dam, see Efrat (1967) and Guiné (1976).

6. In the long run, the Soviet-supported large dams in the Middle East—dams which the World Bank, because of political preference and arguments over water policy, would not help finance—might turn out to be the Soviet Union's longest lasting mark in the region.

Euphrates had become a main source of conflict between two neighbouring Arab states. Iraq *became* a downstream state in a water-political and geopolitical sense with the construction of this lake of about 80 square kilometres which could dam about 12 billion m^3 of water from the Euphrates.

In 1975, Syria and Iraq were on the brink of war, partly because of a conflict concerning rights to the water from the Euphrates (this was one conflict in the Middle East which the western media, researchers and politicians overlooked, because it fell outside the East-West perspective, as well as the Jewish-Arab conflict and the fixation on oil.) Syria's proposal to restrict the flow of water in the river because of the construction of the Tabqa Dam met strong protests from downstream. For two months the propaganda war escalated, and Syrian troops were stationed along the Iraqi border. Not until pressure was exerted by the Soviet Union and Saudi Arabia did Syria yield; it would release more water from the reservoir as an act of "goodwill." But the water-issue was not solved. In, for example, July 1984, Iraq accused Syria of retaining 60% of the Euphrates' normal discharge. This was immediately denied in Damascus. Antagonisms between the two Baath parties and the standpoint taken by Damascus in the war between Iraq and Iran, and the Gulf War in 1991, were influenced and nourished by the perennial conflict of interest between Baghdad and Damascus over the utilization of these water resources.

Until 1983, the year Turkey began its South-Eastern Anatolia Project (SEAP), also called the Great Anatolia Project (GAP), the utilization of the Euphrates was in practice often considered a question concerning two neighbouring Arab countries: Syria and Iraq. However, when the Turkish project started it became crystal clear that the Euphrates was not an Arab River. SEAP was an enormously extensive and complex water system plan; an early version proposed 80 dams, 66 power plants and 66 irrigation systems which were also to be used to irrigate 1.6 million new hectares. Turkey has officially estimated the potential of the Euphrates basin to account for 45% of the country's total hydroelectric potential and 25% of the irrigation potential within the country (Ozal, Kutan and Adak, 1967, pp. 100-101). The first of the Euphrates' dams in Turkey, the Keban Dam, was constructed in 1974. The GAP project that Ankara is now developing includes 21 dams and 17 hydroelectric plants in addition to effecting an Anatolian irrigation revolution, and when completed, it is projected that the irrigation system will require around one-fourth of the Euphrates river flow at Keban.

But can the rivers fill all these reservoirs and fulfill all requirements? On the one hand water is wasted due to inefficiency and evaporation, on the other hand the volume of water needed to irrigate the planned 700 000 hectares in Turkey, the 640 000 in Syria and the 1 230 000 hectares in Iraq between Hit and Hindiya exceeds the river's normal discharge (Beaumont, 1978, p. 39). In the middle of the 1970s about half of the Euphrates' water was utilized by the three river states. In the 1980s, Iraq alone used roughly half of the Euphrates discharge. More and more extensive plans for water utilization have been put on the drawing board. For example, in 1988 Syria used 40% of its budget on irrigation and hydroelectric projects (*Middle Eastern Economic Digest*, 25 June 1991, p. 13). The Euphrates does not have sufficient water for all the projects planned in the three states, nevertheless all the states consider their respective projects of paramount national importance. At the same time the population increases and, consequently, much greater demands than ever experienced earlier, are placed on the limited water resources, and more political pressure is put on the governments in the three basin states. The population of these three watercourse states increased from 38.9 million in 1960 to 87 million in 1990. It is estimated that by around the year 2025, there will be a total of 172 million people living in Iraq, Syria and Turkey.[7] Seen against the background of such a demographic curve, the current scarcity of water in Damascus is more than an acute source of irritation to the population of the city; it may be regarded as a forewarning for the future of the entire area. When in 1990 the water was turned off every night in large areas of the city, what then will the situation be like in 50, 100 or 200 years?

The country which has the greatest utilization potential and whose interests are best served by changing the present utilization profile is Turkey. The drawback for Syria and Iraq is of course that plants upstream along a watercourse will always affect the situation downstream. In addition to the general insecurity inherent to this geographical downstream position, Iraq and Syria have a concrete fear that the Atatürk Dam will divert the water from the Euphrates to the arid, but fertile soil in South-East Anatoli. This fear was exacerbated when Turkey arbitrarily reduced the water flow by 500 m^3 per second whilst they filled up the reservoir at the beginning of 1990. Syria protested and claimed that the country's production of electricity was heavily reduced due to the decreased discharge, while Iraq maintained that 7 million agriculturists were affected. Rather than assessing the truth of these protests it is more important to see them as a gauge of heightened tension between neighbours. Agreements about the Euphrates are also complicated by the fact that several of the tributaries are multinational. The main problem is, however, to what extent Turkey's plans can be reconciled with Syria's and Iraq's plans and downstream water utilization that is already established. The World Bank refused to fund the Atatürk Dam, arguing that there was no long-term, formal agreement with Iraq and Syria.[8] Further, the regional conflict potential is not restricted to these three countries: a 1984 agreement between Iraq and Jordan suggested that the two countries were to investigate the possibility of diverting water from the Euphrates in Iraq to Amman in Jordan (Kolars, 1986, p. 66). This is an extremely expensive project — a 600 kilometre water pipeline where water had to be pumped uphill — but the desperate search for water in Jordan has made such a project quite feasible.

The Tigris has been a source of conflict more between peoples within Iraq and within Turkey than it has been between states. It plays an important, but, by many, neglected role in the Kurdish question. Kurdistan is an upstream area in relation to Baghdad and Iraq's irrigated agriculture. The Kurds also inhabit the areas where some of Ankara's biggest water projects are to be constructed. Any ruler in Baghdad would fear an independent Kurdistan; from his position a new upstream state would be capable of controlling one of the country's life-giving arteries. For Turkey, an independent Kurdistan would be a spanner in the works of the extremely ambitious,

7. Figures as these must generally be taken with a grain of salt. But they clearly show an undisputed tendency in population growth. The figures are calculated on the basis of the *World Resources 1990-1991*.

8. The World Bank's official attitude to the Aswan Dam was the same; support to Egypt's plan was made dependent on water agreements with other basin states. On the same grounds, the World Bank would not support the Wahda Dam on the Yarmouk along the Jordan water course, because downstream Israel would not accept the dam, and because there was no current agreement on water utilization between the river basin states.

core development project which, according to its leaders, will make the 21st century Turkey's century. In the 1980s, Syria's support of the Kurdish revolt in Turkey against Ankara also provided a means of postponing Turkey's water plans: a lever to remind Ankara that it could not develop a water system affecting downstream states without suffering some consequences. A more permanent, but peaceful Western presence in the upstream region of the Tigris, such as the European Ministers of Foreign Affairs agreed to in June 1991, presents a much more dangerous and more permanent threat to Iraq and Saddam Hussein than thousands of Norman Schwarzkopf's marines in Kuwait or the Basra area. Baghdad knows this, and so does Washington. In January 1991, a proposal in the *New York Times* suggested that Ankara, via the USA, could use the "water weapon" against Saddam, a weapon described as being just as moral, but more effective than the oil embargo (Starr, 1991, p. 30).

From a purely regional perspective and seen from the river banks of the classical downstream state Iraq, not to mention Syria, Turkey has the power. Iraq is doubly vulnerable because its eastern areas are dependent on water from rivers which have their sources in Iran. Sumer's downstream position on the river plains was a condition for the development of irrigated agriculture and consequently for the first river civilization. At that time too there were wars over water, but these were between the towns on the plains, which due to expanding irrigation suddenly found themselves with common borders (McNeill, 1963, p. 42). History has constantly reminded the Mesopotamian plains of their strategic vulnerability, and technological development has definitely turned a historical advantage to a prevailing and future disadvantage. In the middle of January 1258, a multi-ethnic force attacked Baghdad, not from the West that time, but from the East: Turks from Central Asia, Mongol nomads, soldiers from Georgia and Chinese engineers. The Mongolian general, Hulagu, lured the Caliph's soldiers into the swamps some 48 kilometres east of Baghdad; the soldiers opened the barrages and dams of the Euphrates and the greater part of the Caliph of Baghdad's army was either drowned or killed. The destruction of the irrigation system by the Mongols was an important factor contributing to Baghdad's disappearance from world history in 1250. The desert spread to where the Hanging Gardens had formerly flowered. Due to the increasing demand for upstream water, Iraq can again fear a development in which continued expansion will have to give way to the major task of keeping the desert at bay. The Iraqis are well acquainted with the social consequences brought about by changes in the river's water supply and the velocity of its flow, which in time may change the course of the river. One of the first known examples of man's destruction of the environment took place right here; on the Euphrates-Tigris plains.[9] When in 2400 BC King Entemena of Lagash had a large canal dug between the Tigris and the Euphrates, and the ground-water rose, there was a catastrophic increase in the salinity of the soil. After a couple of hundred years agricultural production had deteriorated so much that there was a famine in Ur, the capital, one of the main reasons for its disappearance from history. The river changed

9. Salinity processes arising from evaporation of irrigation water — one of the Middle East's "eternal" problems — undermined agriculture in Mesopotamia between 2400 and 1700 B.C. and led to the collapse and disappearance of the Sumerian civilization (see Jacobsen and Adams, 1958, p. 1252).

its course, and today the old centres of civilization lie buried beneath the sand—bearing dramatic and negative witness to the importance of water.

At the beginning of this century Turkey was called "the sick man of Europe." Control of the Euphrates and the Tigris may change the "sick man" into the "strong man of the Middle East" by the beginning of the next millennium. The rivers give the country an enormous development potential and a comparative advantage in an area with scant rainfall. At the same time they are the trump card in Turkey's strategic game with their oil-wealthy neighbours in the South. Since the middle of the 1980s, Prime Minister Ozal of Turkey has proposed the construction of a pipeline through Syria and all the way south to Saudi Arabia to carry water from the Seyhan and Ceyhan rivers which have their estuaries in the Mediterranean. Ankara calls it a "Peace Pipeline," Riyadh appears to regard it as a running noose. The guardians of Mecca and Medina are afraid they will lose their own water independence, and hesitate to place their fate in the hands of what was the centre of the Islamic world until 1924. In recent years the GNP in Turkey has climbed steeply; in 1990 by a good 10% (*Middle East Economic Digest*, 26 April 1991, p. 34). The same year Syria had a growth estimated at 6% (*Middle East Economic Digest*, 12 April 1991, p. 5). Iraq on the other hand was ruined by the Gulf War, not only politically and militarily, but also economically. As a downstream state, the fact that it supplied Turkey with oil before the war was a strong card in regional water negotiations. But this card has been trumped. And whilst Turkey's army of c. 650 000 soldiers is the second largest within NATO, Baghdad's military machine has had its wings clipped. At the same time, and not least during the Gulf War, Turkey showed great interest in new watercourse negotiations. In the long run, this development in power structure between the riverbasin states will make Saddam's reported attempt to be remembered as a new Mesopotamian Nebuchadnezzar appear not only futile, but perhaps lead to his going down in history as an Iraqi Hulagu whose ambition for power to the south was a decisive contribution to destroying the foundation of Iraq's utilization of river water. Iraq's position in water negotiations has been dramatically and strategically weakened.

II. EGYPT

The Nile flows through eight countries, Tanzania, Rwanda, Burundi, Zaire, Uganda, Kenya, Sudan and Ethiopia before it reaches Egypt. Accordingly, the river, which is the main artery of Egypt, is primarily an African river. If the Nile were turned on its axis in Cairo, then its source would be somewhere in the Arctic Ocean, nearly 7000 kilometres from the desert sands which were the granary of the Roman Empire about 2000 years ago and Lancashire's central cotton plantation a hundred years ago. It was the river that created the Pharaonic civilization; that made Egypt the centre of Arab power in the Middle East, and through a technological revolution in water control made perennial irrigation possible in the last century and thus laid the foundation for a tremendous population explosion.[10] Throughout the ages, Egypt's downstream situation on the Nile has influenced the country's geopolitical position.

10. For a discussion of the development of irrigation technology in Egypt in the 1800s, see Tvedt (1986b).

Winston Churchill aptly said that Egypt may be compared to a deep-sea diver whose air was provided by the long and vulnerable tube of the Nile. Never has this position been more vulnerable or created more insecurity in Egypt than during our time. The Nile's hydrological character, the climatic conditions in the Nile valley and Egypt's geopolitical location thus expose the Middle East to developments thousands of kilometres south of the equator and have direct significance for the region's political power structure.

Under the Pharaohs, the years when the Nile floods failed were looked upon as a punishment, a sign of the gods meting out justice. Later, in the Middle Ages, the rulers of Abyssinia exploited the Egyptians' downstream complex and threatened to reduce the Nile flood if the Egyptians did not concede political and religious issues.[11] In the 17th century Muhamed Ali and Ismailia attempted to solve Egypt's problems by military conquest upstream; by extending the country's borders all of the Nile could become an Egyptian river. In the 1890s the British carried out Ismailia's project in their own way. Queen Victoria became ruler of the area from the Mediterranean in the north, to Lake Victoria in the south and the Nile became in reality a British river (Tvedt, 1985). The struggle for control of the Nile waters had a determining influence on Britain's policy concerning border negotiations with Eritrea, Ethiopia and Kenya/Somalia, Uganda and the Congo thousands of kilometres away from the main course of the Nile.[12] For the independent Egypt wanting to play a leading role in the non-alliance movement and in the Arab world, national control of the country's most important resource became a major issue. Nasser's decision in the 1950s to build the Aswan Dam was without question the most important attempt "the free officers" made to ensure new freedom of political action for Egypt in the spirit of the Bandung Conference, first and foremost in relation to the "British" Nile in Africa. The decision to construct a dam was therefore one stone in the foundation of Nasser's panarabism. As Nasser said, the dam was to be a means of making Egypt the "Japan of the Middle East." Despite opposition from Britain and the World Bank, Nasser pushed through the construction of the Aswan Dam with the support of Krutsjov. This resulted in Britain losing its diplomatic trump card. Overnight, control

11. Refer, for example, to Langer (1935) and Hecht (1987). Both these authors give historical examples of how Ethiopian rulers attempted to use their upstream position in order to put pressure on the rulers in the Nile delta by exploiting their downstream-complex.

12. In the Nile diplomacy Britain adopted for border negotiations in the 1890s, the major question that had to be considered was the watersheds of the Nile catchment area. Incidentally, Britain's clear strategy in this matter contradicts the simple, but also widespread interpretation that the colonial powers in Europe drew up borders without having any insight into local conditions. In fact, Britain placed more emphasis on this geographic circumstance than on ethnicity and culture. Later criticism of colonial ignorance often seems to overlook the "river basin criteria." For example, in 1895 agreements with Italy on Ethiopia/Eritrea, with France in 1904, and with Germany and Belgium, the words that occur repeatedly are that partners to the agreement pledge not to "arrest or modify" the flow of the Nile. See Tvedt (1992), Tilahun (1979), and Okidi (1982 and 1990).

Other present borders on the Horn of Africa were influenced by Britain's defence of Nile valley unity. Ethiopia's southern border and King Menelik's annexation of Borana were decisively planned against the background of a Nile expedition sent by Lord Salisbury, Britain's prime minister, in March 1897 under the leadership of Major MacDonald. The secret goal was to confirm Britain's control over the Nile in southern Sudan. The declared aim was to solve border disputes between Italian Somaliland, Ethiopia and British East Africa. Britain's reluctant engagement in this area gave Menelik in Ethiopia almost sole power to decide where the border was to be drawn. See Turton (1976).

of the Nile upstream became worthless as a means of applying pressure; it was impossible to quell the anti-British feeling by cutting off the "life-line"—even if *that* was what they would have liked to do. Conservative British members of parliament could only threaten to "nationalize" the Nile in Uganda, Kenya and the Sudan, in order to "bring the Egyptian government to its sense" (House of Commons, 1956).

The new Aswan Dam and Lake Nasser have had an incalculable importance for Egyptian agriculture, the electrification of country districts and industrial development. It has also saved Egypt from droughts and flood catastrophes (as recently as 1985 and 1988/89) which would have made the tragedy in Ethiopia and the Sudan pale in comparison. But the relatively plentiful and assured water supply of the post Aswan period in Egyptian history was only temporary: now, because Egypt itself is feeling the "hydraulic pinch," it is quite inconceivable that Mubarak will repeat Sadat's offer from the Camp David negotiations in the middle of the 1970s, to divert 1 billion m^3 of water from the Nile to Israel (it is also less likely on more general political grounds).

The need for water already exceeds the capacity of the Aswan Dam and, with the existing plans for agriculture and industry as well as the population growth, there is obviously insufficient water. Egypt already imports more than half the food it consumes. Despite protests from the other states along the watercourse, the government in Cairo has decided to construct canals which can carry the Nile water under the Suez Canal to the Egyptian part of the Sinai Desert. The object is to cultivate 250 000 hectares on both sides of the Canal.[13] The century-old plan to increase the Nile's total volume by excavating a new and more efficient watercourse for the flow of water in the world's largest tropical swamp areas in Southern Sudan has been given top priority.[14] The Egyptian government's ultimate object is to increase the volume of discharge by almost 20%, the gain to be shared equally by the Sudan and Egypt. However, war has raged intermittently in southern Sudan, first from 1955 to 1972 and now from 1983. One of the points of issue connected to these water projects in general, and to the Jonglei Canal in particular, concerns the compensation the population in southern Sudan may expect from Arab neighbours in the North for the radical change that will occur in their local life style. And if the Nile's volume increases, so the African upstream states argue, is it not then reasonable that they should also be entitled to at least some of the water? Egypt and the Sudan are geographically linked to upstream states, they are dependent on an "African resource." In the long-term, the short period during which Egypt appeared to have control over all the water the country needed after the Nasser Reservoir was constructed and became operative, was but an interlude and an exception in recent Egyptian history. Egypt's leaders are aware that they are dependent on having to develop and maintain good relations with the African upstream states, and that Egypt

13. The main point of the discussion was whether the Sinai could be considered a natural part of the Nile Basin. Egypt maintains that the Suez is a man-made canal, and the fact that it was excavated (opened for shipping traffic in 1869) cannot change that fact.

14. The Canal—the Jonglei Canal as it is called—was planned to be 360 km long and increase the Nile's water flow by 4 billion m^3 annually. In addition to the canal itself, a Phase II is planned. This will include reservoirs in connection with the central African lakes and the draining of both the Marchar Marshes and the Bahr al-Ghazal in South Sudan. See Ali (1977) and Samaha (1979, p. 3).

therefore cannot restrict their foreign policy orientation to panarabism or pan-islamism alone.

The Nile is a limited resource with an average flow of only approximately 80 billion m^3 per year. The Nile is the longest river in the world with the most abundant volume of water in the Middle East. However, it is relatively small when compared to its length and its catchment area, as well as its potential importance for the economy of the river basin states. Extreme fluctuations in the volume of water from year to year and from season to season augment the water scarcity — which is a product of supply and demand. The Agreement between the Republic of the Sudan and the United Arab Republic of Egypt for the full utilization of the Nile waters, in 1959, apportioned all of the Nile's discharge and allotted 18.5 billion m^3 to the Sudan and 55 billion^3 to Egypt. The remaining 17-20 billion m^3 is lost through evaporation (evaporation on Lake Nasser accounts for 10 billion m^3 annually), and essential hydrologic discharge into the Mediterranean. The mighty and mysterious Nile of ancient times has, in Egypt, been tamed and made into an irrigation canal. The available water in the whole basin is therefore already apportioned. In reality *more* than is available, if the average and reduced annual discharge of approximately 72 billion m^3 for the period 1977-1987 is used as a measure.

And what of the other seven countries within the Nile basin? What will happen when they attain political stability and an economy strong enough to exploit more of the Nile water for irrigation and urban and industrial consumption? In 1960 the Nile basin states supported a total population of 100 million, in 1990 about 240 million, and in 2025 it is estimated that there will be 600 million. According to the government's plans, the Nile is not only to play a key role in feeding more mouths, but the relative strength of the different states will change as well. During the latter part of this period, Egypt's share of the population will sink from more than 30% to less than 20% and at the beginning of next century it is estimated that Ethiopia will have about 20 million more inhabitants than Egypt.[15]

The irrigation potential based on water from the Nile is by no means fully exploited in the upstream states, and the same may be said of hydroelectric power and regional electrification. While 100% of Egypt's agricultural area is irrigated, only 1% of Ethiopia's and 2% of Kenya's are (Tvedt, 1992). The combined plans the countries have for potential Nile utilization will require a volume of water far greater than the Nile's total discharge. As shown, existing agreements regarding the Nile apportion the water to Egypt and the Sudan only. This distribution profile will be the object of increasing pressure from governments upstream, as well as from different pressure groups within the existing states. Ethiopia, the region's "water tower," distributes over 80% of the Nile's water to the desert areas. But the country utilizes at present hardly any water at all from the Nile, while the most extreme versions of Ethiopian plans outlined will require about one third of the Nile's flow of water (Jovanovic, 1985). Plans have also been presented for the Kagera water system at the extreme south end of the Nile (KBO, 1978 and 1982). Kenya has discussed new, revolutionary plans for utilizing the Nile water system which at the same time opens

15. The figures are calculated on the basis of different tables in *World Resources 1990-1991*. Different sources have different future prognoses, but most agree that Ethiopia (assuming that Eritrea does not become an independent state) will have a higher population than Egypt.

up a completely new field for political wrangling; the country wants to divert water from the Nile *out of* the natural limits of the basin to areas in the east which suffer from drought. There are indications that climatic changes in the region may perhaps reduce the rainfall over the Ethiopian plateau and consequently the flow of water in the Blue Nile, whereas increased rainfall over the central African lakes will increase the flow of water in the White Nile (Hulme, 1990). If this is the case, it will lead to further demands for changes in the present consumption/utilization profile of water. On the other hand, the possibilities of finding large hidden groundwater resources under the Sahara, resources newly discovered by satellite (*Time International*, 5 Nov. 1990, p. 40), will at best reduce the scarcity and mitigate future conflicts. These "new" resources can, however, never be any substitute for the Nile, only an expensive supplement due to the cost of exploiting groundwater and the fact that Egypt's whole irrigation system is built around the canals from the Nile.

One of the reasons for the conflicts over the Nile not ending in open hostilities has been the effect of civil war in Ethiopia, and another has been the postponing effect of economic crisis in upstream states. The role of water in Britain's colonial politics and strategy in the Nile valley in general and especially in the Sudan (Tvedt, 1992), and the plans of the sovereign governments in Cairo and Khartoum to redivert the Nile in southern Sudan have, however, contributed to the development of regional economic imbalance in the Sudan. And this, in turn, helped create the conditions leading to two civil wars in the Sudan. The struggle for water and the desire for a rational utilization of the river, on Egypt's part especially, will probably be an important factor behind any future peace agreement (Tvedt, 1983). To sum up: crises and wars have resulted in the Sudan not being able to utilize their share of water in accordance with the 1959 agreement (in the meantime it is used by Egypt), and the other countries have not had the economic strength necessary to realize their plans. In this situation, Egypt seems to have conflicting aims: (1) peace in the Sudan will increase the possibilities for implementing the Jonglei Project and increase the Nile yield, however (2) continuous instability upstream will reduce the pressure on the existing water and delay water consuming projects.

Developments in Ethiopia will have consequences for possible agreements concerning the Nile. Ethiopia, like Kenya, has not been particularly interested in agreements so far; they claim that they must register their requirements and their technological irrigation possibilities before entering into binding agreements. It is too early to assess the impact of the recent changes in Ethiopia and the fall of Mengistu and to what extent it will expedite the cooperation Egypt has tried to foster between the countries. The Tigré province is a key area in the Nile basin, and the fact that the people of Tigré have been given more power in Addis may create still another element of uncertainty. With an independent Eritrea, the consequences would not be the same, because when Britain and Italy set its borders in the late 18th century, Britain wanted first and foremost to prevent the establishment of a new state within the Nile Basin system. A more independent southern Sudan will definitely have great importance for the whole question of control of the Nile and the apportioning of its water. Despite efforts by Egypt and the international community, the greater number of participants and greater expectations to development in the upstream states reduce the chance for a comprehensive water system agreement in the near future.

At the same time, the world is aware of Egypt's vulnerability. Britain exploited it in 1924, 1929 and in the 1940s and 50s (Tvedt, 1986). Mussolini and Ciano attempted to exploit it (Giglio, 1954). Ethiopia, Israel, the Sudan People's Liberation Army (SPLA) in the Sudan, Washington and Moscow have used an upstream location in Addis to exert diplomatic pressure on the Cairo government several times during the last decades (Tvedt, 1990). Israel reportedly began preparations for the construction of three dams in 1990 and in 1991, and what is important: these rumours were sufficient ground for Ethiopia to send Tefaye Dinka, Ethiopia's Minister of Foreign Affairs to Cairo to calm the anxiety that was expressed in Egypt's national assembly. The USA, (Bureau of Reclamation, 1964), as well as Warsaw Pact states, have through their allies in Addis Ababa, at different times, depending on their respective ties with Cairo, published plans for Ethiopian utilization of the Nile that often had primarily diplomatic motives. In connection with the riot in the Shaba province in Zaire and Cuba's presence, Sadat announced in 1979 that Egypt would not hesitate to go to war if anyone took as much as one drop of water form the Nile. In 1985, the Egyptian Minister of Foreign Affairs predicted that the next war in the region would be over the water of the Nile. Egypt's anxiety is understandable, not least on a background and in a period where the population has increased by one million nearly every tenth month. As mentioned above, many conditions have led to a less acute water scarcity than expected, but the economic crises in the upstream states have had special significance. Many initiatives were also taken to solve the conflicts through dialogues and consultations before they became too acute. But an indication of the heat this water question has the potential to generate may be that when the Muslim fundamentalists demonstrated in Khartoum in 1991 against Egypt joining the USA against Saddam Hussein in the Gulf War, the slogan was: "Destroy Lake Nasser."

III. JORDAN

Theodor Herzel, the founder of political Zionism, was of the opinion that irrigation experts would lay the foundations for a Jewish state in Palestine. Discussions about Palestine's "absorption capacity" had a prominent place on the agenda even during the British mandate period. The potential size of the population was estimated on the basis of the potential development of irrigation.[16] Only efficient water utilization would make mass immigration and kibbutzim possible. The slogan "Make The Desert Flower" has always been a central aim and provided legitimization of the Zionist experiment. Both before and after 1948, the question of water and water rights has been a focal point in the work of creating a Jewish homeland.

The Jordan river is the largest "all-year-round" river in the area. Parts of it run through Lebanon, Syria, Jordan and Israel. Compared with the large rivers in the world it may be likened to a stream and is scarcely 200 kilometres long. In the 1960s, the annual discharge from the Sea of Galilee was 500 million m^3, which corresponds roughly to 19 hours natural discharge from the Nile at Aswan on a normal

16. The Rutenburg concession, which permitted the utilization of the Jordan and Yarmuk rivers, was very important in this connection.

September day. But in such an arid area, its drops are worth more than gold. For example, the annual rainfall throughout most of Israel is under 200 mm and is concentrated around a few days during a few months. Ever since 1948, the country's leaders have constantly run campaigns under the slogan "Do not waste one drop of water." The state has installed water meters in every home and those who use more than their quota are fined. Due to scarcity of water, Israel has been forced to develop one of the most efficient irrigation systems in the world.

The general shortage of water in the area has given birth to a number of plans for the control and maximum utilization of the Jordan river. As early as 1905, N. Wilbush, an engineer, produced a plan aimed at maximum utilization of the river for irrigation and hydroelectric power. He understood that the Jordan alone could not solve the region's water problem in the future.

Therefore, one of his suggestions was that water from the Litani (now in South Lebanon) should be diverted to the Jordan. For the same reason the World Zionist Organization in 1919 demanded that the Litani should become the border of Palestine. This would double the Jordan's water volume. This idea has been aired many times since, for example in a plan from 1955 made by an American engineer, John S. Cotton (Brawer, 1968, pp. 234). Nor is there any doubt that this plan has contributed to forming Israel's later policy regarding Lebanon.[17] Earlier plans aimed at transferring water from the Jordan to the arid areas in the West and South. The most well-known of these, "the Lowdermilk Plan," was presented in the 1940s (Lowdermilk, 1945). Immediately after Israel was founded, work on realizing the plan began, but because of international resistance the plans were modified. That led to the construction of the "National Water Carrier" which was completed in 1964. This carried water from the Sea of Galilee to the Negev Desert, and aggravated the strained relations with the Arab states. The relationship with Syria had led to border incidents as early as 1953 due to the Jordan plans, but Syria took the case to the United Nations Security Council which passed a resolution prohibiting the continuance of Israel's water development work in the demilitarized zone (Smith, 1966, p. 118). In 1964, when Israel started to fill the canal, an Arab Summit Meeting was called, but instead of declaring war, a resolution for an alternative project for diverting the Jordan water away from Israel was passed (*Ibid*, p. 118). Israel's project was implemented. Naturally, the volume and not least the quality of the water in the Jordan river downstream was reduced, but what could the Jordanian government and administration do—apart from wash their hands?

Israel's efforts bore fruit. From 1948 to 1966 alone the irrigated area increased fivefold. Immediately prior to the Six Day War in 1967, Israel was utilizing over 80% of the then potential water resources (Brawer, 1968, pp. 228). With continued immigration, population growth and plans for economic development, Israel appeared to have come up against a brick wall. The extension of the borders resulting from the Six Day War brought its first and foremost water resources: the Yarkon/Taninim Basin. The groundwater basin lies under the territory Israel controlled before 1967, but also to a large extent under the West Bank. The basin is estimated to contain about

17. Geological and topographical investigations along the Litani watercourse were started immediately after the invasion, and Israel's interest in the work is considered to be so strong that UN troups have the task of checking that Israel does not divert water illegally.

one third of Israel's fresh water resources (the Jordan water system accounts for roughly the same amount). There is a sharp disagreement between Jordan and Israel over its geological description, which naturally form the basis of water rights. The war gave Israel greater control over several of the Jordan's sources in Syria,[18] and Syria's plans to dam up the Jordan before it reached Israel were clearly further motivation for the annexing of the Golan Heights. There is no doubt that the Israeli border extensions and the form they took, were closely connected with the desire for more direct control over larger shares of the region's water resources. The resistance to surrendering the West Bank has less to do with territory than the groundwater resources. It is estimated that one-third of Israel's water originates in rainfall over the western slopes of the West Bank. The point is that it is not the area, but the water that is decisive for Israel's "absorption capacity."

In the coming decades—and in the wake of heavily increasing immigration from Eastern Europe—Israel *must* establish new settlement areas. At the same time, the groundwater is sinking and the salinity of the soil is accelerating at an alarming rate. One sign of future scarcity is the development in the Dead Sea. The water level is controlled by the Jordan river. Scientists maintain that if the present tendency continues, the lake will completely disappear—it will just dry up within a few hundred years (*Middle East*, Aug. 1990, p. 44) — for the river is dammed and the water is used to water the soil. In 1979, the lake was divided in two and a bridge of land (Lisan Straits) arose from the salt waves. Just as Moses crossed the Red Sea, so can the Dead Sea be crossed on firm ground.

Although Lebanon and Syria are also riparians, it is Israel and Jordan which have the most acute need for water from the Jordan and are most dependent on this river system. At the beginning of the 1980s, the river satisfied only 5% of Lebanon and Syria's water demand (Naff and Matson, 1984, p. 27). If possible, Jordan is in an even more desperate situation than Israel. The river supplies the country with about 75% of the water it consumes, whereas estimates made before the Gulf War predicted that the need for water will increase by 50% by the turn of the century. In addition, politically as well as militarily, the country is a weak downstream state. During recent decades, population growth, urbanization and economic expansion in Jordan have increased the need for water. Immediately after 1948 alone, the country took in about 350 000 Palestinian refugees. This led to UNRWA taking the initiative for two quite small projects utilizing the Yarmuk and the Jordan. The population growth in Amman has also led to more than one third of the reservoir capacity of the King Talal Reservoir being allotted to urban water systems.[19] In July 1990, King Hussein

18. The 1892 British-French border agreement with Palestine and Syria was aimed at keeping Syria away from Jordan and its lakes. Britain's stance in these negotiations was to include as many sources of the Jordan in Palestine as possible, both banks of the river, Lake Hula and the Sea of Galilee. To achieve this, it was willing to agree to many compromises with France about other parts of the Middle East. The report from the border negotiations is published by H.M. Stationary Office, Cmd. 1910, London.

19. In addition, there are estimates which imply that the need for energy will increase over 20% annually. Or, to be more explicit: Israel and Jordan both plan to carry sea water from respectively the Mediterranean and the Red Sea to the Dead Sea. The fall of some hundred metres down to the Dead Sea will be used for producing electricity. At the UN conference on new and renewable sources of energy in Nairobi in 1981, there was only one thing which caused political conflict: Israel made it known that it intended to construct this canal from the Mediterranean to the Dead Sea. One PLO observer pointed out

declared that only the water issue could incite a war between Jordan and Israel, and together with religious leaders he publicly offered up prayers to Allah to solve the water problem. Contributing to this tension is the constant disagreement over the Wahda Dam on the upper Yarmuk, a dam which Syria and Jordan wish to develop jointly, and which for Syria increases in importance at the same pace as the Turkish exploitation of the Euphrates.

The first large project in Jordan was the East Ghor Canal, completed in 1964. The canal diverts water from the Yarmuk 70 kilometers to the south, and by and large runs parallel with the Jordan river. Small reservoirs and canals, fed by water from small rivers, were constructed east of the East Ghor Canal (Smith and Birch, 1963). Jordan's water sector is relatively extremely weak. In 1975-77, 45% of Israel's arable area was irrigated, whereas the corresponding figure for Jordan was only 9%. Ten years later the figure for Israel had increased to 64% whilst Jordan still had only 11% (*World Resources 1990-1991*). On the other hand, the population growth is higher in Jordan than in Israel, if the new immigration from Eastern Europe is excluded. The population is expected to increase from 4.3 million in 1990 to 13.1 million in 2025, whereas the corresponding figures for Israel are from 4.6 million to about 7 million. The inherent tension latent in population growth and growing water scarcity forms a basic framework of Jordan's political negotiating power and sets its negotiating parameters. In such a situation the work of launching the 1984 agreement with Iraq for diverting water from the Euphrates to Jordan has been of primary importance and established grounds for cooperation and alliance between Amman and Baghdad.

The apportioning of water resources has consequently not only been a question related to military strategy in the Israel/Arab wars, but also a source of diplomatic activity and conflict. In 1953, a proposal was made by the United Nations and the US. In 1955 an American proposal, "The Unified Water Plan for the Utilization of the Jordan-Yarmuk River System" was made on behalf of President Eisenhower's government (the Eric Johnstone Plan). After extensive negotiations the plan was accepted by the state's technical experts as a rational project from a water technological point of view. However, it was rejected on political grounds. Political interests and maximum utilization of water are seldom compatible when there is a scarcity of water in multinational water systems. The chances of such a joint river basin plan succeeding do not look greater in the 1990s than they were in the 1950s or 1970s.

CONCLUSION

The feeling many Middle Eastern leaders have of being imprisoned in the "hydraulic vice" will create new alliances and undermine historical bonds. In the Middle East especially, the volume of water often varies extremely from season to season and year to year and consequently there is a great deal of pressure for gaining control of the water. The rivers, as gifts of nature, traverse state and ethnic borders. The special characteristics of the river resource mean that intervention in one place

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that the canal could probably be used for developing Gaza and possibly flood large Palestinian areas of the West Bank (*Middle East*, Oct. 1981, p. 71).

affects other places which share the same resource, even if hundreds of miles of swamp and desert sand separate them from each other. The total effect is that arid, but water dependent areas are extremely conflict prone.

In the Middle East, the rivers have been creators of history and culture in the fullest sense of the meaning. The rivers gave birth to the first civilizations such as Ur, Nineveh, and Memphis. Changes in the river discharges and changes in water utilization left other river civilizations literally in the sand. The Hanging Gardens of Babylon in "A Thousand and One Nights" disappeared when the water disappeared. There is little indication that the rivers' natural flow altered significantly since the first river civilizations developed.[20] But there has been a great change; present day population growth, industrialization and modern agriculture lead to more people and more sectors wanting to "drink" from the rivers. Revolutionary technological innovations have made it possible to tap them for even more of their drops. In the past, the downstream states were the only ones able to develop any large-scale water utilization. Since the control of water on the desert plains of Mesopotamia and Egypt was a much easier task than upstream in the basin, and since it was much more necessary in these most arid areas, they have therefore also acquired more established water rights than the upstream states. It is especially in the latter decades that the downstream states have had to face a new historical and more vulnerable situation, partly due to the general tendency for the pace of development to vary from country to country, but first and foremost because of the great improvements in technological possibilities for water utilization. Along the Euphrates' watercourse, only a couple of decades have elapsed since the multistate struggle over water began. Along the Jordan watercourse it has been going on since the 1920s, especially in diplomatic negotiations between Great Britain and France. In the Nile Valley it has been a source of conflict between countries and regions for more than a century. The Syrians named their large lake, Lake Assad, just as the Egyptians and Jordanians called theirs Lake Nasser and the King Talal Lake respectively. The Mosul Dam in the Kurdish area of Iraq was given a new name during the first half of the 1980s; the Saddam Hussein Dam (*Middle East Economic Digest*, 8 Feb. 1985, p. 13). In Turkey the largest dam is named after the modern country's founder, Kemal Atatürk. The national prestige, itself connected with the dams and reservoirs, becomes both a conservation and a conflict factor in regional changes of water utilization.

Three essential conditions influence the conflict potential in general: (1) The water scarcity factor. The fact that, for example, Norway is an upstream state in relation to Sweden on the Trysil watercourse (the Klara river in Sweden) has very little influence on the relations between these two neighbour states as the problem for agriculture is not too little water, but quite the opposite. On the other hand, the whole of Egypt and the greater part of the Sudan, Jordan, Iraq, Israel and Syria do not have enough rainfall for agricultural production without irrigation. (2) The distribution and relation of power between upstream and downstream states. A combination of geographical and historical circumstances has a rule led to the

20. It is a fact that the Nile's flow has diminished noticeably since 1900. The average annual discharge for the 1980s is about 10 billion m^3 less than it was at the turn of the century. Researchers in climate changes are not sure if this represents temporary fluctuations only (a modern version of the Bible's seven lean years and seven prosperous years), or if it is a forewarning of more permanent changes in the climate. Notwithstanding, the decrease in water flow makes the writing on the wall clearer.

downstream states utilizing the river more, i.e., their "established rights" to the water are most comprehensive. Along their respective watercourses, Egypt and Iraq are prime cases in point. They have used the water and, they claim with good grounds, have established their rights to it through generations of use. For the same reasons, the downstream states will therefore often be the strongest economically and politically. Technological revolutions and the varied pace of development of states have created a process in which the downstream states are under increasing pressure from the upstream state. The definition of "justice" in the water distribution question will probably continue to change. However, the upstream states will have to consider the needs of the downstream states but first and foremost the downstream states' relative "over-exploitation" will be subject to cross-fire because of these historical developments. The strength behind this pressure, and the downstream states' alternatives to the historically developed dependence on water, will most likely influence the course of conflict and the negotiating possibilities. The power balance between the states in the Euphrates-Tigris basin has been radically altered since the Gulf War. Along the Nile watercourse the situation is very unclear, but peace in several upstream states and consequent stability will have an influence on the water question and the relative power structure between the states. (3) A third variable is the general trust that exists between the states along the watercourse. "Hard" hydrological facts such as annual water flow, seasonal variations and velocity of flow become "soft" political issues due to inability to carry out rational, multipurpose and optimal planning. Jordan, Syria and Israel's utilization of the Jordan watercourse is not only more expensive, but also has greater long-term, detrimental side effects for the agricultural potential of the entire area than other, technically more productive solutions for all the watercourse states.

For different reasons it is the Arabs who have populated the downstream areas and live there today. Panarabism may become a "question of survival" for states and nations in a period when the struggle for fresh and adequate water most likely is taking a new turn. Under such a new world order determined by nature's role rather than President Bush's "visions," Panarabism may become "The Association of the Thirsty." Their tragedy is that central Arab states will be dependent on the non-Arab world's goodwill. Turkey is the "water tower" of the Euphrates-Tigris water system. The country controls large parts of the water supply of downstream Arab states. Geographically, Ethiopia has the same role and position on the Horn of Africa; it controls the sources of the Juba and Shebele rivers in Somalia, as well as the Atbara, the Sobat and the Blue Nile which, together, contribute more than 85% of the Nile's annual volume of water. However, Ethiopia has nothing approaching Turkey's economic, political or military strength, and especially not compared to their downstream states. Egypt is the great power of the Nile watercourse, but the country's geopolitical location is vulnerable. This pattern of distribution of population and cultures within the river basins might bring an additional dimension to the conflict/cooperation potential.

"No water, no Arabs" said the British explorer and imperialist Samuel Baker to the British public nearly 110 years ago (Baker, 1884, p. 8). He was referring to Egypt's vulnerable position, and argued that if the British took control upstream, they would also control Cairo and the Suez Canal and subsequently the sea route to India. Baker himself did not believe it was technically possible to channel Nile water to the desert in northern Sudan (Tvedt, 1986, pp. 124-130) and nor was it at that time, but technological developments have made such interference possible. In 1924, the British were able to establish the largest cotton plantation in the world in arid northern Sudan by using water from the Nile. Today it is technically possible for all upstream states to utilize greater volumes of water than it was only ten years ago.

The combination of the rivers' multinational and multiethnic character, together with technological developments have led to constantly greater complexity in water planning and water utilization. Planning on a solely national scale has proved to be obsolete. There are innumerable examples of how decisions made for water utilization and water development in one country have had decisive consequences for the development potential of another country along the same watercourse. Decisions made in Ankara have already had direct consequences on the life of the poor farmer on the Euphrates' plains in Iraq. In a similar manner, decisions in the Knesset have indirectly influenced the water situation in Amman. Experience from water utilization agreements for the Nile (1929 and 1959) has shown that "just" agreements on water distribution at a particular time will have a tendency to become obsolete and be regarded by some partners to the agreement as unjust a few decades later. "You can't step twice into the same river," said Heraclitus. In the same way it may be said that parties to a water sharing agreement may consider it just today, but unjust tomorrow, because the river has changed and the water demands have developed. The development of western societies and of countries in Asia and the Middle East has shown that development goes hand in hand with increased consumption of water and the development of more water consuming sectors. No leaders in the Middle East can avoid this water challenge, or what is called the "hydrological imperative."

It has proved so difficult to establish conventions and laws for the joint exploitation of rivers that it has been impossible for the international community to agree about quite general guidelines.[21] As a rule, the main conflict in the negotiations has been between upstream and downstream states, because there is a real, enduring, non-ideological conflict of interests. In legal terms, this conflict has tended to be expressed in variations of two mutually exclusive and contradictory legal principles. On the one hand the supporters of absolute integrity and river basin unity argue that no riparian may significantly effect the quantity and quality of the water for downstream users. On the other hand the upholders of absolute sovereignty argue that a riparian has the right to exploit the waters passing through a nation's territory. The problems are intensified by geographical conditions created by nature, and, as a rule, these coincide with deep cultural, historical and ethnic antagonisms. In the Middle East particularly, this is the case: in the Jordan valley, Jew against Arab; in the Nile valley, African against Arab, Christian against Muslim. And along the Euphrates-Tigris watercourse, the thousand-year-old antagonisms between Turk and Arab; and until World War I, between the centre of the Ottoman Empire and the former Ottoman outposts.

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21. An indication of how complicated and confusing the negotiations have been is given in FAO (1980), ILA (1967), ILC (1981), United Nations (1977 and 1980). See also Garretson, Hayton and Olmstead (1967), Falkenmark (1986 and 1990). In a local study of South-West Arabia (Maktari, 1971), it is shown that regarding water rights within the tradition of Islamic law, different interests may appeal to different and conflicting aspects of the established law practices.

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Water Security: The Missing Link in our Mideast Strategy

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ABSTRACT

This paper discusses the growing water scarcity in the Middle East region. The interrelatedness of the region's water resources makes cooperation imperative but, unfortunately, the countries involved have a poor record of regional cooperation. Four examples are discussed: the Nile river basin, the Persian Gulf region, the Jordan and Yarmuk river basins, and the water-rich areas of Lebanon and Turkey. Finally, the growing awareness of the issues, together with some initiatives to tackle the problems are presented.

RÉSUMÉ

Cet article aborde le problème de la pénurie d'eau à laquelle font face les pays du Moyen Orient. Les ressources en eau de la région étant intimement reliées, la coopération entre pays est un impératif. Malheureusement, les pays concernés ont connu des problèmes à cet égard. L'article discute quatre exemples : le bassin du Nil, la région du Golfe persique, les bassins du Jourdain et du Yarmuk, ainsi que les régions riches en eau du Liban et de la Turquie. Il conclut par des observations sur la prise de conscience actuelle du problème ainsi que sur des exemples d'initiatives qui ont été prises pour faire face à la situation.

INTRODUCTION

The Middle East water crisis is a strategic orphan that no nation or international body seems ready to adopt. In spite of irrefutable evidence that the region is approaching dangerous red lines on water availability and water pollution, the halls of western leadership have so far failed to treat the issue as a strategic priority. Yet, when the current Gulf crisis ends, the crisis could erupt. The intensifying security

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issue requires sustained policy attention, as well as new bureaucratic and consultative structures.

As early as the mid-1980s, U.S. government intelligence services estimated that there were at least 10 places in the world where war could break out over dwindling shared water resources — the majority in the Middle East. Jordan, Israel, Cyprus, Malta and the countries of the Arabian Peninsula are sliding into the perilous zone where all available fresh surface and groundwater supplies will be fully utilized.

Morocco, Algeria, Tunisia and Egypt face similar prospects in 10 to 20 years. Morocco's achievements in the water and sanitation sectors are unparalleled in Africa. Still, the country confronts the prospect of a declining water supply beyond the year 2000, when its current population of 24 million is projected to reach 31 million.

Israel, the West Bank and Gaza, Jordan, the Republic of Yemen, Saudi Arabia, in the Middle East, and Algeria and Tunisia in North Africa, are already facing a "water barrier" requiring accelerated efforts, investments, regulations and controls just to keep apace of spiralling population. Middle Eastern and North African countries combined will absorb 400 million people by the close of the 1990s, pitting the Davidian capacity of existing water and sanitation services against the Goliath of demand.

The human toll translates into tragic statistics. UNICEF reports, for example, that 35,000 children worldwide are dying daily from hunger or disease caused by lack of, or contaminated water — a major percentage on the African continent. At the turn of the century, almost 40% of the African population will be at risk of death or disease from water scarcity or contamination. Egypt, the Arab pillar of the Mideast peace process, will hardly be immune.

Yet, contrary to popular assumptions, the Middle East and North Africa region are not confronting overall water shortages. Water consumption for all uses is still less than available freshwater. The challenges are water availability at an acceptable cost in places where it is most needed and vastly improved management of existing water resources.

According to the World Bank, the region has the highest median cost of water supply and sanitation in the world — capital costs reaching a median of $300 per capita in 1985, about twice those in the United States and more than five times the costs in Southeast Asia. The expert community well understands that the region cannot afford to expand sector coverage at current exorbitant figures, while attempting to stay apace with population growth rates.

Israel, Jordan and Tunisia are the only countries in the region that have instituted tariff systems for municipal and industrial water use; Israel is the sole country that also charges a reasonable tariff for irrigation water. The minimal fees levied by other Middle East nations do not recover even the costs of operation and maintenance. Gulf states are also exhausting strategic ground water reserves for the production of crops that could be imported at a lesser price.

But efficient pricing and internal management alone, without effective cooperation between countries, still will not resolve the Middle East water puzzle. Why, for example, should the Gulf states be using their finite oil and gas energy to distill water when regional waters are flowing freely into the ocean? These nations could be rechanneling oil funds to pay poorer countries for available water, while saving their energy and our global inheritance for world prosperity.

Moreover, with Middle East population growth rates averaging a staggering 3%, the mere prospect of over-flowing sewage could bring Middle Easterners to loggerheads. The annual wastewater collected from the Greater Cairo area, alone, is equivalent to the total amount of water used for domestic, industrial and irrigation purposes in Jordan. Short of regional cooperation over water and waste management, the intelligence services of the Middle East could eventually be dealing with sewage as catalyst for armed conflict.

Every nation in the Middle East is linked to another by a common aquifer subject to overwithdrawal or overcontamination. Saddam Hussein's rationale for invading Kuwait was the latter's overpumping of shared oil reserves. How long will it be before aquifer conflict becomes common terminology in the lexicon of Middle East specialists?

I. NILE RIPARIANS SHARE EGYPT'S LIFELINE

"The only matter that could take Egypt to war again is water," declared President Anwar Sadat in the spring of 1979, only days after signing the historic peace treaty with Israel. His unveiled threat was not directed to Israel, but at Ethiopia, the upstream riparian that controls 85% of the headwater of Egypt's life line, the Blue Nile.

A decade of drought in East Africa depleted the Nile waters, literally Egypt's life-line. The river provides 86% of the 158 billion gallons of water used in Egypt each year. During the summer of 1988, the Nile dropped to its lowest point in a century, forcing Egyptian authorities to turn to Lake Nasser reserves to relieve the desperate water situation.

The crisis underscored the economic life-or-death implications for Egypt of a continuing decline in Nile waters. Tourism revenues will be threatened, as hotels are unable to obtain water for drinking and sanitary services. Leisure vessels will not be able to navigate the river. Oil export revenues could dry up, as petrol is diverted to generate the 28% of the country's power normally driven by the Nile.

Egypt's food production could be crippled as almost all of its farming depends on Nile flood irrigation. Egypt is already importing approximately 50% of its food requirements, and an increase in imports would further burden its strained economy. Relaxing state subsidies on food prices is hardly a politically attractive choice, given the food riots President Mubarak faced when he tried to comply with International Monetary Fund austerity measures.

Yet, while regional supplies are falling, Egypt's water needs are increasing at an alarming rate, given the country's astonishing population growth, projected at 75 million by the year 2000. The last nation along the path of the Nile, Egypt has little control over the actions of eight upstream governments. Boutros Ghali, Minister of State for Foreign Affairs, maintains that the "national security of Egypt is...a question of water."

In September, 1989, Dr. Ghali sounded the water alarm to Members of the U.S. Congress. Dr. Ghali's eloquent, but dismal projection of Egypt's water future bears repeating. He forecasted that if present circumstances continue, Egypt and Sudan will experience a severe deficit in water resources by the year 2010, both requiring five billion cubic meters per year. Egypt has almost no rain — and only 50% of Sudan's agriculture is irrigated by rainfall.

The other riparian countries of Lake Victoria — Uganda, Kenya, Tanzania and to a certain extent Rwanda — will require a similar amount of water, meaning at least 10 billion cubic meters per year in the next two decades. "What is worse is that each Nile country expects different benefits from the control and management of water resources," Ghali stated. "The other African countries have not reached the level of agriculture through irrigation that we have, and therefore are not as interested in the problem of water scarcity. It is the classic difference in attitudes found among upstream and downstream countries, which share the same international river."

Even in the best of circumstances, most of the Nile countries will be unable to generate sufficient capital to finance critically needed water storage and management projects without massive assistance from donor nations and lending institutions. The foreign debt of Africa is approximately 240 billion dollars, with Nile Basin countries sharing at least 80 billion dollars of that burden.

"We know it will be impossible to get assistance from international organizations and donor countries unless we have not only stability, but also a consensus among us, and we are trying our best to achieve these goals," Ghali emphasized. Despite years of efforts, however, there is still no formal protocol for a Nile water sharing plan. Ethiopia is torn by internal insurgency, as is Sudan. The Ethiopians also have enduring fears that Egypt is attempting to "steal our water."

Nevertheless, the framework for a comprehensive Nile basin plan does exist. Egypt succeeded in forming a consultative group comprised of all the riparian countries, entitled the "UNDUGU" Group, or "fraternity" in Swahili. In recent UNDUGU planning meetings, the Egyptians presented a promising long-range scheme for tapping the Nile to generate massive electric power for export to other regions in exchange for hard currency — which in turn would be used for water and irrigation projects in the Nile countries.

Specifically, according to the Egyptian plan, the electricity produced by the upstream Inga Dam in Uganda would be linked by transmission lines to the downstream countries including Egypt, and beyond to Jordan, Syria, Turkey, and the European community. Additional hydroelectric dams are envisioned in the Sudan, in Zaire on Lake Mobotu, and in Uganda on Lake Albert, all of which would feed into the intercontinental grid. Pollution-free energy would be sold to the north, as a quid pro quo for capital development funds. A plan of such scope and vision may be the only way to finally bring the nations of the world's longest river to a water-sharing agreement.

By invading Kuwait, Iraq also forged a link between Egypt's water security concerns as an African nation and its Middle East national security agenda. The Kuwaiti Fund and Gulf financial institutions announced in July a commitment to underwrite Egypt's North Sinai agriculture project, designed by the United Nations, at an estimated cost of $1.3 billion.

Egypt is desperately searching for means to expand human settlement in the Sinai, to lessen the staggering population burden on Cairo, Alexandria, and other smaller-but-burgeoning cities. Ninety-seven percent of Egyptian territory is barren desert, with 52 million Egyptians concentrated in 3% of the land. Egypt also gains an additional one million in population every 10 months. The feared loss of Kuwaiti and Gulf assistance to make the desert bloom, was perhaps yet another provocation to rally Egypt to the American side in the crisis.

II. WATER SECURITY IN THE GULF

The fact is that water security will soon rank with military security in the war rooms of defense ministries. Strategic coordination of Saudi Arabia's water supplies, in particular, is crucial for the defense of the Kingdom. Sixty percent of the world's desalination capacity is in the Persian Gulf. Saudi Arabia's desalinated water, alone, is about 30% of the global production, while Kuwait and all of the other Gulf states are almost totally dependent on desalting plants for their fresh water supply.

The Saudis secretly worry that their immense desalination plants, the size of small cities, will become targets for aggression. Indeed, every one of the Gulf states is strategically vulnerable to any power that succeeds in attacking or disrupting their desalting capability. Short of war or terrorist actions, however, even the accidental explosion of an oil tanker would have dangerous intake consequences for Gulf desalination plants.

Saudi Arabia's concerns over water became a priority for the U.S. government when faced with maintaining several hundred thousand thirsty American troops in the Saudi desert. The price the United States would pay to ship water to its troops is at least 10 times the price of oil. Theoretically, the Water Resources Management Action Group (WARMAG), an interagency group under the direction of the Department of Defense, plans for the provision of potable water to troops in the field. In practice, the Defense Department has so far relied on bottled water plants in Saudi Arabia and the United Arab Emirates.

The U.S. also shipped portable desalination units to Saudi Arabia, as well as massive ice-makers to supplement an overstressed factory in Bahrain. Water tankers were given as high a priority on military aircraft as armour or weaponry, a special reserve unit dealing with water supply was activated, and American experts were assigned to identify water sources in unpopulated areas close to the Kuwaiti and Iraqi borders. Nevertheless, the Iraqi crisis has not led to an integrated plan for sustainable water supply for strategic defense planning in the region.

According to Edward Badolato, former Deputy Assistant Secretary for Energy Emergencies at the U.S. Department of Energy, the U.S. government "is doing nothing" to anticipate sabotage of pumping stations, treatment plants, pipelines, or dams in the Middle East. Over a thousand terrorist attacks were directed against energy targets around the world last year. The U.S. Corps of Engineers, which built a 4000 airman camp in Saudi Arabia with state of the art engineering, has developed defensive security plans, relative to domestic facilities, but not internationally. "We're not equipped to deal with it," said Badolato, "We haven't focused on the water problem. We're barely capable of focusing on oil."

Water, communication, and transportation are fundamental to economic survival, with energy as the common denominator. Leon Awerbuch, manager for Power and Desalination with Bechtel, points out that almost all of the desalting plants in Saudi Arabia and Kuwait are dual purpose power desalination facilities. Moreover, the majority of water used for Gulf petrochemical production derives from desalination. The more important works in Saudi Arabia, as in other Middle East countries, are loosely ringed by troops and checkpoints — and even equipped with a few missiles — but the overall level of protection, insists Badolato, is no more than the security provided to postal or telephone systems.

III. JORDAN AND YARMUK RIVER BASINS: THE ISSUE OF JUST ALLOCATION

In May, 1990 Jordan's King Hussein issued a warning to Israel on Jordanian television. "The only issue that will bring Jordan into war again is water," he said. Water sharing between Israel and Jordan has remained relatively stable for the last several decades, even during the worst days of the 1967 and 1973 wars. Thus Israeli government authorities initially dismissed Hussein's sweeping July declarations as a ploy to open up the pipeline of desperately needed Arab aid assistance. Still, there was a sense of foreboding that the King would resort to the water issue to inflame public opinion.

It appears, however, that Hussein's wrath may have been directed less at water sharing than at Israeli refusal to concur in World Bank funding for the Wahda (Unity) Dam on the upper Yarmuk River. The dam will regulate the water supply, ensuring sorely needed water relief for the Jordan Valley. But the World Bank, by charter, cannot proceed with financial support unless all riparians to a particular project signature their agreement. Israel has withheld its approval, contingent on being assured of what it deems a fair share of the waters. Because the Yarmuk feeds the Jordan River, Israel's main source of water, the Israelis contend that the Yarmuk project could seriously affect their national security. Fears and counter-fears have resulted in the loss of valuable time in a race against a common crisis, whereas a resolution could benefit all three riparians.

Israel's strategic concern in a political resolution of the Palestinian conflict is underground: specifically the Yarkon (spring)/Tanimin (crocodile) mountain aquifer which lies beneath both pre-1967 ("Green Line") Israeli territory and the West Bank. What is most remarkable about this aquifer is the lack of consensus concerning its geological description.

A variety of Israeli, Palestinian, and foreign experts will contend that 80, 60, 40, or 20% of the aquifer lies under the West Bank — depending on whom you talk to. There may be more than one truth. Theoretically, 70 to 80% of the aquifer is in the West Bank, as well as 70 to 80% of the recharged waters. However, all of these recharged waters flow westward towards the coastal plain and the Mediterranean Sea. Israel pumps the majority of the naturally recharged waters, and has been doing so since the mid-1960s, to sustain its agricultural, industrial and population growth. The West Bank aquifer supplies 25-40% of Israel's waters, while underground resources, waste water reclamation, catchments, saline springs and other sources provide the remainder.

Israelis, both Jews and Arabs, use more water per capita for domestic purposes than West Bank and Gaza Palestinians. Domestic and industrial use combined, however, account for less than 30% of Israel's supply, while agriculture is the primary water villain not only in Israel, but throughout the Middle East. Water absorbing crops like Israeli cotton or Jordanian bananas contribute to export income while ravishing the water supply.

Palestinian experts generally acknowledge, for example, that Israel provides requisite water to the West Bank for domestic and industrial use. They nevertheless claim that Israel refuses sufficient water for agricultural expansion, which is viewed as the life-force of economic viability for the territories. Israeli authorities respond that agriculture has been the primary culprit draining the aquifer's resources.

The agricultural sector supplies 7% of Israel's GNP and drains more than 70% of the country's water. Israeli farmers have been forced to accept a 30% reduction in water over the last year, while Israelis living in the West Bank are prohibited from engaging in extensive farming. Already exploited to dangerous limits, over-use or free drilling by either side will exacerbate salinity and result in irreparable damage to the aquifer.

Israel alone is currently utilizing its water resources at between 15 and 20% beyond their natural replenishment rate, causing water table levels to drop and shallow wells to go dry. The Sea of Galilee, or Knerret, which supplies almost one-third of Israel's requirements, is at the lowest level in the past century. The country's present overall water deficit is equivalent to its normal water consumption for an entire year.

The Gaza Strip, 50% desert, claims only one aquifer. Contamination is reaching a critical level, due to the heavy local use of pesticides and fertilizers, and the lack of services to remove or treat raw sewage in many towns and villages. Over-pumping has also caused seawater intrusion, with the aquifer's salinity quotient continually rising. Gaza's water will be unusable by the year 2000, when its population will number one million.

Israel is laying pipes to pump water to the Gaza Strip from its own reserves. But with an expected influx of between 1.5 and 2 million Soviet Jews arriving in the coming decade—added to an estimated 5.7 million Israelis by the year 2000—there is simply no way under present circumstances that Israel, the West Bank, or Gaza can meet their water requirements, unless Israel reclaims sewage at a faster rate, desalinates water at accelerated rate and cost, or imports water. Israel had almost no rain over the past year. A prolonged drought could easily turn a critical situation into a catastrophe.

West Bank Palestinians obtain their water through pre-1967 wells at no charge, and through the Israeli water carrier for a fee. Israeli authorities contend that Israeli settlers and Palestinians in the territories pay the Israeli Government equal amounts for water. Palestinians charge that water going to the settlers is subsidized by the Israeli Government and that Israelis are sapping more than their fair share of the waters.

Voluminous articles have been written on this subject, and yet, there is no common pool of reliable, neutral data to draw upon. All parties to the conflict—including academics—have thus far tended to present facts, interpret figures, and recycle newspaper reporting according to their own political preferences. The one fact that is indisputable is that the Palestinians have no decision-making voice in their own water future. Yet, ironically, without a comprehensive water-sharing agreement or understanding between Israel, the West Bank, Jordan, and Syria, on the one hand, and Israel and the Gaza Strip on the other, there can be no policy road map to a just allocation scheme.

The parties to the conflict are combatants in micro-quicksand, quibbling about numbers that may or may not be true. The reality is that Israel, the West Bank and Gaza, and Jordan are facing a combined water deficit of 300 to 400 million cubic meters per year, which is aggravated by drought conditions. A way must be found to meet this deficit, at a cost the parties can afford, either through technological applications or importation of water.

Turkish firms have been negotiating with Israel to purchase water from the Manbagat River, which flows in the south of the country into the Mediterranean, near Anatolia. Turkey built a reservoir there seven years ago, which now contains some 1.5 billion cubic meters of water, and the quality surpasses anything available in Israel. According to descriptions of the scheme, water would be transported by floating reservoirs to a special terminal in the south. The water would then be transferred to Israel by flexible barge or floating bag. Israel, however, must come up with approximately $150 million to buy and transport the water, and additional funds to build a terminal to collect the water and to pump it into Israel's water network.

Fact-finding talks between the Israeli Water Commission and Turkish companies that would be franchised by the Turkish Government to deal with the joint venture are still in the preliminary stages. "If the cost of water is too high," said one Israeli authority, "there will be no deal." Meanwhile, adverse publicity and political demarches in the Arab world have also slowed the discussions.

The Jordan and Yarmuk River basins are well suited to integrated development, but all joint schemes proposed have been victim to Arab-Israeli or Syrian-Jordanian enmity. The proposed Unity/Maqarin Dam, which would store and utilize Yarmuk River water otherwise discharged to the Dead Sea, may in fact only buy Jordan a five-year respite from shortages, given the country's 3.8% population growth rate — one of the highest in the world.

Consequently, to meet its growing water needs, Jordan is relying on bit-by-bit solutions, including deeper drilling for groundwater sources, and relatively expensive technologies like drip irrigation. One promising approach is solar-electric-powered pumping and desalination of brackish groundwater in the Jordan River valley south of the Dead Sea; but the up-front capital costs of purchase and installation are prohibitive for a country in Jordan's economic straits. Technology and engineering can help address Jordan's water problems, but regional political cooperation among the local river-sharing states must be achieved to jointly develop and make use of the area's major surface water sources.

IV. ABUNDANT WATER RESOURCES: A SOURCE OF TENSION OR AN OPPORTUNITY FOR PROSPERITY?

Compared with its neighbours, Lebanon has plentiful water resources, which could be shared. Its numerous rivers and underground systems are reliably recharged from ample precipitation, especially snow stored on the mountains. A national water storage engineering and management system could turn Lebanon into a Middle East water haven, were there the vision and stability to bring it to reality. Instead, the country is crippled by severe water shortages in Beirut, sea water intrusion in the coastal aquifer, farm lands neglected for lack of irrigation water, and pipelines and aquifers severely damaged by war.

Turkey, with its abundance of water, is in a position to serve as a balancing political force in the Middle East. Since the mid-1980s, President and then Prime

Minister Turgut Ozal has been championing the concept of a Turkish water peace pipeline to service both Gulf and Near East countries. The proposal is to take water from two rivers which empty into the Mediterranean, the Seyhan and Ceyhan, southward through Syria and Saudi Arabia to the Gulf. Two massive pipelines would supply water to these countries, one to Syrian and Saudi cities, and the other servicing Kuwait, Qatar, Bahrain, the United Arab Emirates and Oman. Altogether the project could potentially bring potable water to over 15 million people at a construction cost of over $20 billion. Local fabrication of prestressed concrete cylinder pipes and other components would generate industries and jobs in the region.

But the "Peace Pipeline", if it can be financed, would take at least 8-10 years to put in place, and financing itself depends upon all the states involved working out a joint water-sharing agreement, which has not been attainable for even individual projects in the past. The Saudis and Kuwaitis continuously rejected Ozal's request for both approval and investment, on the grounds that the price of water delivered through the pipeline would be too high, as compared to desalination.

Senior officials in Kuwait and Saudi Arabia also fear giving the Turks a role in and possible control over their water sovereignty. The pipeline could attract more favourable attention once the Iraqi crisis subsides, although a water carrier that passes through numerous countries would be vulnerable to attack. Regardless of the constraints, President Turgut Ozal has taken the Middle East water issue to a new level of public diplomacy.

Although Turkey is generously endowed with water, controlling the headwaters of the Tigris and Euphrates rivers, 40% of the arable land in Turkey is in southeastern Anatolia where there is a general shortage of water. To alleviate this shortage, Turkey in 1983 initiated the South East Anatolia Development Project (GAP) which is comprised of a series of 13 irrigation and hydroelectric dam sites, including the massive Ataturk Dam. Seven of these sites are located on the Euphrates River and the other six are on the Tigris.

Upon completion, the project will supply approximately 24 billion kilowatt-hours of energy (almost half of Turkey's current energy needs) and open 1.6 million hectares of land to irrigated cultivation. The Turkish government hopes to sell the additional food production to Europe and the Middle East, which is expected to import $20 billion worth of foodstuffs by the end of the century. However, at present levels of investment for the irrigation infrastructure, it could take the Turkish Government more than 50 years to complete the total development program.

The Anatolia Project has stirred the anxieties of Turkey's downstream co-riparians, Syria and Iraq, over the availability of water for their own agricultural and industrial projects. Syria and Iraq fear that the Ataturk Dam could divert most of the Euphrates' flow into Turkey's Urfa Plain, forcing Iraq and Syria into the role of hydrological dependents. Iraq, long concerned about the effects of Syrian development schemes on the Euphrates, is now arguing that Turkey's dam construction will reduce the river's annual flow into Iraq by more than 50%, from 30 to 11 billion cubic meters. Turkish officials contend that Iraq's nightmare is a technical impossibility and that Turkey would also be injured in any attempt to store water over a prolonged period. Once again, the lack of shared technical data and neutral analysis is a glaring omission in the debate.

This past year was the region's driest in a half century, resulting in a significant drop in the level of the Euphrates. In an average year, the Euphrates' capacity is estimated by the World Bank at 31 820 million cubic meters, a quantity which can satisfy the demands of Turkey, Syria, and Iraq. However, in 1989 the discharge fell to 16 870 million cubic meters, causing serious water shortages in all three countries.

The drought depressed Turkey's economy, but Syria's situation is even worse. The low level of the Euphrates, combined with pollution from Syrian pesticides, chemicals, and salt, has forced the government to cut back on the supply of both drinking water and electricity to Damascus, Aleppo, and several other cities. Damascus is without water most nights, and is estimated to lose as much as 30% of its water from old, leaking pipes.

Unlike Syria, Iraq is fortunate in having access to the less exploited Tigris. Prior to the recent Kuwait crisis, the Iraqi government was planning to invest more than $300 million in over 20 flood control, hydroelectric, water storage and irrigation projects on the Tigris, its tributaries, and Lake Tharther. A major scheme is intended to divert water from the Tigris into Lake Tharther and then into the Euphrates if there is not enough water in the Euphrates to irrigate Iraqi croplands.

Turkey alarmed her downstream co-riparians in early November, 1989 by announcing that it would hold back the flow of the Euphrates for one month, starting in January 1990, in order to begin filling the Ataturk dam. Some Middle East sources suggest that Saddam Hussein read the action as part of a U.S. plot against Iraq. To allay concerns, the Turkish government provided "detailed technical information" to both Syria and Iraq on this water division. In addition, Turkey offered to compensate her neighbours for the month-long loss of Euphrates water by boosting the flow of the Euphrates from November until January.

In a meeting with this writer during the height of the tension, President Ozal emphasized his commitment to resolve water disputes with Iraq and Syria, acknowledging their concerns. "I appreciate their fears," he said, "but we will not harm them. To the contrary, Turkey will more than make up for the water shortage. I have tried to convince Iraq and Syria of our positive intentions." As would be expected, however, Syria and Iraq reacted to the impoundment of Euphrates water with a surge of diplomatic cables, visits, and warnings.

The friction between Turkey, Syria and Iraq over water access can only be defused through an explicit agreement among the three riparians covering water allocations in the Tigris/Euphrates basins. But discussions have dragged on inconclusively since the 1960s. The Trilateral Commission on the Euphrates has met periodically, but has tabled only technical matters such as river flow rates and rainfall data. In the absence of a formal protocol on water basin management and apportionment, the World Bank and other multilateral lending agencies have withdrawn their financing package for the GAP project and related infrastructure.

Meanwhile the downstream riparians are suffering from acute salinity, and none of the parties can meet their development goals. A comprehensive management plan would inherently eliminate Iraqi and Syrian fears, while increasing the generated benefits for all three countries. Continued stalemate and the unilateral construction of new dams, on the other hand, could lead to escalating disputes and armed confrontation.

In 1975, Iraq and Syria came to the brink of war over Syria's reduction of the flow of the Euphrates to fill the Ath-Thawrah Dam, which Iraq claimed adversely affected three million Iraqi farmers. In 1986, there were reports that Turkey uncovered an alleged Syrian plot to blow up the Ataturk Dam, (which Syria views as a threat to its farmers). In 1987, Ankara allegedly hinted at a cut in the flow of Euphrates water to Syria over Syrian support for Kurdish terrorists, an enduring source of tension between the two countries. Syrian MIGs on "a training mission" shot down a Turkish survey plane, well within Turkey's borders, on October 21, 1989. Five people were killed in the incident, which was reportedly linked to Syrian-Turkish tensions over water.

V. AWARENESS OF WATER AS A STRATEGIC CONCERN

In a February, 1985 meeting, Dr. Boutros Ghali launched into a two-hour discourse on the fearsome reality of water scarcity in the Middle East. His prediction, conveyed in an International Herald Tribune op-ed piece, has since become the tolling bell for water awareness in the Middle East. "Water will become a more precious commodity than oil," said Dr. Ghali, "The next war in the Middle East will be fought over water." Rarely, if ever, have two quotes been more often repeated in the international press.

The article, "Egypt is African and Its Principal Problem is Water," drew interest from the inner recesses of the U.S. government. President Mubarak would soon be making a state visit to Washington. Quoted statements by Dr. Ghali and by Ossama El Baz, political advisor to the President, meant that the sensitive issue of water could be placed on the official White House agenda for talks between Reagan and Mubarak.

Such reactions inspired a two-year research project and report to the U.S. government on "U.S. Foreign Policy on Water Resources in the Middle East," (The Center for Strategic and International Studies). The objective was to determine how the American government could best respond to this looming strategic/environmental issue and whether it was prepared to do so.

On a wintry December day in 1987, fierce political foes temporarily set aside their cold and hot wars to share their views with American government officials. Government representatives from Egypt, Turkey, Iraq, Jordan, and Israel addressed 40 American government representatives. Today, such interregional "secret" and "not so secret" meetings dealing with the peace process are occurring with high frequency. A Palestinian colleague describes these conferences as a "booming business." But to think that Middle Easterners were prepared to deal with a shared environmental emergency as early as 1987, still has an unbelievable ring.

Ironically, Members of Congress from water-stressed states also tend to be the least interested in the global dimensions of the problem. So often I've been told by a Senator or Congressman from the South or West, "My constituents would never understand why I'm worrying about water in the Middle East when we have such severe water problems at home."

The U.S. government, through its many departments and agencies, has undertaken extensive water technical assistance programs throughout the world. Projects for every conceivable purpose have been designed and implemented, including waste water treatment plants, dams, feasibility studies, training programs for regional experts, and the like. The quiet pool of dedicated water-related talent all but hidden in the recesses of the U.S. government would mark the United States as a leader in the global effort to respond to the emergency, if only there was the will to lead.

Although there is a remarkable depth of expertise and concern throughout the various agencies, unfortunately, there are scant resources for the most compelling action priorities, including: coordination between U.S. government bodies and other donor governments and institutions, improved data collection in the field, accelerated training programs for Middle Eastern and African water specialists, or investment in breakthrough technologies. We have the talent, but not the means or will to demonstrate significant global leadership.

In 1987 Mr. Peter McPherson, then-administrator of USAID and later under-secretary of the Treasury, noted that the "development of water resources is a critical foreign policy issue for the United States." McPherson was a lone environmental visionary on the American foreign policy stage. Three years have passed, his message on water has not yet caught the attention of those American men and women who have the political power to change the course of human events.

Despite well-intentioned efforts, federal departments rarely undertake comprehensive, anticipatory planning on water challenges abroad. American experts are in the vanguard in developing conflict resolution techniques on water sharing. Yet, no single agency has definitive responsibility, let alone an adequate, Congressionally-authorized budget to carve a foreign policy niche for water. Thus, in place of a macro approach to the water dilemmas of the Middle East, the United States continues to rely on ad hoc responses. The U.S. Agency for International Development has spent billions of dollars on regional water projects, but there is a vacuum with respect to clearly defined, all-encompassing foreign policy objectives.

The most constructive future approach by the United States and other donors would be to highlight water resource management as integral to regional security and stability. This would mean restructuring water resource policies and institutions within Middle East countries, in accordance with plans for integrated economic development. Funds for the water sector must be substantially increased, but on the basis of conditionality. Money for large projects will not ensure stable water futures for Middle East nations, just as past funding for immense pet projects failed to prevent the present crisis.

Grants and loans for the water sector must be conditional on determined efforts to institute appropriate pricing and management policies. The U.S. government must cease to provide piecemeal aid for water projects which have little or no relationship to program planning by other donor institutions and governments. The U.S. Agency for International Development has maintained an informal dialogue with the World Bank over the last decade related to the water sector, which is perhaps more communication than goes on within the various agencies of the U.S. government. This casual approach is ineffective, given the gravity of the situation. There must be systematic coordination among the principle players in the World Bank, the agencies of the United Nations, the United States and other donor governments and funds. Specifically, an office should be created within the U.S. Department of State, reporting directly to the Secretary, which ensures coordination, both among U.S. agencies and with other donor institutions on water resource projects.

The United Nations declared the 1980s as the International Drinking Water Supply and Sanitation Decade. The World Bank and United Nations organizations—notably the United Nations Development Programme, UNICEF, the United Nations

Environment Programme, the World Health Organization and HABITAT, have made a resolute effort to slow the ticking clock. But neither the World Bank, nor any of the major U.N. bodies have the effective political mandate or charter to negotiate water controversies between nations or to dictate appropriate water management. Instead, the most concerned international players find themselves walking a political tightwire leagues above the seas and rivers, with little expectation of a net.

The Decade on Water realized the provision of water installations for 700 million new users and sanitary facilities for 350 million persons. The World Bank and three multi-lateral regional banks—The African Development Bank, Asian Development Bank, and Inter-American Development Bank—marched to the front lines by providing major contributions. But the billions spent on the water sector to date cannot keep up with spiralling population, nor have the funds been linked to foreign policy strategies for sustainable economic growth.

VI. THE GLOBAL WATER SUMMIT INITIATIVE

To respond to this emergency, a Global Water Summit Initiative was launched in January, 1989, to galvanize the highest-level political leadership, both within donor countries and water resource regions, to face their common water future. The inaugural African Water Summit was hosted by President Mubarak of Egypt in June, 1990. Over 40 African nations actively participated in a dialogue for action. The resulting African Water Declaration recognized that through a compact for cooperation, African water and land resources are potentially capable of sustaining several times the present population.

In an effort to respond to the escalating Middle East water crisis, plans have been made for a Middle East Water Summit, to be hosted by President Turgut Ozal of Turkey. The themes of this dialogue will parallel a major new World Bank study on Middle East waters, while also targeting wider regional management issues. The United Nations Development Program will play a central role in coordinating country presentations; the World Bank, agencies of the United Nations and leading donor nations will be instrumental in guiding the event.

The Summit Initiative is directed toward resource management, not political controversy. The survivability of the Middle East will be driven by economic sustainability, no less than politics, in the years ahead. And there is no more compelling resource challenge facing the region than water security.

The Middle East Water Summit, if it takes place in Istanbul, will be the first opportunity for decision-makers to collectively address the need for a comprehensive approach to water management strategy in the Middle East. Its success, however, will be contingent on the readiness of government leaders and the international community to establish the crucial policy linkage and to act decisively thereafter. President Bush, Secretary Baker, their colleagues in the Western alliance, the ex-Soviet Union, and Japan must elevate the water issue to its proper strategic role in future Middle East policy planning.

A senior State Department official stated recently, "Yes, water problems are very interesting. But we're dealing with global warming this year." Leading non-governmental funding groups—reflecting the myopia of government bureaucracies—acknowledge the environmental importance of water, but explain that it is simply not on their agenda. Obliged to await a future year when it is either convenient or trendy to focus on water security, Middle Eastern countries may be beyond the point where our belated attention will stave off disaster.

Richard Armitage, former Assistant Secretary of Defense for International Security Affairs, and currently the United Dam Mediator for the U.S. Department of State, believes that American attention to this security arena is long overdue. "It is time for the United States to acknowledge that the water crisis in the Middle East is worsening and adding an extra dimension to prospective war scenarios," he said in a recent conversation. "Given the long and honourable role played by this country in finding practical, nonpolitical solutions to Middle East water problems, the time may be right for the Administration to organize a long-term, multinational effort in this arena."

The Middle East Water Summit will test the willingness and resolve of the United States and its allies to finally chart a proactive, rather than reactive policy in the Middle East. The Summit is not an isolated event, but the inauguration of a long range, ongoing effort. A principal objective of the Summit will be the adoption of a resolution to establish the Middle East Water Policy Center. As presently conceived, the Water Policy Center activities would include: regional policy data collection, policy coordination, project identification, financing, research and development, and energy preparedness. The Centre would also provide a forum for dispute resolution discussions. The Water Policy Center should be under a multilateral donor nation and development institution umbrella.

The financial requirements for such a center to be effective, and requisite investments in water infrastructure and technology to ensure regional water security, are a mere fraction of present expenditures on armaments. In the view of Farouk El Baz, director of the Remote Sensing Center at Boston University, and a member of the Advisory Committee of the UNDP Center for the Environment, the proposed Center would "strengthen coordination of existing institutions." Middle East water resource development will, however, require the "application of innovative approaches and international cooperation."

To the oft-repeated question, "Can interstate water problems be seriously addressed before the larger political questions in the region are resolved," there is only one response. A passive governmental approach to Middle East water scarcity will doom any future peace initiative. Middle East hatred is bountiful. Middle East water is at the point of no return. A creative response to water cooperation could potentially forge a path to peace, but it is no doubt vital to the economic survivability of regional players to be invited to the negotiating table.

Prospective des besoins et des ressources en eau des pays africains riverains de la Méditerranée : contributions du Plan Bleu

JEAN MARGAT*

RÉSUMÉ

Exercice international de prospective, aux horizons 2000 et 2025, de l'avenir de l'environnement en relation avec le développement dans le bassin méditerranéen, le Plan Bleu achevé en 1989 a donné une large place aux confrontations entre les besoins et les ressources en eau, et aux problèmes en conséquence. On en présente les principaux résultats relatifs aux pays africains concernés, du Maroc à l'Égypte : les projections des besoins en eau par secteur suivant plusieurs scénarios de développement socio-économique et de politique de l'environnement, l'évolution des ressources en eau et des conditions de leur mobilisation, la raréfaction des disponibilités et la croissance des charges économiques entraînées par la maîtrise des eaux, les approvisionnements et les adaptations des utilisations qui en découlent, inégalement suivant les pays mais beaucoup plus fortement que dans les pays méditerranéens du Nord. Les marges et les termes de choix de politique de l'eau s'en déduisent.

ABSTRACT

The 1989 Blue Plan, stemming from an international effort to outline future environmental issues for the year 2000 and beyond, outlined, amongst other things, the confrontations between the countries in the Mediterranean Basin regarding their needs for water and the existing water resources in the region. This paper presents the main outcome of this Plan for the African countries that are involved, from Morocco to Egypt. It outlines projections of water needs by sector according to various scenarios of socio-economic development, the evolution of water resources and the condition of their mobilization, the increased scarcity of and increase in the

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costs of controlling and managing water resources, the uneven supply and adaptation of the uses depending on the countries involved.

INTRODUCTION

Opération intergouvernementale des pays riverains de la Méditerranée lancée en 1977 sous l'égide du PNUE (Nations-Unies), le Plan Bleu a exploré l'avenir de l'environnement dans l'espace méditerranéen (mer et régions littorales) en fonction des formes et des forces du développement socio-économique, ainsi que les incidences de l'état de l'environnement sur les conditions du développement. Il a visé à mettre en lumière les effets possibles des différences de prise en compte de l'environnement dans les politiques économiques et les options d'aménagement du territoire, sans ignorer les incidences des évolutions dans le reste du monde sur un domaine méditerranéen très ouvert.

Cet exercice de prospective aux horizons 2000 et 2025, s'est basé sur la méthode des scénarios : jeux d'hypothèses cohérentes, assez contrastés, sur l'évolution future des facteurs les plus déterminants (démographie, croissance économique, degrés d'intégration des économies nationales, politiques d'environnement), à partir des situations présentes.

Au cœur des interactions entre le développement et l'environnement, l'eau a été un des objets essentiels des analyses et des évaluations du Plan Bleu. Un effort particulier de prospective des ressources et des besoins en eau, et des problèmes qui découlent de la confrontation des unes et des autres a été entrepris. Les aspects quantitatifs et qualitatifs ont été également traités, mais seuls les premiers ont pu faire l'objet de chiffrages globaux.

Il a paru opportun de présenter à ce premier congrès mondial des ressources en eau organisé par l'Association internationale des ressources en eau (AIRE) en Afrique, l'essentiel des résultats de l'exercice de prospective du Plan Bleu relatifs à l'eau focalisés sur les pays africains riverains de la Méditerranée.

I. PROSPECTIVE DES BESOINS EN EAU

A. INDICATIF PRÉSENT

Afin d'ancrer la prospective des demandes sur un état initial, un tableau de données sur les utilisations d'eau actuelles dans les pays méditerranéens a été dressé en 1988 d'après les sources les plus récentes possibles, à des dates de valeur toutefois non synchrones (entre 1980 et 1985 le plus souvent, parfois avant 1980). Le tableau 1 réunit ces données « macro-hydroéconomiques » qui sont inégalement complètes et précises, et résultent de modes d'estimation non homogènes. Soulignons seulement quelques faits dominants :

- Globalement, les prélèvements sollicitent surtout les eaux superficielles (84 %), mais la part prise aux eaux souterraines est souvent forte, voire dominante, dans quelques pays (Tunisie, Libye).
- L'agriculture (irrigation) est partout le principal secteur d'utilisation en prélèvements et encore plus en consommations finales.

Tableau 1

Utilisation de l'eau dans les pays méditerranéens

1	2	3	Demandes en eau globales $10^9 m^3$/an					Demandes en eau sectorielles $10^9 m^3$/an			Consommations finales par secteur $10^9 m^3$/an			15	Ratios m^3/an	
			4	5	6	7	8	9	10	11	12	13	14	Σ 12 à 14	16	17
Pays	Date de valeur (pour l'ensemble des données)	Population M hab	Prélèvements en eau superficielle	Prélèvements en eau souterraine	Prélèvements en eau totaux 4 + 5	Demandes sollicitant d'autres sources d'approvisionnement	Demande totale 6 + 7	Production d'eau potable alimentation des collectivités	Industries non desservies	Agriculture (irrigation)	Collectivités desservies en eau potable	Industries non desservies	Agriculture (irrigation)	Consommation finale totale	Demande per cap. 8/3	Consom. per cap. 15/3
Égypte	~1985	46,7	~52,4	~3,4	52,9	3,5	56,4	3,7	3	49,7	0,42	0,3	~38	~39	1208	814
Libye	1985	3,6	—	2,12	2,12	0,5	2,62	0,72	—	1,9	~0,2	—	~1,5	~1,7	728	583
Tunisie	1985	7,1	1,06	1,23	2,3	—	2,3	0,23	—	~2,1	0,1	—	~1,3	1,4	324	204
Algérie	1980	18,37	1	2	3	0	3	0,7	0,15	~2,15	0,2	0,005	~1,7	~1,9	163	109
Maroc	1985	22,1	8	3	11,0	0	11,0	0,7	0,3	10	0,15	0,02	6,0	6,2	498	280

— L'alimentation en eau potable des collectivités prend des parts variées : de 25 % en Algérie et Libye à moins de 10 % dans les pays à irrigation massive.

B. Méthode exploratoire

La prospective à long terme des demandes ne peut procéder ni de la simple extrapolation des tendances d'évolution du passé récent, ni de l'application de taux de croissance aux demandes actuelles. Trop de facteurs de demande varient chacun pour leur compte pour que des lois simples régissent les évolutions.

Aussi la démarche prospective a-t-elle été menée, séparément pour chaque secteur d'utilisation, par des approches globalisées pour chaque pays et semi-analytiques, en se basant sur des variables « exogènes », c'est-à-dire sur l'évolution des facteurs de demande, présumée différente suivant les scénarios. Par exemple :

— pour la demande en eau potable des collectivités (prélèvements) : populations urbaine et rurale, demande unitaire et taux de desserte respectifs, rendements de distribution;
— pour la demande en eau d'irrigation de l'agriculture (prélèvements) : superficies irriguées, coefficients d'intensité culturale, demande en eau par hectare et par récolte, rendements de transport et efficience d'irrigation.

Ces variables sont néanmoins macroscopiques, exprimées par des moyennes nationales.

Trois des scénarios du Plan Bleu ont été retenus pour la perspective des demandes en eau :

— T2, scénario tendanciel aggravé, prolonge les tendances du passé récent avec une croissance économique faible.
— T3, scénario tendanciel modéré à croissance économique plus soutenue et un meilleur contexte mondial, mais à politique de l'environnement limitée aux palliatifs et aux réparations après coup.
— A, scénario alternatif à croissance également soutenue mais avec meilleure agrégation économique des pays méditerranéens (N-S et S-S) et meilleure intégration des politiques d'environnement dans le développement économique.

C. Résultats

Sans détailler ici les résultats obtenus, relatifs pour chaque pays à deux horizons, trois scénarios, quatre secteurs et à plusieurs étapes des circuits d'utilisation (prélèvements, approvisionnements, rejets, consommations finales en quantités), on présente seulement les sommations par pays entier des prélèvements et des consommations finales calculés (tableau 2). Ils montrent essentiellement que :

— Les plus fortes croissances des prélèvements surviendraient presque partout avec le scénario T3, tandis que les consommations finales s'accroîtraient le plus avec le scénario A (conséquence de prélèvements plus mesurés et d'usages d'eau plus efficients).

Tableau 2

Prospective des demandes en eau totales par pays
Volumes annuels en milliards de m³/an (arrondis)

Pays	Horizon	Prélèvements primaires			Consommations finales		
		scénarios			scénarios		
		T2	T3	A	T2	T3	A
Égypte	2000	58,0	61,5	59,5	43,5	43,3	44,8
	2025	62,5	71,0	69,0	41,5	46,6	51,7
Libye	2000	3,7	3,8	3,0	2,3	2,75	2,4
	2025	4,0	4,3	3,2	2,4	2,9	2,5
Tunisie	2000	2,4	3,0	2,7	1,3	1,8	1,9
	2025	2,8	3,6	3,0	1,8	2,3	2,3
Algérie	2000	4,0	6,2	5,8	2,0	3,2	3,7
	2025	5,3	10,0	8,8	2,8	5,3	5,8
Maroc	2000	11,5	13,0	12,0	5,8	7,7	8,2
	2025	13,0	15,0	14,0	7,8	9,0	10,4

— Les croissances de prélèvements seraient souvent plus rapides jusqu'à l'horizon 2000, qu'ensuite, sauf en quelques pays (Égypte).
— Les prélèvements des cinq pays pourraient totaliser en 2025, suivant les scénarios de 88 à 104 milliards de m³/an, contre 75 actuellement. Mais leurs croissances relatives moyennes, d'ici à 2025, seraient très inégales suivant les pays : modérée (25 à 50 %) en Égypte, en Tunisie et au Maroc ; forte (50 à 100 %) en Libye ; très forte (plus de 100 %) en Algérie.

Ces écarts ne reflètent pas seulement les différences de croissance des besoins, liés principalement à celle des populations ; ils tiennent aussi aux disparités entre les états actuels (retard d'équipement à rattraper en certains pays) ou du plafonnement par la limitation des ressources.

— Les écarts entre les scénarios ne modifient pas les différences d'ordre de grandeur entre les demandes de chaque pays.
— Dans tous les cas de figure, la demande du secteur agriculture (irrigation) restera largement prédominante aux deux horizons. L'évolution des demandes en eau d'irrigation ne sera pas commandée seulement par les nécessités et les objectifs de production alimentaire en fonction de la croissance de population, mais elle sera aussi soumise aux contraintes des limitations de ressource en sol et en eau — notamment en eau mobilisable à des coûts acceptables pour l'agriculture — compensées en partie par le progrès d'efficience d'irrigation.
— Les demandes des collectivités (eau potable) resteront généralement les secondes en importance et leur part relative pourrait grandir sensiblement entre 2000 et 2025 surtout dans les pays à forte croissance démographique (Égypte, Maghreb) : jusqu'à 20 à 30 % des demandes totales.
— Les demandes des industries non desservies et des centrales thermiques resteront négligeables dans la mesure où l'industrie est desservie pour

l'essentiel par les réseaux publics et où les centrales, localisées sur le littoral, sont refroidies par eau de mer.

— Quant aux consommations finales, leur croissance relative serait souvent supérieure à celle des prélèvements (sauf en Égypte et Libye). Elles pourraient globalement augmenter de 40 à 50 % d'ici à 2025, avec les scénarios T3 et A, et totaliser suivant les scénarios de 56 à 73 milliards de m^3/an en 2025.

— Par habitant, les prélèvements et les demandes correspondantes (pour tous secteurs confondus) seraient décroissants, quels que soient les scénarios (sauf en Algérie avec les scénarios T3 et A). Par rapport aux états actuels, ces diminutions pourraient approcher en 2025, 50 % en Égypte et en Libye, 15 à 40 % au Maghreb.

II. ÉVALUATION ET PROSPECTIVE DES RESSOURCES EN EAU

A. Eaux naturelles et ressources

Toutes les eaux présentes et courantes dans le milieu naturel ne sont pas ressources, tant s'en faut. On sait bien que le concept de ressources en eau procède d'un regard évaluateur utilitariste, suivant des critères variés et évolutifs propres aux demandeurs, d'ordre technico-économique, voire écologique. Les données hydrologiques sur les quantités d'eau écoulées ou stockées dans un pays, classées par fréquence d'occurrence, par accessibilité, par qualité, n'en constituent pas moins une base préalable nécessaire pour l'évaluation des ressources en eau, avec l'avantage d'unicité d'estimation, mais insuffisante :

— parce que trop globale dans l'espace, trop moyennée dans le temps et trop exclusivement naturaliste (hydrologique), sans être relativisée à des critères d'exploitabilité;

— parce que la globalisation dans un pays assez étendu néglige les retours d'eau après usage, donc que le flux global estimé devrait en toute rigueur n'être comparé qu'aux consommations finales et non aux prélèvements primaires.

En somme, prendre l'écoulement total d'un pays comme ressources en eau, c'est à la fois trop — car il n'est pas entièrement mobilisable — et trop peu — car une partie est mobilisable plusieurs fois (et cela dépend beaucoup de la structure hydrographique du pays).

B. État actuel des ressources naturelles

Le tableau 3 reprend les principales données hydrologiques globales adoptées par l'exercice du Plan Bleu et qui appellent de brefs commentaires :

— Les ressources renouvelables naturelles, définies par les écoulements formés dans chaque territoire ou issues de pays voisins, peuvent être plus ou moins supérieures aux écoulements sortants réels actuels, du fait des déperditions naturelles et des consommations finales présentes. Ces flux sortant correspondent aux disponibilités théoriques actuelles (moyennes).

— Les ressources en eau pluviale utilisables par l'agriculture non comptées ici sont cependant non négociables, au Maghreb du moins.
— Les flux de ressources d'origine externe (cours d'eau issus de pays voisins) ne sont pas non plus immuables, mais pourraient décroître en fonction de la progression des utilisations consommatrices dans les pays émetteurs.
— Seules les ressources renouvelables en eau douce ont été prises en compte. Bien que non chiffrées, des ressources en eau saumâtre ne sont cependant pas négligeables en plusieurs pays où elles sont utilisables soit comme matière première pour dessalement, soit par mélange avec des eaux douces, soit directement pour certains usages.
— Les ressources non renouvelables (réserves d'eau souterraine extractibles) non mentionnées ici, sont considérables en Égypte, Libye, Tunisie, Algérie; mais leurs volumes exploitables sont évalués sans unicité d'approche ni de critères.

Tableau 3

Ressources en eau des pays méditerranéens

	Ressources en eau naturelles renouvelables (flux moyens annuels d'apport) $10^9 m^3$/an			Flux réel sortant actuel $10^9 m^3$/an		Ressources en eau régulières (comprises dans 4) $10^9 m^3$/an		
Pays	2 Écoulement d'origine interne (flux naturel	3 Affluence de pays voisin	4 Total	5 → Mer	6 → Pays voisin	7 Cours d'eau de surface (étiage)	8 Nappes sout. d'aquifères littoraux à écoulement à la mer	9 Total
Égypte	~1,8	potentiel 56,5 (1)	58,3	~6	0	régulier 55,5 (2)	~0,3	55,8
Libye	0,7	—	0,7	—	0	~0,1	0,1	~0,2
Tunisie	3,75	0,6	4,355	1,1	0	1,38	0,7	~2,08
Algérie	18,9	0,2	19,1	~8,5	0,7	~2	0,7	~2,7
Maroc	30	0	30	~23	0,3	~2,5	1,7	4,2

(1) Écoulement naturel ancien : 85
(2) Écoulement d'étiage naturel ancien : 24

La comparaison des potentialités de chaque pays fait ressortir :

— les disparités des flux globaux, aggravées par les répartitions intérieures tout aussi inégales;
— de grandes différences de structures qui, suivant les pays, concentrent fortement les ressources en un système quasi-unique (Égypte) ou les dispersent en nombreux systèmes indépendants (Algérie);
— la prédominance des flux irréguliers, d'autant plus forte dans les zones les moins pourvues;
— les poids relatifs très inégaux des ressources d'origine externe, donc des degrés de dépendance de pays voisins : négligeable en plusieurs pays (Algérie, Maroc, Libye...), prépondérant en Égypte (97 %) et appréciable en Tunisie (14 %);

— la répartition tout aussi inégale des stocks offrant des ressources non renouvelables, développés surtout dans les régions sahariennes, les plus démunies de ressources renouvelables.

C. Ressources par habitant

Les ressources en eau (naturelles et renouvelables) rapportées aux populations (tableau 4) sont un index commode pour comparer des pays de tailles différentes et révélateur de problèmes.

Tableau 4

Ressources en eau rapportées aux populations

Pays	Ressources en eau naturelles renouvelables per capita en 1985 m³/an)	Densité de population par million de m³/an de ressources naturelles (nombre d'habitants)
Égypte	1 237	808
Libye	195	5 128
Tunisie	610	1 640
Algérie	873	1 146
Maroc	1 369	730
Ensemble	1 102	907

D. Ressources exploitables

L'exploitabilité des eaux naturelles — autrement dit ce qui les qualifie « ressource » — est une notion toute relative, sans unicité ni stabilité d'appréciation, dont les critères dépendent à la fois des objectifs des exploitants et des intérêts de tiers. Des évaluations de « ressources exploitables » (renouvelables) ont cependant été tentées dans la plupart des pays considérés en fonction d'un certain état des connaissances, des besoins et des capacités technico-économiques d'aménagement (de régularisation des eaux superficielles, de captage des eaux souterraines), mais suivant des critères non homogènes (tableau 5)

Tableau 5

Évaluation des ressources en eau exploitables

Pays	Date d'évaluation	Volumes d'eau moyens annuels techniquement exploitables ou mobilisables	Proportion estimée exploitable des ressources naturelles* (%)
Égypte	1979	~55,0	~95,0
Libye	1978	0,6	~90,0
Tunisie	1985	3,8	87,0
Maroc	1980	21,0	70,0

* D'origine interne et externe.

À l'évidence, l'appréciation d'exploitabilité est fortement dépendante du taux d'exploitation réel des ressources naturelles : l'exploitabilité estimée croît en fonction directe de l'indice d'exploitation, donc de la raréfaction des disponibilités, ce qui souligne bien sa relativité.

E. Prospective des ressources

Les ressources de demain seront-elles celles d'aujourd'hui ? À différents égards les ressources en eau, même naturelles, ne sont pas une donnée parfaitement stable à confronter à des demandes, seules variables. Elles sont donc aussi matière à prospective.

D'abord la connaissance des ressources, fruit des études hydrologiques, n'est pas achevée. Les chiffrages dont on a réuni les résultats (tableau 3) pourraient être révisés, généralement en hausse, et la progression de la mobilisation des eaux devrait y contribuer. Une stabilisation des estimations est toutefois à prévoir au début du XXI[e] siècle.

Les ressources considérées exploitables devraient également croître en fonction de la raréfaction des disponibilités, y compris les ressources non renouvelables (révisions en hausse des profondeurs maximales de pompage jugées acceptables).

Les ressources naturelles par habitant — même basées sur des estimations de ressources invariantes — sont évidemment les plus sujettes à évolution en fonction des projections démographiques (tableau 6). Leur prospective est révélatrice de la montée des problèmes dans certains pays.

Tableau 6

Ressources en eau per capita en 2025, en m^3/an, suivant les projections démographiques du Plan Bleu

Pays	Hypothèse de population basse	Hypothèse de population haute*
Égypte	686	600
Libye	70	56
Tunisie	360	310
Algérie	410	338
Maroc	767	667
Ensemble	582	498

* Correspondant au scénario tendanciel aggravé du Plan Bleu.

En 2025, dans les cinq pays cet index serait inférieur à 1 000 m^3/an, seuil jugé critique par différents experts et indicateur de pénurie chronique.

Enfin, à long terme les incidences de changement de climat induits par les activités humaines (effet de serre) sur les ressources en eau ne peuvent être éludées, malgré les fortes incertitudes et la divergence des pronostics des divers spécialistes à ce sujet. Une aridification entraînant une péjoration significative des ressources en eau des pays méditerranéens dans le courant du XXI^e siècle n'est pas à exclure, même si sa probabilité n'est pas calculable.

III. CONFRONTATION ENTRE BESOINS ET RESSOURCES : PROBLÈMES EN PERSPECTIVE

La comparaison entre besoins futurs et ressources totalisés par pays entiers est à l'évidence trop globalisante, surtout dans les pays très étendus. Elle néglige à la fois la structure spatiale et économique des demandes et celle des ressources naturelles, souvent très compartimentée. Aussi les ratios suivants 1) Prélèvements/ ressources = indice d'exploitation, et 2) Consommation finale/ressource = indice de consommation, n'ont que la signification d'index sommaire.

Un indice d'exploitation qui atteint déjà 20 à 25 % signale des nécessités d'effort d'aménagement des eaux dont les charges commencent à peser dans l'économie nationale, ainsi que des problèmes locaux ou conjoncturels probables. Lorsqu'il approche ou dépasse 50 %, il est révélateur d'une forte pression sur les ressources, impliquant une présomption de conflits d'usage et une nécessité de planification et d'allocations prioritaires. Lorsqu'il atteint et surtout dépasse 100 %, il traduit soit un taux assez ample de « remobilisation des ressources » renouvelables, soit une part appréciable prise par les ressources non renouvelables dans les sources d'approvisionnement non conventionnelles dans l'économie de l'eau du pays, ces causes pouvant se cumuler.

À l'échelle d'un pays entier l'indice de consommation traduit mieux en principe la réalité des pressions exercées par les usages sur les ressources, puisque toutes les consommations finales sont additives. Les deux indices diffèrent peu dans ces pays du fait de la prédominance des irrigations, à fort taux de consommation finale parmi les utilisations. Toutefois la croissance à venir de la part des collectivités, à plus faible taux de consommation, va rendre plus utile de distinguer les deux niveaux de consommation, car les ressources « secondaires » réutilisables à ajouter aux ressources naturelles vont augmenter.

A. DISPARITÉS PRÉSENTES

Suivant leur « richesse en eau » (en ressources renouvelables) et leurs « dépenses en eau » (prélèvements) par habitant, les pays de la région se classent en quatre groupes (tableau 7).

Les indices d'exploitation actuels (années 80) sont variés, mais déjà supérieurs à 50 % dans trois pays et à 100 % dans un pays : Algérie, 16 % (mais sans doute sous-estimé du fait de compter comme ressources des « productibilités » à partir de réserves); Maroc, 37 %; Tunisie, 53 %; Égypte, 90 %; et Libye, 300 %.

B. PROSPECTIVE DES TENSIONS SUR LES RESSOURCES

Les inégalités actuelles pèsent naturellement sur les évolutions prospectées des degrés d'utilisation des ressources, qui apparaissent en général sans écart notable

Tableau 7

Classement des pays de la région selon la demande en eau et les ressources existantes

		Richesse en eau		
		très faible <200 m³/an	faible <1000 m³/an	moyenne 1000 à 1500 m³/an
Demande	modérée <500 m³/an		Algérie Tunisie	
en	forte 500 à 1000 m³/an		Libye	Maroc
eau	très forte >1000 m³/an			Égypte

suivant les scénarios en un pays donné, mais très contrastés entre les pays, en aggravant les disparités de situation.

Le tableau 8 indique les indices d'exploitation et de consommation finale des ressources renouvelables que l'on pourrait atteindre en 2025 suivant les scénarios.

Tableau 8

Indices d'exploitation et de consommation (en %)

Pays	Indice d'exploitation	Indice de consommation
Égypte	109 à 124	73 à 90
Libye	457 à 614	343 à 414
Tunisie	64 à 83	41 à 53
Algérie	28 à 52	15 à 30
Maroc	43 à 50	26 à 35

CONCLUSIONS

Dans les pays à disponibilités encore notables et à croissance appréciable des besoins (Maghreb), ceux-ci seront satisfaits d'abord par l'intensification des aménagements classiques de maîtrise des eaux : régularisation et transferts. En particulier, la correction des discordances entre la géographie des ressources en eau et celle des besoins va amplifier les transferts d'eau — en volume et en distance — en sus de ceux déjà réalisés ou en cours dans plusieurs pays, et moyennant des coûts financiers et énergétiques croissants.

L'intensification de l'utilisation des eaux va cependant amplifier aussi des rétroactions négatives sur l'exploitabilité des ressources :

— La pollution des eaux superficielles ou souterraines, qui résulte partout du fait que les efforts de traitement des eaux retournées au milieu après usage ne sont pas à la hauteur des efforts entrepris pour les approvisionnements et aussi de modes d'utilisation du sol par des agents négligeant les effets externes de leurs activités dont ils ne supportent pas les coûts (agriculture intensifiée grâce aux fertilisants).

L'eutrophisation des eaux retenues contribuera aussi à dégrader les ressources exploitables.

— La « consommation » des sites de retenue par l'envasement des réservoirs, dont la durée de vie peut être inférieure à 50 ans. Les capacités de maîtrise des crues risquent donc de diminuer au cours du XXI^e^ siècle, malgré les efforts d'équipement (le « gisement » en sites de barrage d'accumulation s'épuisera) et d'aménagement pour ralentir les comblements.
— La dégradation des productivités d'aquifères et l'épuisement de réserves (ressources non renouvelables), conséquence d'exploitation intensive, voire de surexploitation de nappes souterraines.

Malgré les progrès des aménagements de régularisation, l'ambition d'utiliser une proportion de plus en plus élevée des écoulements moyens rendra les utilisations plus vulnérables aux risques de défaillance, aux sécheresses conjoncturelles.

Enfin, la raréfaction des ressources naturelles disponibles et l'enchérissement de leur mobilisation en conséquence fera évoluer les critères de leur exploitabilité tout en rendant plus compétitives les « ressources en eau non conventionnelles », et en rendant acceptables dans les deux cas les coûts plus élevés. Elle agira aussi, en contrecoup, sur les demandes elles-mêmes qui devront s'adapter (économies d'eau, progrès d'efficience d'usages).

Dans les pays déjà engagés — ou appelés à l'être inéluctablement — dans une « gestion de la rareté » l'économie de l'eau se disjoindra progressivement de la seule exploitation des ressources naturelles : à des prélèvements primaires per capita nécessairement décroissants devront correspondre des utilisations d'eau plus efficientes et séquentielles — la même eau devant servir plusieurs fois — complétés par les recours à des « ressources artificielles » (eau saumâtre ou eau de mer dessalée), les grandes différences de coût entre ces sources d'approvisionnement engendrant de vives rivalités et requérant des arbitrages.

Une « croissance 0 » des demandes primaires sollicitant les eaux du milieu — non seulement en les prélevant mais aussi en les chargeant d'assimiler et évacuer des déchets — non incompatible avec une croissance des quantités d'eau en usage, s'imposera tôt ou tard. Mais plus tôt vaudra mieux pour l'état de l'environnement que plus tard.

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Water Resources Development in West Africa beyond the Year 2000: Problems, Needs and Priorities

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ABSTRACT

West Africa is endowed with abundant surface water resources (in excess of 500×10^9 m^3/yr). However, during this decade, only 24% of the average runoff could be available as live storage in reservoirs. Estimates put groundwater reserves at more than 1500×10^9 m^3, of which a renewable extraction of 165×10^9 m^3/yr could be available , but only a small fraction of this quantity is being profitably tapped. Certain constraints — the high costs of developing water supply sources, persistent drought, population explosion, poor programming and planning, faulty pricing and inappropriate technology — have resulted in water shortages and have prevented a truly sustainable development of the economies of the region. Reversing the above patterns and trends, and forging administrative and technical cooperation among the developing countries of the region — particularly through interbasin water transfer programs — is imperative in order to achieve sustainable development during this decade and beyond.

RÉSUMÉ

L'Afrique occidentale est dotée d'abondantes ressources en eaux de surface (plus de 500×10^9 $m^3/année$). Cependant, durant la présente décennie, seulement 24% de l'écoulement moyen serait disponible sous forme d'emmagasinement dans des réservoirs. Quant aux réserves souterraines, celles-ci sont estimées à plus de 1500 $\times 10^9 m^3$, dont 165×10^9 $m^3/année$ seraient disponibles. Cependant, seule une fraction de ces réserves est utilisée. Certaines contraintes — coût élevé du développement des ressources en eau, sécheresse prolongée, explosion démographique, mauvaise planification et gestion des ressources, technologies non

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appropriées — se sont conjugées pour aggraver la pénurie d'eau et entraver le développement durable de la région. Or, un tel développement ne pourra se faire que si les tendances actuelles sont renversées. Il s'agira notamment de forger des liens de coopération administrative et technique entre les pays de la région et de mettre l'accent sur des programmes appropriés de transfert d'eau entre bassins.

INTRODUCTION

Water resources development in most of West Africa proceeded for a long time in an uncoordinated manner and without any serious attempt to evolve a sound plan to orient the development of this vital resource. As a result of this inadequacy in planning for the region, water shortages have become so acute as to constitute an increasing constraint to the economic growth and development of the region.

A number of pressing needs have made the developing economies of the region aware of the need to develop their water resources based on sound environmental principles. Among these were the expansion of agricultural, domestic and industrial activities, and the ever-increasing population which has an estimated annual growth rate of the order of 3 to 3.5%. Natural disasters in particular have aggravated the poor living conditions of the inhabitants of the region. The Sahelian droughts of 1971-76 and 1984-86 brought about severe losses of crops, animals and human lives and intensified the process of desertification.

The era of a more purposeful attempt at water resources development in West Africa seemingly coincided with the attainment of self-rule in most nations. The first attempts at integrated planning and development of water resources were made during the 1962-68 period when the Lake Chad Basin Commission (four countries) and the River Niger Commission (nine countries) were established to promote coordinated and cooperative water resources assessment, monitoring, development and utilization in these areas of West Africa. This served as the forerunner to the establishment of a nation-wide, comprehensive, multi-purpose planned development of water resources in Nigeria. This step was taken during the 1975-80 Development Plan Period and a Ministry of Water Resources was established in the first year of the plan period. 1976 also saw the creation of 11 River Basin Development Authorities (RBDA's), meant to impart effective regional coordination of water resources planning and development in their delineated areas of jurisdiction. Three of the RBDA's serve the Sahelian zone. Much however remains to be done to improve the programming and planning in all the RBDA's in order to ensure effective implementation of the water resources programs to achieve truly sustainable development.

I. DROUGHT AND DESERTIFICATION IN THE SUDANO-SAHELIAN ZONE

An increasing trend of droughts has been observed in sub-Saharan Africa, particularly in the African Sahel, Ethiopia and southern Africa where it is regarded as a recurring hazard. Much attention is now being given to the long-range effects of population explosion, urban sprawl and rapid social change which cause diverse effects of droughts and desertification to accumulate much more frequently than in earlier times (Vlachos, 1987). When the next drought does come there is every reason to believe that it will be perhaps as bad or even worse than the one before it, because of the vulnerability of these societies which tend to magnify the effects of droughts.

The droughts of 1968-73 and, to a lesser extent, of 1982-84 with their disastrous consequences on the inhabitants of the Sahelian region of Africa compelled people to focus on the problem of drought menace in the African Sahel. The annual rainfall for 1972-73 at the peak of the drought dropped to less than half the average, and approximately 250 000 people died in six Sahelian countries of Africa while millions of refugees poured into cities during the drought. Agricultural production dropped to 70% of the pre-drought level and millions of cattle died as cattle raisers lost 30 to 40% of their herds. In Mali, millet and sorghum production dropped from 830 000 tonnes in 1967/68 to 474 000 in 1972/73. And in Senegal, groundnut production dropped to 570 000 tonnes in 1972/73 from 1 005 000 tonnes in 1967/68 (UNDRO, 1988).

The drought was hardly worse than others that preceded it, but its effects were catastrophic. During 1956-66, Sahelian countries, which had become independent around 1960, were expanding range lands and grain fields towards drier marginal lands, hence the heavy impact. Drought severity is dependent not only on the duration, intensity and geographical extent of a specific drought episode, but also on the demands made by human activities and by vegetation on a region's water supplies.

In the Sudan, the effects of the drought of 1982-84 were more severe, and the impact during the rainy season of 1984 was disastrous. In central and northern Sudan that year's rain was the poorest since the beginning of the century. Some eight million people (40% of the country's population) were said to be affected by the famine that resulted by mid-1985 (Sudan Meteorological Department, 1988).

There is ample evidence that the persistence of the Sahelian drought as a phase of the climatic fluctuation or change has also taken its toll on the water availability, particularly on the reliability of the Niger, Senegal, and Chari rivers as major sources of the West African Sudano-Sahelian region's water. The total annual yield of the Niger into the Kainji Dam reservoir in Nigeria steadily decreased from 51×10^9 m^3 in 1969/70 through the low of 24.5×10^9 m^3 at the height of the drought in 1973 to a new more or less stable level of below 35×10^9 m^3 in 1989/90 (Tables 1 and 2, Fig. 1). The effect of the drought on the flows of the Senegal River is also shown in Table 2 and Figure 1. The river flows for 1984 as percentages of the flow up to 1967 from beginning of observation vary from 16% for the Chari to 28% for the Senegal. The flow reduction is even more severe for smaller rivers such as the Bani. For all four rivers, the post-1967 flow is just about a quarter of the flow for the preceding period. The low value for the Chari has serious implications for the flow of Lake Chad as the former contributes more than 90% of the inflow into the lake (Table 4). This is a major factor contributing to the progressive shrinking of the lake since 1967.

Table 1

Hydrological Evidence of Decreasing Water Availability in the Upper Niger and the Resultant Downstream Effect on Flood Yields

Date	Peak flow in m^3/s at Koulikoro (Mali Rep.)	Black flood peak in m^3/s at Jiddere-Bode (Nigeria)	White flood peak in m^3/s at Jiddere-Bode (Nigeria)	Total annual runoff yield into Kainji Lake ($\times 10^9$ m^3) (Nigeria)
1968/69	7850	—	2386	—
1969/70	5850	1868	—	51.5
1970/71	5720	1868	2604	37.1
1971/72	3800	1906	2446	37.8
1972/73	1280	1690	1878	27.3
1973/74	6260	1571	1570	24.5
1974/75	6830	1872	2850	40.4
1975/76	5060	1990	2307	39.7
1976/77	4100	1882	1428	33.1
1977/78	5510	1497	1682	24.7
1978/79	5920	1797	1759	31.4
1979/80	4510	1935	2222	36.4
1980/81	4660	1566	1589	26.3
1981/82	3730	1721	1752	28.9
1982/83	3600	1481	1760	24.5
1983/84	2420	1369	1376	19.9
1984/85	4500	1190	1283	16.5
1985/86	3700	1354	1886	25.1
1986/87	3020	1297	1573	22.6
1987/88	3714	1596	1211	17.9
1988/89	2380	—	2878	30.2
1989/90	—	—	1744	—

Table 2

Sahelian Water Resources and their Variations

(a) Annual contributions of some rivers (10^9 m^3)

Period	Senegal at Bakel	Niger at Koulikoro	Bani at Douna	Chari at Ndjamena	Total
Up to 1967*	24.7	48.7	22.1	40.4	135.9
Up to 1985*	22.3	46.2	17.3	35.1	120.9
1968-1985	13.7	37.7	8.3	24.6	84.3
1984	6.9	20.1	2.2	6.3	35.5
1984 as % of Beg. of Record to 1967	28	41	10	16	26

* From beginning of observation (see [c] below).

(b) Variation of Average Daily Flows (modules) (m^3/s)

Station	No. of Years	Up to	Mean Module	Max. Module	Min. Module	5 wet Years	5 dry Years
Senegal at Bakel	84	1986	702	1247	215	1027 (54-58)	285 (82-86)
Niger at Koulikoro	81	1987	1428	2300	636	2024 (24-28)	773 (83-87)
Chari at Ndjamena	54	1985	1115	1720	213	1500 (60-64)	533 (81-85)

(c) Flood flows of the rivers (m^3/s)

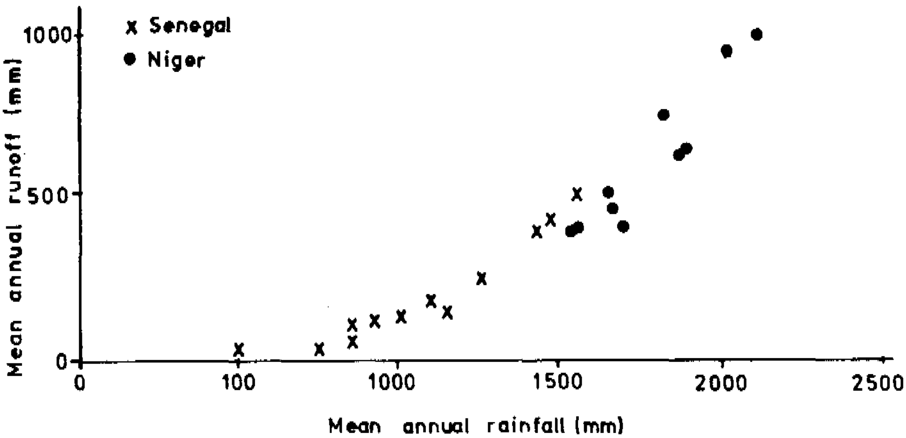
Station	Period	Median	Std. dev.	Years 1913	Years 1972	Years 1984
Senegal at Bakel	1903-86	4200	1815	1040	1430	917
Niger at Koulikoro	1907-87	5880	1410	3580	3830	2400
Chari at Ndjemena	1932-85	3520	924	—	1430	785

Source: Sircoulon, 1990, p. 972.

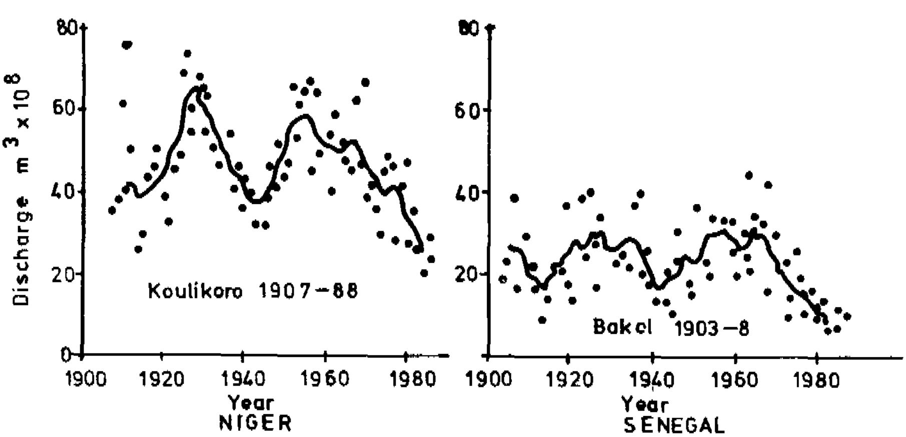
Figure 1

Rainfall and Runoff in the Niger and Senegal Rivers

a) Mean annual rainfall and runoff Niger and Senegal tributaries



b) Annual and seven-year moving mean flows of Niger and Senegal



Source: Sutcliffe and Lazenby, 1990.

Table 3

Water Balance of the Niger River Basin

River	Station	Climate	P(mm)	E(mm)	Q(mm)	Qs ($ls^{-1}km^{-2}$)
Niger	Singuiri, Guinea	Equatorial	1640	1220	420	13.3
Niger	Koulikoro, Mali*	Sub-humid	1550	1155	395	12.5
Niger	Niamey, Niger*	Semi-arid	1094	1013	81	2.6
Niger	Lokoja, Nigeria	Sub-humid	1221	1027	194	6.0
Niger	Mouth, Nigeria	Equatorial	1250	1048	202	6.0

P = precipitation, E = evapotranspiration, Q = runoff, Qs = specific yield.

* In this zone, 55-65% of the Niger's flow is lost by evaporation and infiltration in an extensive swamp of the "Interior Niger Delta".

II. WATER RESOURCES AVAILABILITY AND DEVELOPMENT

A. Climate, Soil Water Balance and Hydrology

The Sudano-Sahelian Zone (SSZ) extends over several countries of Africa, has a rainy season of not more than 2.5 months, and a growing season length of 60-150 days, with a large part having less than 120 days (Fig. 2). Shortage of water in the semi-arid tropics is not just a consequence of poor annual rainfall. The problem of human settlement, particularly for agriculture, the seasonal distribution of rainfall and the rate at which water is "lost" by evaporation, both from land surfaces and natural and man-made lakes, are of great relevance. In humid climates, evaporation is a small fraction of annual rainfall, but in semi-arid regions, it is a major component of the water balance in all years and it is the main mechanism for "loss" in very dry years (Monteith, 1991). Figure 3 shows the daily rainfall and five-day means of estimated daily evaporation for the SSZ together with the predicted daily change in soil water deficit. Because the regional mean rainfall for the exceptionally dry year of 1984 was only 335 mm and daily totals exceeding 20 mm were rare at the stations used, runoff was negligible and soil moisture carried over from 1984 to 1985 should be zero (Monteith, 1991). On the other hand, in 1988 when the mean rainfall was 563 mm, available soil water exceeded 30 mm for much of the season and an excess (238 mm) of rainfall over evaporation implies that water was available for runoff and groundwater recharge.

In its projection to the year 2000, the FAO (1981) indicated that a bulk of the future crop production increases (60%) in the semi-arid regions will have to come from higher yields per unit area of land. Under rain-fed agriculture in the SSZ, where rainfall is low, variable and undependable, increases of crop yields per unit area will depend on making the most efficient use of the limited rainfall, surface flows and groundwater resources (Sivakumar and Wallace, 1991). It is therefore clear that development of management options for sustainable production in the SSZ needs systematic studies of soil water balance to achieve higher water use efficiency in order to manage water resources most profitably for crop production. It is known that two different soils in the same climatic regime may show significantly different water profiles at the time of sowing and at harvest, as Figure 4 shows.

Figure 2

Some of Africa's Principal Vegetation Zones and River Systems

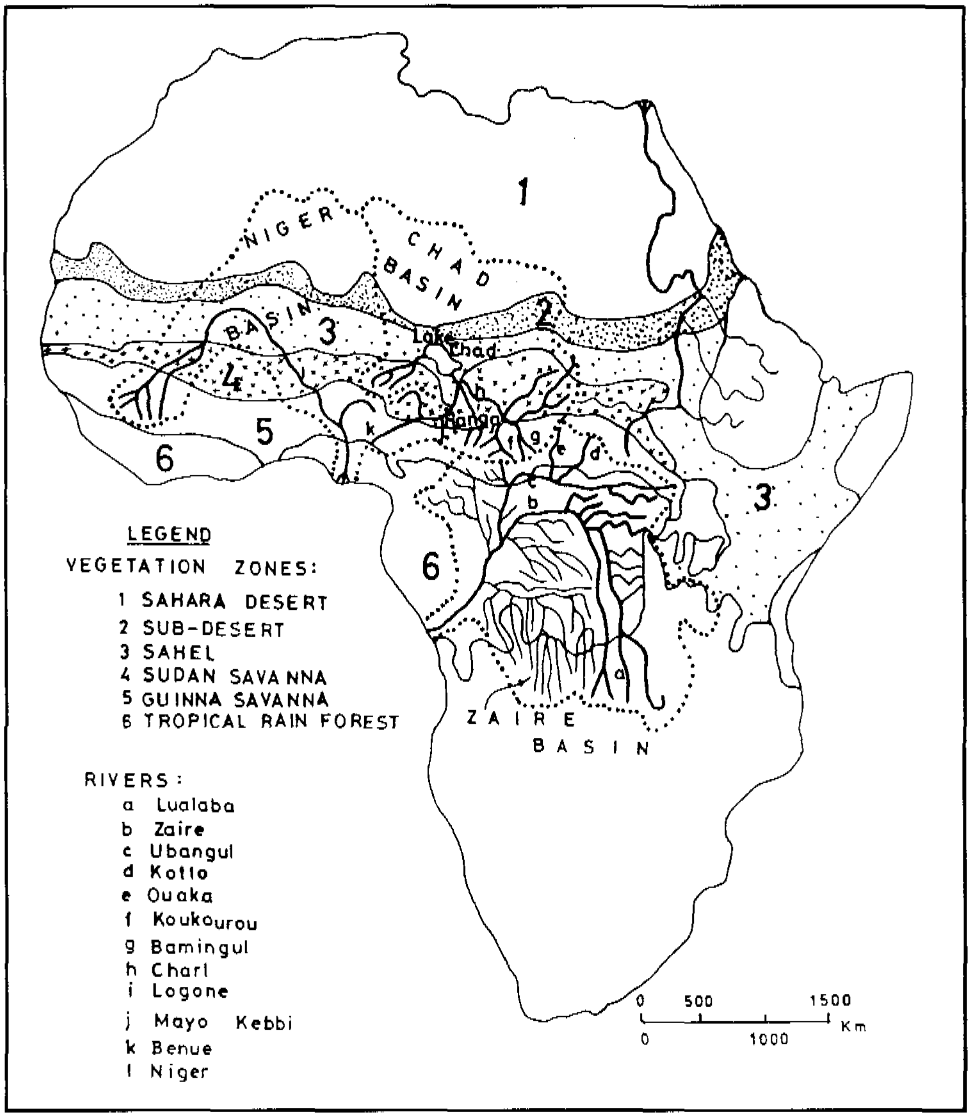
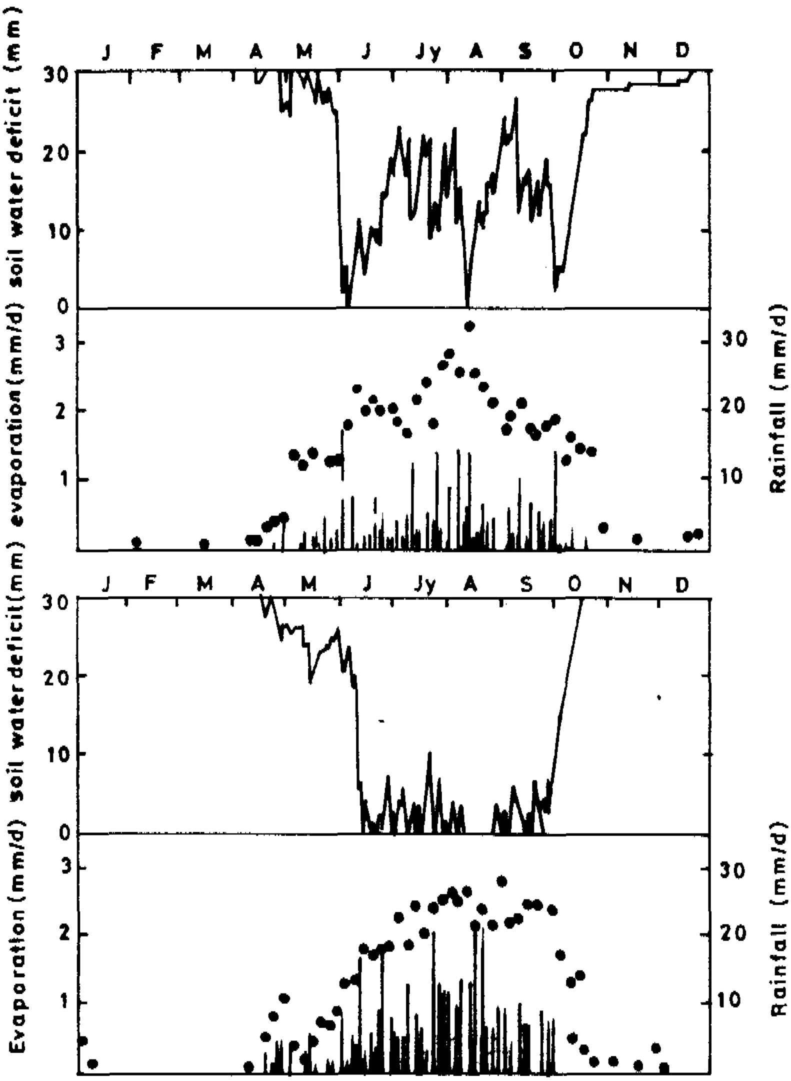


Figure 3

Daily Rainfall and Five-Day Means of Estimated Daily Evaporation for the Sudano-Sahelian Zone (SSZ)

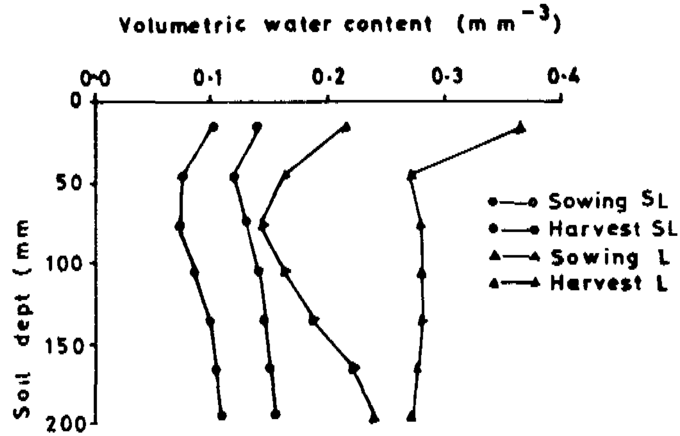


Source: Monteith, 1991.

Note: The lower part of each graph shows the estimated actual evaporation for southern Niger (•). The upper part shows the moisture deficit in soil layer containing 30 mm of water at field capacity. Results are shown for a dry year (1984) and a wet year (1988).

Figure 4

Soil Water Content Profiles



Source: Sivakumar and Wallace, 1991.

Note: Soil water content profiles at the time of sowing and harvesting of millet in two soil types, a sandy loam (SL) and a loam (L), during the rainy season.

Table 4

Inflows Into Lake Chad and Elements of its Water Balance

River	Area 10^3 km^2	Absolute Annual Mean Discharge 10^6 m^3	Relative Discharge %	Specific Discharge ls^{-1} km^{-2}
Yobe	97	380	1	0.12
Ngadda	7	250	0.6	1.22
Yedseram	5	290	0.7	1.96
Ebeji	16	1,700	4	3.33
Chari	600	39,900	94	2.11
Undrained	875	0	0	7.51
Lake Chad	1.6	42,520	100	0.84

Elements of the annual water balance of Lake Chad: Qs-Qg-(E-P)A- S = O

Qs = discharge of rivers into Lake Chad 42 × 10^9 m^3 (3818mm)

Qg = leakage through bottom of the lake 36 × 10^9 m^3 (327mm)*

E = evaporation from the open water surface 2.3 m (2300mm)

P = precipitation on the open water surface 0.4m (400mm)

S = change in storage

A = open water surface area

* Another estimate puts Qg at 20 × 10^9 m^3 instead of ORSTROM's 36 × 10^9 m^3. (It is assumed that there is no groundwater flow into the lake.)

The relation between average rainfall and runoff of the Niger and Senegal rivers with their tributaries shows that flows are derived from limited areas of higher rainfall (Fig. 1). The river systems appear sensitive to both periods and areas of low rainfall. Because of the sensitivity to dry periods long-term flow series of the Senegal at Bakel and the Niger at Koulikoro provide a history not only of river flows but of the climate of a wide region. Figure 1 presents both the annual series and seven-year moving means and illustrates the extremely low flows of recent years (Sutcliffe and Lazenby, 1990).

Table 3 shows the water balance of the Niger River. The river exhibits different regime types and anomalies that reflect climate and physiography of its component basins. From its headwaters in the humid tropical zone of Guinea, it traversed a semi-arid zone between Koulikoro and Niamey as the specific yield indicates.

The discharges of rivers which flow into the inland drainage of Lake Chad are shown in Table 4. It is not surprising that the lake level correlates highly with the fluctuations in the flow of the Chari. The specific yields of the inflowing rivers indicate that more areas of Lake Chad basin experience drier conditions than the Niger basin. Table 4 also shows the elements of the water balance of Lake Chad. Recent isotopic studies have shown Lake Chad as an important source of recharge for the Chad Basin aquifers. This means that the effect of desiccation may be far reaching for many of the communities of the sub-region which at present rely heavily on groundwater.

B. Surface Water

The most important sources of surface water in the West Africa region include the Lake Chad system and the Niger, Volta, Logone, Senegal and Gambia rivers. The Niger is the major river system in West Africa. It drains about 2 million km^2 and encompasses nine West African countries. To ensure the harmonious use and management of the common resources in the Basin, the countries jointly created the Niger Basin Authority (NBA). The member states are Guinea, Mali, Niger, Benin, Nigeria, Côte d'Ivoire, Cameroon, Burkina Faso, and Chad (Fig. 5). The NBA is charged with the following activities, among others:

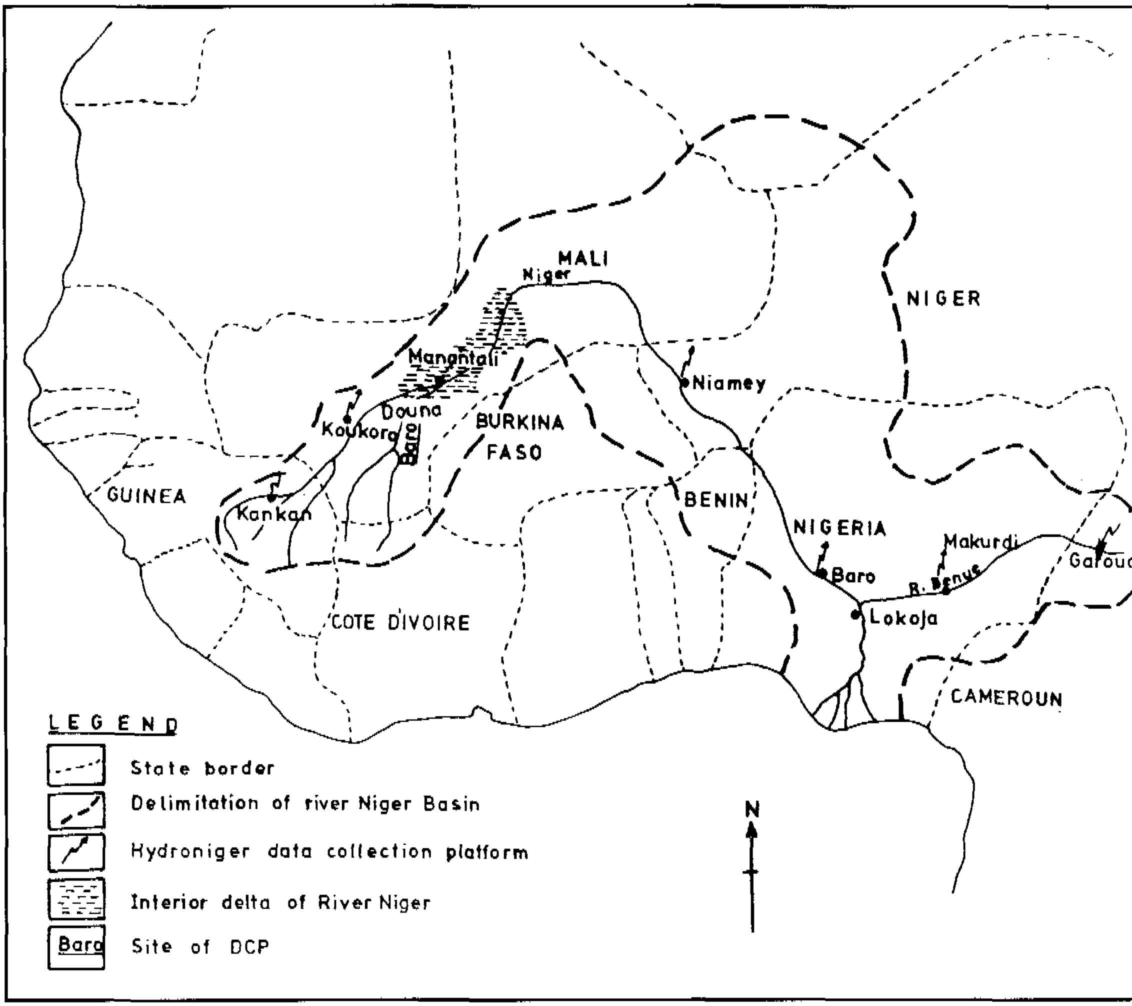
- — collection of regular and reliable hydrological data;
- — control of water resources projects and hydraulic structures on the river system; and
- — real time hydrological forecasting for management and planning.

The Hydro-Niger Telemetric (hydrological network) Project, initiated through the efforts of the NBA in 1970 has become operational. It uses data collection platforms equipped with a teleprinter to collect water level and rainfall data from 67 stations basin-wide which are transmitted to the International Prediction Centre at Niamey as well as the National Forecasting Centre in each member country.

Other projects are present in the Niger Basin. These include four dams: Kainji on the Niger River in Nigeria mostly known for hydropower generation; the Selingue dam on one of Niger's major headwaters, the Sankarani River in Mali, which currently irrigates 2 000 ha of farmland but produces only 44 Mw of electricity; the Markalla irrigation project on Niger River also in Mali that abstracts approximately

Figure 5

West Africa and the Niger Basin



450 m^3/s, from the Niger River to irrigate 60 000 ha, currently the largest in black Africa; and the Lagdo dam in Cameroon, on the Benue River.

Examples of the continuing exploitation of the Niger as a surface water source for water resources development are two proposed projects, the Tossaya and Kandadji projects. The latter is planned to have a large-scale irrigation component of about 83 000 ha and an energy production potential of 40 Mw and water storage of 2.5 to 4.5×10^9 m^3. It is a joint venture of the Mali, Niger, and Burkina Faso governments. There is also the Manantali dam which controls about 50% of the flow down the main Senegal valley. It provides for a regulated flow of about 200 m^3/s allowing over 300 000 ha of irrigated farms in the area. It could also meet most of the electricity needs of Mali, Mauritania and Senegal.

The mean annual total river runoff from the savanna region of West Africa and West Central Africa is estimated at 500×10^9 m^3 (from the Rivers Senegal, Gambia, South West catchments, Volta, Niger, Benue, Lake Chad and the South East catchments). The water storage in dams existing or under construction or identified at sites having a storage of more than 10×10^6 m^3, totals about 400×10^9 m^3. In addition, considerable volumes are stored in small dams. However, the live storage is of the order of 30% so that only a live storage of some 120×10^9 m^3 or 24% of the average total surface discharge would be available on completion of those projects.

As of 1978, some 230 000 ha were under irrigation, while 350 000 ha made up of flood recession areas on the perimeters of large and small dam reservoirs and floodplains (*fadamas*) were available for cultivation. Total water use for agriculture was 10×10^9 m^3 per year (Inter-African Committee, 1978). Planned irrigation development beyond 2000 in the five major basins (Senegal, Gambia Niger, Volta and Logone) totals 885 000 ha.

C. Groundwater

The paucity of surface water sources in the drier parts of West Africa, exemplified by reduced water availability in both the Lake Chad basin and the Upper River Niger, has led to intensified groundwater abstraction for domestic and industrial supplies.

The quantity of groundwater available in any given area has two components: a vast reservoir accumulated over thousands of years when the climate was more humid, and the seasonally replenished storage, if any. When abstraction exceeds annual replenishment as in the case of some deep-seated aquifers, the accumulated reservoir will be drawn down, an occurrence known as mining of the groundwater resources. This is likely to be prevalent in sub-humid regions and in other areas influenced by the Sahelian drought. Doubts now arise as to whether the middle and lower aquifers around Lake Chad are being mined in view of reduced recharge water emanating from Lake Chad (Table 4).

Ahmad (1990) has stated that the Sahelian countries can benefit from the knowledge of deep aquifers in the Libyan Sahara, particularly the Kufra Production Project, the Kufra Settlement Project and the Savir Production Project which have been in operation for over 15 years with designed extraction of water for the Great Man-made River Project, which would transport 2×10^6 m^3 of groundwater daily from the Sahara to the coast.

Figure 6

Major Ground Water Sources of the Sahel

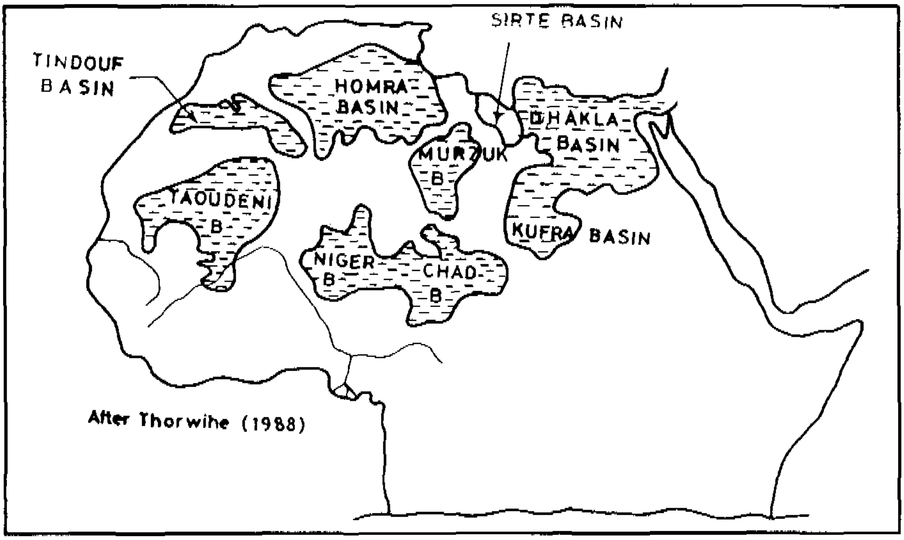


Figure 6 shows some of the huge and productive sedimentary groundwater basins with which the Sahel is endowed. The first is the Taoudieni which extends from Mauritania through Senegal to Mali and is traversed by River Niger. The aquifer is heavily recharged by 3.2×10^9 m^3 per month during the flood season between Koulikoro and Dire, assuming that one half of the losses recharges the aquifers. There is also the Niger sedimentary basin which extends from Niger to include Niger/Nigeria's Sokot-Rima sedimentary basin and continues eastward to link up with the Chad basin formation aquifers. Again, the Chad sedimentary basin is being recharged substantially by Lake Chad as well as by the Hadejia/Yobe River system.

As of 1980, the groundwater development of the savanna and the Sahel region of West Africa was very limited, compared to availability. The total volume of water abstracted from groundwater sources was about 0.5×10^9 m^3 per year, half being required for domestic and industrial purposes and the other half for livestock. The Sahelian countries of Niger, Mauritania, Senegal, Mali and Burkina Faso together with the north-eastern and north-western states of Nigeria obtain their livestock water supply from groundwater. Irrigation from groundwater is limited except in southern Niger where an aquifer is exploited in the Dallo Bosso for growing sorghum and maize.

The order of magnitude of exploitable static groundwater in West Africa is 1500 to 2000×10^9 m^3 with a renewable extraction of 165×10^9 m^3/yr. (Sedimentary reservoirs accounting for 85.5×10^9 m^3 and basement reservoirs about 79.5×10^9 m^3). About 85% of groundwater held in reserve is in the sedimentary basins. The last decade has, however, witnessed increasing exploitation of groundwater aquifers in the vicinities of large urban centres such as Jos, Kano, Maiduguri, Dakar, Lome, Cotonou, Lagos, and other coastal cities as well as thousands of rural communities.

In Nigeria, since the National Borehole Program, including hydrological reconnaissance and inventory as well as geophysical exploration by resistivity sounding, was launched in 1981, groundwater development has increased dramatically. A major constraint to groundwater development in West Africa, however, remains the high cost of both well construction and of pumping equipment. Construction of rural hand-dug wells equipped with hand pumps costs about $5,000 per unit, while that of boreholes equipped with hand pumps, also for rural supply, is about $10,000. For urban supplies which require elaborate pumping and storage facilities the latter figure must be multiplied by a factor of 3 to 4.

III. WATER SUPPLY IN WEST AFRICA

The West African region, as a whole, experiences chronic water problems which are largely off-shoots of inept water resources development planning. The norm has been to concentrate on addressing urban water supply shortfalls while scant consideration is given to the rural areas. This has become somewhat perpetual despite lack of success in meeting set objectives in urban water supply. The neglect of the rural water supply becomes more unacceptable when the large proportion of the population inhabiting the rural areas is brought into focus (Table 5).

Table 5

Population of Africa and West Africa

(a) Total population and growth rates

	Size in million			Average annual growth (%)		
	1980	1985	1987	1975-80	1980-85	1985-90
Total Population (Africa)	452	525	557	3.7	3.0	3.1
Total Population (West Africa)	144	169	180	3.2	3.2	3.4

(b) Rural pollution as % of total population

	1981	1982	1985	1988
Africa	74.5	73.5	72.2	70.8
West Africa	77.3	76.7	75.2	74.0

The U.N. Water Conference convened in 1977 in Mar del Plata addressed the need for wise management and development of water resources as a prerequisite for sustainable development in the developing countries. The conference's eight major recommendations anchored its 10 resolutions which include topics such as water resources assessment, community water supply, technical cooperation among developing countries in the water sector, river commissions, international cooperation in the water sector, and water policies. The subsequent designation of the 1980s as the International Drinking Water Supply and Sanitation Decade (IDWSSD) was a follow up in the area of community water supply.

At the beginning of the decade in 1980, 60% of the urban population in Africa had access to water supply. The corresponding figures for some West African countries are: Ghana, 94%; Côte d'Ivoire, 51%; Guinea, 48%; and Liberia, 16%. That same year the percentages served in rural communities were: Africa, 22%; Ghana, 30%; Côte d'Ivoire, 75%; Liberia, 15%. By 1985, however, 78% of the urban population and 25% of the rural population had access to water supply in Africa. The figures rose to 78% and 46% respectively, in 1988, and some countries such as Togo achieved 100% urban water accessibility; 95% of Ghana's urban population had access, while 43% of the ruralites were served in 1988 (UNDRO, 1988).

In Nigeria as of the mid-decade (1985), 95% of the urbanites were served 62 litres per capita per day while only 25% of the ruralites had access to 24 litres per head per day.

IV. IMPROVEMENT STRATEGIES

It is now realised that losses caused by droughts are not expected to be completely eliminated in the next decade especially in view of the potential global climate changes induced by increased green house gas emissions. This underlines the drastic measures that must be employed to implement an effective and efficient water resources management program in the region beyond the year 2000.

A. Interbasin Water Transfers

Interbasin water transfers have great potential for bringing about sustainable water resource development. It will inevitably become a major, and perhaps, routine instrument of water resources management in West Africa. At the national level, Nigeria is investigating some interbasin water transfer schemes (Table 6 and Fig. 1). All the schemes seek to transfer surplus water from the Sudan savanna to the Sahel, mainly for irrigation purpose, but also for domestic and industrial water supply.

In order to convert Zaire's wasted discharge (70 000 m^3/s) to the drier parts of the Sahel, Umolu and Oke (1986) suggested the Zaire-Chad-Niger (ZCN) interbasin water transfer scheme, meant to transfer water from the Zaire River into Lake Chad and thence to the Niger (Fig. 7). The proposed scheme entails construction of a series of dams on the Upper Zaire tributaries. An alternative scheme, the Trans Aqua, originated by Bonifica of Italy is apparently endorsed by the Lake Chad Basin Commission. While the ZCN is a conglomeration of canals, tunnels, and pipelines linking neighbouring catchments in a phased expansion program, the Trans Aqua, is a 3 000 km canal, keyed to an east-west transport axis.

The proposed transfer is particularly attractive to the Sahelian areas of West Africa because it has the potential of checking desertification and, at the same time, actualizing irrigation potentials of the zone. It is also envisaged to channel an annual flow of 100×10^9 m^3 through the canals of the Trans Aqua scheme to generate up to 35×10^3 Gwh of electricity. The transfer is, however, an expensive venture in

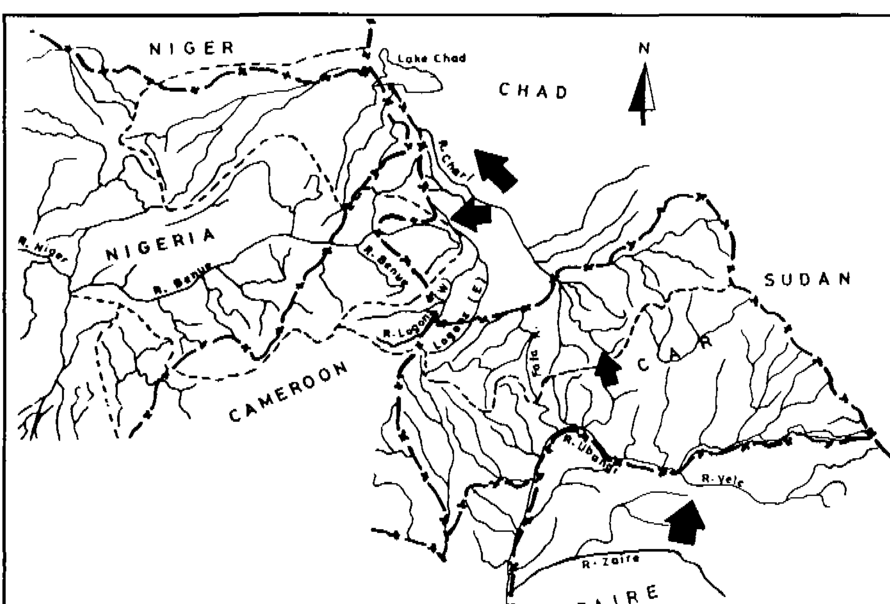
Table 6

Interbasin Water Transfer Projects in Nigeria

Name of Project	Exporting Basin/ River(s)	Importing Basin/ River(s)	Volume of Transfer Mm^3	No. of Reservoirs	Approximate Length (km) & Means of Transfer	Potential Uses of Transfer
1. Dindima	Gongola	Misau	600-1000 (40 m^3/s)	2	65, Tunnel	Irrigation
2. Hawal	Hawal	Ngadda	300 (70 m^3/s)	2	80, Canal Pipe Culvert	Irrigation & Water Supply
3. Tum (Alternative to Hawal)	Tum	Yedseram	300 (20 m^3/s)	1	25, Tunnel Pipe Culvert	Irrigation
4. Mara	Mara	Katagum	300 (20 m^3/s)	1	100, Canal	Irrigation & Water Supply
5. Gurara	Gurara	Kaduna	1300 (80 m^3/s)	1	30, Canal Tunnel	Irrigation & Hydropower
6. Zamfara	Zamfara and Ila	Sokoto	300-700	2-4	50, Tunnel Canal	Irrigation & Water Supply

Figure 7

Zaire-Chad-Niger Interbasin Water Transfer Plan



terms of both investment and exploitation and entails hydrological, environmental, political and jurisdictional matters which need to be carefully considered and settled before the irreversible actions on inter basin water transfers are taken.

B. Policy Objectives and Implementation

Individual national governments having, in principle, recognised the importance of water and the need to accord it commensurate priority, must match their words with action. Their policy objectives must identify priorities which will orient water resources planning and development. Coordinated efforts in the following areas are imperative, if water availability is not to continue to be a brake in their wheel of development. They must:

1. Identify the water needs of the people and economic activities; assess national water resources for national development, including unconventional sources such as brackish waters of the lagoon system; and recycle or re-use water, especially for agriculture.
2. Harness local interests and commitment through the involvement of the local governments and communities in water projects.
3. Set up and enforce national minimum standards and targets. For instance, it should be ensured that equipment and materials such as pipes, pumps, starters, chemical dosers and treatment chemicals are as much as possible locally manufactured, and in any case, to specified standards.
4. Run urban water supply agencies as autonomous and semi-commercial enterprises — the disengagement may be phased in a gradual manner to make the burden bearable. For rural schemes, all tiers of government, including the local community should bear the investment costs equitably. Realistic tariffs should be charged for water and efficient use encouraged.
5. Plan, monitor and design criteria. An appropriate authority should monitor water supply activities, stimulate generation of reliable data, coordinate water supply planning and updating, and provide guidelines for equipment and specifications for materials and construction works.
6. Review institutional arrangements to reduce proliferation of agencies in water resources, in order to increase coordination and efficiency of water administration.

CONCLUSION

It has been established that overcoming shortages of water supplies requires providing access for more people as well as permitting a higher per capita water use. The population of the region which is increasing at a rapid rate makes the task very difficult. Thus, there is urgent need to limit the annual population growth rate at a figure closer to 2%. In order to reduce the enormous cost of providing adequate water supply for all West Africans in the next century, there is the need to adopt appropriate technologies in the water industry. Since regional or state governments find funding of water projects very difficult, cheaper ways of harnessing and distributing water must be sought and adopted, particularly in rural areas and smaller towns. The work of UNICEF and other similar agencies in low-cost rural water supply in the countries of West Africa should be encouraged and extended to other areas. To further reduce costs, local fabrication of materials and equipment should be encouraged through appropriate budgetary and fiscal measures. As well people must be educated that water is not a free commodity.

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Ressources en eau des pays africains : utilisations et problèmes

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RÉSUMÉ

La diversité des climats qui règnent sur le continent africain est la clé de la répartition tant des ressources que des besoins en eau, ainsi que des problèmes contemporains ou futurs posés pour y faire face. Zones aride, semi-aride ou humide sont autant de mondes très contrastés, mais non indépendants et que les structures hydrographiques et géologiques font largement communiquer. Malgré les inégales validités et les lacunes des sources d'informations, des statistiques sur les ressources et les demandes en eau par pays ont été tentées. Leur présentation permet de quantifier les analyses de situation et de classer les pays suivant des macro-indicateurs révélateurs du type et de l'acuité des problèmes. C'est dans les pays de la zone semi-aride que se cumulent le maximum de problèmes, souvent aggravés par les sécheresses, tandis que les problèmes des zones arides ou des zones intertropicales humides sont plus spécifiques et largement conditionnés par l'état des ressources économiques.

ABSTRACT

The climatic diversity of the African continent underlies both the needs and the present and future issues related to water resources. However, because of the interconnection of the geologic and hydrological structures, arid, semi-arid and humid zones offer contrasting, but not necessarily independent worlds. In order to quantify the analysis of the situation and classify countries according to macro-indicators, we have attempted to compile statistics on water resources and water needs on a country basis. Thus, we find that the most acute problems can be found in the semi-arid zone, a situation aggravated by droughts, while, in arid and humid zones the problem is more of an economic nature.

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INTRODUCTION

En prologue à la session spéciale de ce congrès consacrée à l'Afrique, il a paru instructif d'esquisser un panorama des ressources en eau du continent, de leurs utilisations présentes et des problèmes d'eau prédominants, en s'efforçant de quantifier autant que possible les analyses, malgré les grandes incertitudes et les lacunes des données dont nous disposons. Sur tous ces plans l'Afrique accumule les contrastes, les diversités et les inégalités : cela autorise à tenter des chiffrages le plus souvent flous dans l'absolu, mais dont les ordres de grandeur diffèrent assez entre les régions et les pays pour permettre des comparaisons valables du point de vue des contraintes qui pèsent sur l'économie de l'eau.

I. LES RESSOURCES EN EAU DE L'AFRIQUE

En assimilant d'abord les ressources en eau naturelles et renouvelables à l'écoulement global (superficiel et souterrain) formé sur les territoires et en commençant par une vision très macroscopique, rappelons que pour l'ensemble du continent les estimations de l'écoulement moyen annuel tournent autour de 4 000 milliards de m^3/an (3 400 à 4 600 suivant les auteurs). Une telle globalisation n'a qu'un intérêt académique et fixe seulement la moyenne par rapport à laquelle pourront être appréciés les écarts dans l'espace et dans le temps : environ 130 000 m^3/an par km^2. Faut-il rappeler que par la diversité de ses climats et de ses structures hydrographiques et géologiques, l'Afrique est un bon résumé de la variété du Monde et qu'elle offre le maximum de contrastes puisqu'on y trouve le désert le plus vaste et le plus extrême aussi bien que des records de hauteur de pluie locale et le second fleuve mondial par l'étendue de son bassin comme par son débit (Zaïre) ainsi que le plus long (Nil).

La première disparité significative résulte naturellement des différenciations climatiques. Les essais de cartographie continentale des potentiels d'écoulement moyen (Com. IHD-URSS, 1974/UNESCO, 1978; Baumgartner et Reichel, 1975) mettent bien en lumière l'extrême inégalité de leur répartition sous l'effet direct de la zonalité des climats et des précipitations (Fig. 1). On en déduit que la zone intertropicale humide, complétée par les franges méditerranéennes humides (42 % de l'étendue continentale) produit 95 % de l'écoulement global du continent, alors que les zones arides et semi-arides en produisent seulement 5 %[1]. Plusieurs grands fleuves, vecteurs « transclimatiques » (Nil, Niger, Sénégal, Chari, Zambèze, Orange) corrigent heureusement un peu cette disparité en doublant les ressources des zones arides et semi-arides par des flux transférés spontanément des zones humides, ce qui est très appréciable pour les premières mais atténue seulement le grand déséquilibre des ressources, en le ramenant de 90 % à 10 %, tout en créant des situations de dépendance accusée en certains pays.

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1. Pour mémoire, la répartition de l'espace africain (continent et îles) par zones climatiques est la suivante :

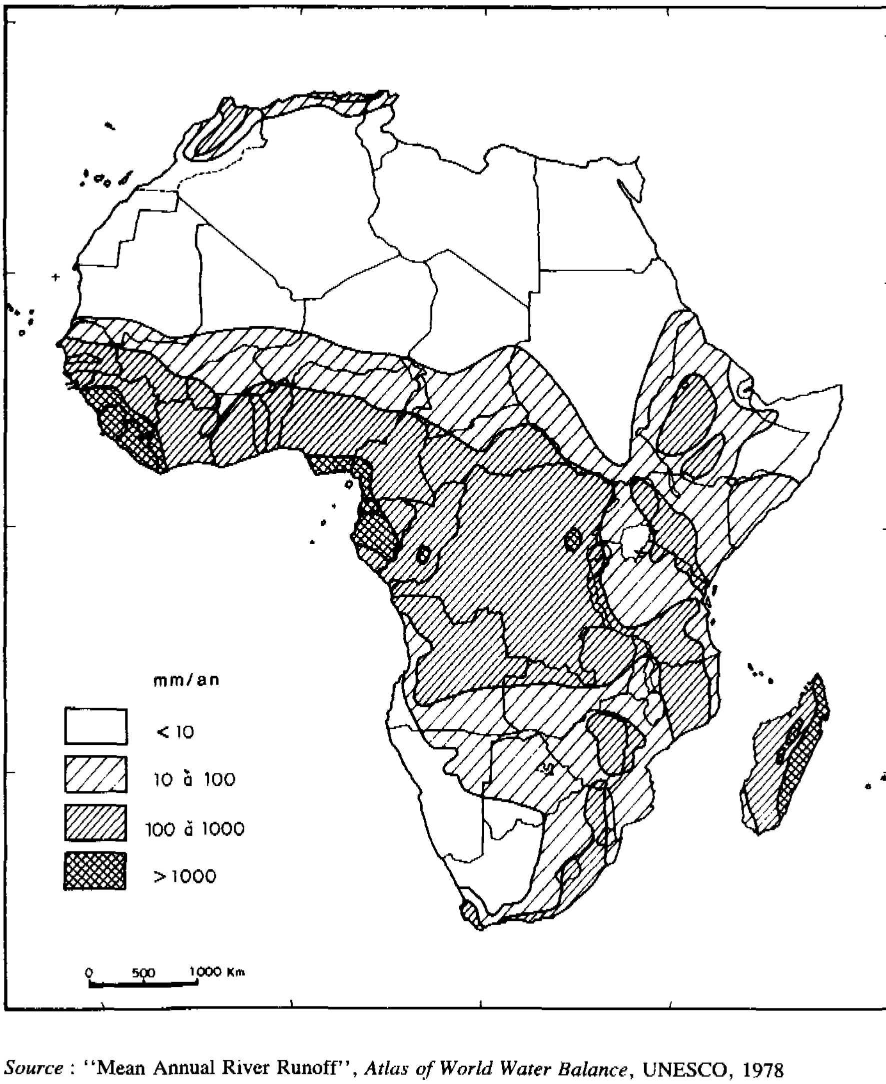
— zone hyper-aride	15 %	58%
— zone aride	24,5 %	
— zone semi-aride	18,5 %	

— zone humide, intertropicale et équatoriale ou méditerranéenne 42 %

L'Afrique est le plus mal partagé des grands continents.

Figure 1

Distribution de l'écoulement potentiel moyen annuel en Afrique (en mm)



Source : "Mean Annual River Runoff", *Atlas of World Water Balance*, UNESCO, 1978

Une géographie des ressources en eau adaptée à la confrontation avec les besoins nécessite des estimations plus fractionnées, au minimum par pays, même si elles sont encore bien globales à cette échelle. Aussi a-t-on tenté de dresser un tableau de ces estimations par pays, toujours basées sur des données « macro-hydrologiques » moyennes d'après des sources documentaires nationales ou internationales inévitablement hétérogènes et frappées d'approximations variées (tableau 1). Malgré les effets des différences de taille des territoires nationaux, des écarts de validité des chiffrages et des incertitudes sur les transferts entre pays, ces estimations traduisent bien l'incidence prépondérante des conditions climatiques. Suivant les pays, les ressources naturelles se chiffrent en milliards (parfois moins), en dizaines ou en centaines de milliards de m^3/an : donc un écart de plus de 1 à 1 000 entre les extrêmes. Les « géants » des ressources en eau sont d'abord le Zaïre (plus de 1 000 milliards de m^3/an) suivi du Congo, du Nigeria et de Madagascar. Les plus dépourvus sont les plus inscrits en zone aride (Libye) et/ou les plus exigus, notamment les états insulaires (Cap Vert, Comores, Djibouti).

Ces estimations par pays conduisent à prendre en compte les « échanges spontanés » dus aux fleuves transfrontières nombreux en Afrique, ou les partages de fleuves frontières. Les proportions des affluences de pays voisins sont des indicateurs de degré de dépendance des ressources en eau à caractère géopolitique : cette dépendance est très accentuée en certains pays receveurs (Égypte, Soudan, Niger, Mauritanie, Tchad, Congo, Botswana, Mozambique) (Fig. 2); mais en réciproque les contraintes que les pays donneurs peuvent être tenus de respecter (exemple : Soudan) ne sont pas pour autant négligeables. Les ressources en eau des bassins partagés sont autant de motifs de conflit ou de concertation.

Le ratio *ressources par habitant* est un indicateur de « richesse en eau » relative plus significatif pour comparer et classer les pays et qui va mieux au devant de la confrontation entre ressources et besoins, même si la ressource est encore définie comme flux naturel moyen et globalisé, en comptant des apports extérieurs au risque de quelques doubles comptes. Les pays s'échelonnent alors dans une gamme de richesse en eau très étendue allant actuellement (1985) de quelques centaines ou quelques milliers de m^3/an en zone aride ou semi-aride à plusieurs centaines de milliers de m^3/an en zone équatoriale, le numérateur ressource et le dénominateur population jouant l'un comme l'autre (Fig. 3).

Les estimations de ressources en eau citées jusqu'ici, qu'elles soient globales ou réparties par pays, sont naturellement beaucoup trop sommaires car elles souffrent de trois défauts principaux :

— Elles négligent les *ressources pluviales*, facteur essentiel des productions agricoles non irriguées ou irriguées seulement en complément (en zone semi-aride essentiellement).
— Elles s'en tiennent à des *flux moyens*, moyennes annuelles qui lissent les variations saisonnières; pour en revenir à l'échelle continentale, la phase stable de l'écoulement est estimée, en année moyenne, à près du tiers de l'écoulement total (1 500 milliards de m^3/an, source UNESCO), l'Afrique n'étant pas, à cet égard, le continent le plus irrégulier; mais cette proportion est bien inférieure en zone semi-aride et parfois nulle en zone aride, où seul l'écoulement des eaux souterraines est pérenne.

Figure 2

Proportions des ressources en eau naturelles totales de certains pays d'Afrique d'origine externe reçues de pays voisins par les fleuves transfrontières (en %)

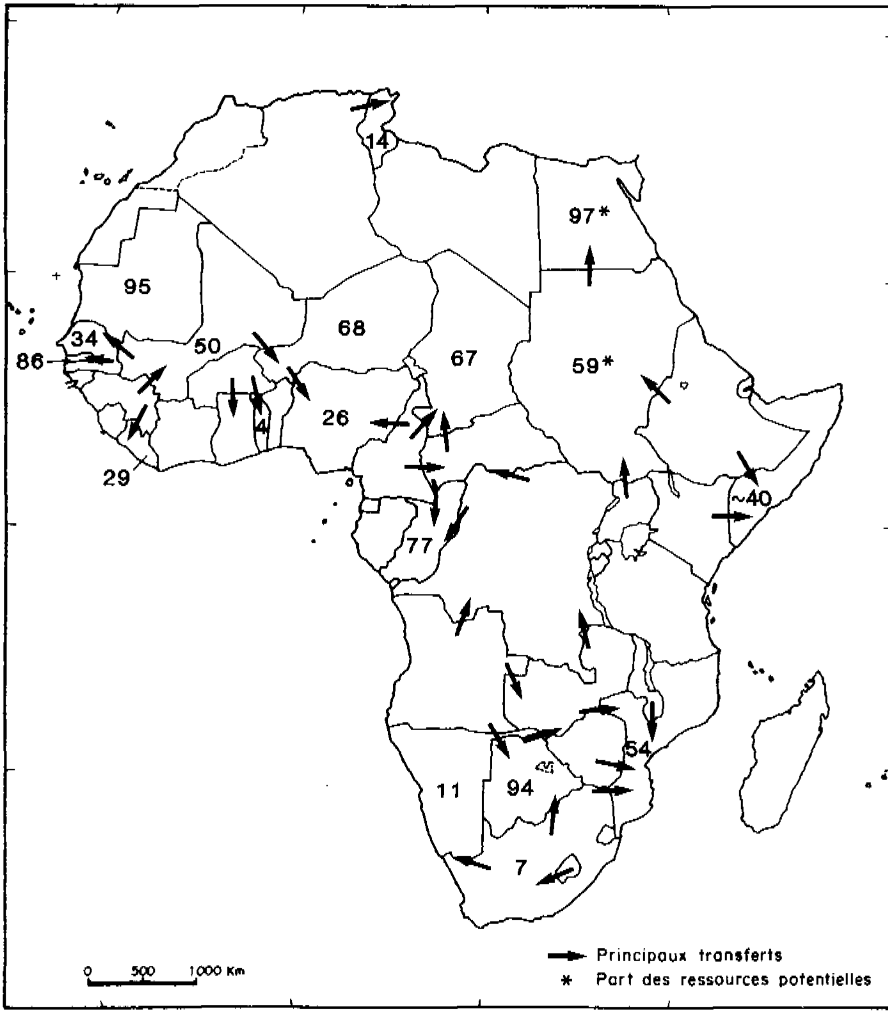


Tableau 1

Ressources en eau renouvelables naturelles par pays, totales et par habitant (état actuel et prospective 2020)

PAYS	Ressources globales par pays		Ressources par habitant (flux moyens annuels)	
	Écoulement total moyen annuel (1) 10^9 m^3/an	Affluences de pays voisin significatives comprises dans le total (2) 10^9 m^3/an	État actuel (1985) (3) m^3/an	Prospective 2020 (4) m^3/an
Afrique du Sud	54	4	1 655	764
Algérie	19,1	0,2	874	405
Angola	158	—	18 036	7 108
Bénin	26	—	6 436	2 260
Botswana	18	17	16 822	4 890
Burkina Faso	28	—	3 550	1 540
Burundi	3,6	—	766	326
Cameroun	268	0	26 300	10 580
Cap Vert	0,2	0	606	300
Comores (avec Mayotte)	0,4	0	1 000	400
Congo	800	620	427 800	184 760
Côte d'Ivoire	75	—	7 450	2 750
Djibouti	0,3	0	830	280
Égypte	58,3*	56,5*	1 238	680
Éthiopie	115	0	2 720	1 034
Gabon	164	—	164 000	68 330
Gambie	22	19	29 730	15 940
Ghana	53	—	4 170	1 265
Guinée	226	0	37 355	15 850
Guinée-Bissau	31	—	34 830	16 760
Guinée Équatoriale	30	0	81 080	34 480
Kenya	15	—	736	200
Lesotho	4	0	2 650	1 117
Liberia	140	40	63 927	20 895
Libye	0,7	0	194	70
Madagascar	337	0	33 000	13 070
Malawi	9	0	1 278	450
Mali	100	50	13 315	4 580
Maroc (avec Sahara Occ.)	30	0	1 369	780
Maurice	2,2	0	2 115	1 410
Mauritanie	7,4	7	4 379	1 420
Mozambique	213	116	15 445	6 235
Namibie	9	1	7 965	2 210
Niger	44	30	6 886	2 570
Nigeria	415	110	4 164	1 375

Tableau 1 (suite)

PAYS	Ressources globales par pays		Ressources par habitant (flux moyens annuels)	
	Écoulement total moyen annuel (1) 10⁹ m³/an	Affluences de pays voisin significatives comprises dans le total (2) 10⁹ m³/an	État actuel (1985) (3) m³/an	Prospective 2020 (4) m³/an
Ouganda	50	0	3 232	1 015
Réunion (F/D.O.M.)	5	0	9 434	6 330
Rép. Centre-Africaine	190	0	73 640	32 370
Ruanda	6,3	0	1 045	340
Sénégal	35,2	12	5 366	2 160
Sierra-Léone	90	—	24 000	12 850
Somalie	11,5	~4,5	2 137	1 040
Soudan	66*	39*	3 010	1 300
Swaziland	15	0	19 737	7 940
Tanzanie	76	—	3 417	1 020
Tchad	45	30	9 036	3 940
Togo	12	0,5	3 947	1 480
Tunisie	4,35	0,6	609	356
Zaïre	1 019	—	33 344	12 480
Zambie	96	—	14 458	4 540
Zimbabwe	23	—	2 735	795

* Ressource potentielle comprenant la part du débit du Nil attribuée.

Notes

(1) Somme de l'écoulement d'origine interne (estimé par interpolation ou extrapolation des données hydrologiques et comprenant les écoulements superficiels et souterrains) et des affluences de pays voisin. Les flux calculés par pays ne sont donc pas tous additifs. Les flux moyens annuels n'ont pas une référence temporelle homogène.

(2) Seules les affluences appréciables sont estimées ici.

(3) Ratio calculé sur la base des populations estimées en 1985 (Source : *Atlas de la Banque Mondiale*, 1987).

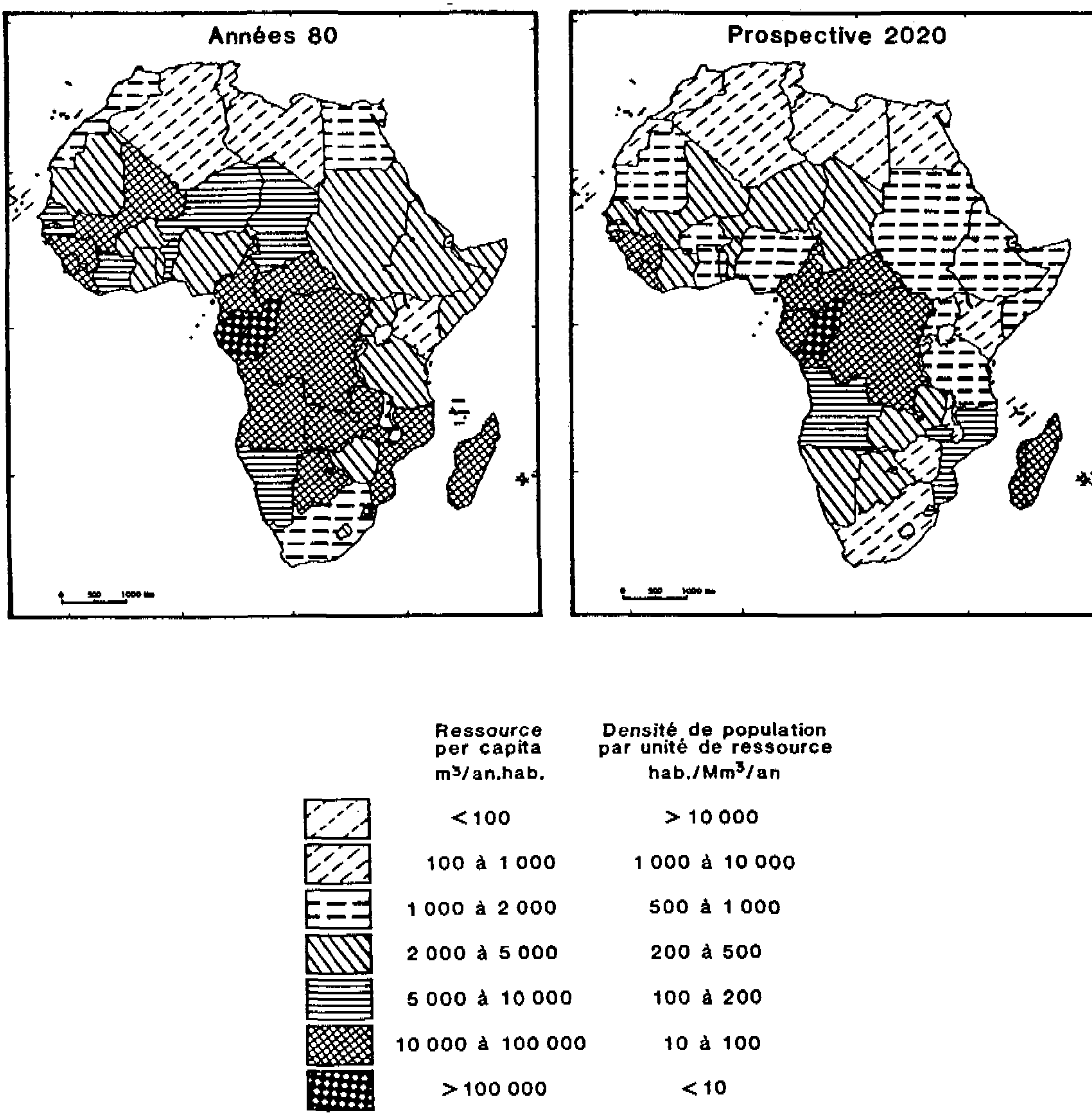
(4) Ratio calculé sur la base des projections démographiques opérées par les Nations Unies en 1984/Hypothèse « Medium variant » *World Population Prospect, Estimates and Projection 1984*, U.N., 1986.

— La composante relativement stable ou régulière de l'écoulement total, en année moyenne, serait ainsi de l'ordre de 15 à 30 % en moyenne dans les pays du Maghreb, 20 à 30 % en Afrique sahélienne (en excluant les fleuves « importateurs »), 25 % en Afrique orientale et australe, et bien sûr moins encore dans certains bassins dépourvus de réservoirs aquifères ou de lacs stabilisateurs.

— Moyennes pluriannuelles qui nivellent les effets des alternances d'années (ou de séquences pluriannuelles) de sécheresse ou de pluviosité excédentaire, particulièrement amples, là encore, en zones semi-aride et

Figure 3

Ressources en eau des pays d'Afrique rapportées aux populations
État actuel (1985) et prospective (2020)
(d'après la projection démographique moyenne des Nations Unies)



aride; cette variabilité affecte certes d'abord les « ressources pluviales », mais largement aussi les écoulements superficiels peu soutenus par des régulateurs à capacité d'amortissement pluriannuelle, et même certains écoulements souterrains dans les aquifères à faible réserve (terrains de socle notamment).

— Enfin elles ne tiennent pas compte des grandes différences de maîtrisabilité, d'accessibilité des eaux qui rendent les ressources naturelles très inégalement *exploitables*, même si les critères d'exploitabilité dépendent beaucoup des utilisations de l'eau et du degré d'exploitation déjà réalisé à un stade donné. La variété des régimes d'écoulement, annuels et pluriannuels, est un premier facteur de différenciation des possibilités de maîtrise des eaux, dont la difficulté croît avec l'irrégularité, en exigeant des capacités de retenue accrues. Mais la maîtrise et l'exploitation des eaux est aussi fortement dépendante des conditions physiographiques qui structurent les ressources.

Les ressources en eau de l'Afrique sont non seulement très inégalement réparties dans l'espace et le temps, elles sont aussi très diversement structurées :

— variété de taille et de densité de drainage des réseaux hydrographiques. Un seul bassin fluvial (Zaïre) concentre environ 30 % de tout l'écoulement du continent, les dix plus grands fleuves (y compris ce dernier) se partageant ensemble 50 % du total;

— importance des domaines « endoréiques », à bassins fermés, ou « aréiques », sans écoulement organisé : près du tiers du continent;

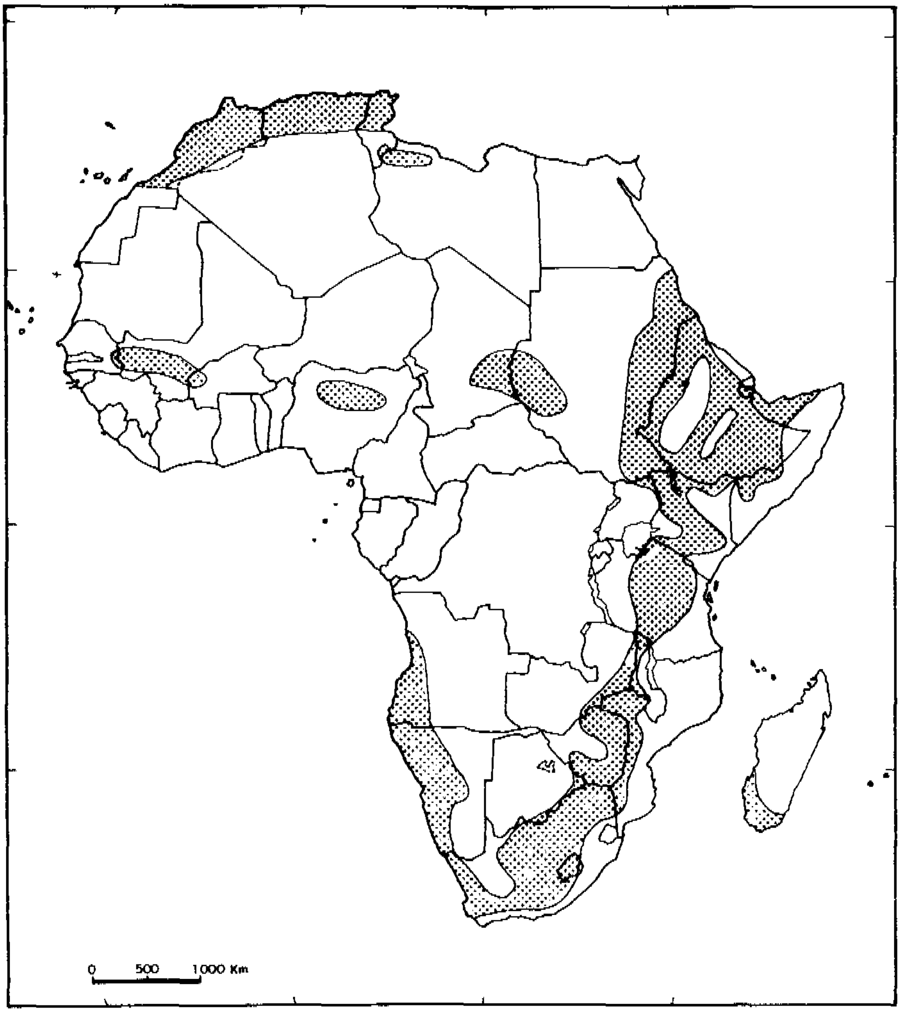
— développement d'un semi-endoréisme fonctionnel dans les bassins fluviaux du domaine semi-aride où des artères fluviales ont des débits décroissant d'amont en aval, soumis à déperdition par évaporation, notamment dans des deltas intérieurs (Nil, Niger, Okavango, cours d'eau sahariens), ce qui limite les opportunités d'ouvrages régulateurs aux parties amont de ces bassins;

— répartition très inégale des sites de barrage-réservoirs concentrés dans les zones de relief, et sensibilité très variée des retenus aux risques de comblement par les sédiments (« envasement »). C'est encore en domaine semi-aride que les reliefs sont le plus sujets à l'érosion des sols et que les retenues sont les plus exposées au risque d'envasement qui abrège leur durée de fonctionnement efficace (Fig. 4). Un seul exemple, hors du Maghreb où les durées de vie des retenues sont souvent inférieures à 50 ans, dans le bassin du Nil au Soudan : le réservoir de Khasm-El-Girba, sur l'Atbara (à débit solide de 80 MT/an, a perdu en 12 ans (1965-1977) 40 % de sa capacité totale initiale de 1 300 Mm^3;

— variété des structures hydrogéologiques qui conditionnent les écoulements et les stocks d'eau souterraine, les rôles régulateurs des aquifères et leur exploitabilité. À l'opposé de grands, voire très grands réservoirs à eaux profondes, relativement à l'abri des aléas climatiques, souvent très productifs et heureusement en partie situés en domaine aride (Sahara septentrional, Nubie, bassins du Sahel et du Tchad, Kalahari), de vastes territoires ne disposent que d'aquifères discontinus, donc d'accès aléatoire, bien que peu profonds, et faiblement productifs, offrant néanmoins des

Figure 4

Zones les plus exposées aux risques de comblement des retenues par les sédiments



ressources adaptées aux besoins ruraux dispersés, mais peu capacitifs et sensibles en zone semi-aride aux aléas de renouvellement en cas de sécheresse. Par ailleurs, dans les domaines à structures plus complexes et plus humides, méditerranéens ou australs, de nombreux aquifères locaux contribuent de manière appréciable à l'entretien des écoulements permanents des cours d'eau tout en étant aussi directement exploitables, de même qu'en zone intertropicale humide où, malgré l'abondance et la permanence des eaux superficielles, les eaux souterraines offrent une ressource de meilleure qualité au plan sanitaire.

Toutes ces diversités structurales soulignent, s'il en était besoin, les significations très limitées des chiffrages globaux ou nationaux indiqués précédemment.

II. LES UTILISATIONS D'EAU ACTUELLES

L'Afrique est le continent où les statistiques disponibles sur les utilisations des eaux sont les plus lacunaires et hasardeuses. Aussi l'exercice d'estimation dont le tableau 2 présente les résultats repose-t-il largement sur des extrapolations basées sur des indicateurs macroscopiques de demande recensés (population, surface irriguée) et a-t-on jugé préférable de rapporter ces estimations à des agrégats de pays à structures et niveaux de demandes présumés similaires, en dehors des pays d'Afrique septentrionale et de l'Afrique du Sud, à statistiques récentes disponibles. La sommation tentée des prélèvements en eau actuels probables dans tout le continent — quelques 140 milliards de m^3/an — et sa répartition par secteurs, permettent surtout de mesurer les parts relatives de certains pays ou secteurs.

On observe que l'agriculture (irrigation pour l'essentiel) prend la part du lion (près de 85 % du total dont la moitié est concentrée dans le bassin du Nil : l'Égypte et le Soudan utilisent ensemble plus de 60 milliards de m^3/an pour l'irrigation) et que les collectivités prennent ensuite une part triple de celle de l'industrie. Un pays (l'Égypte) prélèverait à lui seul 37 % du total, tandis que les pays de la zone intertropicale humide d'Afrique centrale et occidentale ne prélèveraient ensemble que moins de 10 %.

Pour inciter à la modestie quant à la validité de ces chiffrages, il suffit de les comparer aux estimations globales antérieures, dont les écarts paraissent relever plutôt des incertitudes et des différences entre les hypothèses de base des calculs que des évolutions réelles des demandes en eau (tableau 3).

Rapportées aux populations, les quantités d'eau utilisées probables actuellement par habitant diffèrent assez par leur ordre de grandeur pour que les écarts soient significatifs malgré les incertitudes soulignées. Les pays d'Afrique peuvent être classés en groupes très contrastés de ce point de vue :

— la plupart des pays de la zone intertropicale humide sans agriculture irriguée, où les prélèvements seraient inférieurs à 100 ou même à 50 m^3/an per capita;

Tableau 2

Prélèvements en eau totaux et par secteur d'utilisation, estimés ou supputés, Années 80 (en 10^9 m^3/an).

Groupe de pays	Pays	Prélèvement total	Prélèvements sectoriels: Collectivités (eau potable)	Industries non desservies*	Agriculture (irrig. + élevage)	Sources (Cf. Biblio.)
AFRIQUE septentrionale	ALGÉRIE	3,0	0,7	0,15	2,15	2,4
	ÉGYPTE	53,0	3,7	3	46,3	1,2,4
	LIBYE	2,1	0,2	—	1,9	2,3
	MAROC	11,0	0,7	0,3	10,0	1,2,4
	TUNISIE	2,3	0,2	—	2,1	2,4
AFRIQUE sahélienne	Burkina Faso Mali, Maurit., Niger, Tchad.	5,0	0,5	0	4,5	3 7
	SOUDAN	14,0	0,5	0	13,5	3
AFRIQUE de d'Ouest	Bénin, Cameroun, Côte d'Ivoire, Gambie, Ghana, Guinée, Guinée B., Cap Vert, Libéria, Nigéria, Sénégal, Sierra L., Togo	10,5	3,5	0	7	1 7
AFRIQUE Centrale	Angola, Congo, Gabon, Guinée Eq., Centre-Afrique, Zaïre	1,0	0,9	0,1	0	7
AFRIQUE de l'Est	Burundi, Djib., Éthiopie, Kenya, Ouganda, Rwanda, Somalie, Tanzanie	9,0	2,3	0,2	6,5	1,3 7
AFRIQUE australe	Botswana, Lesotho, Malawi, Mozambique, Namibie, Swazil., Zambie, Zimbabwe	2,9	1,4	0,1	1,4	1 7
	AFRIQUE du Sud	12,2	1,6	1,8	8,8	5
OCÉAN INDIEN	MADAGASCAR	16,3	0,2	—	16,1	1
	Îles : Comores, Maurice, Réunion	0,7	0,3	0,1	0,3	1 6,7
Ensemble de l'AFRIQUE		143,0	16,7	5,7	120,6	—

* Y compris les centrales thermo-électriques (refroidissement).

Tableau 3

Quelques estimations antérieures des utilisations d'eau en Afrique (en 10^9 m^3/an)

Date de valeur	Alimentation des collectivités	Industrie	Irrigation	Énergie	Total
1950	2	1,5	60	—	63,5*
1970	4	3	110	—	177
					130
1979	12	4,4	60,8	11	88 **
1980					168 ***

* USSR Com. IHD, 1974 et UNESCO, 1978.
** Annuaire statistique des Nations Unies (cité par J. Bethemont, 1987).
*** I.A. Shiklomanov, UNESCO, 1990.

— les pays de la zone aride ou semi-aride où l'irrigation plus ou moins développée est le premier secteur d'utilisation, mais où les ressources sont un facteur limitant (Maghreb, Afrique sahélienne, Afrique orientale, Afrique du Sud), où les prélèvements sont de plusieurs centaines de m^3/an per capita.
— quelques pays à irrigation massive, permise par des ressources intérieures ou « importées » abondantes (vallée du Nil et Madagascar), où les prélèvements approchent ou même dépassent un millier de m^3/an per capita. (Fig. 5).

Ainsi est encore mis en évidence le poids prépondérant de l'irrigation comme facteur des demandes en eau présentes, mais aussi l'influence des modes d'irrigation et de l'incidence plus ou moins modératrice de l'état des ressources offertes et mobilisables sur les quantités d'eau utilisées pour l'irrigation par habitant : par exemple, en Égypte celles-ci sont le double de celles utilisées en Libye et le triple de celles utilisées en Tunisie. Aussi les pays les plus riches en eau sont paradoxalement les moins utilisateurs, parce que ce sont ceux où l'irrigation n'est pas nécessaire, mais du fait aussi de leurs difficultés à satisfaire les besoins théoriques des populations agglomérées aussi bien que dispersées. Les demandes en eau effectives par habitant sont à l'évidence liées, à climat égal, au niveau de développement économique.

III. COMPARAISON ENTRE RESSOURCES ET UTILISATIONS

Les classements respectifs des pays africains suivant leur richesse en eau et leurs demandes présentes par habitant sont apparus assez contrastés pour permettre d'ébaucher une classification combinant ces deux indicateurs (tableau 4). Elle confirme l'absence de relation simple entre les ressources et les utilisations, en quantités globales, et suggère une typologie des situations des « économies de l'eau » indicatrices des problèmes : des pays riches en eau sont très inégalement demandeurs,

Figure 5

Prélèvements en eau, pour toutes utilisations, par habitant dans les pays d'Afrique (ordre de grandeur, années 80)

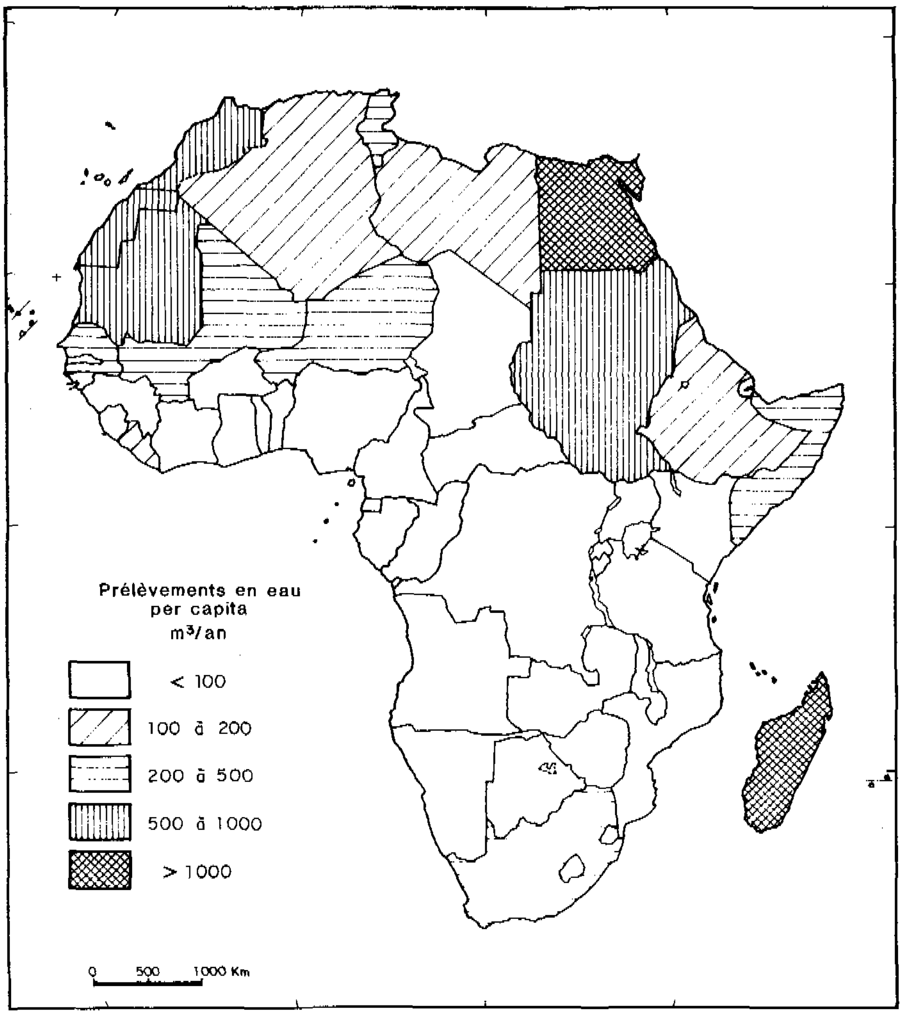


Tableau 4

Classement des pays africains suivant leur richesse en eau et leurs demandes en eau actuelles par habitant (d'après les populations de 1985).

Richesse en eau (ressources) m^3/an per capita	PAYS					
Demandes en eau (Prélèvements) *m^3/an per capita*	Indigents <500	Très pauvres 500 à 1 000	Pauvres 1 000 à 2 000	Moyens 2 000 à 10 000	Riches 10 000 à 100 000	Pléthoriques >100 000
Très faible <100 (* <50 probable)		Burundi Kenya*	Comores* Malawi Ruanda*	Benin* Burkina Faso* Côte d'Ivoire Ghana* Lesotho* Namibie Nigeria Ouganda* Tanzanie* Tchad* Togo* Zimbabwe	Angola* Botswana Cameroun* R. Centre-Afr.* Gambie* Guinée* Mozambique Sierra Léone Zaïre Zambie	Gabon* Congo*
Faible 100 à 200	Libye	Algérie Cap Vert		Éthiopie	Libéria	
Modérée 200 à 500		Djibouti Tunisie	Afrique du Sud	Maurice Niger Réunion Sénégal Somalie	Mali	
Forte 500 à 1 000			Maroc	Mauritanie Soudan		
Très forte >1 000			Égypte		Madagascar	

tandis que la faiblesse des demandes peut tenir aussi bien à la réduction des besoins du fait du climat, qu'au plafonnement par la rareté des ressources en eau ou l'indigence des ressources économiques.

La comparaison directe des quantités d'eau utilisées et des ressources par le ratio « indice d'exploitation », malgré son caractère très global, est également révélatrice des degrés très divers de pression des demandes sur les ressources naturelles en Afrique. Cet indice est encore minime, voire infime (<1 ou 0,1 %) dans la plupart des pays de la zone intertropicale humide ; faible (1 à 10 %) en quelques pays à ressources plus modestes d'Afrique sahélienne, orientale ou australe (exemples : Sénégal, Mali, Niger, Éthiopie, Kenya, Zimbabwe) ; déjà appréciable et révélateur de problèmes (10 à 25 %) en pays plus développés ou à irrigation importante (Afrique du Sud, Soudan, Mauritanie) ou encore à ressources limitées, notamment insulaires (Cap Vert, Djibouti, Maurice); cet indice est le plus élevé dans les pays d'Afrique septentrionale à irrigation développée (Maroc 37 %, Tunisie 53 %, Égypte 91 %) et il dépasse 100 % en Libye sous l'effet de l'exploitation intensive de ressources non renouvelables (Fig. 6).

Naturellement prendre comme dénominateur de cet indice les ressources naturelles moyennes le rend beaucoup trop optimiste et il serait plus réaliste de se baser sur les ressources régulières et relativement faciles à mobiliser. Ses valeurs élevées sont d'autant plus significatives de situations critiques et de raréfaction des disponibilités d'eau.

IV. REGARDS PROSPECTIFS

Dans la plupart des pays d'Afrique au sud du Sahara, à part les jalons des projections démographiques, on dispose de bases et d'hypothèses beaucoup trop fragiles pour se hasarder à un exercice de prospective des besoins en eau (on renvoie, pour l'Afrique septentrionale, aux travaux du Plan Bleu qui font l'objet d'une communication particulière).

Aussi se bornera-t-on ici à évoquer la prospective des ressources, sous trois aspects.

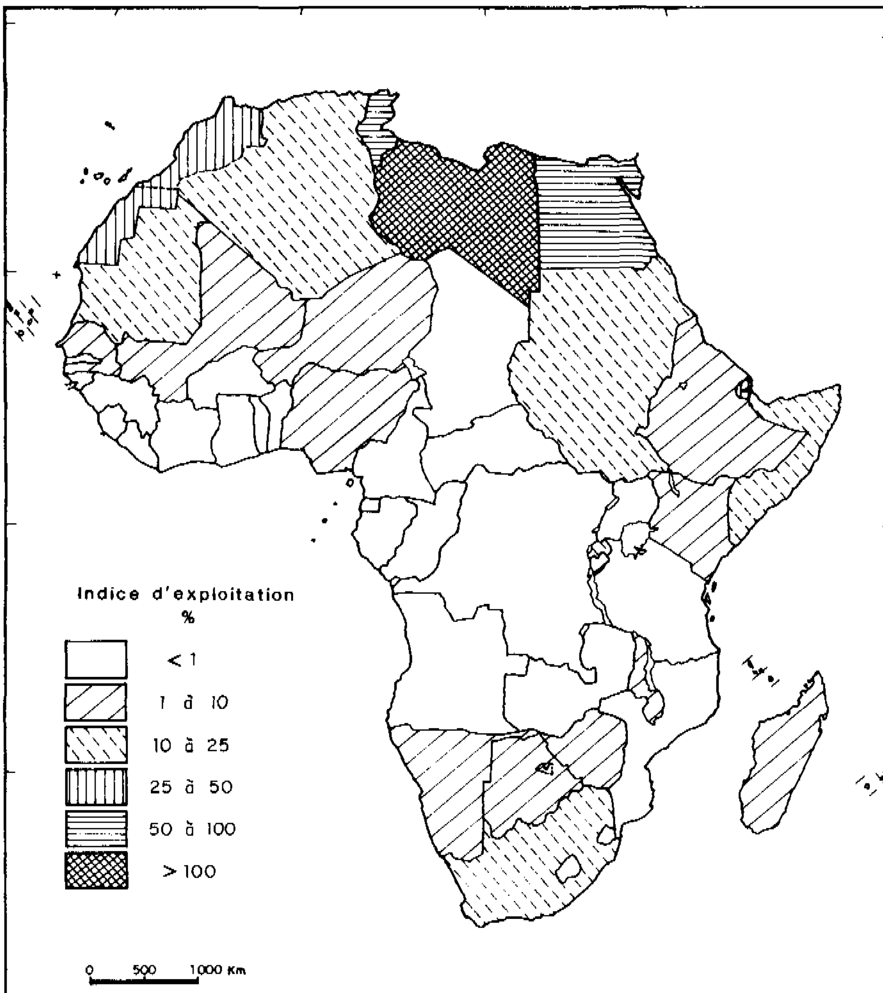
D'abord en supposant les ressources en eau naturelles renouvelables, exprimées en flux moyen, comme un invariant, il est possible de conjecturer l'évolution de leur rapport aux populations — à partir de l'état actuel — en fonction des projections démographiques. Le calcul a été opéré par pays pour l'horizon 2020, suivant les hypothèses moyennes des estimations des Nations Unies (tableau 1). Il laisse prévoir des diminutions parfois drastiques des ressources par habitant qui se rapprochent sensiblement des besoins par habitant projetables, voire même présents dans certains pays : cet indicateur pourrait s'abaisser en 2020 au-dessous de 500 m^3/an per capita en Algérie et Tunisie, au Kenya, au Burundi, au Ruanda, au Malawi, et dans les pays insulaires; il serait inférieur aux demandes actuelles par habitant en Égypte (Fig. 5). Cette raréfaction des ressources par habitant, pourtant définies sur la base des ressources naturelles incomplètement mobilisables, est par elle-même indicatrice de la montée des problèmes d'eau dans ces pays.

Par ailleurs, les ressources ne sont pas nécessairement à l'abri d'évolution, en dehors de leurs fluctuations conjoncturelles. En particulier, leur part affluente de pays voisin — notable on l'a vus dans certains pays — peut être sujette à des réductions sous l'influence de la croissance des utilisations dans les pays « fournisseurs » : le problème pourrait notamment se poser dans le bassin du Nil où le taux d'utilisation global des ressources est dès à présent très élevé.

Plus généralement, la progression de la *désertification* dans les zones semi-arides pourrait dégrader sensiblement les ressources en eau qui s'y forment : réduction des écoulements et surtout amplification de l'irrégularité des débits et des apports de sédiments dans les retenues. La dégradation et la raréfaction des ressources en eau sont, en effet, d'abord une conséquence des processus de désertification, même si

Figure 6

Pays d'Afrique classés suivant l'indice d'exploitation global probable des ressources en eau théoriques (années 80) (ratio: Prélèvements totaux/Écoulement total moyen)



elles peuvent en retour contribuer à les aggraver en période de sécheresse. C'est dans les zones, aujourd'hui bien identifiées, en voie de désertification (Fig. 7) que les ressources en eau locales sont ainsi le plus fragilisées.

Rappelons encore que les ressources non renouvelables exploitées activement dans certains pays (Algérie, Libye, Égypte, Tunisie...) s'épuiseront fatalement, à des termes qui dépendent des stratégies d'exploitation choisies, mais qui se chiffrent en décennies plutôt qu'en siècles et qui seront vraisemblablement atteints au cours du XXI[e] siècle.

De même la réduction croissante des capacités des retenues par la sédimentation — déjà évoquée — particulièrement rapide en zone semi-aride neutralisera à terme les efforts d'aménagement qui épuiseront progressivement les sites disponibles et réduiront les possibilités de maîtrise des écoulements irréguliers : dans les pays les plus menacés par ces pertes de potentiel de régulation une partie des eaux de crue est aussi, d'une certaine manière, une ressource non renouvelable.

Enfin, à plus long terme, on ne peut éluder les risques de répercussions sur les ressources en eau des changements de climat — dans le sens d'une aridification — supputés en conséquence de l'effet de serre, même si ces changements sont encore très problématiques (on n'est pas aujourd'hui en mesure d'en prévoir l'ampleur, ni l'échéance, ni la probabilité d'occurrence, ni toutes les conséquences sur le régime des eaux).

V. SURVOL DES PROBLÈMES

Dans les domaines arides et semi-arides du continent le peuplement et les modes de vie humains se sont longtemps adaptés à la rareté des ressources en eau. La croissance démographique moderne, les transformations de l'habitat et des modes de production, les ambitions d'amélioration des niveaux de vie ont rompu l'équilibre ancien. L'essentiel des problèmes d'eau contemporains en découle, qu'ils soient posés par l'alimentation humaine, urbaine et rurale, ou par les nécessités d'accroître les productions agricoles vivrières.

Une autre cause de problèmes est le sous-développement économique et la rareté des capacités d'investissement qui empêchent ou restreignent la maîtrise de l'eau et la satisfaction des besoins en eau, même là où la nature n'en est pas avare.

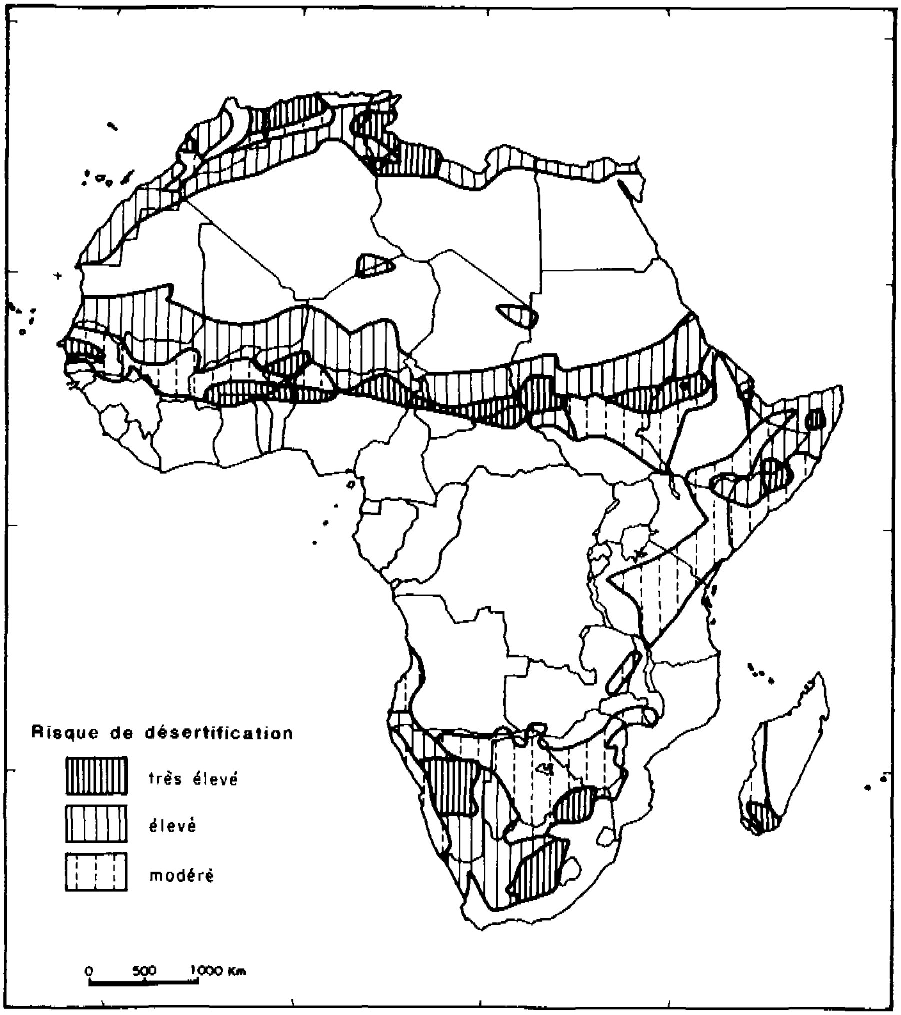
Tensions besoins/ressources et pauvreté des moyens sont à l'origine des problèmes d'eau dominants dans le continent, et c'est naturellement là où l'une et l'autre coexistent que les situations sont les plus critiques. Ainsi peut-on esquisser une géographie des problèmes d'eau en Afrique.

— En zone aride et hyper-aride le choix d'une stratégie de gestion à long terme des ressources non renouvelables offertes par les grands aquifères profonds est la question majeure : il s'agit de planifier les investissements et les valorisations de l'eau en même temps que la préparation des relais (ressources de substitution transférées ou changement d'activités) et de leur accorder les objectifs de développement socio-économique.

C'est dans les zones semi-arides que s'accumulent le plus de problèmes.

Figure 7

Zones sujettes à la désertification en Afrique



Source : Carte mondiale de la désertification, PNUE/FAO/UNESCO/OMM, 1977.

— Le parachèvement de la maîtrise des eaux, déjà très avancé en quelques pays (Maghreb, bassins du Nil, du Sénégal, du Zambèze...) impliquera des coûts d'aménagement des ressources internes et de transfert de plus en plus élevés, à mettre en compétition avec l'adaptation des demandes (économies d'eau, déplacements d'utilisations, arbitrages des « conflits d'usage » notamment entre les demandes agricoles et urbaines). Les objectifs de production hydro-électrique des aménagements hydrauliques de « première génération » passent au second plan et seront à l'avenir davantage subordonnés aux objectifs hydro-agricoles, voire de sécurité contre les risques d'inondation. Des efforts d'aménagement des bassins pour retarder le comblement des retenues seront à amplifier, conjugués avec les opérations de dévasement et avec le développement d'autres techniques de régularisation des crues (notamment par une forte expansion de la recharge artificielle des aquifères, couplée avec l'intensification de leur exploitation).

— Les retards de l'assainissement des agglomérations et de l'épuration des eaux usées urbaines et industrielles, aggravés par une urbanisation explosive, ont souvent dégradé les qualités des eaux réceptrices, en réduisant d'autant plus des ressources déjà limitées. Des efforts accrus d'assainissement et de prévention des pollutions n'auront pas seulement une justification sanitaire et de « protection de l'environnement », mais seront à intégrer dans l'aménagement des eaux, en concourant à la conservation des ressources.

— Le contrôle des ressources « importées » vitales pour certains pays, nécessitera l'extension de la concertation et de la coopération entre pays, notamment pour faciliter la maîtrise des écoulements par des aménagements réalisés dans les pays amont, en partie au bénéfice de pays aval, à l'exemple des aménagements du Nil ou du Sénégal.

— Parmi les objets de ces aménagements, la récupération des pertes par évaporation dans les deltas intérieurs et les marécages associés (au moyen du drainage et de dérivations appropriées, exemple : canal du Jongleï au Soudan, gain visé 18.10^9 m^3/an) rivaliseront avec les ouvrages classiques d'accumulation, comme nouveau moyen de mobilisation des ressources.

— Même si la structure spatio-temporelle des ressources demeure inchangée, leurs défaillances conjoncturelles — effets des *sécheresses* — seront à l'avenir plus pénalisantes face à des demandes croissantes et au désir de sécurité d'approvisionnement grandissant (qu'il s'agisse d'alimentation humaine ou d'irrigation).

C'est bien en zone semi-aride que les sécheresses sont le plus préjudiciables et qu'il importe le plus d'en prévenir les effets et compenser les conséquences. Toutefois cela ne relève pas des seuls efforts d'aménagement des eaux accru — tant en « grande » qu'en « petite hydraulique » — dont on a dit les limites de faisabilité technico-économiques, mais d'une conjonction adéquate (dans des proportions spécifiques à chaque pays) de plusieurs mécanismes régulateurs : régulation des flux d'eau, certes, mais aussi des flux de production alimentaire (par les stockages) et des flux financiers (par les procédures d'assurance). Néanmoins les capacités régulatrices pluriannuelles des réserves d'eau souterraine — là où elles sont appréciables et identifiées — pourraient davantage être utilisées à cette fin dans bien des régions, par des exploitations plus modulées et éventuellement stimulées. De même les ressources non renouvelables reconnues de grands bassins sédimentaires pourraient être utilisées en priorité comme appoint pour compenser les défaillances des ressources renouvelables plutôt que de manière autonome, dans une optique de valorisation à court ou moyen terme.

En somme ce qui caractérise le plus les problèmes d'eau en zone semi-aride, c'est leur interdépendance et la complémentarité des solutions d'ordres variés qui nécessitent une gestion intégrée des ressources et des utilisations, et par conséquent une intégration plus poussée de l'économie et de la politique de l'eau dans le développement socio-économique sur lequel elles pèseront dans une mesure croissante.

— Enfin, en domaine intertropical humide où les ressources en eau abondantes se doublent de potentiels hydrauliques encore largement inexploités et pouvant motiver de grands ou petits aménagements hydro-électriques, le principal problème est de faire face aux demandes croissantes mais peu solvables d'approvisionnement en eau potable d'agglomérations de plus en plus gigantesques (25 villes pourraient dépasser 2 millions d'habitants en 2010, dont 10 de plus de 5 millions). Les problèmes de financement (investissement et fonctionnement) l'emportent ici de beaucoup sur les difficultés techniques des solutions.

— Néanmoins les qualités sanitaires des eaux utilisables laissent souvent à désirer et nécessitent tant des traitements correcteurs que des mesures de protection, aussi bien pour les dessertes urbaines que pour l'alimentation rurale. Ici aussi l'assainissement est très en retard et les situations tendent à se dégrader, posant des problèmes de financement encore plus difficilement surmontables, mais également des problèmes techniques dus à la faiblesse des utilisations d'eau.

Les images très macroscopiques et le tableau sommaire esquissé ne visent pas à conclure, mais seulement à proposer une toile de fond et quelques repères en introduction aux analyses qu'il convient d'approfondir et d'affiner sur le présent et l'avenir des problèmes d'eau en Afrique.

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Water Resources of the Middle East

JOHN KOLARS*

ABSTRACT

This article presents an overview of the water resources available in the Middle East region (Israel, Jordan, Lebanon, Syria, Iraq and Turkey.) The countries of the Arabian peninsula as well as those of Northern Africa are not considered here. Water balances are presented for the countries studied and the water supply and consumption patterns in the main river basins of the area (Euphrates/Tigris, Jordan, Litani and Orontes) are described. The point is made that the combination of rapid population growth, together with limited water resources is creating a potentially very dangerous situation. Possible solutions include conservation measures, more efficient use of the limited water resources and future interbasin transfer schemes within the region.

RÉSUMÉ

Cet article présente une vue d'ensemble des ressources en eau du Moyen Orient, c'est-à-dire l'Israël, la Jordanie, le Liban, la Syrie, l'Irak et la Turquie. Les pays de la péninsule arabique ainsi que ceux de l'Afrique du Nord ne sont pas discutés ici. On présente le bilan hydrologique pour les pays concernés ainsi que les scénarios d'approvisionnement et de consommation en eau des principaux bassins de la région (Tigre/Euphrate, Jourdain, Litani et Oronte). L'article souligne également que la conjoncture actuelle — croissance démographique rapide et ressources hydrologiques très limitées — risque de créer une situation potentiellement dangereuse. On recommande donc de prendre des mesures énergiques de conservation, de mieux utiliser les ressources en eau et d'adopter un plan de transfert de l'eau entre les bassins de la région.

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INTRODUCTION

Human dependence upon limited water supplies underlies any consideration of water resource management in the Middle East. The populations of this region utilize a combination of local springs, wells and rivers, transboundary streams, and in more limited cases, fossil water from deep wells and springs.

The following discussion omits all North African countries often subsumed under the terms Middle or Near East. Also, for reasons given below, it does not discuss the populations and aquifer-based water supplies of countries of the Arabian Peninsula south of the Jordan and Iraq borders.

The populations of the Middle East, as defined for this discussion, are essentially Arabic — with the exception of Israel. Two other nations which figure in this discussion are Turkey and Iran, both linguistically and in many ways culturally different from their Arab neighbors although all, except Israel, share Islam as their predominant faith. Syria, Iraq, Lebanon, Jordan and Israel and the Occupied Territories (the West Bank and Gaza) have a combined population of nearly 39 million. Of these people an estimated 41.5% rely on transboundary streams flowing from non Arabic countries, 52.5% utilize springs, wells and rivers supplied by local precipitation which at best is unpredictable, highly variable, and too often sparse. The remaining 6.0% turn to water pumped from deep wells (Table 1). Table 2 shows the distribution of water from surface and underground sources. As will be seen, these water supplies at the present time are being taxed to their limits.

Table 1

Middle East Populations (1000s) and the Water Resources upon which they Depend

Country	Current Total Population (Yr. 2020)	Trans-boundary Rivers	Local Springs, Rivers, Wells	Non-Renewable Deep Aquifers
Iraq	16,000 (41, 808)	10,800	5,200	—
Israel	4,400 (6,643)	1,400	2,900	100
West Bank & Gaza	1,800 (4, 200)	—	1,000	800
Jordan	3,450 (9,964)	1, 650	700	1,100
Lebanon	2,500 (4,433)	—	2,500	—
Syria	10,500 (26,094)	2,200	8,000	300
Total	**38,650**	**16,050 (41.5%)**	**20,300 (52.5%)**	**2,300 (6.0%)**
Turkey	55,300 (83,849)	—	55,300	—
Iran	49,800	500	26,300 plus 23,000 (qanats)	

Table 2

Dependency upon Surface and Underground Sources

Country	Population	Surface	Subsurface	Other
Iraq	16,000	15,680 (98%)	320 (2%)	—
Israel	4,400	1,760 (40%)	2,508 (75%)	132 (3%)
West Bank & Gaza	1,800	300 (17%)	1,500 (83%)	—
Jordan	3,450	1,760 (51%)	1,690 (49%)	—
Lebanon	2,500	875 (35%)	1, 625 (65%)	—
Syria	10,500	8,715 (83%)	1,785 (17%)	—
Total	**38,650**	**29,090 (75%)**	**9,428 (24%)**	**132 (1%)**

Turkey and Iran are essentially self-sufficient with regard to water. At the same time, the former is the source of 98% of the flow of the Euphrates and 43% of that of the Tigris River. The Zagros Mountains on the border of Iran and Iraq, form catchments for waters of tributaries entering from the left bank of the Tigris in Iraq. Other significant streams, all of which originate within the Arab Middle East, are the Jordan River rising in Lebanon, Syria and Israel, and its major tributary, the Yarmouk, which rises in Syria and forms the boundary first between Jordan and Syria and thereafter between Jordan and the Golan Heights. The Orontes (Asi) River which rises in the Bekaa Valley of Lebanon and flows north through Syria and Turkey to the Mediterranean Sea also takes its place among the disputed rivers of the Middle East. The Litani River, which rises and flows entirely within Lebanon, demands attention as the only reliable source of pure, surplus water adjacent to Israel and Jordan.

I. CLIMATIC CONTROLS OF MIDDLE EASTERN WATER SUPPLIES

In order to understand the hydrologic systems found within the Middle East it is necessary to review the associated climatic factors. The dominant control of this region is the subtropical high pressure belt located at approximately 30° north latitude. This introduces cold, dry air which warms as it descends and diverges over northern Africa and the Arabian Peninsula. Evapotranspiration in excess of one meter results and severe desiccation is the rule. This arid belt shifts northward with the June solstice and brings Sahara-like, summer conditions to the southern shores of Turkey. In the winter, lower temperatures and small amounts of precipitation occur in coastal Egypt and the Levant as the system and the jet stream move south. Snow sometimes falls on Jerusalem and the heights of northern Jordan, as was the case in the winter of 1991-92. Aridity is somewhat ameliorated by westerly winds which move moist air masses from the Mediterranean and Black Seas onto the land with subsequent orographic precipitation on the Taurus, Anti-Taurus, and Pontic Mountains and highlands of eastern Turkey. Similar conditions occur on the Elburz and Zagros

Mountains on the border of Iran and Iraq. The Jebel Alawi in Syria and on Mount Lebanon and the Anti-Lebanon Mountains of the country sharing their name also have orographic precipitation, as do the hills of the West Bank and northern Jordan.

The nations of the Arabian Peninsula lack precipitation adequate to maintain significant agriculture without irrigation. Nor are those countries graced with exotic streams flowing from areas of surplus water as in the case of Syria and Iraq which share the Euphrates and Tigris Rivers with Turkey. Inland areas at higher latitudes, such as the Anatolian Plateau of Turkey and the steppes of northern Syria (the Jezirah) experience continental climate with convectional showers in the summer, though not in great quantities. In every case, both precipitation and resulting stream flow show extreme seasonal and annual variance. For example, the 50 year record for the flow of the Euphrates River at Hit, Iraq shows a peak flow of 7 390 m^3/s in 1969, and a minimum peak flow of 850 m^3/s in 1930. The average annual flow for the period 1924-1973 was 903 m^3/s. Similarly, the average annual maximum and minimum flows for the period 1937-1961 were 2 509 m^3/s in April and 288 m^3/s in September.

The result of all this is that most countries in the Middle East labor under grinding aridity which is only partially offset by exotic stream flow or the pumping of underground supplies. In the latter case, water drawn from deep aquifers is essentially non-renewable, having infiltrated those strata fifteen to twenty-five thousand years ago as the continental glaciers of the northern hemisphere melted. While these stores of water are remarkably pure and impressively large, they are finite. Evidence exists that such stocks are being steadily depleted. An argument can be made by analogy with the Ogallala aquifer in the American West that even the largest of these Middle Eastern aquifers are capable of quick exhaustion. Thus, their use should be considered temporary if not ephemeral.

Two approaches are possible in assessing prospects for water use in the Middle East. A country-by-country view tells much about each nation's water situation and future; at the same time, the transboundary nature of most important streams necessitates an accounting from headwaters to final destination of each stream's flow. Both methods are beset by problems of sparse and incomplete data, conflicting data sets and numerous interpretations of such data as do exist. The values that follow are open to revision and improvement but represent an accurate picture given the above caveats.

II. AN ACCOUNTING BY RIVER BASIN

A. The Euphrates and Tigris Rivers

The Euphrates River is the longest river (2 700 km) in southwest Asia. The Tigris River (1 840 km) has greater volume (49 100 Mm^3/yr vs. 32 720 Mm^3/yr), but while the use of both rivers has been significant for millennia in lower Mesopotamia (now Iraq) the Euphrates at present has assumed greater importance because of the ambitious development plans being carried out on it by the Turks and the Syrians. Turkish projects center upon the Southeast Anatolia Development Project (Turkish acronym GAP) which when completed proposes seven sub-projects on the Euphrates River including 15 dams, 14 hydroelectric power stations and 19 irrigation projects totalling 1 350 000 hectares (Kolars and Mitchell, 1991, p. 208). Another, separate project, the Keban Dam, completed in 1974 also generates hydropower and impounds 300 Mm^3/yr of water. Syria, in turn, has completed the Tabqa (Ath-Thawra) Dam as well as smaller diversions along the river and contemplates irrigating as much as 397 000 hectares with mainstream and tributary waters. Iraq has traditionally irrigated approximately 1 550 000 hectares with water from the Euphrates.

In assessing the Euphrates and its flow, three values must be considered (Table 3). Estimates by Kolars and Mitchell show a total average, natural flow at Hit, Iraq of 32 720 Mm^3/yr. Of this, 30 670 Mm^3/yr originate as surface flow into the main stream in Turkey. Another 2 050 Mm^3/yr are added in Syria although most of this comes from Turkish aquifers. Iraq adds no flow worth reporting. At the time the Keban Project was begun (ca 1970) approximately 820 Mm^3/yr were being removed from the river in Turkey for irrigation purposes. Another 2 000 Mm^3/yr were similarly removed in Syria. Iraqi irrigation averaged about 17 000 Mm^3/yr with perhaps 4 000 Mm^3/yr return flow. Thus, Syria received 29 850 Mm^3 annually and Iraq about 29 800 Mm^3/yr while 16 800 Mm^3/yr remained to combine with the flow of the Tigris River to form the Shatt Al-Arab, the lowest reach of the stream before it enters the Arabian/Persian Gulf.

Table 3

Sources and Uses of the Euphrates River (Mm^3/yr)

Natural Flow				
	Observed at Hit, Iraq	29,800		
	Removed in Turkey (pre-GAP)	820		
	Removed in Syria (pre-Tabqa)	2,100		
	Natural flow at Hit	32,720		
Pre-Keban Dam (< 1974)			Flow in Turkey	30,670
			Removed in Turkey	− 820
			Entering Syria	29,850
			Added in Syria	+ 2,050
			Removed in Syria	− 2,100
			Entering Iraq	29,800
			Added in Iraq	—
			Iraqi irrigation	− 17,000
			Iraqi return flow (est.)	+ 4,000
			To Shatt Al-Arab	16,800
Full Use Scenario (ca. 2040)			Flow in Turkey	30,670
			Removed in Turkey	− 21,600
			Entering Syria	9,070
			Removed in Syria	11,995
			RF & Tributaries (Turkey / Syria)	+ 9,484
			Entering Iraq	6,559
			(Removed in Iraq)	(− 17,000)
			(RF in Iraq)	(+ 4,000)
			(Deficit to the Shatt Al-Arab)	(− 6,441)

If all the proposed irrigation projects that Turkey envisages are completed, by the year 2040 as much as 21 000 Mm^3/yr might be removed or lost to evaporation from reservoirs in that country. Only 9 000 Mm^3/yr would enter Syria in the main stream although nearly 7 000 Mm^3/yr return flow would reach the river via the Balikh and Jagh-Jagh tributaries in Syria. This plus natural tributary flow of 2 050 Mm^3/yr would allow Syria to extract up to 12 000 Mm^3/yr for its own planned use. The remainder, about 6 500 Mm^3/yr, would not suffice for Iraq and a possible shortfall of 10 000 Mm^3/yr might occur for this last downstream riparian. This would also result in a shortfall of minus 6 500 Mm^3/yr to the Shatt Al-Arab. Obviously, such a situation should not, and could not develop, given world opinion and international pressures. Nevertheless, the possibility for impending crisis is apparent given this accounting.

The Tigris River presents similar problems (Table 4). Turkey provides at least 43% of the natural flow of this river. An additional 30 700 Mm^3/yr enters in Iraq resulting in an estimated, annual natural flow at the Shatt Al-Arab of 49 100 Mm^3/yr. Contemporary conditions bring 18 500 Mm^3/yr into Iraq from Turkey. Additions, removals and return flow in Iraq leave a balance of 24 000 Mm^3/yr reaching the Shatt Al-Arab to combine with the flow of the Euphrates River. By sometime after the year 2000, nearly 7 000 Mm^3/yr could be removed in Turkey for scheduled projects and those already under construction. Again, considering the total balance sheet for Iraq, something less than 10 000 Mm^3/yr will reach the Shatt. This, combined with the negative balance estimated for the Euphrates adds up to an impossible situation for Iraq and for the ecology of the Gulf, one which must be favourably resolved if peace and sustained development are to be maintained in the region.

Table 4

Sources and Uses of the Tigris River
(Mm^3/yr)

	Pre-project	2000 +	Natural Flow
Flow from Turkey	18,500	18,500	18,500
Removed in Turkey	—	− 6,700	
Entering Iraq	18,500	11,800	
Inflows to Mosul	2,000	2,000	2,000
Greater Zab	13,100	13,100	13,100
Lesser Zab	7,200	7,200	7,200
Other	2,200	2,200	2,200
Subtotal	43,000	36,300	43,000
Reservoir Evaporation	—	− 4,000	
Irrigation (to Fatha)	− 4,200	− 4,200	
Return Flow	+ 1,100	+ 1,100	
Adhaim River	+ 800	+ 800	800
Irrigation (to Baghdad)	− 14,000	− 14,000	
Return Flow	+ 3,600	+ 3,600	
Domestic Use	− 1,200	− 1,900	
Diyala River	+ 5,400	+ 5,400	5,400
Irrigation	− 5,100	− 5,100	
Return Flow	+ 1,300	+ 1,600	
Subtotal	30,700	19,200	49,200
Reservoir Evaporation	—	900	
Irrigation to Tokut	− 8,600	− 8,600	
Return Flow	+ 2,200	(2, 200 to Outfall Drain)	
Total to Shatt Al-Arab	**24,300**	**9,700**	**49,200**

B. THE JORDAN RIVER

Rational management of the Jordan River is currently even more critical than that of the Euphrates/Tigris basin. Israel, Jordan, and the inhabitants of the West Bank all have interests in the waters of this stream and its tributaries. Syria also has much to gain or lose from their management, and Lebanon, while having less at stake, nevertheless contributes to the flow of the Jordan's northern tributary, the Hasbani (Table 5). (In order to understand the complexities of this issue the reader is advised also to review the country water budgets for Jordan and Israel given later.)

The northern tributaries of the Jordan come from Lebanon (the Hasbani River, flow 125 Mm^3/yr), from Israel (the Dan Spring, 250 Mm^3/yr), and the Golan Heights (the Banias River and Hermon Spring, 125 Mm^3/yr). These combined waters flow south through the Huleh Valley and after local extractions, runoff and return flow, deliver 540 Mm^3/yr to Lake Tiberius (Lake Kinneret or the Sea of Galilee). Lake Tiberius receives local runoff, precipitation, and flow from the Yarmouk and has 500 Mm^3/yr extracted for the Israeli National Water Carrier which transfers water as far south as the Gaza Strip. Salt springs feeding into the lake have been diverted by Israel and led to the southern stem of the Jordan, which below its confluence with the remainder of the Yarmouk is too saline for use.

The Yarmouk, in turn, provides water for Syria (see Table 5 for conflicting estimates of this amount), and Jordan (158 Mm^3/yr to the East Ghor Canal), and as much as 100 Mm^3/yr to Israel via Lake Tiberius. Runoff from the west and east banks below the Yarmouk add another 500 Mm^3/yr to the Jordan River before it empties into the Dead Sea. Inspection of Table 5 shows that of a possible natural flow of 1 593 Mm^3/yr that might reach the Dead Sea, only about 700 Mm^3/yr actually do, and the latter flow may be much diminished and polluted by use on either bank. It should be noted further that these figures are for average times and that in the late 1980s and early 1990s drought conditions seriously reduced all the flows listed above. Evidence of this is that the Dead Sea now consists of two smaller basins instead of one large surface.

C. THE LITANI RIVER

The Litani River is an exception to the usual transboundary nature of Middle Eastern streams for it rises and flows entirely within the borders of Lebanon. This fact, however, does not diminish its political and international importance for there has long been speculation over its possible use by either, or both, Israel and Jordan. There is also strong geological evidence that the lower Litani may provide water for the Hasbani River and Dan Spring mentioned above.

The river rises midway along the north-south treading Bekaa Valley and receives almost all of its flow from numerous springs along its course. Upstream additions are somewhat offset by irrigation which extracts 80 Mm^3/yr. Approximately 455 Mm^3/yr reaches the Qirawn Dam and Reservoir, the only such construction on its course. Midstream inflows add another 121 Mm^3/yr, but immediately below the dam a major diversion takes place where 236 Mm^3/yr are directed through the Markaba Tunnel to the Awali River in order to produce hydroelectric power. Downstream inflows on the Litani add 264 Mm^3/yr with perhaps another 77 Mm^3/yr being removed for local irrigation along the east-west or Qasmiyeh section of the

Table 5

Sources and Uses of the Jordan River*
(Mm^3/yr)

	Estimated Observed Flow		Estimated Natural Flow
North Jordan System			
Hasbani River (Lebanon)	125		125
Dan Spring (Israel)	250		250
Banias River (Golan Heights)	125		125
Local Runoff (Upper Valley)	140		140
Irrigation-Return Flow (Huleh Valley)	− 100		
Subtotal to Lake Tiberius	540		640
Lake Tiberius			
Spring Flow (salty)	65		65
Precipitation	65		65
Local Runoff	70		70
From Yarmouk	100		—
Subtotal	+ 840		840
Evaporation	− 270		− 270
To Nat'l Water Carrier	− 500		
Subtotal to Lower Stem of Jordan River (N. Jordan)	**+ 70**		**570**
The Yarmouk River	(Al-Fataftah) (Salameh)	(Beaumont) (Gruen)	
Flow from Syria	+ 400**	495**	400
Syrian Irrigation	− 90	− 250***	
Syrian Return Flow	+ 20	+ 50 (est.)	
To East Ghor Canal	− 158**	− 150**	
To Israel (via Tiberius)	− 100**	− 80**	
Subtotal to Lower Stem of the Jordan River (Yarmouk)	**+ 72**	**+ 65**	**970**
Lower Stem of Jordan River			
Lower Jordan Spring Flow	+ 185		185
Zarqa River and Wadis	+ 322	+ 539	322
East Ghor Return Flow	+ 32		
Total	**+ 611********	**+ 604********	**1,477**

* In an average year; climatic variations can change the values given below by +/- 30 %.
** Conflicting sources of date account for these variations.
*** Smaller values from the Johnston Plan; recent evidence indicates as many as 20 small diversionary dams have been built on the headwaters of the Yarmouk in Syria. Larger withdrawal values reflect such possible diversions.
**** Once in the main stream, this water is unusable due to high salt concentrations.

river. Natural flow would amount to about 920 Mm^3/yr entering the Mediterranean. In practice, perhaps 500 Mm^3/yr reach the sea (Table 6). Careful accounting of stream flow and precipitation along sequential segments of the river indicate that 100 Mm^3/yr disappear in the last downstream segment. This water apparently charges a large synclinal aquifer which may deliver water to the Dan Spring and Hasbani River on the Jordan River.

The Awali River has a natural flow of 124 Mm^3/yr to which are added 236 Mm^3/yr from the Litani and 30 Mm^3/yr from seepage in the Markaba Tunnel. This water after passing through three generating stations finds its way to the coast where part of it is used for irrigation before escaping to the sea.

There appears to be no significant removal of water from the lower Litani by human means at the present time. Some water may be being trucked to settlements in South Lebanon and a small pipeline and pumping station may also be serving some of the same villages. On the other hand, population growth and future development in this area will undoubtedly use up any surplus water reaching the lower stream. There is little or no additional land that can be irrigated in the Bekaa Valley and barring increased removals to the Awali, the use of the stream above Khardale should remain essentially the same as it is now. If large removals were to occur — for example, larger diversions to the Awali or over the headwaters to the Orontes (see below) — repercussions could be felt in the reduced flow of the northern Jordan tributaries.

Table 6

Sources and Uses of the Litani and the Awali Rivers
(Mm^3/yr)

	Observed Flow	Natural Flow
The Litani River		
Upper Valley Springs	+ 325	325
Upper Valley Runoff	+ 210	210
Irrigation Withdrawals	120	
Return Flow	+ 40	
Subtotal to Qirawn Reservoir	455	535
Qirawn Reservoir — Evaporation / Seepage	− 26	
Mid-Valley Inflows	+ 121	121
Markabah Diversion to Awali	− 236	
Lower Valley Inflows	+ 264	264
Qasmiyeh Irrigation (-RF)	77	
Total	**501**	**920**
The Awali River		
Local Flow	124	124
Markabah Tunnel Inflow	30	(30)
From the Litani	236	
Total	**390**	124 (154)

D. THE ORONTES (ASI) RIVER

The Orontes rises in the Bekaa Valley north of the headwaters of the Litani River and flows north through Syria and Hatay Province in Turkey before reaching the Mediterranean. While little noticed in the Middle Eastern hydrologic scene, developments along its course may well cause tension among the three nations which share its waters.

Table 7

Sources and Uses of the Orontes (Asi) River
(Mm^3/yr)

	Observed Flow	Natural Flow
Headwaters (Lebanon)	420	420
Irrigation	− 80	
Return Flow	+ 30	
Upstream Inflow (Syria)	+ 370	370
Irrigation (Homs to Hama)	− 200	
Return Flow	+ 70	
Subtotal	+ 610	790
Irrigation (Ghab)	− 580	
Return Flow	+ 230	
Inflows to Afrin River	+ 60 (est.)	60
Inflows to Turkey (Afrin)	+ 250	250
Turkish Withdrawals	??	
Total to Turkish Hatay	570	1,100

Small amounts of irrigation water are at present being removed from its headwaters in Lebanon (Table 7). Much of this water was apparently used for the production of opium poppies during the long wartime period just ended. Of 420 Mm^3/yr about 370 Mm^3/yr enter Syria where another 370 Mm^3/yr raise the flow to 740 Mm^3/yr. Irrigation between Homs and Hama remove 130 Mm^3/yr and a further 330 Mm^3/yr are depleted (after removal and return flow) in the Ghab area. Farther north the Afrin River rises in Turkey and flows through a corner of Syria before re-entering Turkish Hatay. Sixty Mm^3/yr are added in Syria and as much as 250 Mm^3/yr more in Hatay. It is not clear how much water is used in Hatay, but natural flow reaching the sea would be about 1 100 Mm^3/yr. Syria plans to build two additional dams on the Afrin which may further reduce downstream flow. In any event, the waters of this river will undoubtedly become a bargaining chip in future hydrodiplomacy between Syria and Turkey. Syria also has important interests in maintaining an unimpeded flow from Lebanon and will likely maintain control of the stream's headwaters by its physical presence or diplomatic pressure.

III. A COUNTRY-BY-COUNTRY BALANCE SHEET

The above account indicates that every country in question depends not only upon a variety of sources of water but also shares such waters with its neighbors. Thus, knowledge of a stream's flow does not tell all the story of water and its uses, and a further reckoning must examine each country in its turn.

A. Israel

Israel relies upon three general sources of water: Lake Kinneret (Tiberius) and that lake's sources, aquifers extending from the West Bank into Israel, and a variety of aquifers and streams the sources of which are within its own boundaries Table 8). Lake Kinneret provides 500 Mm^3/yr to the National Water Carrier. The coastal plain aquifer adds another 280 Mm^3/yr to Israel's fund along with another 720 Mm^3/yr (of which 220 Mm^3yr are recycled waters) from within the Green Line which demarcates the nation's uncontested national borders, and 450 Mm^3/yr out a total of 545 Mm^3/yr are generated by West Bank aquifers. This constitutes a supply of 1 950 Mm^3/yr (although drought conditions in 1991 reduced the available overall supply to 1 600 Mm^3/yr).

Table 8

Estimated Water Budget of Israel
(Mm^3/yr)

Sources			*Supply / Demand*
Lake Kinneret			500
West Bank			
Yarqon-Taninim Aquifer	340		
Northern Aquifer	135	545	450
Nablus-Jenin	70		
Eastern Aquifer			—
From inside the Green Line (est.) various sources			500
Coastal Plain Aquifer			280
Recycled			220
Total			**1,950**
Current (The result of the current drought)			1,600
Consumption			
— Including the Occupied Territories			2,100 – 2,200
OR			
— Not including the Occupied Territories*			1,820
Shortfall / Overage			+ 130 or – 250
— With current drought			– 220 or – 600
Projected Need (2020)			**2,900**

* See Naff, 1991b.

The latter waters originating on the West Bank are the subject of considerable debate. Palestinians and other Arab groups cite that Israel uses 83% of those supplies. Israel counters that since there is a natural flow of aquifer water from the West Bank downslope into Israel, only about 20% of West Bank water is used by Israelis and that the remainder should not be counted as a depletion because any such water that is removed by pumping in Israeli territory legitimately belongs to that state. Which of these interpretations is correct remains to be decided in a court of international law.

Water consumption in Israel at the present time is estimated to be 2 100 to 2 200 Mm^3 annually (including that of the West Bank and Gaza). J. Schwarz, an Israeli hydrologist, cites a lower figure of 1 820 Mm^3/yr although he does not specify whether his data include the occupied territories (Naff, 1991 b). In any event, a current balance from +130 to as much as −600 Mm^3/yr is indicated for Israel.

The population of Israel is currently 4 563 000. Another one million immigrants from the ex-Soviet Union are expected in the next two to three years. Population projections anticipate a total population of 6 643 000 by the year 2020. If no new sources of water are found, severe shortages are inevitable as population grows beyond six million. Israel has, in the past, used about 75% of the water available to it for irrigated agriculture. During the drought of 1991 water for agriculture was cut back by 30%, an unprecedented austerity. Whether or not this restriction will continue is uncertain. As is the case for many of the countries in question which seek some modicum of security based on domestic food production, one way out of the water shortage dilemma that Israel faces would be to devote less water to agriculture.

B. JORDAN

Jordan's water supply, of all the nations in the Middle East, is the least secure. Table 9 shows that its present use of 730 Mm^3/yr is based upon diversions from the Yarmouk into the East Ghor Canal of 158 Mm^3/yr, flow from the Wadi Zarqa (and the King Talal Dam) of 237 Mm^3/yr, water from underground sources such as the Azraq Oasis (279 Mm^3/yr), and the Disi deep aquifer in the south, 56 Mm^3/yr (of which 45 Mm^3/yr is used for subsidized wheat cultivation and 11 Mm^3/yr for the city of Aqaba).

If it is possible to build the Unity (Wehdah) Dam on the Yarmouk in order to retain seasonal flood waters an additional 100 Mm^3/yr might be utilized by the Year 2005. Recent sources speak of as much as 200 Mm^3/yr already being removed from the headwaters of the Yarmouk in Syria by up to 20 small diversionary dams. Similarly, the water from the Disi aquifer in the extreme south, which is shared with Saudi Arabia, might safely be increased to between 78 and 100 Mm^3/yr (Al-Fataftah). Waste water recycling, water harvesting along the lower stem of the Jordan, and use of brackish water may provide another 120 Mm^3/yr, making a total of 1 028 Mm^3/yr by the year 2005. On the other hand, renewable groundwater supplies are already being over extracted by some 20%, and with Jordan's rapid population growth projected deficits range from 172 Mm^3/yr (with the Wedah Dam) to 272 Mm^3/yr (without the dam).

Table 9

Estimated Water Budget of Jordan
(Mm^3/yr)

a) Circa 1992	
Available from the Yarmouk River	158
Flow from the Zarqa (King Talal Dam)	237
Other (Azraq Oasis, etc.: non-renewable)	279
Disi Aquifer (southern Jordan and Saudi Arabia: non-renewable)	56
Total	**730**
*b) Circa 2005**	
Available from the Yarmouk (with Wehdah Dam)	258
Disi Aquifer	78
Wastewater reuse	70
Flow from the Zarqa	237
Small dams (water harvesting — new)	30
Brackish water use	20
Other	325
Total	**1,018**

* Al-Fataftah and Abu-Taleb, basing their prediction on an estimated safe water supply of 862 Mm^3/yr, predict a deficit in the year 2025 of 172 Mm^3/yr with the Wehdah Dam, and a deficit of 272 Mm^3/yr if the latter is not built. See Al-Fataftah and Abu-Taleb, 1992.

C. Lebanon

The story of Lebanon's water use is told by Table 10. Population in the country (2 897 000 in 1989) is expanding at 2.1% per annum, and 4 330 000 people are expected by the year 2020. Arable land is about 3000 km^2, 29.4% of the total country, of which 860 km^2 can be irrigated (8.4%). As mentioned earlier, there seems little opportunity to expand irrigated agriculture in the Bekaa Valley, and with the exception of additional water being used in southern Lebanon, domestic and industrial demands will be the most urgent need of the future. Given proper management, Lebanon should be able to meet its own hydrologic needs barring the intervention of outside powers.

D. Syria

Syria's hydrologic budget is less clear in its details. Reference to Table 3 indicates that Turkey's use of the water of the Euphrates may diminish water available for Syrian use. However, there would be only a slight chance that the minimum flow of 500 m^3/s requested by Syria from Turkey would be violated. On the other hand, maintaining such use within Syria would seriously short change Iraq's share of the river (also described as a minimum of 500 m^3/s, although Iraq in 1991 raised its minimum request to 750 m^3/s, a figure as yet to be verified as official policy). A more serious problem may be the quality of the water which is returned to Syria via the Euphrates, Balikh and Khabour Rivers after passing through Turkish fields.

Syria's population was estimated at 11 719 000 in 1989 with a growth rate of 3.8%. This means a doubling in size every 18 years, and a projected population of

22 533 000 by the year 2010. Syrian agriculture is estimated to use more than 90% of available water. The geographic location of large centers of population (Damascus, Aleppo, Homs) presents problems of transporting water from the Euphrates and/or the Khabour River in the north to areas of domestic need.

Table 10

Estimated Water Budget of Lebanon
(Mm^3/yr)

a) Water Reserves			
Total Precipitation		9, 200	
Lost to Evapotranspiration		4,324	
Runoff and Infiltration		4,876	
Total Available Reserve		3,713	
Total Consumed (ca. 1975)		854	
Unused Available Reserve		2,859	
b) Water Consumption ca. 1975			
Utilization	Surface Water	Subsurface Water	Total
Irrigation	422 (79%)	247 (78.3%)	669 (78.4%)
Domestic	105 (20%)	40 (12.3%)	145 (16.9%)
Industrial	10 (1%)	30 (9.4%)	40 (4.7%)
Total	**537** (100%)	**317** (100%)	**854** (100%)
c) Major Rivers			
Litani	920	24.8%	
Awali	124	3.3%	
Orontes (Asi) (to Syria)	420	11.3%	
Hasbani (to Israel)	125	3.4%	
All other Waters	2,124	57.2%	
Total	**3,713**	**100%**	

Aleppo's water supply once came from the Queik River flowing south from Turkey. This source was preempted some years ago for irrigation both in Syria and Turkey. In recent years Aleppo's water is siphoned from Lake Assad behind the Tabqa Dam on the Euphrates. Any shortfall or pollution of that reservoir would have serious consequences for the city. The Barada River which supplies the city of Damascus has recently been described to this author as "a trickling sewer." Syrian hopes to supplement the Barada with water from the Golan Heights or from Lebanese waters remain frustrated by the present political situation. Syria will undoubtedly face severe water shortages accompanying continued rapid urban growth. Syria also needs as much hydroelectric power as it can generate, but low levels at Lake Assad have curtailed electric production. Syria has also wanted to cooperate with Jordan in building the Unity Dam on the Yarmouk (see contradictory comment bottom of p. 114). Jordan would receive additional water and Syria would be given additional power generated at the dam. To date, financial problems deriving in part from Israel's unwillingness to accept this proposed modifying of the Yarmouk's flow have prevented construction at this site.

E. IRAQ

Iraq's population of 18 800 000 (1990) with a growth rate of 3.9% should reach 30 932 000 by the year 2010. The hydrologic future of Iraq is tied almost entirely to the future condition of the Euphrates and Tigris rivers upon which it depends (Tables 3 and 4). The extreme variance in flow of the Tigris presents special problems for Baghdad and farming areas in the lower reaches of the Tigris. Elaborate engineering projects were underway at the time of the Gulf War which include a drainage canal (the Main Outfall Drain) intended to remove used water from the farmlands between the rivers and siphon them into the headwaters of the Gulf. Additional plans to redistribute water from the Tigris to the Euphrates drainage system by way of the Thar-Thar depression, and eventually to move Euphrates water to the lower Tigris were well underway when hostilities began. The severe damage that Iraq sustained during the Gulf Wars has slowed, but not stopped, such plans. It remains to be seen what new schedule can be achieved for realizing these projects.

F. TURKEY

Turkey's population was 55 541 000 in 1989. A growth rate of 2.1% suggests a population of nearly 75 million by 2010. The country, however, is graced by large areas suitable for rainfed agriculture as well as its being the source of two major Middle Eastern rivers. Table 11 summarizes the water resources of the nation. Of about 185 billion cubic meters of runoff annually, the State Hydraulic Organization (Devlet Su Isleri) estimates about 95 billion cubic meters should be available for all types of use. An additional fund of 9.5 billion cubic meters of renewable ground water supplements surface flows. The total amount of water used in 1982 has been estimated at slightly more than 14 billion cubic meters. Further projections after all future needs, irrigation, industrial and domestic have been deducted, indicate an available surplus of nearly 43 billion cubic meters sometime after the year 2000.

Table 11

Estimated Water Budget of Turkey
(Mm^3/yr)

Available Water Reserves	
Euphrates	33,480
Tigris	21,810
Other Surface Waters	129,640
Subtotal	184,930
Unavailable for Consumption	90,000
Available for consumption	94,930
Available Subsurface Water	9,500
Total Water Reserves Available	104,430
Total Used (1982)	14,100
Projected Total Used (ca. 2000 +)	61,770
Available Surplus (ca. 2000 +)	42,660

Source: Government of Turkey, General Directorate of State Hydraulic Works, 1983.

G. Iran

Of all the countries in the Middle East, Iran has the least hydrologic involvement with its neighbors. Admittedly, the Gulf War may have begun over the placement of the two countries' mutual boundary somewhere along the Shatt Al-Arab, but that is a diplomatic matter beyond the scope of this discussion. The most severe threat of discord between the two nations regarding water consumption would be if Iran were to divert waters of some of the left bank tributaries of the Tigris back into Iran. The likelihood of this is not great at present. The Karun River which rises in the Iranian Zagros Mountains and flows to the Gulf is entirely within Iran's borders and an unlikely source of contention. As to Iran's long-term internal water needs, the intricacy of tracing such a budget is beyond the scope of this paper.

CONCLUSION

The above accounting has been presented in as dispassionate a manner as possible, and therefore the seriousness of the water situation in the Middle East may have been muted. The impending shortages are everywhere real and urgent. These are fired by rapid population growth in every country. High variance of precipitation and stream flow complicates matters, as does the non-renewable nature of most deep aquifers. Transboundary water sources, both surface and underground, further exacerbates the situation. Finally, the large percentage of water every nation commits to agriculture, which in turn is felt to offer some measure of security and/or income, makes the rational planning of resources for domestic and industrial uses much more difficult.

Desalination costs and pumping costs from sea level to higher elevations are prohibitive at today's prices, and an international "Manhattan" type project to obtain inexpensive sweet water from the sea should be given a major priority by all concerned. Similarly, improved efficiency of existing delivery facilities would go far to save water, as would the choice of crops which use less water or those which can flourish on brackish water.

In the realm of engineering, numerous solutions to impending or real shortages have been suggested in the form of interbasin transfers. Israel has led the way in this with its moving of 500 Mm^3 annually from the Jordan River basin via the National Water Carrier to other parts of the country. Transfers from the Litani to Israel and/or Jordan are frequently suggested. In the past few years Jordan has considered pumping water via a pipeline from the Euphrates in Iraq or possibly from desalination plants on the Gulf, but these have been deemed either too expensive or politically uncertain. President Sadat of Egypt once offered Nile water to the Sinai and the Gaza, though that idea was given little credence. More recently, President Ozal of Turkey has suggested a Peace Pipeline which would carry water from Turkey as far as Jeddah in Saudi Arabia and Sharjah in the U.A.E. A Mini-Peace Pipeline which would bring water to Amman, Jordan would be far less expensive, less complex politically, and would alleviate an imminent crisis. However, changes of political fortunes in Turkey and the selection of a new Prime Minister has curtailed talk of either proposal.

In general, all such schemes are expensive and clouded by the vulnerability of the lines themselves and the uncertainty of the guarantees of continuous long term flow. Thus, the solution to the overriding problem of water availability in this region (or to the myriad smaller individual puzzles which this presents) depends heavily upon diplomatic interactions between the needy and the needy, as well as between the needy and the well endowed. The necessary engineering technology exists. Does the international will also exist to achieve a water-based peace within the Middle East, a true pax aquarum?

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*Irrigation Management Strategies for the 21st Century**

ROBERTO LENTON**

ABSTRACT

This paper addresses some major issues in the field of irrigation management. It describes various factors affecting the present situation, outlines the progress that has been made to date, and points to the challenges to be met in the remainder of this century. Special attention is given to the need to increase the efficiency of irrigation procedures in order to produce more with the limited water resources that are available.

RÉSUMÉ

Cet article aborde les principaux problèmes dans le domaine de la gestion de l'irrigation. Il décrit les différents facteurs qui ont une incidence sur la situation à l'heure actuelle, trace les progrès qui ont été faits et souligne les défis qui restent à résoudre dans cette fin de siècle. L'accent est mis également sur le besoin qui existe d'améliorer les techniques d'irrigation afin d'accroître la production malgré la paucité des ressources en eau.

INTRODUCTION

The purpose of this paper is to describe some of the major issues that the world must address in the field of irrigation management as we approach the 21st century. The paper is one of a series presented during a Round Table Discussion held at the IWRA Congress in Rabat on overall water strategies for the 21st century; together,

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* This paper was first presented at a round-table discussion on "Water Strategies for the 21st Century: Guiding Ideas and Tendencies," held during the Seventh World Congress on Water Resources of the International Water Resources Association in Rabat, Morocco, May 13-18, 1991. The author gratefully acknowledges the discussions with other participants as well as with colleagues at the International Irrigation Management Institute, which substantially influenced the contents of this paper.

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these papers aim at developing an integrated view on land use and water resources management in order to generate water resources management strategies that can overcome future water scarcities for both biomass production and other water needs. This subject has direct relevance for the Middle East and Northern Africa, where a great deal of water is used for irrigation.

The paper is divided into three sections: context, progress to date, and remaining challenges. The first section describes the most important irrigation management problems that the world faces today, and outlines the way in which these problems are likely to evolve as we approach the 21st century. The second section describes some potential solutions to these irrigation management problems and reviews progress to date in their implementation. The third and last section describes the more significant challenges that need to be addressed in the remainder of this century.

I. CONTEXT

The world's irrigation in the closing decade of the 20th century is characterized by low performance, increased demand for higher agricultural productivity, decreased availability of water for agriculture, potential uncertainties resulting from global climate change, and a changing public sector role. Each of these factors is analyzed below.

A. Low Irrigation Performance

Principally as a result of inadequate technologies, management practices and policies, most irrigation systems around the world, in both developing and developed countries, are performing far below their potential. This is true in virtually every dimension of performance: efficiency, productivity, equity, sustainability, and impact on rural livelihoods.

In most countries around the world, significantly more water is delivered per unit area than is required, leading to low irrigation efficiencies. The area irrigated in many irrigation systems is much less than the area commanded, and annual cropping intensities are lower than anticipated (IIMI, 1989). Water deliveries rarely correspond in quantity and timing to the true requirements of the farmers crops, leading to losses in productivity; thus, for example, the yields of irrigated wheat and rice in India are only half of what they could be (Postel, 1989). In many irrigation systems, water is distributed inequitably between farmers near the head-end reaches of the system, where water is short, and those less fortunate farmers located downstream (IIMI, 1989). Increases in areas affected by water logging and salinity, declining and increasingly saline ground water tables, and shrinking lakes and seas raise worrying concerns about the sustainability of irrigation systems (Postel, 1989). Biswas (1991) has estimated that the share of irrigated land damaged by salinization amounts to 27% of the total irrigated area around the world.

B. Increased Demand for Higher Agricultural Productivity

A recent World Bank/UNDP report (World Bank, 1990) stated the problem as follows:

> The world's population is expected to grow from 5 billion today to 6 billion by the year 2000, and to at least 8 billion by the year 2025, with more than 90% of the increase being added to the developing world. Achieving food security, alleviating poverty and improving the quality of life in developing countries will, therefore, continue to pose major challenges to decision-makers well into the next century. Expanding agricultural production and enhancing rural incomes, in a sustainable manner, will be a significant strategy in responding to these challenges. Without agricultural growth, the rise in population would be far too large in relation to the productivity of the resource base.

Since achieving agricultural growth can no longer be realized through expansion of cultivated land, such increases will require significant growth in agricultural productivity of both rainfed and irrigated land. However, in view of the lack of real prospects for substantial increases in rainfed agricultural productivity, a disproportionate share of future agricultural growth will need to come from the irrigated sector (Yudelman, 1990). The UN Food and Agriculture Organization estimates that irrigation will have to increase by 40% over the next two decades to meet projected demand (FAO, 1985). And the World Bank report referred to earlier estimates that irrigated agriculture yields will need to grow by 3% a year to meet demand and achieve food security in the decades ahead.

Improvements in irrigated agriculture are unlikely to come from increases in irrigated areas, since new irrigation expansion is declining, continuing a trend that commenced in the late 1970s. The current rate of expansion in the world today, according to the World Bank report referred to earlier, is no more than 2 million hectares a year — under 1% of the world's total irrigated area of about 250 million hectares, and less than half of the irrigation growth rates of 2-4% per year experienced during the sixties and seventies (Postel, 1989). Since the decline in growth results both from the increased cost of new irrigation development and from the reductions in irrigation lending by the major international donors, prospects for a turn-around in the next couple of decades are unlikely.

C. Decreased Availability of Water for Agriculture

Undoubtedly, the next decade will be characterized by growing scarcity, competition and conflict among water users; growing demands for water for other uses, including in particular for drinking and for industry; declines in the share of water available for agriculture; and declines in investments in irrigation expansion. This decrease in the availability of water for agricultural purposes, coupled with the requirement for higher agricultural productivity in irrigated areas referred to earlier, means that the world has no option but to improve the efficiency with which it uses its water for agriculture in order to achieve "more with less."

A particularly ominous concern is the growing prospects for competition and conflict among water users. Water scarcity is already leading to conflict in North and East Africa (particularly in Egypt), China, India, Mexico, the Middle East (Israel, Jordan, the West Bank, and Syria), the ex-Soviet Union, and the United States (Postel, 1989). By the end of this century, several countries, including in particular

Egypt and Morocco, will have annual renewable water supplies of less than 2000 cubic meters per person, a level that Falkenmark (1989) warns can lead societies to experience "water stress."

D. Climate Change

Although the extent and effects of the global climate change that is expected to occur over the next several decades are not yet properly understood, any such change has the potential to affect both the supply of irrigation water and the demand for water by crops. Not all these changes would be negative — indeed, some areas of the world could benefit from increased rainfall, and increases in carbon dioxide in the atmosphere could well lead to greater crop water use efficiency. However, the net impact of global warming is likely to be an increase in existing mismatches between supply and demand — and between original design and subsequent management. Thus, although the ways in which this will occur cannot be predicted accurately at the present time, it is likely that even small changes in climate and in the global patterns of supply and demand could lead to an increase in the cost of developing and sustaining irrigated agriculture, as a result of supply/demand mismatches (Postel, 1989).

E. Changes in the Role of the Public Sector

A growing problem for many developing country governments is an increasing inability to foot the recurrent cost bill for operation and maintenance (IIMI, 1991). As a result, government decision makers around the world are suggesting wide-ranging policy and institutional changes for their irrigation sectors, including the privatization of irrigation institutions and the turnover of responsibility for key aspects to users.

A further change results from the increasing constraints on the ready availability of funds for irrigation development — a problem that is exacerbated by the increasing costs of irrigation expansion. Thus, as pointed out by Yudelman (1989), irrigation strategies in the future will require increasing attention to "raising revenues, reducing subsidies, ensuring cost-effectiveness, and promoting selectivity in investment."

All this suggests that in the future, irrigation will be characterized by (1) a lower direct involvement of the state in the management of irrigation systems; (2) a decrease in public sector resources available for new irrigation development; and (3) a consequent rise in private sector approaches to irrigation development and management.

II. PROGRESS TO DATE

The problems outlined in the previous section all point to serious deficiencies in the performance of existing irrigation systems, and to an emerging challenge: how to increase and sustain the yield of irrigated agriculture while at the same time reducing the consumption of water.

A large part of the answer will lie in finding ways to achieve greater efficiency, productivity, and equity in irrigation systems. Such an approach will help us not only to achieve greater levels of agricultural production with lesser amounts of water, but also to address some of the world's major environmental problems — water logging and salinity, declining ground-water tables, shrinking lakes and seas — whose root cause is over-watering. But finding such ways will require that a wider range of alternative approaches than heretofore considered will need to be developed, tested, and implemented — such as small-scale irrigation, conjunctive use, water reuse, and more effective use of irrigation at night (Chambers, 1988). This will require much greater imagination and flexibility on the part of irrigation policy makers, managers, and planners, and points to the need for technological, managerial, and policy innovation and adaptation. In particular, technologies, management practices, and policies that lead to greater control by end users will be needed if the required increases in agricultural productivity are to be achieved.

The need to address growing competition and conflict among water users will also require increased attention. Urgent needs include (1) greater efforts to integrate irrigation planning and management with other uses of water, as well as with other sectors of the economy that impinge on water use (World Bank, 1991); and (2) greater attention to conflict resolution, both at the national and at the international level. Any amelioration of conflict and competition among water users will have positive effects on efforts to improve irrigation efficiency and productivity, since the incentive to improve efficiency is often limited when long-standing conflicts over the use of water remain unresolved, both within and between nations.

Fortunately, in recent years the world has witnessed several important efforts along these lines. These include increased experimentation with technological, managerial and policy innovation; more attention to conflict resolution; and greater international support to technological and managerial change in the irrigation sector. The examples that follow will help illustrate the progress that is being made.

A. IRRIGATION MANAGEMENT POLICY SUPPORT IN SRI LANKA

During the last decade, and as a result of strong concern about some of the generic problems described earlier in this paper, there has been a revolution in thinking and attitudes of Sri Lankan irrigation professionals (Merrey, 1991). In particular, the government has adopted a participatory management policy in the irrigation sector, and the need for irrigation agencies to work with well-organized farmer organizations in a system of joint management of irrigation systems is now well accepted. In addition, the country has taken a number of steps to prepare itself for the future, as is well described in a recent special issue of Sri Lanka's *Economic Review* entitled "Irrigation in the Year 2000" (*Economic Review*, 1991). These include institutional reform — enabling farmers organizations to take control of irrigation systems, and shifting the role of government agencies to provision of supporting services — and policies to encourage diversified cropping to enable farmers to improve their incomes (Merrey, 1991). As Dr. Merrey notes, "if by the year 2000 the country can implement these important institutional and policy reforms, Sri Lankan farmers will be well placed to become prosperous contributors to the further development of the Sri Lankan economy." This shift in emphasis marks a radical departure from the policies prevalent up to the early 1980s, during which investment was directed primarily at creating irrigation infrastructure.

B. Breakthroughs in Conflict Resolution in Pakistan

For the last 30 years since the signature of the Indus Water Treaty between Pakistan and India in 1960, the internal sharing of the Indus River among the four provinces of Pakistan remained unresolved. A significant breakthrough in solving this long outstanding issue has recently been achieved through an accord reached by consensus among the provincial governments (Badruddin, 1991). This long delay in the allocation of the Indus waters to the provinces of Pakistan had led to wasteful and inefficient use of available water, since the establishment of historical rights became the overriding objective. Furthermore, the expansion of irrigation systems remained suspended, while a sizeable amount of water was wasted; and the release of storage water from the major surface storage areas of the Indus River could not be efficiently undertaken, with serious consequences in terms of water-logging and salinity.

With the accord, the Prime Minister of Pakistan has gone on record that agricultural production will significantly increase during the next five years and that an additional five million acres of arid and rainfed land could be brought under cultivation. In addition, all provinces are expected to increase their efforts to improve irrigation water use efficiency, since the accord has heightened awareness among the provinces on the need to make the most of each province's share of the water that is now available. Finally, the accord has lead to the creation of the Indus River System Authority, which could play a vital role in the future management and development of Pakistan's limited water resources (Badruddin, 1991).

C. International Cooperation in Technological and Managerial Innovation

In the last decade, two important international programs have been established to address the need for greater technological, managerial, and policy innovation and adaptation in the irrigation sector. In 1984, the International Irrigation Management Institute (IIMI) was established with headquarters in Sri Lanka in an effort to strengthen national efforts to improve and sustain the performance of irrigation systems in developing countries. Its principal activity is the development and dissemination of management innovations in the irrigation sector. Since its foundation, IIMI has progressively decentralized its operations through regional and country programs located at present in more than 10 countries in various parts of Africa and Asia. Current programs focus on irrigation systems performance, management of water for irrigation, management of irrigation organizations, institutional change and policies, farmers and the farming community, and the environment.

A more recent effort is the establishment of the International Program for Technology Research on Irrigation and Drainage (IPTRID), which is co-sponsored by the World Bank, the United Nations Development Programme (UNDP), and the International Commission on Irrigation and Drainage (ICID). This program, which is managed through a Secretariat established in early 1991 in the World Bank headquarters in Washington, has three research thrusts: modernizing irrigation and drainage systems, ensuring sustainable land and water use, and improving technology for maintenance. Under these research thrusts, IPTRID assists developing countries to formulate policies for technology research in irrigation and drainage, develop and monitor research proposals and projects, and assess priority research needs.

III. REMAINING CHALLENGES

Although as outlined earlier several important advances have been made over the last several years, significant challenges still remain in the areas of technological, managerial, and policy innovation and adaptation; human resources development; and information transfer. Each of these is analyzed below:

- ***Technological, Managerial, and Policy Innovation and Adaptation***: More and better technological, managerial, and policy innovation and adaptation is needed. Subject areas identified by IIMI and IPTRID as of particular importance include:
- ***Performance Monitoring***: In order to address the key problem of low irrigation performance outlined at the start of this paper, procedures and practices for the assessment of the performance of irrigation systems at all levels must be improved. Special needs include validation of performance indicators, field testing of assessment methodologies, identification of performance determinants, and generation of principles conducive to the development of a performance orientation in irrigation institutions (IIMI, 1991).
- ***Canal Water Management***: Key needs include the development of better management systems for water conveyance, allocation and distribution, based on an understanding of the complex technical, economic and social cultural factors that underlie the operation of irrigation systems (IIMI, 1991).
- ***Irrigation Organizations***: Key needs include the development of management techniques that improve performance and cost effectiveness of the range of organizations involved in irrigation management, including irrigation departments, water-user associations, and non-governmental organizations (IIMI, 1991).
- ***Institutional Change***: Irrigation policy makers need to better understand the interrelations among the institutions responsible for irrigation and the impact of external and internal changes on irrigation management and performance. In view of the strong interest of most developing country governments to turn over management authority from government agencies to farmers, this particular form of institutional change is of key research importance (IIMI, 1991).
- ***Farmers***: Research is needed to ensure that the productivity, income and quality of life of farmers and the farming community are enhanced rather than negatively affected by irrigation (IIMI, 1991).
- ***Environment***: In view of the significant environmental dimensions of irrigation, research is needed on such issues as the impacts of irrigation on

the environment, the impacts of the environment on irrigation, and the effects of possible climate change (IIMI, 1991).

- ***Modernization of Irrigation and Drainage Systems***: Research is needed on the improvement of existing traditional systems and the adoption of new designs of future systems; this includes the technology of canal networks in regulation structures as well as micro-irrigation techniques (UNDP/World Bank, 1990).
- ***Technologies for Sustainable Land and Water Use***: Of particular importance is research in the area of waterlogging and salinity control, and wastewater reuse for agriculture (UNDP/World Bank, 1990).
- ***Improving Technologies for Maintenance***: Research is needed to develop improved designs to facilitate easier and more cost effective maintenance of irrigation and drainage systems that will lead to reductions in the incidence of sedimentation, weed growth, vector survival and bank erosion (UNDP/World Bank, 1990).
- ***Developing National Systems of Innovation***: Since international institutions cannot address the entirety of research needs, particularly in the areas of development and adaptation, a crucial need is to develop strong national systems of innovation and adaptation. This will require significant attention to capacity strengthening efforts, since in most developing countries national scientific capacity to conduct research on irrigation technology and management is very weak and fragmented (IIMI, 1991). In particular, much of the research done by national systems in the area of irrigation technology and management is of a single discipline, following conventional disciplinary lines.
- ***Human and Institutional Resource Development***: If changes in irrigation technology, management, and policy are to be effectively implemented, national irrigation management and research institutions will need to be significantly strengthened in both developed and developing countries alike. Since in most countries, irrigation agencies administer rather than manage irrigation systems, there is a great need to strengthen the organizations responsible for the management of irrigation systems, and to help develop the human resources needed to staff such organizations. In addition, since in most developing countries national scientific capacity to conduct research on irrigation is weak, there is a need to both strengthen national research institutions and to pay attention to the development of individual researchers. The International Water Resources Association (IWRA) can play an important role in this area through its workshops, conferences, and other programs, which provide opportunities for researchers to meet and exchange ideas both among themselves and with representatives of operating agencies.
- ***Information Exchange and Dissemination***: Clearly, if irrigation designers, managers, policy makers and researchers are to be more effective in their work, they will need more and better information. For this reason, significant attention has to be given to the distribution of information to and among developing and developed countries.

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*Wastewater Reuse Implementation in Selected Countries of the Middle-East and North-Africa**

NADIM KHOURI**

ABSTRACT

The countries of the Middle East and North Africa region are engaged in large-scale investments for the collection and safe disposal of wastewater produced by their rapidly expanding cities. Wastewater reuse is a tested strategy for pollution abatement, it also increases water resources availability. Implementing reuse requires a systematic consideration of the various sectors affected. The study summarized below interprets the data collected in 10 countries of the region with respect to sociological, climatic, environmental, institutional, and economic aspects of water supply and sanitation. Regional conditions clearly favor the consideration of wastewater reuse in water and sanitation projects in these countries. The results of the study are used to define the elements of regional collaboration to facilitate the inclusion of safe, economical and socially acceptable reuse in development projects related to the management of natural resources around cities.

RÉSUMÉ

Les pays du Moyen Orient et de l'Afrique du Nord ont engagé des sommes importantes pour recueillir et disposer des eaux usées provenant des villes sans cesse en expansion de la région. L'une des stratégies permettant de minimiser la pollution tout en augmentant la quantité d'eau disponible est le réemploi des eaux usées. Une étude systématique préalable des secteurs affectés est cependant nécessaire avant d'aller de l'avant. Cette étude interprète les données recueillies dans 10 pays de la

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* This paper was presented at the VIIth World Congress on Water Resources, Rabat, Morocco (May, 1991). The study on which this paper was based was made possible by funds from UNDP projects INT/87/035 and RAB/88/009, as well as the support of FAO, WHO, and the World Bank. The author would like to thank the following persons who contributed to data collection and interpretation, and reviewed earlier versions of the paper: D. Howarth, R. Cestti, E. McClelland, A. Hamidi, A. Arar, K. Baum, M. Haddadin, I.S Hespanhol, M. Suleiman, C. Bartone, K, Shankar. The assistance of country officials is also acknowledged with thanks.

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région sur les aspects sociologiques, climatiques, environnementaux, institutionnels et économiques des ressources hydrologiques et de l'assainissement, et montre que les conditions régionales favorisent le réemploi des eaux usées dans les projets d'assainissement et d'irrigation. Les résultats de l'étude servent également de base pour définir les éléments d'une collaboration régionale en ce qui a trait à la gestion des ressources naturelles dans la périphérie des villes.

INTRODUCTION

Water scarcity and water pollution are rapidly becoming major concerns in most countries in the Near East (North Africa and the Middle East). Even in countries where the overall (country-wide) water resources appear to be adequate, there are water-short areas, especially around cities (Shahin, 1989). Exacerbating this water shortage situation is the reduction of the usable yield of many existing water supply sources because of pollution from the uncontrolled discharge of raw wastewater or even from partially treated industrial and municipal wastewater effluent (e.g. Bino, 1988). Wastewater reuse[1] has been identified as having a potentially significant role in alleviating the quantitative and qualitative constraints on regional water resources (ESCWA, 1985).

I. RATIONALE FOR REUSE IN THE NEAR EAST REGION

A. Reuse: A Tested Practice

It is now widely accepted that adequately treated wastewater can be reused to satisfy part of the demand for water while decreasing the pollution load on the environment (Metcalf and Eddy, 1991). In developing countries, the most common form of reuse is in the use of wastewater effluent for agricultural purposes, generally in irrigation (Strauss and Blumenthal, 1991). In many cases, however, this is done through the non-recommended practice of farmers tapping directly into sewers or wadis to retrieve untreated wastewater. This practice presents many health risks to farmers and consumers (Mara and Cairncross, 1990). To remedy such practices and ensure the safe reuse of treated wastewater, there are water quality guidelines that can be achieved by an array of treatment technologies which satisfy most of the financial and environmental constraints existing in urban and peri-urban areas around the world (e.g. WHO, 1989; and California Department of Health Services, 1978). Available guidelines allow the safe reuse of treated wastewater for agricultural, industrial, municipal, and domestic non-potable reuse through a variety of technological means (Donovan et al., 1980).

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1. Wastewater reuse is defined here as the direct and voluntary utilization of treated wastewater. Direct reuse is to be differentiated from: (i) "indirect reuse", e.g. by discharge of an effluent into a stream that is used downstream as a water source; and from (ii) "recycling" which is a water-saving operation internal to a given process (e.g. recycling of water within industrial processes). "Controlled reuse" is the reuse of wastewater after adequate treatment and using proper health guidelines; it is the only form of direct reuse that is recommended here (assuming it is socially and economically feasible) and should be differentiated from "uncontrolled reuse" of raw or poorly treated wastewater.

B. Is the Rationale for Reuse in the Region Misstated?

Theoretically, the substantial knowledge we have on wastewater reuse and the general agreement on its usefulness in the Middle-East and North Africa region should lead to a region-wide application of reuse . In reality, only a handful of countries (including Bahrain, Israel, Kuwait, Saudi Arabia, and Tunisia) have significant reuse projects that go beyond the "pilot-scale." And even plans calling for the "integrated" management of wastewater and water resources do not always recognize a potential role for wastewater reuse (Correia, 1990).

A collaborative study on the potential for wastewater reuse in selected countries of the region revealed that problems of scope and process are probably hampering the wide-scale adaptation of wastewater reuse in the region. The scope constraint can be summarized as being the belief that "Reuse is rarely applicable because the amount of water that can be reused is negligible, compared to global water resources." As to the process-related constraint, it can be summarized as follows: "In general, reuse policies are mainly adopted on political grounds and not on sound technical and economic bases." While the first of these constraints (scope for reuse) is dealt with in Box 1, the remaining sections of this paper are concerned with the definition of objective ("non-political") criteria that determine the relative applicability of reuse to solve specific problems of integrated water management in the region.

C. Assessing the Reuse Potential

Based on a detailed review of literature and on field observations, the following criteria were selected as indicating the general degree of desirability of reuse in terms that can be directly used in the appraisal of water sector and environmental projects. The criteria cover the various technical, institutions, and socio-economic aspects of such projects.

There is increasing potential for reuse in an area, if:

a) The area includes, now or in the future, a sewered urban settlement;
b) Some form of reuse of wastewater is already taking place;
c) Water supply is limited relative to demand;
d) Existing or future fresh water supply is relatively expensive;
e) The project area includes individual users of large volumes of water;
f) Existing wastewater discharges meet (or could economically be treated to meet) acceptable standards for reuse (e.g. WHO, 1989; or any available national quality standards);
g) There are enforceable pollution control regulations requiring that wastewater be treated or that currently treated effluent be upgraded before disposal in the environment (in sewers, on land, or in surface or groundwater water);
h) Wastewater disposal without reuse (e.g. sea outfall or land application) is relatively expensive.

In large part, the list above was adapted from Schmidt and Ross (1976) and Ernst and Ernst (1979). Clearly, many of the criteria above are interrelated and some of them (e.g. "relatively expensive") have to be defined within local socio-economic conditions. Ten countries that are representative of the wide variation in climatic, economic, and social conditions in the region were selected. They are Cyprus, Egypt, Jordan, Kuwait (before the Gulf War of 1991), Morocco, Saudi Arabia, Syria, Tunisia, Turkey, and Yemen (only Northern Yemen was visited, before reunification of the country). The data for this study were collected through desk review of technical documents, topical questionnaires sent to government officials in the respective countries, and joint multiagency missions to the 10 countries.

II. MAJOR FINDINGS

In this section, the results of the study concerning the status of the above criteria in the countries visited are summarized. A more detailed presentation of the results is presented elsewhere (Anonymous, 1992).

1. *Cities are Growing and Wastewater Collection is Expanding*

Of the 10 countries surveyed, all except Yemen had an urban population percentage ranging between 46% (Egypt) and 95% (Kuwait). Yemen's urban population rate (after reunification) represented 28% of the country population but the average annual growth of its urban population (between 1980 and 1989) was one of the highest in the world (IBRD, 1991), at more than 7% per year. In this study, other countries' annual urbanization rates ranged between 3% (Egypt and Tunisia) and 6.6% (Saudi Arabia). Since many of these cities have grown in a rather unplanned fashion, many countries are only now implementing development projects for the improvement of municipal services and health conditions in their cities. Most cities in the countries studied have adequate water supply systems (almost 100% coverage) and are now placing special emphasis on developing urban sanitation systems that can produce a quality of effluent that can be disposed of safely. The potential flows that could be captured and reclaimed in the region are shown in Table 1. In the Near East region as a whole, water supply and sanitation projects totalling more than US$1 billion of World Bank loans are expected to be initiated between 1990 and 1993 (IBRD, 1989). The projects that are being planned now should consider the reuse alternative at the early stages of design in order to achieve the full potential benefits from reuse (Asano and Mills, 1990.)

2. *On-Going Reuse Operations Indicate a Real Demand, But at What Cost?*

In all 10 countries that were visited, there is some form of direct reuse of wastewater already taking place. In this respect, it may be useful to distinguish between the oil-rich countries, and the oil-poor countries since the availability of capital can ease greatly both problems of water supply and treatment. Tunisia should be placed in a category by itself because of the extensive and widespread controlled reuse that is currently practiced there. At the time of the visit, the oil-rich countries of Saudi-Arabia and Kuwait were reusing most of the tertiary treated effluent from treatment plants in Riyadh (153 Mm^3/yr — million cubic meter per year) and Kuwait

Table 1

Water Flows in Selected Countries in the Middle East Region (Mm^3/yr)

Country	Year of Data	Produced*		Collected**		Treated***	
		Actual	Projected (2000)	Actual	Projected (2000)	Actual	Projected (2000)
Cyprus	1989	22	24	4	15	4	15
Egypt	1985	986	1,802	493	1,138	—	1,095
Jordan	1986	53	113	29	96	23	61
Kuwait	1985	92	143	80	136	78	115
Morocco	1985	244	555	219	500	6	200
Saudi Arabia	1989	480	759	380	683	380	657
Syria	1985	189	550	156	550	0	300
Tunisia	1986	124	227	83	204	60	180
Turkey	1987	1,086	2,177	760	1,815	139	1,231

Sources: The figures from this table were assembled from a number of World Bank working documents as well as publications and survey information provided by the countries.

* Actual volumes of wastewater refer to volumes produced in urban areas during year of data as indicated. 'Projected' refers to expected quantities to be produced in the year 2000.

** Collected wastewater flow refers to the total volume of wastewater that is or will be collected by sewer systems but not necessarily treated.

*** Treated wastewater flow refers to volumes of wastewater that are or will be treated to a level that will allow safe and controlled reuse.

City (92 Mm^3/yr) respectively. The treated effluent was being employed for crop production and landscape irrigation covering about 7 000 ha in the Riyadh area and 1 700 ha around Kuwait city.

In Tunisia, about 3 000 ha were being irrigated under controlled conditions with secondary-treated wastewater effluent. For this purpose, a total flow of about 7 Mm^3/yr of treated effluent (approximately 10% of its treated effluent) was being reused. The Tunisian experience with controlled reuse can be considered more relevant for promoting safe and economical reuse in the region than the experience of oil-rich countries because the extent of subsidies for water sanitation and irrigation afforded by oil-rich countries cannot be equalled in most LDCs. Tunisia has had a cautious and gradual approach to expanding reuse since the mid-1960s, with a definite, strategic approach. This strategy has resulted in extending wastewater treatment to the major urban areas (26 wastewater treatment plants in 1989 aiming at 123 plants by 2010). The ultimate goal in Tunisia is to irrigate about 30 000 ha with treated wastewater, a ten-fold increase over present operations (Bahri, 1989). Although the stated policy of the country is the achievement of 100% reuse, this target is likely to be lowered as a result of on-going studies to evaluate the feasibility of reuse in Tunisia. Nevertheless, Tunisia is actively engaged in a policy of intensification of wastewater reuse, especially in irrigation.

In most other UNDP-supported countries of the region, two types of reuse activities have been observed: research and pilot operations to study various aspects of reuse, and uncontrolled reuse by farmers in the vicinity of urban areas. Uncontrolled reuse is being practiced with varying degrees of legitimacy or tolerance on the part of the governments. Typically, farmers divert untreated wastewater from sewer outlets and irrigate vegetables that are sold in the urban markets. This type of uncontrolled reuse is considered unacceptable for health reasons (Shuval et al., 1984). It presents the first priority for corrective action (see Annex). From the observation of on-going reuse in the 10 countries under study, it was clear that there was: (1) official endorsement of safe reuse; (2) a need (and potentially, a market) for this effluent; and (3) acceptance by the local population of the concept of reuse. This should encourage the introduction of measures such as treating the effluent before reuse and controlling the type of crops produced to reduce the health risks associated with uncontrolled reuse.

3. *Water Supply Is Increasingly Limited Relative to Demand*

The countries of the region are either arid or semi-arid and the majority of countries are water short or will be in the near future. Except for a few (notable) perennial rivers, surface water supply sources are limited and supplies from upland reservoirs and groundwater sources dominate. Largely due to high population growth rates, water demand for irrigation, industry, and municipal uses (see Table 2) is outracing supply and most countries are having to make difficult decisions with respect to water resource allocation between the competing sectors. Where water shortage is causing allocation problems, reuse could play a significant role in diminishing these problems by facilitating the safe implementation of sequential water use (see Box 1).

4. *Fresh Water Supply is Getting More Costly*

It was not possible to use a uniform methodology for the evaluation of water supply costs (or wastewater treatment costs) in the 10 countries studied. The data in Table 3 should therefore be considered as an approximate indication of water costs in selected areas of the region. Production costs per cubic meter of incremental domestic water were as follows: Limassol, Cyprus \$0.71; Cairo, Egypt \$0.26; Amman, Jordan \$1.20; Kuwait City \$2.00 (desalinization); Riyadh, Saudi-Arabia \$2.13 (average cost, including desalinization and transport to Riyadh) (1991, US\$). A separate regional study of water supply projects showed that the unit cost of supplying additional water to a city is two- to three-fold the current cost of water, with average incremental costs of about US\$ 0.67 per cubic meter of "new" water supply (IBRD, 1990). This increase in cost reflects water-short conditions as well as the deterioration of water quality in the vicinity of cities. The financial cost of secondary treated wastewater in the area, often at less than \$0.5/m^3 (Table 3), is therefore competitive with the cost of fresh water supplies for particular uses. This water could be used by the sectors that can adapt to the specific effluent quality produced. Particularly beneficial would be the use of treated wastewater to replace water which is currently being used for domestic and industrial purposes, freeing up

Table 2

Water Resources Availability, Withdrawal, and Wastewater Flows in Ten Countries in the Middle East Region (Mm^3/yr)

	Fresh Water		Wastewater Flows			Water Use			
	Available*	Utilizable**	Year of Data	Actual ***	Projected (Year 2000) ****	Year of Data	Irrigation	Municipal and Industrial	Total Water Use
Cyprus	950	600	1989	4	24	1986	425	38	463
Egypt	86,000	66,000	1985	493	1,802	1985	49,700	6,700	56,400
Jordan	1,234	896	1986	29	113	1986	518	160	678
Kuwait	180	6	1985	80	143	1985	20	289	309
Morocco	30,000	21,000	1985	219	555	1985	10,000	1,000	11,000
Saudi Arabia	2,200	2,200	1989	380	759	1985	7,600	1,900	9,500
Syria	35,800	14,200	1985	156	550	1985	6,437	525	6,962
Tunisia	4,356	2,624	1986	83	227	1985	2,100	230	2,330
Turkey	203,000	88,000	1987	760	2,177	1985	9,100	6,600	15,700
Yemen (North only)	3,100	2,060	1986	11	72	1985	1,500	150	1,650

Sources: The figures from this table were assembled from World Bank working documents as well as survey information provided by the countries.

* Available Resources include internal renewable water resources as well as river flows from other countries.

** Utilizable Resources include the amount that is both technically and economically exploitable (including evaporation losses, geographic distribution, storage dams, etc.).

*** Total volume of wastewater actually collected from urban areas in the year indicated.

**** Total volume of wastewater that will be available for collection and potential reuse.

the highest cost and highest quality water for future drinking water supplies. One feature of the region is that the cost of water production is rarely being recovered from the largest users of water: agriculture and industry.

5. *Water Supply to Large Users of Water: Industries and Municipalities, but Will they Pay?*

One large user of water in the vicinity of a city could represent a convenient client for a large amount of treated effluent, thus facilitating the feasibility and implementation of reuse. The water resources of the region are used primarily for irrigation. Of the total water withdrawals, approximately 80% is used for irrigation, 15% by domestic consumers and 5% by industry (Table 2). Around cities, water is usually the main factor that limits agricultural development. Ideally, wastewater reuse would lead to improvements on three levels: (1) the "creation" of a new water resource at the local level that could be used without significant negative impact on the environment; (2) a decrease in the cost of treatment/disposal of wastewater;

Box 1

REUSE: Why the fuss?

Nature recycles water day in and day out, and for free. A simplified view of the *natural* water cycle (Fig. A) would have three components: Precipitation, Storage (in seas, rivers, groundwater, and biomass) and Evaporation. On a global scale, this natural "reuse" process exceeds by far any human-designed scheme to treat and reuse wastewater in the volume of water that is recycled. The significance of reuse is in the supply of localized relief to quantitative and qualitative pressures exerted by concentrated human activities on high quality water resources. Reuse does *not* contribute to the total amount of water resources.

Figure B presents a more localized schematic view of the water cycle, focussing on a particular area affected by human settlements. The site-specific parameters that favor man-induced reuse of wastewater are discussed in the main text. Figure B can schematically illustrate conditions of water abundance and/or high degree of wastewater treatment, allowing the discharge of effluent directly in water storage areas. In this widely used scenario, there is the assumption (conscious or not) that natural water resources can supply the simultaneous needs of the various sectors of human activities and that the resulting effluent can be returned to the available water sources with relatively high "assimilative capacity."

However, under more arid conditions, and the increased concern for limiting the negative impact of human activities on the "stored" water, one can visualize a shift to the "sequential use" model of Fig. C. The inter-sectoral exchange of water shown in Fig. C leads to a "closed loop" of reused water that decreases the amount of "top-quality" water needed at any one time. Perhaps more importantly, Fig. C also shows the preponderant role that irrigation can play in serving as an "evapo-transpirational by-pass" to limit the contamination of stored water resources.

Sequential reuse does not apply only to inter-sectoral problems of water allocation. Within the agricultural sector, for example, the widely accepted principle of blending saline waters with water of better quality — to increase total water quantities of acceptable quality — has recently been questioned (Rhoades, 1991). The alternative, of course, is to use top quality water for the most economical crops. Successive drainage waters would then be used, separately, on successive crops that are known to be tolerant to salts. Therefore, it might be interesting to test the following principle across the various sectors of water use: As water supply becomes more limited with respect to demand, waters of different qualities should be kept separate. The direct reuse of each of these water qualities would be the means by which many water allocation conflicts can be alleviated.

(3) additional revenue generation through the sale of treated wastewater to farmers to cover the costs of treatment and disposal. This last advantage would be difficult to achieve because farmers in most countries of the region are currently not charged for fresh irrigation water. Charging farmers for reclaimed wastewater, however, was done in Kuwait, Tunisia, and the Marrakesh area of Morocco.

6. *Wastewater Quality: The "Appropriate Technology" Issue*

About two-thirds of the wastewater produced in the countries studied is discharged untreated into the environment (Table 1). Most of the flow that is treated goes through "conventional" treatment plants using activated sludge processes. These systems were designed to produce effluent that had good pollution control characteristics vis-a-vis biochemical oxygen demand (BOD) and suspended solids load on the receiving environment. However, according to the WHO guidelines (WHO, 1989), this does not address a health problem specific to reuse: the need to reduce the risk of infection from helminth eggs. In warm climates, prolonged

Figure A

The Global "Pristine" Water Cycle

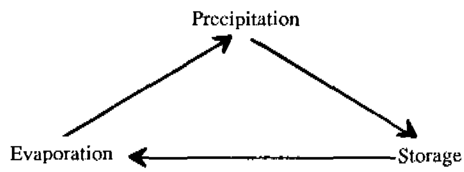

Figure B

The "Assimilative Capacity Model"

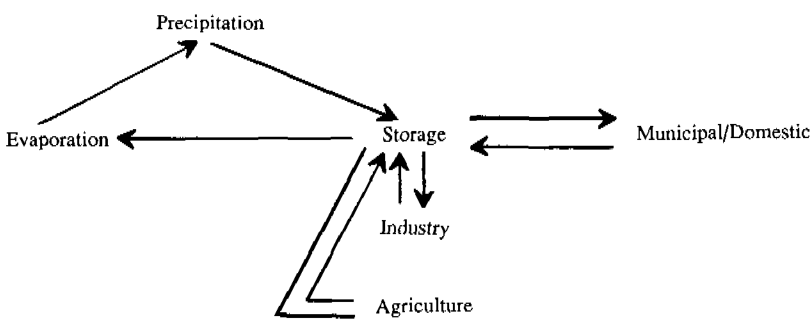

Figure C

The "Sequential Use Model"

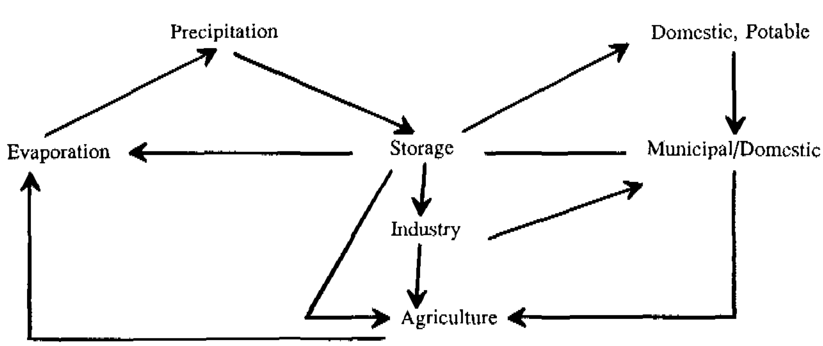

Table 3

Water Cost and Price in Selected Countries of the Middle East Region (1989 US$ per cubic meter)

Country	Municipal Water Supply		Agricultural Water Supply		Wastewater	
	Cost*	Price**	Cost	Price	Cost ***	Price ****
Cyprus Nicosia, Larnaca, and Limassol (SCP)	0.71	0.58	0.69	0.15	0.27 (M)	0.11
Egypt (Urban Areas)	0.26	0.05				0
Jordan (Jordan Valley)	1.15	0.77	0.23	0.01	0.37 (M)	0.08
Kuwait (Urban Areas)	2	0.50			0.4 (T)	0.03
Morocco (Casablanca and Doukala)	0.5	0.33	0.46	0.04	0.12	
Saudi Arabia (Urban Areas)	2.63	0.10	0.4		0.28 (T)	
Syria (All Syria)		0.29			0.19 (S)	0.08
Tunisia (All Tunisia)	0.44	0.31			0.12 (S)	0.03
Turkey (Ankara, other urban areas)	0.65	0.47		0.004	0.26 (M)	0.23

Sources: The figures from this table were assembled from a number of World Bank working documents as well as publications and survey information provided by the countries. The figures should be considered as approximate and no attempt was made to standardize the data. Some figures, for example, include transport costs while others only include treatment of water for distribution.

* Cost of water supply includes desalination in the cases of Kuwait and Saudi Arabia.
** Price of water supply represent average values of tariff structures.
*** Cost of treatment: (M) Mechanical, usually secondary treatment; (T) Tertiary treatment; (S) Stabilization Ponds.
**** Price is from fees paid for municipal water or sanitation services.

residence time in lagoons (e.g. 21 days in a stabilization pond) is among the most effective (and economical) ways to practically eliminate the threat of exposure to helminths and allow reuse in irrigation (Shuval, 1984).

Pilot and full-scale projects in Cyprus, Kuwait, Saudi-Arabia and Tunisia have shown that treated effluent was better than other, mainly underground, sources of irrigation water with respect to non-microbiological effluent characteristics. Wastewater discharged to the sewerage system had generally low salinity. The other chemical ''contaminants'' such as nitrogen and phosphorus are usually beneficial nutrients to plants and therefore do not need to be removed if the water is to be reused in irrigation. Cities with certain types of industries would have to regulate the wastewater discharged by these industries in order to protect the treatment plants and prevent the accumulation of potentially toxic compounds in the treated effluent.

7. *Pollution Control Regulations: The National Interest*

There is a direct link between effective pollution control regulation and the potential for wastewater reuse. The 10 countries visited had some kind of pollution control regulation, mostly to control the quality of wastewater that can be discharged into the sewer system. In most cases, these regulations also included the control of effluent discharge into the environment. Practically, they imposed a minimum required treatment of wastewater. If these regulations are enforced, the economics of reuse would be greatly enhanced by strict effluent regulations. In essence, a city that is required to treat its wastewater at least to a secondary treatment level is more likely to find that the reuse option imposes little, if any, extra cost than if the city was not required to treat its wastewater at all.

The state of pollution control in the 10 countries was representative of the region in general and could be summarized as follows: (1) Pollution control regulations were either inadequate or not enforced; (2) The requirement that responsibility for pollution control be at the central governmental level was sometimes perceived as going against the trend of administrative decentralization that is being implemented in many countries of the region; and (3) Newly created environmental protection entities at the central level have difficulty exercising their authority. The present trend toward strengthening the regulatory and operational aspects of pollution control in the 10 countries visited (and the region in general) would favor the economics of reuse and reduce its risks (Donovan et al., 1980).

8. *The Local Interest: Is Reuse Part of the Least-Cost Sanitation Scheme?*

The main priority of projects that can lead to reuse is to dispose of wastewater in the least-cost way that is consistent with central pollution control and water resource management requirements. Decision makers in coastal cities of the region were often in the difficult position of having to choose between: (1) a sea outfall that would cheaply dispose of primary treated effluent and solve the local problem at hand (effluent disposal); and (2) a more complicated and, often, more expensive system of treatment and reuse that is favored by a "political" concern for the maximization of water use. This study did not result in a clear message concerning the trends in the cost of non-reuse wastewater disposal systems. In Egypt, for example, planning for the Alexandria sewage treatment and disposal scheme started in 1979 but was still not approved in 1991 because of the lack of consensus among decision makers on the "value" of treated wastewater, compared to the cost of a sewage outfall (no reuse). The latter was reportedly found to cost less than the reuse alternative, but the local population objected to "wasting" the treated wastewater by disposing of it in the sea. In Cyprus, the no-reuse alternatives (sea outfall) for four coastal agglomerations would probably cost less than the reuse options currently selected but, as in Tunisia, reuse is increasingly a matter of policy decision, mainly to protect the aesthetics of the coastal zones of the country. Inland, the situation is different than in the coast, because in many cases (such as Marrakesh and Damascus) a "zero-load" effluent has to be targeted because of the aridity of the climate and the virtual disappearance of any "assimilative capacity" of surface waters. Achieving such a high degree of treatment would probably be possible only at a prohibitive cost for many municipalities of the region. Wastewater reuse, through land application, could represent a significant saving on the cost of advanced wastewater treatment and disposal (CSWRCB, 1990). In all cases, improving the cost-effectiveness of reuse would reconcile local and national priorities by improving the general efficiency of water use, reducing the cost of wastewater disposal and limiting the effects of pollution downstream.

CONCLUSION AND PROPOSED ACTION

This paper has presented the major quantitative criteria that should be considered in specific projects to determine the feasibility of reuse. The general tendency in the countries visited favors the consideration of reuse. The relative importance of the eight criteria considered differed between countries and would have to be evaluated in specific project areas. Urban areas across the region are under the combined pressure of increasing environmental awareness, tightening pollution control legislation and rapidly rising costs of additional potable water supply. This does not mean that they should "blindly" apply wide scale reuse. It means that the reuse alternative should increasingly be considered in the many urban sanitation projects being implemented in the region. While country-specific recommendations can be defined for the promotion of water reuse (Anonymous, 1992), there is also an opportunity for regional collaboration within a common strategy for the application of safe and economical reuse. The appended Annex presents the major elements of such a strategy. Of particular importance is the proposal to discontinue, everywhere in the region, the practice of uncontrolled reuse of wastewater. Other areas of potentially fruitful collaboration include applied research in appropriate wastewater treatment strategies that will improve the cost effectiveness of reuse, and systematic quantitative evaluation of the cost of water supply, treatment, and disposal. The goal of the above activities would be to improve the level of decision-making in integrated water resources management in order to take full advantage of the reuse option only where it is truly feasible, economically, socially, and politically.

Annex

ELEMENTS OF A STRATEGY FOR REUSE

The reuse of treated wastewater for agricultural, industrial, or municipal purposes depends greatly upon site-specific conditions. In many countries of the Middle East and North Africa, climate and culture are similar enough to allow comparisons and learning opportunities from one country to another. With this in mind, a broad strategy for approaching wastewater reuse in this region is outlined below.

Immediate Action: Discontinue Uncontrolled Reuse of Raw Wastewater.

Reuse of untreated wastewater should not be encouraged, and efforts to treat wastewater should be initiated where this practice is occurring. The controls should be implemented with the participation of the people currently using untreated wastewater.

Large-scale investment

At the country level: Evaluation, research, training, and institutional development activities should be implemented to include the consideration of reuse operations in the planning and design of water supply and sanitation projects in the countries of the region.

Project evaluation

At the country and regional levels: The evaluation of existing reuse projects in countries (e.g. Tunisia) with a relatively long history of reuse, should be implemented and disseminated to the region.

Research and pilot projects

At the country and regional levels: Continuous adaptive research is needed to address site-specific constraints to reuse. Research topics include: Appropriate technologies in wastewater treatment; Improvement of the quality of effluent from conventional treatment plants; Development of simplified monitoring techniques; Investigation of "new" (non-irrigation) uses for treated effluent; Long-term effects of agricultural reuse on agricultural productivity, public health, and the environment; The development of integrated sanitation/reuse systems that reduce the cost of the overall system.

Country and regional networks should be established to allow a suitable "division of labor" in research, avoid duplication, and share information.

Human resources development

At the country and regional levels: Training should be provided to persons working on the sanitation-reuse continuum (from sanitation personnel to extension personnel).

Participatory approaches should be used in communicating the information on sanitary precautions and regulations to farmers, so that decisions about procedures can reflect their priorities.

Institutional development

At the country level: Proper legislation and institutional structures should be established to address pollution control and public health issues in each country, particularly focussing on the regulation of industrial discharge to sewers and effluent standards for specific reuse/disposal options.

Countries should promulgate reuse standards and guidelines based on their particular conditions and experience. As a start, the WHO, 1989 reuse guidelines should be adopted in those countries that have not yet developed their own regulations;

A clear understanding of the responsibilities of the various organizations in charge of reuse within each country should be developed. Coordination and information sharing among agencies in the water and sanitation sectors should be facilitated at all levels.

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Les stratégies pour le développement des ressources humaines dans la région Afrique du Nord et Moyen Orient

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RÉSUMÉ

Le manque de main d'œuvre qualifiée constitue l'un des freins les plus importants à la promotion du processus de développement du secteur des ressources en eau dans la région de l'Afrique du Nord et du Moyen Orient. Le présent article aborde la question du développement des ressources humaines dans le domaine de l'eau autour des points suivants : le constat de la situation, les principaux obstacles, les leçons de l'expérience des années 1980, et les stratégies futures.

ABSTRACT

In the Middle East and North African region (MENA) the lack of skilled personnel is a major constraint confronting the development of the region's water resources. This article surveys the present situation, outlines some of the training efforts and transfer of knowledge to the region, lists some important obstacles to effective water resources training, and describes elements for a water resources training strategy for the MENA region based on the helpful insights gained from the UN Water Supply and Sanitation decade 1980-1990.

INTRODUCTION

Le développement des ressources en eau est, depuis la conférence internationale sur l'eau de Mar del Plata, l'objet d'une attention permanente de la communauté internationale et l'une de ses préoccupations majeures. Trop longtemps abandonné

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à son sort, le secteur des ressources en eau a reconquis avec le Plan d'action de Mar del Plata, ses titres de noblesse.

Face au constat alarmant sur les conditions d'approvisionnement en eau et d'équipement sanitaire présenté à la conférence de 1977, et le contexte économique international favorable des années 1970 aidant, la communauté internationale a sans doute péché par excès d'enthousiasme et d'ambition. Les résultats plutôt décevants de la décennie internationale de l'eau potable et de l'assainissement sont là pour le montrer.

Il est vrai certes que la détérioration de la conjoncture économique internationale dès le début des années 1980, et ses impacts catastrophiques sur la croissance de la majorité des pays en développement, ont porté un coup très sérieux à la réalisation des programmes mis en route. Il n'en demeure pas moins que l'explication des résultats peu performants est aussi à rechercher dans l'interaction des lois complexes régissant le processus de développement du secteur des ressources en eau et les intérêts mis en jeu.

Les avis concordent largement pour souligner que l'un des freins les plus importants à la promotion du secteur a été le développement insuffisant des ressources humaines. Les résistances persistantes relevées dans ce domaine font peser un grand risque sur le devenir du secteur de l'eau, celui de le voir continuer d'absorber des investissements colossaux pour des résultats peu probants.

Nous proposons ci-après une discussion de la question du développement des ressources humaines dans le domaine de l'eau dans la région de l'Afrique du Nord et du Moyen Orient, autour des points suivants:

1. le constat de la situation actuelle;
2. les principaux obstacles au développement des ressources humaines;
3. les leçons de l'expérience des années 1980;
4. les stratégies futures pour le développement des ressources humaines.

I. LE CONSTAT DE LA SITUATION ACTUELLE DANS LES PAYS EN DÉVELOPPEMENT

A. DÉLIMITATION DU THÈME

Le terme ressources humaines recouvre l'ensemble des acteurs impliqués directement ou indirectement dans les processus de gestion des systèmes hydrologiques, la mobilisation, la production et la distribution d'eau à des buts divers, ainsi que dans les différents usages de l'eau.

Les actions de développement des ressources humaines visent en premier lieu les professionnels du secteur de l'eau, du niveau de l'employé aux niveaux de l'ingénieur et du décideur; elles visent également les usagers industriels et agricoles, et enfin l'ensemble de la population, au titre de sa participation à la réalisation et la gestion d'ouvrages ou tout simplement de son comportement vis-à-vis de l'eau (économie de l'eau et protection de l'environnement). Elles comprennent:

— la gestion des personnels professionnels: recrutement, encadrement, formation, perfectionnement, promotion et valorisation;
— la formation scolaire et universitaire spécialisée;
— la sensibilisation et l'information du public.

B. LE DÉVELOPPEMENT DU RÉSEAU INTERNATIONAL DE FORMATION, QUATORZE ANS APRÈS MAR DEL PLATA

La mise en œuvre des recommandations de Mar del Plata en matière de développement des ressources humaines a donné lieu à un vaste déploiement de stratégies au niveau international, régional et national.

Au niveau international et régional, un certain nombre d'institutions de formation spécialisées ont vu le jour. C'est ainsi que dès 1976 le gouvernement français et le PNUE mettaient en place le Centre de formation internationale à la gestion des ressources en eau (CEFIGRE). Les agences du système des Nations Unies, chacune dans le champ de ses compétences, ont lancé de nouveaux programmes de formation et renforcé leur appui à des programmes existants. Des volets «ressources humaines» — trop modestes et trop tardifs — ont été progressivement introduits dans les projets soutenus par les agences de financement et de coopération bilatérales ou multilatérales.

Dans le cadre de la Décennie internationale de l'eau potable et de l'assainissement, une task force a été établie auprès du Comité de direction de la décennie, avec mission de mettre à la disposition des agences nationales et internationales les éléments de base d'évaluation et de prospective pour un développement des ressources humaines en harmonie avec les objectifs de la décennie. Par ailleurs, le PNUD, la Banque Mondiale et un certain nombre d'agences de coopération bilatérales ont mis en place un réseau international de formation (ITN) destiné d'une part à promouvoir de nouvelles approches de développement du secteur, et d'autre part à favoriser et développer les échanges entre pays en développement.

C. SITUATION DU DÉVELOPPEMENT DES RESSOURCES HUMAINES DANS LA RÉGION AFRIQUE DU NORD-MOYEN ORIENT (MENA)

1. *Au niveau international*

La région MENA ne semble pas avoir profité au niveau souhaité des efforts de la communauté internationale ayant tendu à développer une infrastructure de développement de capacités des pays en développement à mieux gérer leurs ressources en eau. On peut relever en particulier que le réseau ITN n'a jusqu'à présent pas concerné la région. À noter toutefois, l'action du CEFIGRE qui a réellement fait de la région MENA un champ privilégié de sa stratégie d'action. Encore que cette stratégie ait plus concerné le Maghreb que l'ensemble de la région.

La politique maghrébine et moyen orientale du CEFIGRE a permis de réaliser au long de ses quatorze ans d'existence, un vaste programme de formation spécialisée dans tous les secteurs de l'eau. Le premier secteur bénéficiaire a été incontestablement le secteur de l'eau potable et de l'assainissement. Plus de 200 cours d'une durée moyenne de deux à trois semaines ont été organisés au bénéfice de plusieurs centaines de cadres des secteurs public et privé sur les thèmes les plus divers de la gestion de l'eau urbaine et de l'assainissement. Ils ont couvert les aspects techniques comme les aspects financiers et institutionnels. Assurés par d'éminents experts actifs dans des sociétés et services de distribution d'eau et d'assainissement des pays du Nord comme des pays du Sud, ces cours ont contribué au transfert des connaissances et de savoir faire du nord au sud, aux niveaux de la planification, l'étude, la réalisation, la maintenance et l'exploitation des réseaux d'eau et d'assainissement, de l'introduction de l'informatique, de la gestion tarifaire, comptable et financière et du management général des services et sociétés concernés.

Dans le domaine des irrigations, les actions du CEFIGRE ont visé à renforcer les capacités des offices et sociétés d'irrigation pour une meilleure utilisation de l'eau dans les périmètres irrigués, grâce à une gestion rationnelle des réseaux d'irrigation, une amélioration des pratiques et des techniques d'irrigation et la promotion d'une gestion de la demande en eau d'irrigation adaptée aux conditions de rareté et de cherté de la ressource en eau, spécifiques à la région MENA. En collaboration avec les institutions spécialisées (École nationale du génie rural et Société du Bas Rhône Languedoc), le CEFIGRE a mis en place, depuis deux ans, un cycle annuel permanent de formation à la gestion des périmètres irrigués se déroulant en trois modules de quatre semaines chacun:

— management stratégique et gestion des ressources humaines et financières;
— exploitation et maintenance des équipements;
— irrigation à la parcelle, organisation des irrigants, conseils et vulgarisation.

En matière de gestion globale des ressources en eau, les programmes du CEFIGRE ont comporté un nombre important de cours, sessions, séminaires régionaux et internationaux sur:

— la gestion des ressources en eau souterraines: aspects quantitatifs (connaissance, évaluation par la modélisation notamment, mobilisation par puits et forages) et qualitatifs (qualité de l'eau, vulnérabilité des nappes, périmètres de protection, pollution, etc.);
— la gestion des eaux de surface: aspects hydrologiques, aménagement des rivières (barrages, canaux, etc.);
— la planification de l'eau: évaluation des ressources et des besoins, études et choix des schémas de développement des eaux, planification par besoin, planification nationale;
— la gestion intégrée des bassins versants: dégradation des sols, érosion et envasement des barrages;
— l'application des outils mathématiques et informatiques à la gestion des ressources en eau;
— les aspects institutionnels, tarifaires, économiques et financiers liés au développement du secteur de l'eau.

Depuis la fin des années 1980, la formation dans les domaines de l'utilisation des ressources en eau, appelées non conventionnelles, et de la gestion environnementale des ressources en eau est de plus en plus à l'honneur. En particulier les sessions internationales du CEFIGRE, sur le thème de l'épuration des eaux usées domestiques et industrielles et de leur réutilisation notamment dans l'agriculture, rencontrent un franc succès auprès des cadres ressortissants des pays de la région MENA.

Enfin, les sessions régionales de formation ayant pour thème l'étude d'impact des projets de développement sur l'environnement en zone littorale organisées dans le cadre du volet «Développement institutionnel» du Programme d'assistance technique pour la protection de la Méditerranée (METAP) ont réuni, chaque fois, une trentaine de participants dont une bonne majorité est active dans des secteurs en rapport direct ou indirect avec la gestion des eaux.

2. *Au niveau national*

Des politiques de formation plus ou moins ambitieuses ont été poursuivies par les pays de la région. Des résultats variables certes, mais relativement importants sont enregistrés dans l'ensemble des pays de la région. Dans la plupart des pays, les politiques de formation universitaires d'ingénieurs et cadres de maîtrise ont largement atteint leurs objectifs. L'encadrement, au niveau supérieur dans les sociétés et services d'eau, très faible ou presque inexistant, il y a une vingtaine d'années, atteint aujourd'hui un niveau numérique comparable à celui des sociétés des pays du Nord. Il reste que tous les profils et spécialités ne sont pas présents de la même manière, si bien que qualitativement, l'offre réelle présente souvent des distorsions importantes par rapport à la demande. Ces distorsions se trouvent être aggravées par le fait:

— que la formation universitaire reste souvent relativement académique et théorique, sans compter que certaines disciplines, pourtant indispensables à la majorité des ingénieurs, continuent d'avoir mauvaise presse dans les amphithéâtres des écoles d'ingénieurs qui les inscrivent à leur programme; nous voulons parler des sciences humaines, de la communication, de l'organisation du travail, de la gestion financière et comptable;
— que les systèmes de valeur dominants dans les entreprises et services d'eau de la région favorisent peu l'apprentissage sur le tas, de l'ingénieur et du cadre supérieur en général;
— que les politiques de gestion et de promotion des personnels, dans nombre de pays, privilégient le background universitaire au détriment de l'apprentissage et l'expérience professionnels.

En ce qui concerne la formation d'agents de maîtrise et de métier de l'eau, il y a lieu de signaler que cette formation demeure paradoxalement peu développée. Outre que les centres de formation de la maîtrise et d'ouvriers spécialisés ne sont pas en nombre suffisant, leur fonctionnement souffre d'une insuffisance en moyen budgétaires et humains. La formation des formateurs demande à être renforcée notamment dans les disciplines de pointe et les techniques novatrices.

Pour ce qui concerne la conscientisation et la sensibilisation du consommateur et de toute la population concernée à un degré ou un autre par la gestion de l'eau, les actions de formation et d'information demeurent timorées. Le chemin est encore long sur la voie de l'éducation de la population, hommes, femmes et enfants. Les premiers pas dans cette voie montrent que des progrès peuvent être réalisés rapidement. En particulier, l'expérience atteste que l'Association des femmes à la gestion des points d'eau donne des résultats très encourageants. La participation communautaire qui n'est pas une invention de la fin du XX^e siècle, mais un mode de vie ancestral qui a résisté à toutes les tentatives d'étouffement, est encore largement répandue et ne demande qu'à être soutenue.

II. LES PRINCIPAUX OBSTACLES AU DÉVELOPPEMENT DES RESSOURCES HUMAINES DANS LE SECTEUR DES RESSOURCES EN EAU EN MENA

La crise économique internationale des années 1980 a porté un coup dur aux programmes globaux de développement des ressources en eau mis en route dans les pays en développement au lendemain de la conférence de Mar del Plata. Plus spécifiquement, le développement des ressources humaines, perçu dans la culture très technocratique du secteur de l'eau comme non prioritaire, a fait l'objet d'un désintérêt quasi-généralisé. Cette situation regrettable a été favorisée par:

— l'absence de politiques globales cohérentes de formation. Rares, en effet, sont les pays qui ont élaboré des politiques et des plans de formation pour l'ensemble du secteur de l'eau basés sur des allocations budgétaires adéquates et une évaluation quantitative et qualitative des besoins réels de formation; plus rares encore sont ceux qui les ont effectivement mis en œuvre;
— le manque de coordination des programmes de formation au niveau national et au niveau des interventions des agences internationales de financement et de coopération;
— l'attitude des ingénieurs à marquer leurs préférences pour des projets grandioses et des techniques sophistiquées au détriment du non conventionnel et des technologies simples et peu coûteuses;
— la prééminence accordée, dans le secteur public comme dans le secteur privé, aux fonctions d'équipement et d'investissement par rapport aux fonctions de maintenance et de gestion, et les tendances des sphères de décision à préférer le hardware au software;
— l'intérêt insuffisant accordé aux résultats d'exploitation et aux post-évaluations des projets;
— le manque de conviction quant à l'intérêt de la participation communautaire et de la contribution de la population à la bonne gestion des ressources en eau.

III. LES LEÇONS TIRÉES DE L'EXPÉRIENCE DES ANNÉES 1980

Les leçons les plus importantes à retenir de l'expérience des dernières années concernent, à notre sens:

— la nécessité d'une approche globale du secteur de l'eau et de l'intégration des problèmes de développement et d'environnement;
— l'avenir des technologies peu coûteuses et de leur contribution à apporter des solutions appropriées aux problèmes des milieux ruraux et peri-urbains;
— l'apport de la participation communautaire et en particulier du rôle de la femme à une gestion économe, sanitaire et environnementale du secteur de l'eau et de l'assainissement;
— la nécessité de coordonner et d'harmoniser les politiques de développement des ressources humaines et les politiques de développement général du secteur.

IV. LES STRATÉGIES FUTURES POUR LE DÉVELOPPEMENT DES RESSOURCES HUMAINES EN MENA

La demande en infrastructures hydrauliques et en équipements sanitaires dans les pays en développement demeure importante à court et moyen termes en raison, d'une part des énormes retards à rattraper et d'autre part des besoins additionnels induits par une croissance démographique que peu de pays parviennent à réguler. À la sollicitation quantitative croissante des système hydriques, viennent s'ajouter les impacts environnementaux d'une gestion peu adaptée des rejets urbains et industriels et d'une maîtrise insuffisante de la mise en valeur des sols et des forêts.

Dans les conditions de ressources financières limitées de la plupart des pays de la région, une gestion environnementale saine des ressources en eau exige de tels niveaux de ressources budgétaires que leur mobilisation ne peut être envisagée que si le secteur de l'eau est l'objet d'une attention toute particulière. Les stratégies futures de développement des ressources humaines sont conditionnées par la volonté des pays à traduire cette attention en priorité nationale et leur détermination à garantir au secteur les conditions indispensables au développement harmonieux de l'ensemble de ses composantes et au premier chef, la composante formation et éducation.

Il s'agira en premier lieu de mettre en place des arrangements institutionnels appropriés afin de a) délimiter les attributions des différents départements ministériels impliqués, et les compétences des secteurs public et privé, b) définir les voies de la participation communautaire et de la mobilisation de l'initiative privée, et c) instaurer une coordination adéquate entre toutes les activités, nationales ou d'appui international, de gestion des ressources humaines et d'intégration de cette gestion aux politiques globales de mise en valeur des ressources en eau et de gestion de l'environnement.

Plus que par le passé, les pays devront veiller à allouer aux programmes de formation et d'éducation des ressources budgétaires suffisantes et stables. L'efficacité des plans de formation et d'éducation est tributaire en dernier ressort de l'intérêt qui sera porté à leur réalisation par l'ensemble des acteurs du secteur, en particulier par les sphères de décision et les structures d'encadrement dont les comportements et les attitudes gagneraient à évoluer vers plus de convivialité et de concertation dans l'entreprise Eau.

Les plans de formation devront s'articuler sur les politiques de recrutement et de gestion des personnels, et viser à développer les compétences techniques, scientifiques et de gestion en fonction des besoins réels déterminés par les objectifs de développement du secteur de l'eau.

Compte tenu de la situation prévalant actuellement, les programmes de formation continueront, à court terme, d'être dominés par des actions destinées à répondre aux besoins les plus urgents des pays en développement dans les domaines de l'entretien et de la maintenance des équipements existants, de l'extension de la desserte en eau et assainissement dans les zones rurales et périurbaines, à savoir:

- la formation professionnelle de techniciens et ouvriers dans les métiers de l'eau;
- la formation universitaire d'ingénieurs, de cadres et techniciens spécialisés;
- la formation continue sur les lieux de travail et dans les institutions spécialisées à tous les niveaux;

— l'éducation sanitaire des femmes et des enfants et la sensibilisation de la population à l'utilisation rationnelle de l'eau;
— la production de manuels, guides et autres supports de communication.

Une attention spéciale devra être accordée à la formation des formateurs et à l'encadrement dans l'entreprise, moyens privilégiés pour élever le niveau de qualification dans le secteur.

À moyen et long termes, l'objectif sera de développer les capacités nationales des pays à prendre en charge les problèmes d'étude, de conception et de planification, à maîtriser la réalisation, l'exploitation et la gestion, et enfin à développer la recherche et l'innovation.

Forte de son expérience diversifiée des dernières années, la communauté internationale a un rôle crucial à jouer dans l'appui à l'élaboration et à la mise en œuvre des stratégies nationales de développement des ressources humaines dans les pays du MENA.

Le projet de charte méditerranéenne de l'eau et le projet de mise en place d'un réseau méditerranéen de l'eau destinés à favoriser les échanges d'expériences et de données, le transfert de savoir et savoir faire entre les pays du pourtour méditerranéen, actuellement à l'étude par la Commission des Communautés Européennes, sont des initiatives heureuses d'encouragement des pays de la région à plus de coopération régionale et une meilleure préparation pour relever les défis d'une situation critique de ressources en eau.

Jordan's Water Action Plan

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ABSTRACT

Of all the countries in the arid Middle East, Jordan potentially faces the worst water crisis. The exacerbating conditions contributing to this crisis include the arid climate, the unsolved water sharing disputes in the region, the high population growth rate, the acute financial constraints, and the lack of a sustained peace in the area. The impacts of these and other factors are presented in this study, inasmuch as they pertain to Jordan's ability to provide water for its people. This paper begins by analyzing the problems associated with the use and distribution of water in Jordan. The data-set presented includes the most recently available figures on water supply and demand, and is used to develop a comprehensive plan of action for water management in Jordan. The plan involves the identification of a number of future directions that are consistent with the country's national objectives. The plan thus incorporates rational decision making with water supply and demand management to cover short, medium, and long term planning horizons. In addition, given the inherent scarcity of water within Jordan's territory, regional cooperation is discussed as an important component of such a plan.

RÉSUMÉ

La Jordanie risque de se trouver bientôt devant une situation catastrophique en ce qui a trait à l'approvisionnement en eau. Le climat aride, une croissance démographique élevée, un manque de capitaux et de paix durable dans la région, et le fait que les pays mitoyens ne peuvent s'entendre pour partager équitablement les ressources en eau existantes, sont parmi les facteurs qui entrent en jeu. Cette étude présente le rôle de ces facteurs dans l'incapacité de la Jordanie de pourvoir à ses besoins en eau. Est d'abord présentée une analyse des problèmes reliés à l'emploi

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de l'eau et à sa distribution. Un plan d'action de gestion de l'eau est ensuite proposé qui est basé sur les données les plus récentes d'offre et de demande en eau. Ce plan — dont une des composantes majeure est la coopération régionale — propose des mesures compatibles avec les objectifs nationaux et allie la prise de décision rationnelle à la gestion à court, à moyen et à long terme des ressources en eau. De plus, étant donné le manque d'eau en Jordanie, la coopération régionale est abordée comme faisant partie intégrante d'un plan de gestion de l'eau.

INTRODUCTION

Water management problems in arid regions are generally characterized by water shortages, environmental quality issues, and supply distribution concerns. In most developing countries, efforts to resolve these problems have focused almost exclusively on the development of additional water supplies. The institutions that have evolved to deal with the water scarcity have been committed to the construction of storage and conveyance facilities, while at the same time ignoring the full impact of these projects or their alternative designs on socio-economic and environmental objectives. Presently, these institutions need to look elsewhere to deal with the projected water scarcity because of the rapidly increasing costs of developing new water supplies, especially in Jordan, where typical water projects are relatively more expensive to design and build than in other countries due to the terrain and topography. In such cases, water resources planning must incorporate appropriate objectives, constraints and methods, utilizing the available physical data to provide efficient and comprehensive solutions.

The purpose of this study is to present Jordan's experience with a plan of action that involves such comprehensive planning strategies for the short, medium and long terms. Notwithstanding "normal" water management problems, Jordan also faces its water problems without the benefit of an international law agreement insuring individual country rights to shared river basins and groundwater aquifers in the Middle East. Therefore, in the case of Jordan, adequate long range planning requires a reliable method for allocating the international waters of the Jordan River system, a system that is shared by four riparian countries in the Middle East.

Due to the complex "hydropolitics" of the region (a term originally coined by John Waterbury of Princeton), the countries in the arid Middle East are subject to what Elliot (1991) terms "conditions for water related tension." These conditions are (1) the region's arid climate with only a few rivers, most of which have low annual flows, (2) the physical sharing of rivers by more than one country, (3) the high population growth rates, and (4) the fundamental political, cultural and religious rift among the nations.

The sharing of jointly owned water resources is a complex issue in many areas of the world. The number of shared river basins in Africa, for example, is 57, covering 60% of the total area of the continent. There are 40 shared basins in Asia, accounting for 65% of its area (Anderson, 1991a). In the special case of the international rivers in the Middle East region, the Nile is shared principally by four countries (although it threads its way through nine African states), and the Tigris-Euphrates is basically divided between three. However, there is probably no other area as difficult as the Jordan River Basin, where, in addition to the hydrologic complexities of the river, socio-economic, historical, political and strategic dimensions interfere and overlap.

Another exacerbating water resources issue is population growth. The rate of population growth in many Middle East countries continues to be among the highest in the world (Imran, 1988). Furthermore, this population is concentrated in urban areas such as Cairo, Amman and Damascus, which will increase the need for sewage collection and wastewater treatment facilities. Supplying domestic water for this growing population and water for agriculture and industries to provide required food and job opportunities will call for additional water supplies. If such supplies are not available, the difficult process of reallocation from current uses to higher preferential and more valuable uses will be required. In this paper, it will be shown that the problem of water resources scarcity in Jordan is becoming increasingly more pronounced. This lends itself to the premise that, even under the fundamental rift that exists in the area, regional cooperation in water issues is a necessity that must be considered.

I. BACKGROUND

Jordan is located in a semi-arid to arid climate east of the Mediterranean Sea. Its only access to the sea is through its port city of Aqaba on the Red Sea. Of its 90 000 square km land area, 94% receives less than 200 mm of rainfall per year and is thus considered a desert country. The eastern and southern regions are arid cold (deserts), while the Amman region and the northern highlands are considered to be more temperate (see Figure 1). Figure 2 illustrates the location of Jordan, and its capital city, Amman. Also illustrated in the figure is the Dead Sea, which is 400 m below sea level.

Water available to Jordan is derived from surface water sources, groundwater sources and wastewater reuse. Approximately 70% of surface water flows are presently being utilized (future development of other sources is fraught with political concerns), while at least 20% of renewable groundwater supplies are being extracted over and above their safe yields. Non-renewable groundwater is abundant in the Southern deserts (the Disi aquifer), but these sources are over 300 km away from the major demand centers in the North, and until a national water conveyor is constructed to permit water transfers, the water is being mined to support subsidized wheat production. Presently water demand exceeds supply in most areas of Jordan, so that overextraction of groundwater sources is common. To alleviate some of this overextraction, forced water cuts in municipal water supplies have been applied in the summer since the mid-1980s.

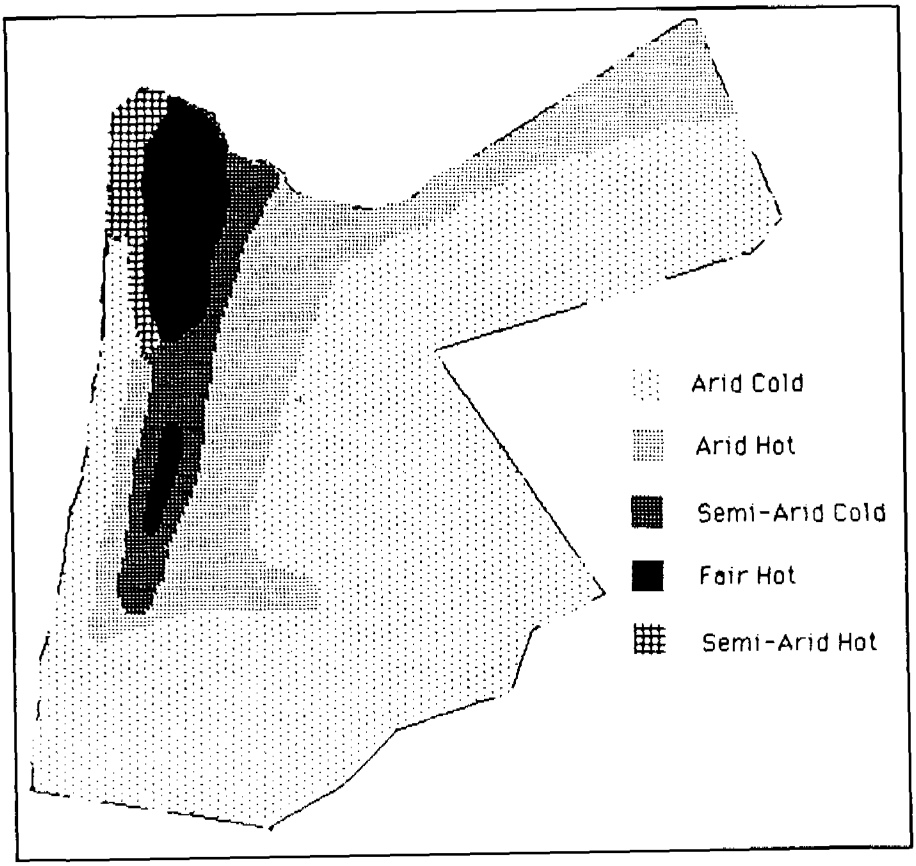
A. Population Growth

Jordan's current total population is 3.45 million. Over 90% live in the Northern areas, and over half the population is concentrated in the urban belt around Amman and Zarqua.

The country's population (see Figure 3) is increasing by 3.4% per year (double the world average of 1.7%), which means that the population will double within roughly 20 years at present rates. The growth in the population of Jordan has been

Figure 1

Climatic Regions of Jordan



affected by the arrival of Palestinian refugees during the past four decades, and most recently from an influx of more than 300 000 Jordanians arriving to settle in Jordan after the Gulf War. The latest estimates for 1991 show that over 500 000 visitors were in Jordan during the summer. With this rapidly growing population, water consumption has risen in the face of limited water supplies. This has forced the country to exceed the safe yields of its groundwater supplies. The consequences of this uncontrolled depletion rate for the future is a cause for alarm, since it ultimately translates to reduced water supplies through quality deterioration.

In essence, Jordan is living beyond its means, primarily due to the external shocks that have affected its hydrobalance; the increased number of returnees from Kuwait and Iraq to Jordan will increase water consumption and the need for treatment. Therefore in striving for a higher standard of living, Jordan must obviously provide for increased per capita consumption of water for hygienic, nutritional, recreational and non-essential items, along with improved environmental standards. The basic

Figure 2
Location Map of Jordan

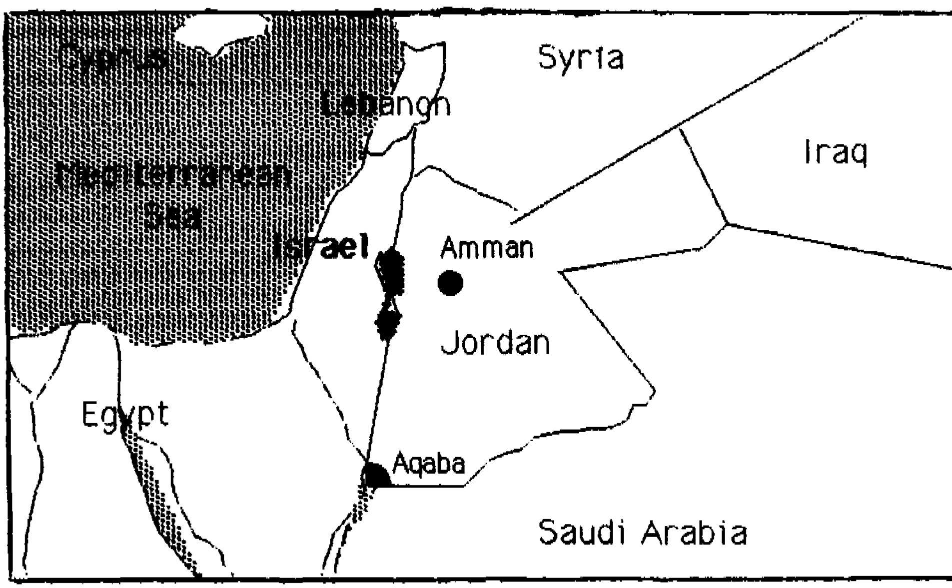
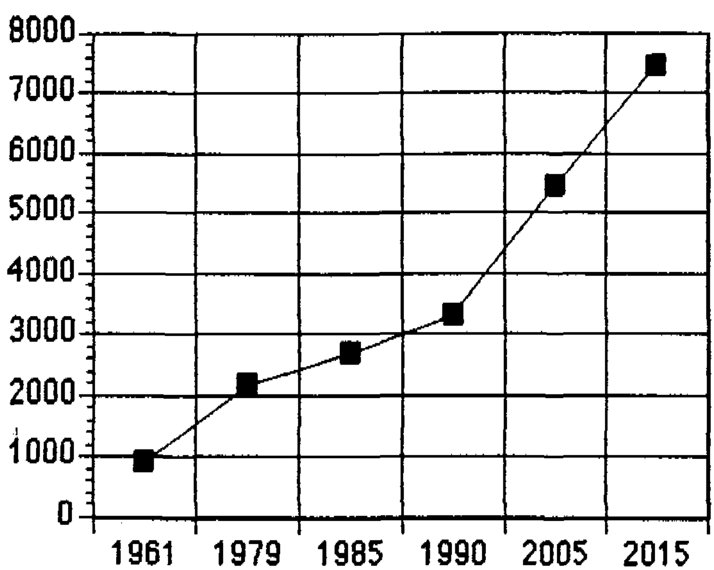


Figure 3
Population in Jordan for Selected Years
(in thousands)



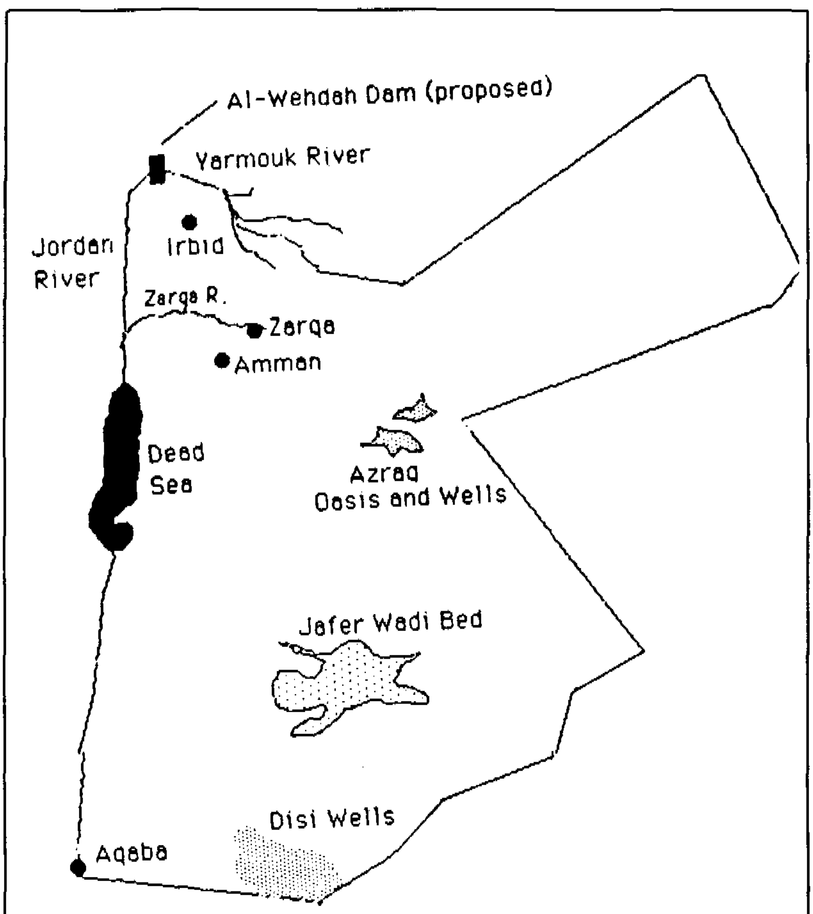
premise of this paper, then, is that the demands by all sectors (municipal, industrial and agricultural sectors) are likely to increase due to greater urbanization and high growth rates, potentially causing huge water deficits.

B. Water Resources

An outline of the quantities and locations of annual renewable and non-renewable groundwater supplies, along with annual surface water resources in Jordan is now presented. The assessment of water supplies includes present and potential water yields from all basins, the most important of which are illustrated in Figure 4 below.

Figure 4

Jordan's Water Resources



In Jordan, ten major groundwater basins are defined according to regional water divides, aquifer limits or important topographic features. The most important of these basins are the wells in the North, the wells in the Amman-Zarqa region, the Azraq area, the Jafer basin in the Southeast, and the Disi fields in the Southern deserts. Thus there is a need to convey future supplies considerable distances from sources in the South to the major urban centres in the Northwest Highlands. Overall, safe yields from major renewable sources are being exceeded by an average of 20-30%. According to the Ministry of Water and Irrigation (MWI), the long-term safe yield of renewable and nonrenewable groundwater supplies is estimated at 388 million cubic meters (Mm^3) per year (including the southern fossil aquifers). Other sources (e.g. Naff and Matson, 1984) give estimates within that range. The nonrenewable Disi Fossil Aquifer with an estimated safe yield of 100 Mm^3 per year, is regarded as a strategic resource. This source is being currently exploited to meet the demands of irrigated agriculture in the southern desert (45 Mm^3/yr) and to provide some 11 Mm^3/yr of water to Aqaba.

In terms of surface water, the Jordan River basin is the dominant resource in Jordan with the Yarmouk and the Zarqa Rivers forming its major tributaries. According to the MWI (Jordan MWI, 1990), the total available flow in the surface basins (consisting of base flow and flood flow) is 750 Mm^3 on an average annual basis. However, the maximum economically exploitable quantity available to Jordan, even after all dams including the Al-Wehdah Dam are built, is only 474 Mm^3. This difference is due to the extensive use of the Yarmouk by others, and the lack of dams on the Yarmouk and major wadis. The Yarmouk River itself flows into the Jordan River after draining the high plains of Golan in Syria, and the desert plateaus of both Syria and Jordan. The drainage area of the basin near its confluence with the Jordan River is about 6 970 square kilometres with a mean annual runoff of 411 Mm^3 (Abu-Taleb et al., 1991b).

A total safe yield figure of 862 Mm^3/year (ground and surface combined, 388 + 474) will be used for the maximum potential of conventional water supplies in Jordan. Non-conventional sources such as wastewater reuse, desalination of brackish waters, or extremely expensive pumping from deep aquifers are not included in this estimate.

At the present time, only 730 Mm^3/yr (of which at least 20% of groundwater supplies being "overused") out of this 862 Mm^3 is presently being exploited and utilized annually to meet demand. It is only after the completion of the Al-Wahdeh Dam, with a storage capacity of 200 Mm^3/yr per annum (effective additional supply 75-100 Mm^3), and other supply augmentation projects that the figure will approach the 862 Mm^3/yr total available supply from conventional sources.

C. Current and Future Water Demand

Three main subsectors compete for water in Jordan: the municipal, the industrial and the agricultural subsectors. The quantity consumed in Jordan in 1990 (730 Mm^3) was distributed in the following proportions: 175 Mm^3 for municipal use, 35 Mm^3 for industrial use and 520 Mm^3 for irrigation purposes (Abu-Taleb et al., 1991a).

The figures for municipal demand are a reflection of the following factors: population growth rates, per capita consumption, water supply efficiency, and conservation measures. In terms of individual consumption statistics, the currently accepted figure is 138 liters per capita per day (lpd). This includes residential demand (66%), small industrial and commercial demand (14%), and losses (20%). Such losses in municipal supply networks imply that physical inefficiency is an acute problem that must be addressed thoroughly.

Industrial demand for water in Jordan depends primarily on the level of industrial production from the various industries, such as the phosphates mines, the mineral extraction plants on the Dead Sea, the cement and fertilizer industries and others. Because of the economic slowdown in the mid-to late 1980s, industrial production growth from 1986-1990 was negative. The figures for industrial water demand for the year 1990 were 35 Mm^3, representing only a slight increase on demand in 1985.

Agricultural activity in Jordan is centered around the Jordan Valley, the northern highlands, and the Disi area in the South near the border with Saudi Arabia. Agriculture provides 10% of nominal GDP, with crop production and livestock (sheep, poultry and eggs) contributing 75% and 25%, respectively, of the value added in this subsector. However, the impact of agriculture is quite broad, and affects the industrial and service subsectors. The total land area under irrigation is 55 000 hectares, mostly in the Jordan Valley. The King Abdullah Canal (KAC) is the main lifeline for most irrigation in the area. The canal, which was completed in 1966, draws water from an intake tunnel on the Yarmouk and conveys it for irrigation in the Valley. Water supply networks in the Valley provided water by surface gravity systems (45%) and pressure pipe systems (55%).

In the Disi area, approximately 45 Mm^3 of good quality water is used to produce highly subsidized wheat in the southern deserts. It is estimated that this aquifer (shared with Saudi Arabia) can provide Jordan with more than 100 Mm^3 annually for the next 100 years. A conservative supply estimate of 78 Mm^3 is used in subsequent analyses in this paper.

Figure 5 provides a perspective on recently available forecasted values of water demand for the different subsectors, in relation to a total safe yield figure of 862 Mm^3 from conventional sources. For ease of presentation, Municipal and Industrial (M&I) demand has been grouped together.

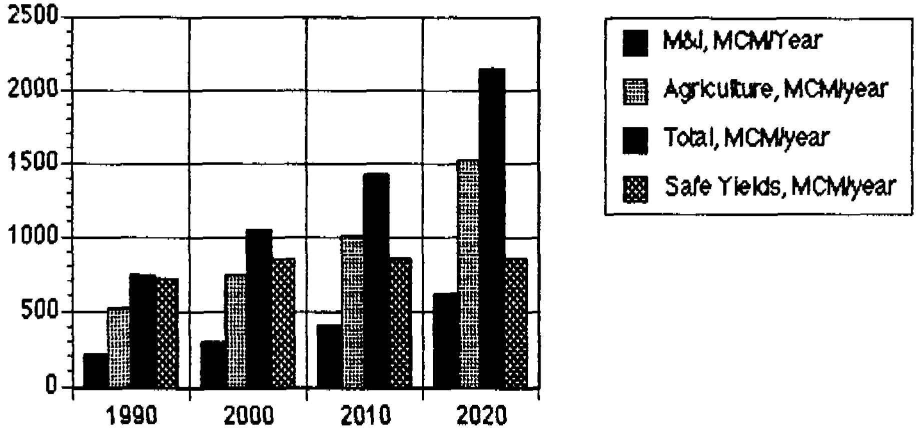
The projected demand figures were based upon a number of assumptions. First, demand for M&I water was based on 190 litre per person per day including losses. Second, irrigation water demand was assumed to be equivalent to 1000 cubic meters per 0.1 hectare, with a constant population growth rate of 3.8% over the entire period.

Now that we have looked at water supply and demand figures, we can perform some accounting procedures to analyze the balance of water in Jordan for the future. To begin with, if water resources development were halted, total water supply would remain as it was in 1990, namely 730 Mm^3. Therefore given the previous water demand forecasts for the future, Jordan would experience 15%, 28% and 38% deficits for the years 1995, 2000, and 2005, respectively. These numbers were calculated before the influx of returnees from the Gulf, so that in actual fact, these deficit percentages are likely to be higher.

Due primarily to the urgency of the situation, a number of measures have to be adopted to cover these deficits, including some efficiency enhancements, water

Figure 5

Projected Demand by Each Subsector
(MCM = Mm³)



demand management through pricing and regulatory measures, and the construction of supply augmentation projects, such as the Al-Wehdah Dam. Table 1 presents an accounting framework for the water balance in Jordan through the year 2005.

The above figures clearly indicate that the deficit will grow even with the construction of the Wehdah Dam, to reach 172 Mm^3/yr in 2005. Because of this, efficiency enhancements, water demand management and other options must be applied in a comprehensive manner in the short term, since any of the projects mentioned would take between 5-10 years for completion.

D. Environmental Concerns

In recent history, water supplies in Jordan have been augmented to keep pace with demand as much as possible. With this expansion in water production and use, the volume of low quality return flows into the rivers has increased, causing concern for the quality of future water supplies and the overall environment.

For Jordan, environmental problems are a direct externality of the supply-demand imbalances. Because of the generally low flows, surface streams have relatively low assimilative capacities. Treatment levels of wastewater are inadequate in view of these low assimilative capacities, and therefore, downstream uses are adversely affected. In the case of groundwater, overpumping (mining) to meet growing demand is degrading the quality of the remaining water the basins. Although Jordan is well aware of the importance of environmental protection and has undertaken significant measures to face the problems facing its water supplies, much remains to be done.

The waters of the Jordan River are highly saline for a number of reasons (Ahmad, 1989). It receives the return flows from irrigated fields on both sides of its

Table 1

Water Balance Projections (Mm³/yr)

Item	Year			
	1990	1995	2000	2005
Current Sources[1]	730	730	730	730
Wehdah Dam	—	—	55	100
Disi Aquifer	—	—	78	78
Wastewater reuse	—	45	60	70
Small Dams	—	10	20	30
Brackish water use	—	—	10	20
TOTAL (with Wehdah)	730	785	953	1028
TOTAL (without Wehdah)	730	785	898	928
Projected demand	730	890	1045	1200
Deficit (with Wehdah)	—	105	92	172
Deficit (without Wehdah)	—	105	1417	272

Sources: Abu-Taleb et al., 1991; Ministry of Water and Irrigation figures.

1. Figures for current sources include a 20% overextraction beyond safe yields, which will probably not be sustained into the future. If this is taken into account, the deficit projections will be even higher.

banks, and now directly receives the flow of the saline springs that were diverted into the Jordan River by Israel. The diversion of these springs was undertaken unilaterally by Israel in order to conserve the quality of Lake Tiberias, which provides a substantial portion of Israeli water. This practice has made the Jordan River unsuitable for use in its present condition. In terms of water quality, increased development coupled with domestic pollution of the upper Jordan, has resulted in increased salinization and deterioration of the agricultural usefulness of the water. Further studies are required to determine the extent of damage and possible adjustment tactics.

The Yarmouk River waters are of good quality at the present time. The Zarqa River, on the other hand receives industrial and municipal treated wastewater. In the summer months, the flow of this river consists almost entirely of treated wastewater.

In the case of groundwater, which provides about 90% of municipal supplies, water quality is even more important. Detailed studies of groundwater pollution can be found in Salameh (1989, 1991). The reports indicate that the two main sources of groundwater contamination are water mining practices and seepage of wastes. Contamination due to water mining refers to the general propensity of saline water to intrude into the higher levels of aquifers following extraction rates which are greater than the natural recharge of the aquifer. The first experience with saltwater intrusion in a groundwater basin occurred in the Jafer region. In the 1960s and early 1970s, salinity levels escalated due to overextraction of water. To this day, salinity levels are not low enough to render this basin completely usable. In the Wadi Dhuleil well fields near Zarqa, which are mainly used for irrigation, salinity levels have grown to high levels. In the Azraq basin, water is used for both irrigation in that area and for domestic supplies to Irbid and Amman. In that basin, water withdrawals began to exceed safe yields in 1982, and presently water levels have been lowered by 3-5 meters. Subsequent measurements of salinity revealed an increase from 500 mg/L to 700 mg/L in this basin. In the nonrenewable fields of the Disi aquifer, water levels have dropped by as much as 8 m since the early 1980s.

Future protection of groundwater basins is a matter of paramount importance. The following initiatives are considered to be high priorities by national policy makers: prevention of mining in groundwater basins; development of the wastewater infrastructure for a large part of the population and improvement of the operations of wastewater treatment plants; careful selection of landfill areas; monitoring of pesticide and fertilizer use in most areas; development of a sound industrial licensing policy and related laws and guidelines for the protection of the environment (Abu-Taleb et al, 1991a).

E. Economic and Financial Constraints in the Water Sector

During the past three decades, Jordan's small open economy has been subjected to a number of external shocks; the adverse ones resulted in severe balance of payments difficulties, while the favourable shocks helped Jordan immensely. For example, between 1964 and 1982, Jordan exhibited the highest per capita GDP growth rate per annum of any developing country (McCarthy et al, 1986). Jordan thus became a success story of the developing world, achieving high growth rates, superior education levels, and political stability, while aspiring towards democratization and political moderation. By April, 1989, however, Jordan was $8 billion in debt and had the second highest per capita debt of any country in the world (Piro and Brown, 1991).

The impressive economic performance of Jordan came to an end in 1983. Real GDP growth dropped from over 10% during 1979-1980 to 8.7% in 1981, and further to 5.5% in 1982 (Jordan Ministry of Planning, 1986). In 1983, real GDP growth dropped to 0.2% and in the mid-1980s, growth rates remained modest due to the ongoing regional economic slowdown which was followed by a domestic recession in 1988. The rise in the country's external debt during the 1980s was mainly due to the choice of financing over the more unpleasant alternative of structural adjustment policy. The major recession, and subsequent IMF-sponsored adjustment measures were closely followed by an even greater external shock: the Gulf Crisis.

According to a United Nations report (U.N., 1990), Jordan's losses are estimated at U.S. $8.3 billion, due to the continuing economic embargo on Iraq and the Gulf War. Among other things, the report refers to the insecurity presently associated with the region.

Because of these economic conditions, investments into the water sector have been on the decline. Table 2 illustrates public investment figures in the water sector over the past two decades. Most of the investment went into construction of dams, wastewater treatment facilities, water supply networks and irrigation works. The table also contains water supply figures for illustrative purposes.

As the above data indicate, investment as a percentage of government budget has decreased, even in light of the increasing population and continued socio-economic development. The current financial difficulty is especially magnified by the effects of the U.N. sponsored embargo on Iraq and the ensuing hostilities. A continued and sustained level of investment will be key to any comprehensive plan of action.

Table 2

Water Supply and Public Investments

Period	Average Water Supply Mm^3/year	Public Investments in million Jordanian Dinars	Investment as % of Govt. Budget
1976-1980	520	520	16%
1981-1985	625	245	10%
1986-1990	678	280 (planned)	9%
1991-	730	—	—

Source: Jordan Ministry of Planning figures.

II. FRAMEWORK OF JORDAN'S WATER ACTION PLAN

Most recent efforts to address the water resources problems of Jordan represent short term solutions devised in response to immediate pressures, rather than long term plans derived from a comprehensive strategy for overall economic and social development. Moreover, they focus almost entirely on construction of facilities such as dams, reservoirs and conveyance facilities, ignoring the possibility of changes in economic water demand, i.e., demand management. Yet the potential of these non-structural alternatives in conjunction with efficient water development projects and programs may be great.

Many international experts in the field of water resources have addressed the need for integrated approaches. Munasinghe (1990), for example, calls for an integrated approach that links the totality of sectors within the economy in order to produce the greatest beneficial impact and effectiveness. Munasinghe also identifies influential broad areas of concern to assist in the development of national objectives, a process he calls "a useful starting point for developing a national water supply strategy." Loucks and Somlyody (1986) argue for the use of the multiobjective methodology for water resources planning in developing countries. In a recent report, (U.N., 1989), systems analysis (including the field of multiobjective optimization) was advocated as a tool for water resources development and planning in developing countries.

Such integrated approaches may be helpful in all subsectors. Consider the case of agriculture, currently by far the biggest user of water in Jordan. Water is subsidized in the Jordan Valley, suggesting that farmers apply more than is economically justified. In addition, surface application methods are still used by farmers in the Valley, partially because of these water subsidies. In contrast, in the highlands, farmers who do not received subsidized water, use drip systems almost exclusively.

Current water pricing also fails to take into account costs due to environmental effects and resource depletion. No attempt is made to charge upstream farmers for the reductions in productivity downstream due to salinization caused by agricultural discharges. Farmers utilizing groundwater may pay the full cost of pumping and delivery, but are not charged the user cost of aquifer depletion. This is likely to be especially important in the case of the Disi Aquifer, a fossil aquifer receiving no recharge that is being exploited to grow wheat in the desert.

Municipal water use is another area that deserves further scrutiny. Metering and billing is a useful tool in water demand management. Per capita water consumption is currently relatively low. If water demand rises as urbanization and incomes increase, friction between municipal and other uses will grow, and in such cases, water transfer capabilities have to be erected to handle different allocation requirements. Whenever possible, it is preferable to consider all such prospects in planning water development strategy. This is what this Action Plan for Jordan entails: an integrated, comprehensive approach that involves such non-structural measures as water pricing, and regulation, with proven efficient engineering projects and programs, in order to satisfy stated national policies and objectives. These national objectives would include the impacts of water resources on the economy, the environment, health, and social ideals and values of Jordan. Before we outline the plan of action, a description of each of these impacts follows.

1. *Economic Impacts*

In general, the economic objectives of a nation include cost minimization and output maximization. Water enters economic and social development in a variety of ways, all of which must be addressed in a plan of action. Water resources development is often an important component in fostering an increase in the value of output. Many industrial processes rely on water as an input, for example, phosphates and chemicals processing. Hydroelectric power generation may become a key energy source in some areas of Jordan. Energy use is an important factor in water resources development, since at the present time, 15% of all Jordan's electricity supply is diverted to pumps and other water units. Physical efficiency enhancement implies that planners should consider projects which can reduce water losses in municipal, industrial, and irrigation systems. Agriculture depends on adequate water supplies for irrigation, and irrigated area and/or output value may be increased with adequate strategies. Development of the tourist industry depends on the availability of water. Water is also a human necessity, so that water availability may constrain the size of the resident labour force, and thus overall economic development.

2. *Environmental and Health Impacts*

In Jordan, environmental concerns involve preserving water and soil quality, and protecting archaeological, biological, and ecological systems. Environmental impacts include most of the effects on surface water quality, forestry, and undesirable changes in the physical environment, as described previously. Irrigated agriculture may be an important source of water pollutants such as fertilizers, dissolved solids and pesticide residues, necessitating consideration of tradeoffs between food and fibre production and environmental quality.

Water is also important in promoting objectives that are not easily incorporated into standard economic measures such as growth of GDP or national income. For example, development of safe drinking water supplies and collection and treatment of waste water improve the quality of life directly and are also often critical in reducing disease incidence. They thus bring about tangible increases in the standard of living, albeit ones that are not easily assigned a monetary value. Moreover, they may contribute to economic growth indirectly by fostering increases in labour productivity.

In the following section, we present a characterization of the water problems and identify some socio-economic impacts of significance to Jordan. From there, it will become clear that water resources is an increasingly important constraint to Jordanian economic growth.

A. Characterization of Problems in the Water Resources Sector

Table 3 identifies the major physical manifestations of the water resources problems in Jordan and presents their consequences as well as a qualitative statement of their associated levels of economic and social significance (Abu-Taleb et al, 1991a). An overall feature of this characterization is the inherent water supply-demand imbalances. In simple terms, these imbalances, if not alleviated, imply that Jordan can never realize its full potential for social and economic development.

Due to some of the above factors, as well as the limited fertile land base, irrigated land in Jordan is not expected to increase substantially in the future. Any anticipated increase in irrigable land area will mostly be in the Jordan Valley, since irrigation projects in the highlands utilize only groundwater supplies, therefore future land development there is very limited.

Therefore, if we assume that in the base year of 1990, 100% of needs were covered by agricultural production, then according to the anticipated population growth rates, agricultural production will only cover 92% of needs in 1995, 85% in 2000, and just over 50% of needs by the year 2015. These figures clearly illustrate the impact of water scarcity on agricultural production with respect to the increasing population of Jordan. Indeed, after such an analysis, the socio-economic consequences of the water scarcity in Jordan become even clearer.

B. A Plan of Action Based on Comprehensive Water Resources Management and Regional Cooperation

Based upon the information discussed above concerning projected water deficits, and the problems and constraints outlined, it may be concluded that (1) demand will begin to exceed supply by 1995, even if all conventional sources have been developed, (2) there is a clear necessity for developing non-conventional water supplies, (3) there is a clear indication of the need for conservation and efficiency enhancement measures within the water sector, and (4) there is a clear need for overall integrated water resources planning and development, linked to a regional cooperation plan involving water resources issues.

On that basis, recommended solutions can be divided into four broad categories. The solutions include: (1) measures to increase supply from conventional sources, (2) measures to increase supply from non-conventional sources, (3) measures to promote greater efficiency and conservation, and (4) development of an integrated comprehensive planning and management framework.

Generally speaking, the first three categories have received a significant degree of attention in previous studies and reports. Conversely, the fourth category has

Table 3

Characterization of Water Resources Problems in Terms of Social and Economic Significance

Physical Manifestation	Consequences	Economic and Social Significance
1. Semi-arid climate, low precipitation, high evap. rates.	Fluctuations in water supply; periodic droughts; naturally limited water resource base.	Planning, development targets plagued with uncertainty.
2. High population growth rates.	Increased demand and competition for water; non-renewable ground water depletion; pollution.	Reduced living standards; health problems.
3. Conflicting demands.	Inequitable allocations and subsidies, regional price structuring.	Emergence of water lobbyists.
4. Riparian conflicts.	Critical supply augmentation projects cannot be undertaken.	Destabilizing to the economy.
5. Absence of effective conservation program.	Water logging, environmental impacts, overall inefficiencies, losses.	Decline in productivity.
6. Financial constraints.	Supply augmentation cannot meet demand requirements.	Increasing health problems, loss of productivity (chain reaction).
7. Lack of integrated water policy.	Most of the above apply.	Low potential for social and economic development.

Source: Abu-Taleb et al., 1991a.

heretofore received scant attention in Jordan, despite the fact that it represents an important approach to solving complex water resource quality and quantity problems in a number of more developed nations.

The first of the four categories involves increasing water supplies by 150 Mm^3 annually, by constructing dams (e.g., Al-Wehdah, Karameh, Yabis, Al-Wala), fully utilizing side wadi flood flows, and developing the Disi, Al Jafer, and other groundwater basins. The development of these groundwater basins could produce an additional quantity of 60-80 Mm^3 per year for 100 years. The construction of a national water network spanning the entire length of the country from the Disi in the South to the Al-Wehdah in the North would also fall in this category. Such a network would facilitate water transfers and ensure close management of water supplies.

The second solution category (increasing supply from non-conventional water sources) involves developing practical and safe methods for wastewater reuse for irrigation purposes, and desalination of brackish water from the Azraq and the Jafer regions. Wastewater reuse could potentially provide 70 Mm^3 of water by the year 2005, while desalination of brackish water from Azraq and Jafer could provide 145-220 Mm^3/yr in the long term future.

The third category of promoting greater efficiency and conservation is briefly described as the reduction in the following parameters (Abu-Taleb et al. 1991): physical losses from municipal water supply networks; losses from irrigation canals;

water demand quantities by industries through the adoption of water saving technologies; water demand by residential users; adverse environmental impacts on water supplies; water demand through the modification of water pricing policies. Potential water savings from the above reductions could be anywhere between 85-100 Mm^3 per annum.

The fourth solution category for solving the water problems in Jordan involves the adoption of an integrated comprehensive planning and management framework that envelops all of the above considerations to ultimately satisfy the objectives of socio-economic development and environmental protection. It is an accepted fact that Jordan's long term future water requirements exceed its available resources within its borders. Because of this, regional cooperation must be an important component of any plan of action. Thus, by necessity, any viable plan of action for water in Jordan must involve a double track approach. The first track would involve comprehensive management of domestic water supply and demand, as mentioned above. The second would involve some measure of regional cooperation, which may include the Turkish Peace Pipeline, river diversions and others.

In the short run, the plan of action would initiate the major water supply augmentation projects and networks, and include efficiency enhancements, non-structural measures such as regulatory options and managerial incentives. In the medium term, the supply augmentation projects would progress and come on line. In the longer run, regional cooperation would play a major role.

Because of the uncertainty involved in any regional endeavour in the Middle East, the regional component of the plan is considered as a long term prospect, but can be accommodated at the earlier stages of the plan as political changes occur. Indeed, the flexibility of the overall plan would allow regional cooperation efforts to benefit Jordan immediately. In fact, such cooperation efforts may produce the necessary funding for other components of the comprehensive plan. In sum, this comprehensive plan would be based upon a national water network and the necessary demand and supply management options available to Jordan.

The remainder of this section deals with the possible regional projects in the water resources field. Some of these proposed regional cooperation programs are briefly described in Abu-Taleb et al. (1991b).

The Turkish Peace Pipeline is a project initially proposed by Turkish Prime Minister Turgut Ozal in 1986. The project would consist of two pipelines conveying water from the catchments of the Seyhan and Ceyhan Rivers in Southern Turkey to a number of countries in the South. According to the proposal, an eastern pipeline would convey water to Kuwait, eastern Saudi Arabia, Qatar, Bahrain, and the United Arab Emirates. The western pipeline would convey water to Syria, Jordan, the West Bank, and western Saudi Arabia. It has been reported that terrain feasibility studies have been completed and that possible obstacles and threats from terrorism can be overcome (Anderson, 1991b). Other major obstacles to the project include its cost and political objections. The cost of the project is estimated at U.S. $20 billion (Starr and Stoll, 1987), most of which will be financed by countries receiving the water. Political considerations, on the other hand, are not as easily quantifiable; downstream countries argue that it is difficult to imagine relying on water supplies that are controlled by outside sources. However, according to Starr and Stoll, the proposal argues that (1) regional conflicts could be reduced by virtue of the pipeline;

(2) cooperation among countries would improve; and (3) standard of living indicators throughout the Middle East would rise.

Another regional project, the diversion of Euphrates River water, was studied by the Jordan Government (with an understanding between Jordan and Iraq) to determine the technical and financial feasibilities of conveying water from the Euphrates River in Iraq to Jordan. The project would consist of treatment facilities and pumping stations to provide Jordan with 80 Mm^3/yr in the first stage, ultimately providing 160 Mm^3/yr in later stages. The proposed 1.2-1.5 m diameter steel pipelines would cover a distance of 590 km, and the pumping stations would raise the water through a head of 1 400 m. The estimated capital cost of the first stage of the project in 1982 prices was the equivalent of U.S. $1 billion. A similar amount is required for the final stages. Thus, the economic feasibility aspect of this project has been the main obstacle.

There has been wide speculation that Israel, after invading South Lebanon in 1982 and controlling the lower reaches of the Litani River, is contemplating its diversion in the headwaters of the Jordan River system. In that same year, Israel built a new road and a new bridge over the Litani, and fortified military camps in the region (Cooley, 1984). The speculations have only added to raising the level of unease over the water situation in the Middle East.

Another regional project is the proposed dam on the Yarmouk River, discussed previously. The Yarmouk, which forms part of the border between Jordan and Syria in the North, is the largest and most important underdeveloped surface water resource in Jordan. The proposed Al-Wehdah Dam would store winter floods for irrigation in the summer, regulate flow of the Yarmouk, and provide hydropower for Syria and Jordan. Without Al-Wehdah Dam, future water needs of the agricultural and municipal sectors in Jordan cannot be met.

More details on Middle East regional cooperation in terms of water resources can be found in Merhav (1990, Chapter 3). The projects mentioned in that report invariably place Israeli territory as the intermediate storage location for water to Jordan, e.g., diverting the Yarmouk waters to Lake Tiberias, then providing Jordan with its requirements, or diverting the Litani into Lake Tiberias, then providing Jordan with its requirements. However, to seriously entertain any such solutions, the concept of equity must necessarily be applied, so that benefits can accrue to all parties concerned roughly in the same proportions.

SUMMARY AND CONCLUSION

The ever increasing demand for water in Jordan is a direct result of population growth, and continued economic and industrial development. Coupled with the scarce water resources due to low rainfall, this has produced a water crisis involving frequent water shortages and water quality concerns. In 1990 and the summer of 1991, total water demand could not be met, and as such, forced cuts in water flows were practised by the water authorities to limit aquifer drawdown. While Jordan currently exceeds by 20% the safe yields of its supplies in most aquifers, the ultimate result will be lower supplies in the future due to quality degradation, increased salinity and contamination.

With all of the economic problems and constraints, there is a wide range of options available to Jordan. An array of planning options can be envisaged for the near, medium and long terms involving both demand and supply management in an integrated comprehensive planning approach. The most efficient options are those which address Jordan's regional economic and political role, its food security concerns, its future industrial production capability and processing technology, as well as others in a more comprehensive manner. The gains from improved comprehensive management are likely to be large.

Before such issues can be adequately addressed within the scope of a regional plan of action, however, the underlying instability in the region must give way to a new feeling of confidence in the future. According to a recent address by HRH Crown Prince Hassan of Jordan, "...democracy, security and prosperity provide the most solid foundation for a new stable Middle East." (March 23, 1991). Indeed, in the very short term, the alleviation of tensions could contribute enormously to the attainment of equitable, least cost solutions in Jordan's water sector. This in turn could enhance prospects for regional cooperation on a grand scale for the mutual benefit of all concerned.

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Water Resources Assessment for Egypt

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ABSTRACT

Egypt is unique within the region in that it is a desertic country that is almost totally dependant on the Nile river for its water resources. Irrigated agriculture accounts for the vast majority (84%) of all the water used. Although the Nile flows through nine African countries, only Sudan and Egypt have a joint agreement in the use of these waters. Signs of environmental degradation of the waters are increasing; salinity rates are rising and pesticides and fertilizers have reached high levels in recent years. Reuse of waste waters is increasing as attempts are made to use water more efficiently. Various structural and operational changes in water use are described, which are designed to enable Egypt to cope with water quantity and quality problems. Finally, the effects of present water policies and estimated future forecasts are given.

RÉSUMÉ

L'Égypte est un pays désertique qui dépend presque entièrement du Nil pour satisfaire à ses besoins en eau. La demande en eau d'irrigation de l'agriculture représente 84 % du total de la consommation. Bien que le Nil traverse neuf pays africains, seuls le Soudan et l'Égypte ont signé un accord régissant l'utilisation des eaux de ce fleuve. Or, il y a des signes inquiétants de dégradation de la qualité des eaux : le taux de salinité augmente, ainsi que celui des pesticides et des engrais. Des efforts ont été entrepris pour utiliser les ressources hydrologiques de façon plus efficace, entre autres par la réutilisation des eaux usées. L'article décrit divers changements structurels et opérationnels visant à permettre à l'Égypte de surmonter les problèmes tant de la quantité que de la qualité des ressources en eau. Des prédictions sont faites également en ce qui a trait aux conséquences des politiques actuelles ainsi qu'aux besoins à long terme.

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INTRODUCTION

Egypt covers an area of slightly over one million km^2 of the arid belt of North Africa and Western Asia. About 3.4% of this area is occupied by a population of 56 millions, of which 99% are concentrated along the coastal zones and in the Nile Valley where the population density is about 1 300 people per km^2.

The Nile Valley is composed of a floodplain about 18 km wide and bordered by flat terraces that are in many areas suitable for land reclamation, and the large Delta that is 150 km long and 220 km across at the coastline. The seven branches which, in the first century A.D., led the Nile waters across the Delta to the Sea, are now reduced to the two main Rosetta and Damietta branches, leaving large areas of prime quality arable land. In the Mediterranean coastal zone, rainfall declines from 200 mm in the east to 125 mm in the west and drops dramatically inland to only about 20 mm/year around Cairo, 200 km from the coast.

The Nile Delta with its associated Nile River valley is one of the World's oldest agricultural areas, having been under continuous cultivation for more than 5 000 years. Except for a few oases and some arable land in the Sinai, most of Egypt's 2.83 million cultivated hectares are confined to the River area. Historically, agriculture has been the dominant sector in the Egyptian economy, providing the bulk of employment and output crucial to foreign exchange earnings, and has received substantial budgetary support. More recently, growth of the Egyptian economy in the late 1950s and early 1960s was based upon expansion of the industrial sector. Agriculture's share of the Gross Domestic Product (GDP) fell from 34.3% in 1955 to 20% in 1990, while its share of employment fell from 56% to 10% over the same period. Nevertheless agriculture remains a key sector of the economy.

Egypt was self-sufficient agriculturally, and agricultural production grew at over 3% annually during the 1960s. In the 1970s and the early 1980s, the pace of growth declined to around 2%. Several factors contributed to the slow-down in agricultural growth. First, year-round irrigation without proper field drainage led to a rising water table; second, agricultural labor costs rose as alternative employment opportunities in urban areas and abroad rose dramatically; and third, a system of controls over production and marketing of cotton, rice, and other major crops had an adverse impact on incentives for farm production. Farms have become steadily smaller with an average area now of less than one hectare each.

The major challenge facing Egypt now is the absolute need to better develop and manage the very limited natural resources (water, land and energy) to meet the needs of a population growing at a rate of 2.5%. The population in Egypt was 36 million in 1960, 56 million in 1990, and is expected to go up to 70 million by the year 2000.

To meet demands of a more prosperous population of urban consumers, farmers were able to shift crops of their lands to vegetables, fruits or even flowers to increase income from their small plots of land. With a rapidly rising population, a dramatic increase in per capita consumption, a very limited agricultural land area, and the shift towards horticultural crops, Egypt has had to import a great share of its basic grain needs. The country is now importing two-thirds of its wheat and vegetable oil.

The government has responded to the slowdown in economic growth by initiating a reform program, the implementation of which has been in progress since

1986. Some progress has been made in adjusting the agricultural sector policy, an area of priority attention because of its potential to erase the foreign exchange burden and contain the mounting dependence on food imports. Further macro-economic reforms are presently the subject of dialogue between the World Bank within the context of a proposed Structural Adjustment loan. At the same time, there is a pressing need for complementary additional external resources to meet identified critical needs of the economy.

Egypt's agriculture sector is unique in that over 95% of its agricultural production is derived from irrigated land and its irrigation waters originate outside of its borders. The multi-year regulatory capacity provided by the High Aswan Dam (HAD) has given stability to Egypt's water resources by providing a reserve storage capacity during years in excess of requirements and providing supplemental resources during lean years. The recent African drought of 1976-87, while being devastating to many parts of Africa has had limited impacts on Egypt. The High Aswan Dam's water reserves were seriously reduced, but the high inflows during 1988 have restored reserves to approximately the 1983-84 level. As a result, Egypt is now focusing more effort on water management and forecasting to improve utilization of its water resources to meet future demands and to improve preparedness should a long drought threaten the availability of water resources in the future.

There are four broad categories of constraints impeding agricultural development in Egypt. These include policies, institutions and organizations, resources and technology. The several policies and controls over the agricultural sector have sent economically inefficient production signals to farmers and acted to seriously constrain the growth of Egyptian agriculture. These policies cause too much land to be put into low value crops such as wheat, barley, maize, and berseem (clover). Too little land is used for the production of crops such as cotton that would produce higher returns for the nation. Reflecting the prevalence of state intervention that once characterized Egyptian agriculture, there are a number of institutions with key and overlapping responsibilities. Many regulations restrict private sector competition and lower efficiency.

The amount of fertile arable land and quantity of irrigation water are key constraints to increased agricultural production in Egypt. Highly productive agriculture depends on a reliable stream of improved technology. Because of the relatively high levels of productivity already achieved in Egypt, the technological constraints on Egyptian agriculture are greater and more sophisticated than those operating on other countries' agriculture in the region. While much improved technology is already available, it is also likely that other technologies developed elsewhere and not yet evaluated in Egypt could be adapted to Egyptian conditions.

I. WATER RESOURCES

Egypt is a very arid country, where the average annual rainfall seldom exceeds 200 mm along the northern coast. The rainfall declines very rapidly from these coastal to inland areas, and becomes almost nil south of Cairo. This meagre rainfall occurs in the winter in the form of scattered showers, and cannot be depended upon for extensive agricultural production. Thus, reliable availability of irrigation water is a mandatory condition for agricultural development.

The main and almost exclusive source of surface water is the River Nile. The Nile Water Agreement of 1959 with the Sudan clearly defines the division of the River water travelling north from the Sudan to Egypt. Nearly 85% of the water to both countries originates from the Ethiopian Highlands. The 1959 Agreement was based on the average flow of the Nile during the 1900-1950 period. The average annual flow at Aswan (Egypt) during this period was 84 billion m^3. The average annual evaporation and other losses in the High Dam Lake were estimated at 10 billion m^3, leaving a net usable annual flow of 74 billion m^3. Under the 1959 Treaty, 55.5 billion m^3 were allocated to Egypt and 18.5 billion m^3 for the Sudan.

The High Aswan Dam was constructed in 1968 to assure the long term availability of water for both countries. Its lake has a live storage capacity of 130 billion m^3. Figure 1 shows the annual and short-term mean flows of the River Nile at Aswan as a percentage of the past 110 years average flow. It indicates that the average flows vary slightly if shorter durations are considered. The annual discharges from the High Dam Lake during the period 1968 to 1990 are shown in Figure 2. There is a potential for increasing the Nile flow at Aswan. The joint Egyptian-Sudanese Committee has outlined several development programs, the first of which is the construction of the Jonglei Canal. The project was expected to canalize the River channel in the Sudd region of the Sudan and thus reduce the substantial evapotranspiration losses (Figure 3). The construction of Phase I of the canal was started in 1978, but had to be abandoned in 1983 due to security problems in southern Sudan. Initially, this phase was expected to be completed around the mid 1980s, which would have provided an additional 4 billion m^3/yr of water at Aswan to be shared equally by the two countries. A total of 7 billion m^3/yr was expected to be shared by the two countries after the completion of Phase II of the Jonglei canal. Joint efforts are being taken to resume the construction of the canal (Phase I) where over 70% of the work was completed.

The discharges in the streams from Bahr El-Ghazal (another sub-basin of the Equatorial Plateau) are about 14.0 billion m^3 in a normal year, of which only 0.6 billion m^3 reaches the White Nile at Lake Noo, and the rest is lost in the swamps. Proposed schemes for conserving the water of Bahr El-Ghazal are expected to yield a saving of 9 billion m^3 annually at Malakal, or roughly 7 billion m^3/year at Aswan.

The total loss in the Machar swamps by evapotranspiration is about 10 billion m^3/yr. Conservation schemes in this sub-basin are expected to yield an average gain of 4.4 billion m^3/yr at the White Nile, or about 4.0 billion m^3/yr at Aswan, to be shared by Egypt and Sudan. The above estimates of water savings from the proposed conservation projects in the Upper Nile sub-basins adds to a minimum of 18 billion m^3/yr to be shared by the two countries. Finalization of such schemes depends only on agreements between the Nile basin countries and investment requirements (Figure 4).

Groundwater in Egypt can be divided into two categories. The first comprises the Nile Valley and Delta system. The total storage capacity of the Nile Valley aquifer system is about 200 billion m^3, with an average salinity of 800 ppm. Another 300 billion m^3 is the storage capacity of the Delta aquifer. The current annual rate of abstraction of groundwater from the Valley and Delta aquifers is 2.6 billion m^3. This could be increased since the potential annual extraction rate from the aquifer system is currently estimated at 4.9 billion m^3.

Figure 1

Annual and Short-Term Mean Flows of the River Nile at Aswan

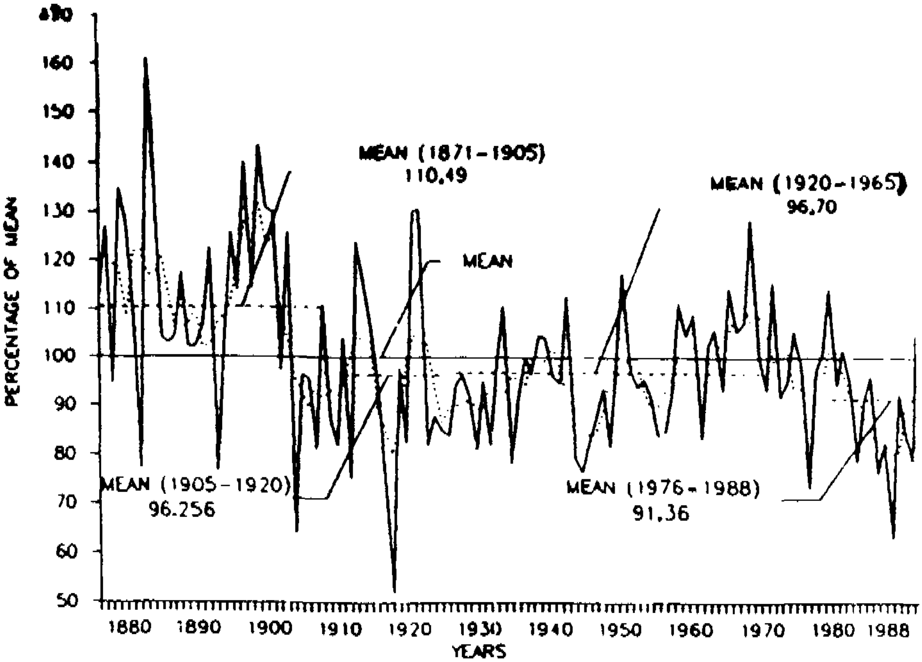


Figure 2

Annual Discharges from the High Dam Lake
(1968-1990)

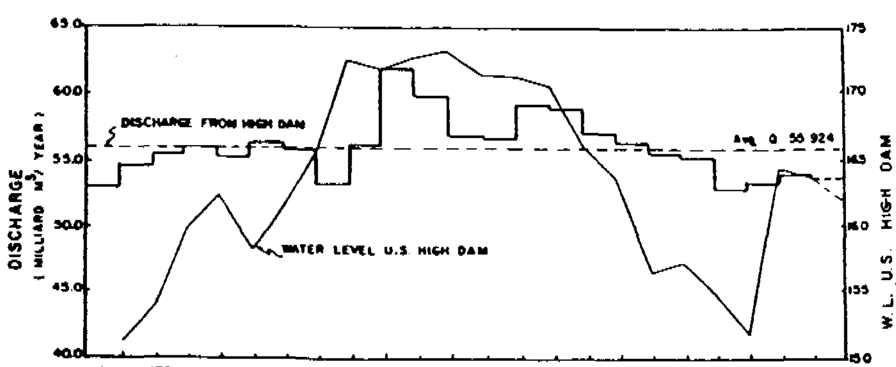


Figure 3

Schematic Diagram of the Nile Basin Yield Upstream of the High Aswan Dam

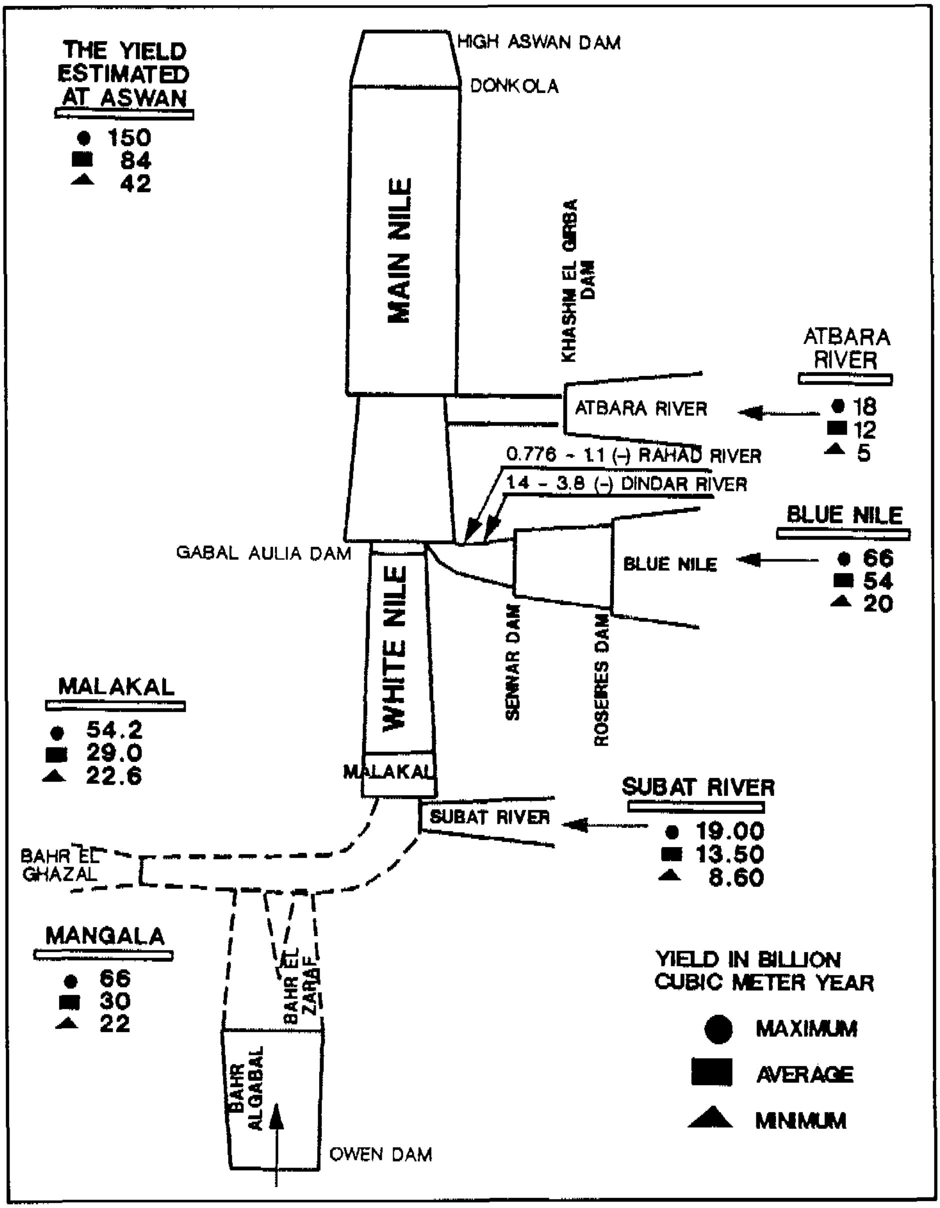
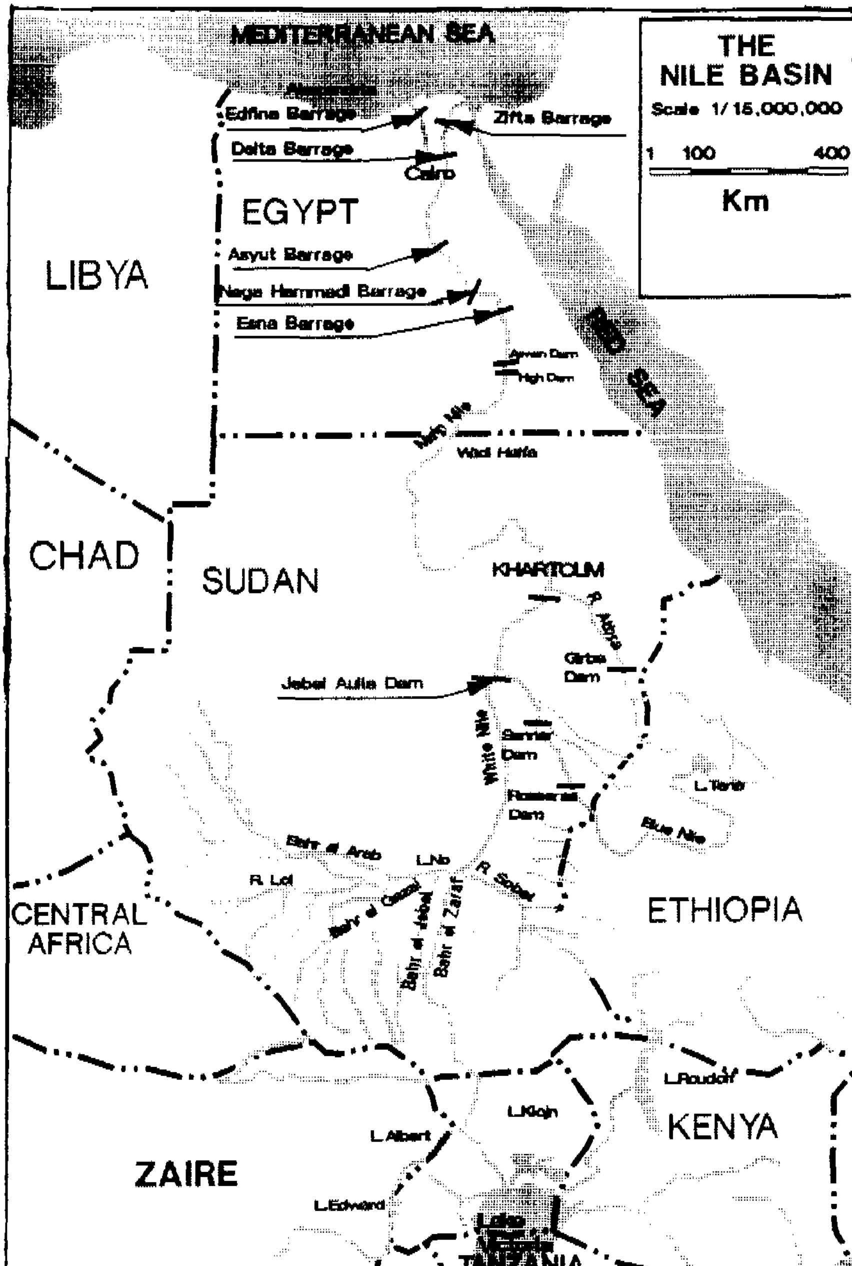


Figure 4

The Nile Basin



Groundwater exists in the Western Desert, generally at great depths. Most recent studies have indicated that this is not a renewable resource. Preliminary estimates indicated that the total groundwater storage in this area is of the order of 40 000 billion m^3, with salinity varying between 200 and 700 ppm. Use of this fossil water depends on the cost of pumping, depletion of storage, and potential economic return over a fixed time period. Investigations at New Valley indicate that annually about one billion m^3 of groundwater can be used at an economic rate. This will allow irrigation of 60 700 hectares, of which 17 400 hectares are already being irrigated. An additional 76 900 hectares can be irrigated at the East Owainat area (southern part of the Western Desert) by groundwater from the deep Nubian Sandstone aquifer. More studies are underway to investigate the groundwater potentialities within this regional aquifer. The work is carried out in co-operation with Sudan and Libya. Groundwater is available in Sinai in numerous aquifers of varying capacities and qualities, but in general it is believed that it is in very limited scale.

Shallow aquifers in the northern coastal areas are replenished by the seasonal rainfall. The thickness of the aquifer varies between 30 and 150 m and its salinity increases from 2000 ppm up to 9000 ppm near the Coast. In the north and central parts of Sinai, groundwater aquifers are formed, due to recharge by the rain storms falling, and collected in the valleys. Deep aquifers with non-renewable water exist in Sinai where wells are drilled to a depth of 1000 m to supply water for domestic use.

The El-Arish-Rafaa Coastal area aquifer in north Sinai has always been of importance. The present extraction rate from the Quaternary aquifer at El-Arish area is estimated at 52 000 m^3/day. The extraction from El-Sheikh Zuwayiad and Rafaa is estimated now at 43 000 m^3/day. Currently, this area is facing a state of quality deterioration in space and time. The system is being exploited, and it needs to be safely managed.

The groundwater investigations in South Sinai included several shallow and deep reservoirs which have a promising potential for development but again of limited scale.

II. WATER USE IN EGYPT

The total annual water use in Egypt was estimated at 59.2 billion m^3, of which agricultural use accounted for 84%. Industrial, municipal and navigational use accounted for 8%, 5%, and 3% respectively. Current estimates indicated that the total water use will increase to 69.4 billion m^3 by the year 2000. The percentage of water used by the agricultural and municipal sectors will remain almost similar to 1990, but the share of industry will increase by 50%, and navigational use will decline very substantially.

1. *Agricultural Water Use*

While, in percentage terms, the amount of water used for agriculture has declined slowly during the past decade, currently (1990) agriculture accounts for the largest share of water use at 84% or 49.7 billion m^3 per year. This amount does not include an annual estimated loss of 2 billion m^3 due to evaporation from the irrigation system. Annual evapotranspiration losses are estimated at 34.8 billion m^3.

Surface irrigation systems are used in most cultivated lands of the Nile Valley and Delta. The efficiency of these systems is considered low. Excess irrigation water applications contribute to salinity and high water table problems. The government has launched a national program for irrigation improvement and water management. It should be noted, however, that excess irrigation water contributes to groundwater, a good part of which is partially re-used through recycling. This recycling brings up the overall water use efficiency to a reasonable value. The measured drainage water out of the system amounted to about 12 billion m^3 during 1989.

For the new land, modern irrigation systems are used. The government does not give any water permits for new lands unless new irrigation systems (drip or sprinkler) are used.

2. *Domestic Water Use*

The annual domestic water use for 1990 was estimated at 3.1 billion m^3. It is estimated that the present level of distribution losses is 50%. It is assumed that the domestic water use could be held at 3.1 billion m^3 by the year 2000 by reducing losses from 50% to 20%.

3. *Industrial Water Use*

The 1990 estimate is based on the extrapolation of the 1980 survey carried out for the Water Master Plan. It is estimated at 4.6 billion m^3 for 1990.

4. *Navigational Water Use*

From February to September, water released for irrigation is sufficient to maintain water levels in the River Nile for navigation. Irrigation demands, however, are not enough during October to January to maintain appropriate navigational level in the River. This period also is the peak tourist season, where numerous tourist boats make regular trips between Aswan and Luxor. At present, some 1.8 billion m^3 of water have to be released during this period to maintain navigational levels. Currently the Esna Barrage is being re-built, which would provide better control of the Nile water level. It is expected that by the year 2000, annual navigational water requirements could be reduced to only 0.3 billion m^3 by better control of the water level and implementation of storage in the northern lakes.

5. *Reuse of Treated Wastewater*

Wastewater has been reused indirectly in Egypt for centuries, but the first formal use of wastewater was initiated in 1915 in the eastern desert area of Jabal Al-Asfar north east of Cairo. After primary treatment, wastewater was used for desert agriculture, which has allowed an area of 1 000 hectares to be cultivated. Since water is the major constraint to the further expansion of agricultural areas, treated wastewater must be considered to be a new source of additional irrigation water. As new wastewater treatment plants come on stream in Cairo and other urban centers, amounts of treated wastewater that could be available for agricultural activities would increase steadily during the next three decades. It has been estimated that the total annual amount of wastewater that would be available from Greater Cairo, would increase from 0.9 billion m^3 in 1990 to 1.7 billion m^3 in 2000 and 1.93 billion m^3 by 2010.

Currently, in Egypt, detailed experience on wastewater reuse has been somewhat limited. From a policy viewpoint, urgent steps should be taken to establish some major pilot projects on the use of treated wastewater for agricultural production. Such pilot projects would also convince the general population that such practices, as long as they are properly carried out, impose no risk to human and animal health. Proper sewage treatment, in addition to providing treated wastewater, could make another major contribution to agriculture. Dried sludge can be effectively used as a soil conditioner for agricultural land. During 1988-89, some 46 000 m^3 of dried sludge were produced and sold to the farmers and other organizations at Jabal A-Asfar and Abu-Rawash. It is estimated that at full development of the Greater Cairo wastewater project in the year 2010, 3410 t/d of dry solids would be produced in Cairo. A conservative estimate of the total annual market demand for sludge is 779 000 m^3.

6. *Reuse of Agricultural Drainage Water*

Agricultural drainage water in Upper Egypt is discharged back into the River Nile. This slightly affects the quality of the Nile water as its salinity increases from 250 ppm at Aswan to 350 ppm at Cairo. The drainage water in the Nile Delta is of lower quality, and accordingly, it is collected through an extensive drainage network for disposal to the Mediterranean Sea.

The total amount of drainage water discharged to the Sea depends on many factors: amount of water released at Aswan, cropping patterns, and irrigation efficiency. The total amount of drainage water discharged annually has varied from 14 billion m^3 in 1984 to 12 billion m^3 in 1989 (Table 1, Figure 5). The salinity of this water ranges between 1000 and 7000 ppm; about 25% (1984) to 70% (1988) of this water had salinity of less than 3000 ppm (Figure 6). The effect of reducing the quantity of water released from the HAD on the quantity and quality of drainage water is indicated in Table 1. The Ministry of Public Works and Water Resources is imposing strict policies for the releases of the Nile water downstream of the HAD. Further decrease in drainage water quantity and increase of its salinity will occur when the irrigation efficiency is improved both in the conveying system and at the farm level.

Surveys and monitoring of the quality and quantity of the agricultural drainage water in the Nile Delta have shown that it is possible to reuse part of this water in irrigation. When the salinity is low, the water is used directly, and when it is high, it is mixed with fresh canal water. Neither water of high salinity nor water contaminated by municipal and industrial wastes can be used in irrigation. Under any circumstances a substantial portion of drainage water must be discharged to the sea to maintain the salt balance in the Nile Delta.

The amount of drainage water presently reused in irrigation is 4.7 billion m^3 annually, of which 2.6 billion m^3 is re-used in the Nile Delta (Figure 7), 0.95

Figure 5

Annual Drainage Water Flow to the Sea

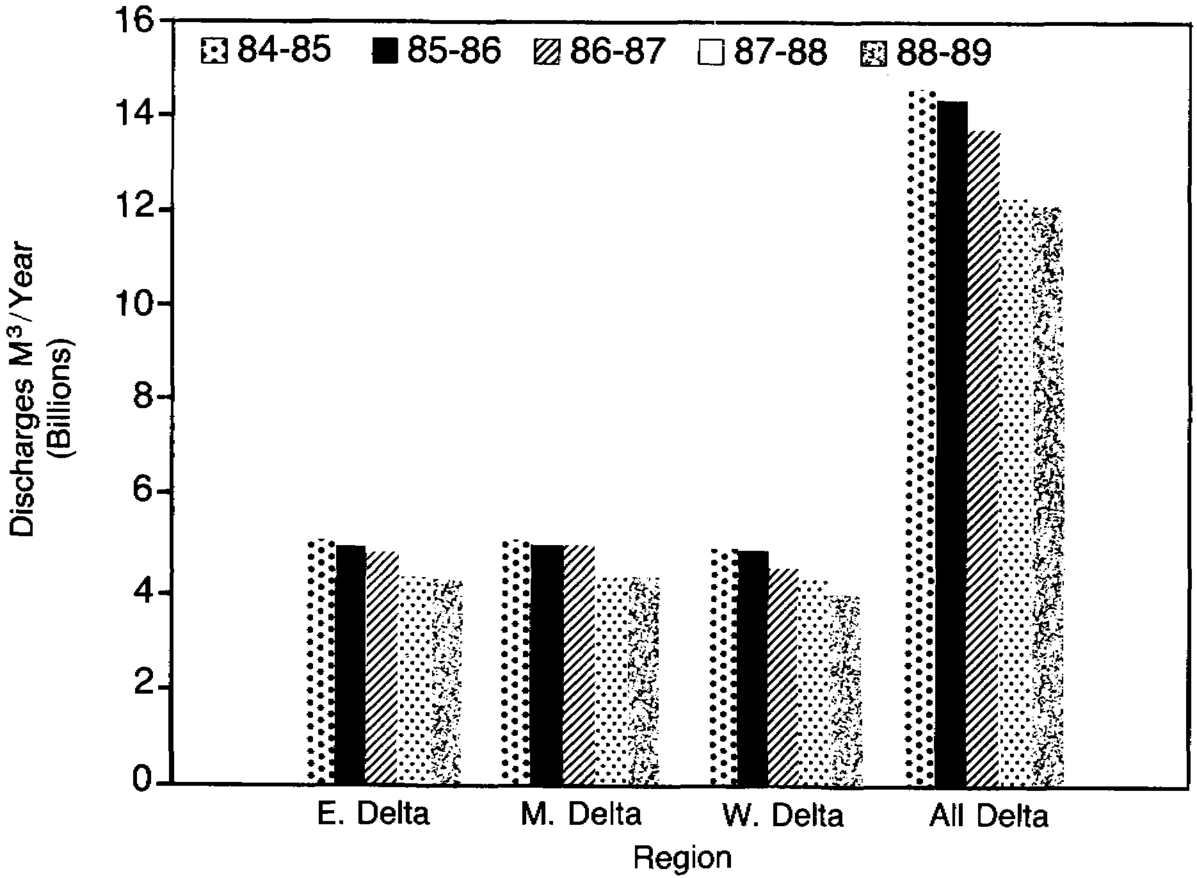


Figure 6

Salinity of Drainage Water to the Sea

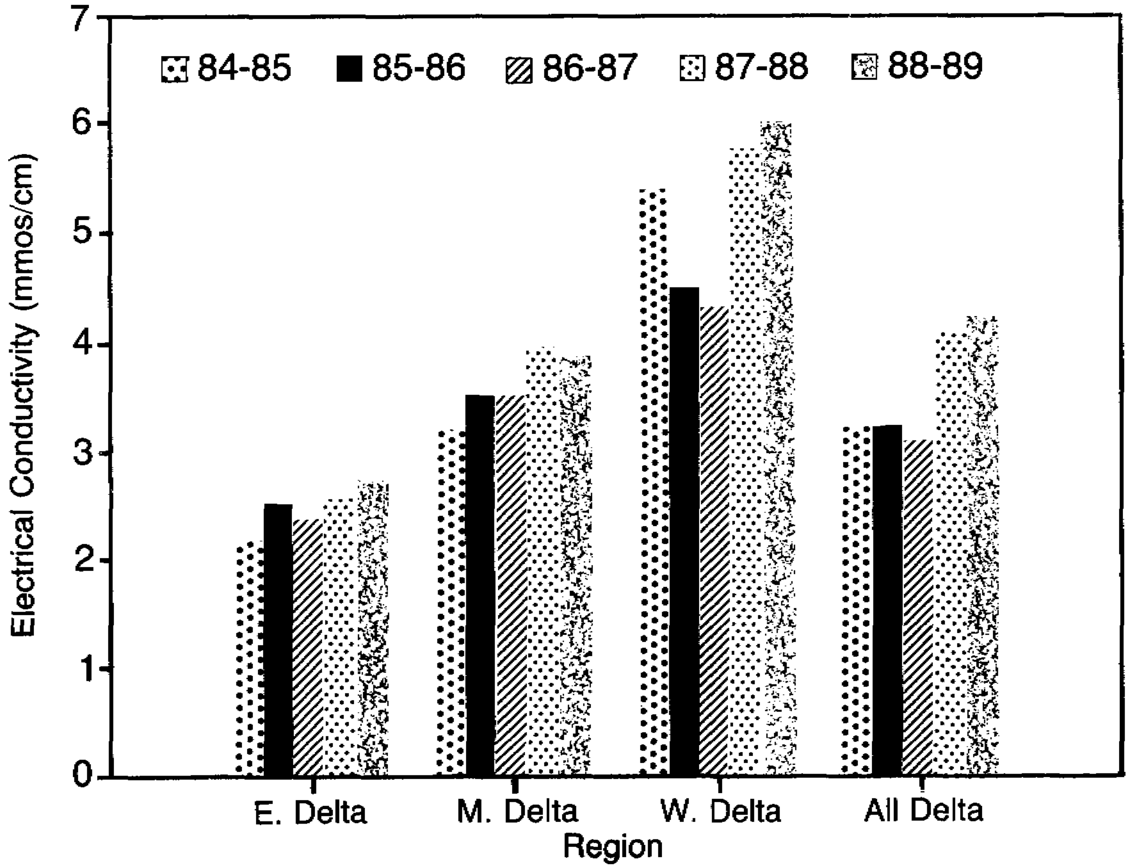


Table 1

Nile River Flow Downstream of the High Aswan Dam (HAD) and the Drainage Water Flowing to the Sea

Year	River Nile Flow Below HAD (billion m^3)	Drainage Water	
		Quantity (billion m^3)	Salinity mmhos/cm
1984-85	56.40	14.30	3.71
1985-86	55.52	14.07	3.72
1986-87	55.19	13.59	3.59
1987-88	52.86	12.27	4.12
1988-89	53.24	12.03	4.26

billion m^3 in Fayoum, and 1.15 billion m^3 is returned to the Nile in Upper Egypt The amount reused is expected to reach 7.0 billion m^3 by the year 2000. The salinity of the water reused in the Delta is shown in (Figure 8).

It should be noted that the potential savings from improved water management (e.g. more efficient operation of the system to reduce outflows to the Sea as practiced in 1987-88 and 1988-89) and increasing drainage water reuse are not mutually exclusive. There is a real danger that the salinity could increase steadily over the years. Thus, a cautious approach to increasing the use of drainage water, especially in terms of water quality, is likely to be the long-term interest of the country.

III. WATER QUALITY AND ENVIRONMENTAL ASPECTS

Environmental issues in Egypt, as in most other developing countries, have received limited attention in the past. However, with increasing human activities, protection of land and water resources of the country is becoming a priority consideration.

A reasonably clear and detailed picture of environmental issues confronting the land and water sectors did not exist. Nor are there any accurate estimates on the cost of land and water degradation to the national economy. The cost is already significant at present, and if no drastic actions are taken, the existing trends show that it is likely to become even higher during the 1990s.

Water pollution already is a serious problem in certain parts of Egypt. While a reasonably clear picture exists in terms of salinity of water, availability of usable information on other water quality parameters is very limited. Time series data on various water quality parameters are basically non-existent. Some data are available for a few parameters, but their potential use for water quality management is extremely limited since they are collected at long intervals, often in a random time sequence, and only at a few selected places. There is no question that a rational water quality data collection and management programme has yet to be implemented.

Some have claimed that a large percentage of wastewater is untreated, and this is discharged into the Nile, irrigation canals and drainage ditches. While one can question the actual percentage figure, there is no question that a very high proportion

Figure 7

Quantity of Reused Drainage Water in the Delta Area

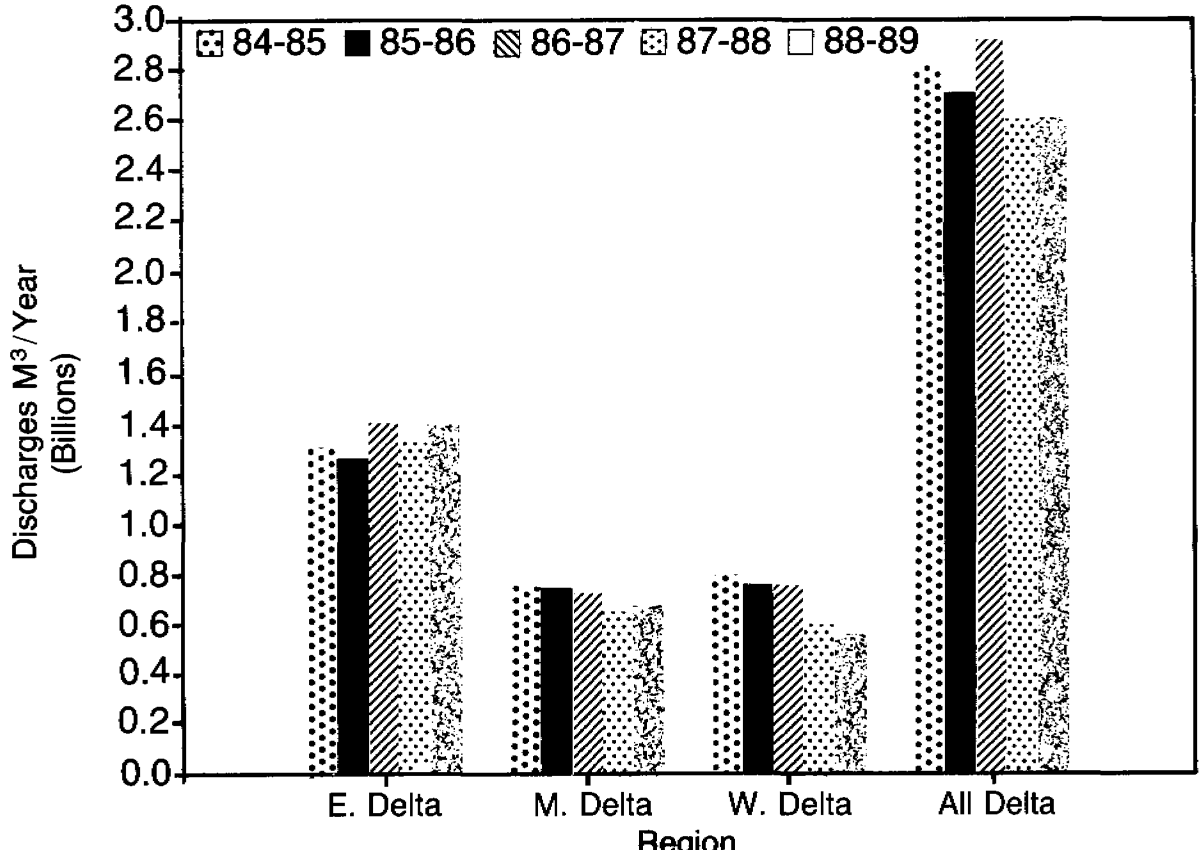
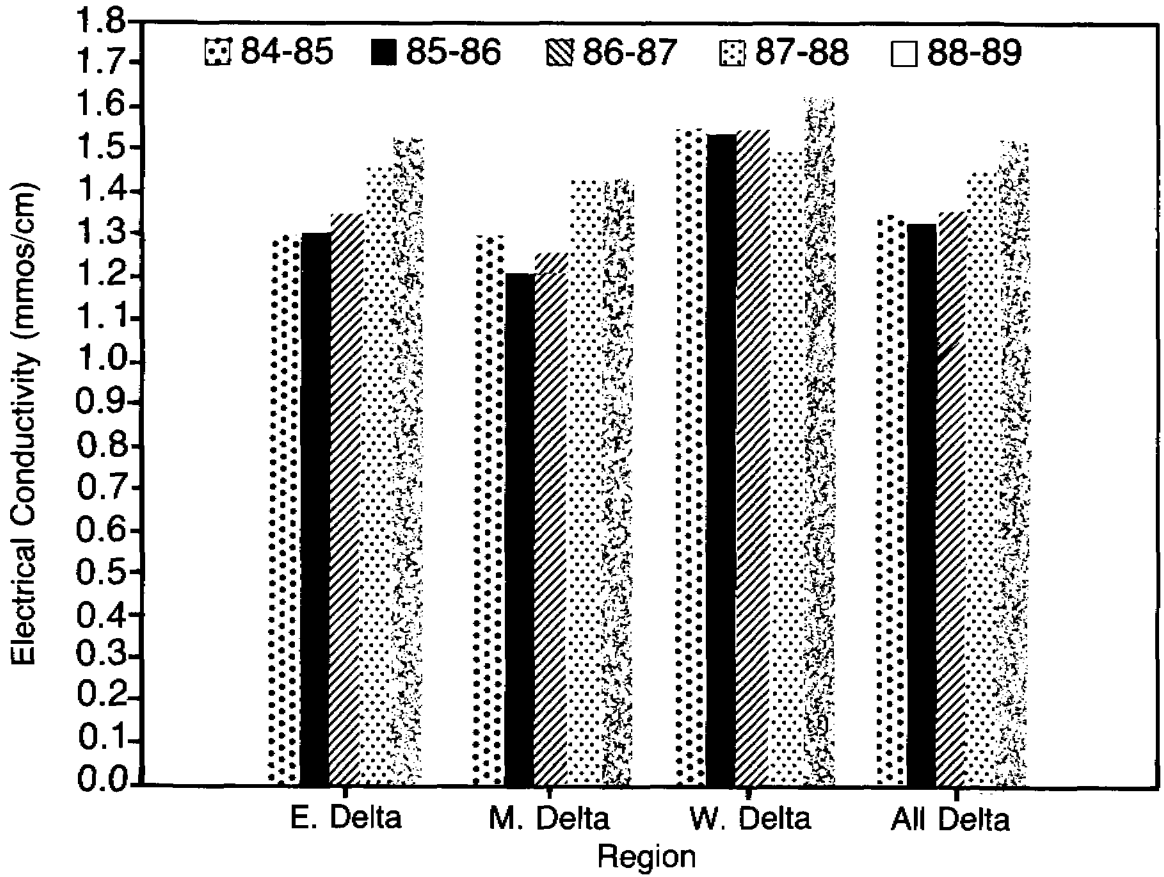


Figure 8

Salinity of Reused Drainage Water in the Delta Area



of domestic and industrial effluents are untreated at present. One study of 66 agricultural drains estimated that they carried an annual discharge of 3.2 billion m^3, which included raw sewage from 5 000 rural agglomerations, and semi-treated or untreated wastewater from Cairo and other urban centers, and mostly raw sewage from the rapidly growing unserviced peri-urban areas (World Bank, 1990).

In addition, significant proportions of fertilizers and pesticides leach into the water system. Potential groundwater contamination from fertilizers could be a concern since groundwater is used extensively for drinking purposes, and it is more vulnerable than surface water in terms of fertilizer contamination. Table 2 shows that the application of nitrogen, phosphate and potash fertilizers in Egyptian agriculture increased nearly fourfold during the 1960-1988 period. Nitrate contamination of groundwater from agricultural activities has been a major environmental concern in many developed countries. It is now increasingly becoming a subject of some concern in a few developing countries, especially in those areas where extensive irrigated agriculture is practiced.

Table 2

Use of Different Types of Fertilizer in Egypt, 1960-61 to 1987-88 (based on data from Ministry of Agriculture)

Crop Year	Nitrogen		Phosphate		Potash	
	Actual (1000 tons)	Index (1960-61 = 100)	Actual (1000 tons)	Index (1960-61 = 100)	Actual (1000 tons)	Index (1960-61 = 100)
1960-61	192	100	48	100	2.0	100
1965-66	314	164	43	90	0.7	35
1970-71	325	169	46	96	1.6	80
1975-76	428	22	66	138	2.8	140
1980-81	568	296	104	218	2.9	145
1981-82	626	326	134	279	3.6	180
1982-83	660	343	143	296	3.0	150
1983-84	746	389	160	333	5.5	275
1984-85	639	333	164	342	7.5	375
1985-86	775	404	183	382	7.6	380
1986-87	777	405	185	386	n.a	n.a
1987-88	791	412	190	396	n.a	n.a

Use of pesticides, which are mostly imported, has increased as well (Table 3) but not at the same rate as fertilizers. Depending on specific years, 48 to 88% of the imported pesticides were used for cotton.

In early 1991, use of herbicides to control aquatic weeds became an important media and political concern. Acrolein was used in canals to control submerged weeds, and ametryn to control water hyacinths in drains. Aquatic weeds are a major concern for efficient water management. In 1990, 13 000 km of canals and drains were estimated to have been infested by submerged aquatic weeds, and another 1 900 km were covered by water hyacinths. Because of the political and public concern, use of ametryn has now been canceled for 1991. Also, acrolein will be used only for another two to three years, after which only manual, mechanical and biological means will be used for weed control.

Table 3

Import of Pesticides in Egypt, 1971-72 to 1988-89
(based on data from Ministry of Agriculture)

Crop Year	Pesticides (1000 tons)	Imported Value (L.E.million)
1971/72	18.2	10.90
1980/81	22.50	61.60
1981/82	31.40	56.70
1982/83	32.30	37.90
1983/84	34.30	53.10
1984/85	32.60	54.10
1985/86	24.50	53.50
1986/87	14.80	54.90
1987/88	9.30	55.00
1988/89	9.60	55.00

Extensive use of manual control would likely increase the incidence of bilharzia among the laborers used for weed removal. Expansion of mechanical control would require additional investments in terms of imported equipment and spare parts, as well as for constructing roads on the canal and drain banks. For economic, environmental and water use efficiency considerations, the best solution would probably be to use integrated means for controlling aquatic weeds, including rational use of herbicides.

Increasing water pollution from industrial and domestic sources, if allowed to grow unchecked, is likely to reduce the amount of water available for various uses in the future. This clearly is not in the long-term interest of the country. In addition, the total economic and health costs to the country due to unchecked water pollution would be substantial. For example, the Second Pumping Station Rehabilitation Loan report of the World Bank concluded that excessive pollution of drainage waters around Alexandria reduced the lifespan of irrigation pumps from 20 years to only four, and required more sophisticated pumps and piping at higher costs. The irrigation system is currently kept functional by some 675 pumping stations, which clearly cannot be allowed to deteriorate due to water pollution.

A legal basis for controlling water pollution already exists through Law 48 of 1982 on the "Protection of the River Nile and Waterways from Pollution." The law establishes stringent effluent standards for various organic and inorganic pollutants. Unfortunately, the water quality standards stipulated were too strict and rigid with no flexibility, exceptions or possible recourse. Reconsideration should be given to adopt these regulations. No appreciable consideration was given to adopting these regulations to the country's economic, social, and technological conditions or in terms of implementation and institutional arrangements, availability of adequate funds, trained manpower and sophisticated laboratories for analyses, monitoring, inspection and enforcement requirements. Shortly after the law was promulgated, the government of Egypt was forced to grant dispensations to polluters, many of whom were public-sector companies, since it was not possible for them to comply with the regulations. It is clearly accepted now that the law has to be amended.

Salinity and waterlogging from irrigation practices has been a problem. However, Egypt has embarked on the construction of an extensive drainage system, a significant part of which is already operational. For the long-term sustainability of agriculture, drainage should continue to receive priority.

In terms of environmental health, much has been written on the adverse impact of the expansion of irrigated areas due to the construction of the High Aswan Dam because of increasing incidence of schistosomiasis. Unfortunately, nearly all of these reports were based on spurious data, which justified the biases of the writers. On the basis of data collected over the past two decades, it can now be said that the situation was overtly dramatized by some people. A detailed and independent evaluation carried out in 1985 indicated that in many parts of Middle and Upper Egypt, schistosomiasis is no longer a serious public health problem. Between 1977 and 1984, prevalence rates were reduced from 30 to 8%, and serious disease, indicated by high worm burden, became rare.

A. Egypt's Present Water Policy

Preparation for water policies for Egypt dates back to 1933 when a policy was set up to make use of the additional storage capacity due to the second heightening of the old Aswan Dam and the construction of Gabal El-Awlia Dam in the Sudan. It included at that time programs for horizontal land expansion, conversion of some basin irrigation to perennial irrigation in Upper Egypt and an increase of areas under rice cultivation to 384 600 hectares. In 1974, the water balance was reviewed and the water policy was updated. After the construction of the High Aswan Dam, a new detailed water policy was drafted in 1975 including Egypt's water resources at that time and expected resources in the future, that is surface and groundwater resources, reuse programs, and suggested development actions.

During the past ten years, several events took place that have direct impact on water planning in Egypt. Accordingly, the water policy was updated again in 1988. Among the most important events are the following:

1. The drought that took place during the period 1979-1988 when the average annual River Nile flow was reduced to 48.6 billion m^3. In 1985, the MPWWR started a management program where the releases from the HAD dropped to 54.0 billion m^3 during the year 1990. The live storage in the HAD reservoir dropped to its minimum of 6.84 billion m^3 during the month of July 1988 where the upstream water level of the reservoir reached 150.62 m.
2. The construction works on the Jonglei Canal was stopped in 1983 and the expected water share of Egypt (2.0 billion m^3) in 1985 was delayed.
3. The country decided to start a land reclamation program of 60 700 hectares annually, an area that requires about one million m^3 of additional water resources annually.

To accommodate such events, the MPWWR has made several decisions, the most important of which are the following:

— no additional releases are allowed from HAD for power generation (31.6 billion m^3 were released annually from the HAD reservoir during the period 1976/78 to 1983/84 for power generation only);
— construction of the New Esna Barrage to prevent any releases of excess water for reducing excessive head on the old barrage due to drop of downstream bed levels. Until the completion of the new barrage which started in late 1990, temporary upstream pumping stations were constructed;
— elongation and selection of different winter closure periods for upper and lower Egypt and restricting the releases from the HAD reservoir during that period to 70 million m^3/day instead of values up 140 million m^3/day;
— launching of the National Irrigation Improvement Program;
— minimizing releases of the fresh water to the Sea through the Rosetta branch (1.8 billion m^3 in 1990).

Following these actions, the water policy up to year 2000 was updated in June 1990 and has the following highlights:

1. The surface water resources are limited to Egypt's share in the flow of the River Nile according to the 1959 Nile Agreement with the Sudan. It is expected that by the year 2000, the first phase of Jonglei Canal will be completed and Egypt will get its additional 2.0 billion m^3.
2. Present annual outflows of drainage water into the Sea and terminal lakes are estimated at 12 billion m^3 for the year 1990. This amount cannot be reused in full because of several constraints. Among those constraints are the high level of pollution in some drains and the need to drain a certain volume to the Sea to maintain the salt balance of the Delta. There is a potential to increase present reused values from 4.7 to 7.0 billion m^3 annually by the year 2000.
3. The present rate of extraction of groundwater from the deep aquifers in the eastern deserts can be increased from the present level of 0.5 billion m^3 annually to 2.5 billion m^3 annually by the year 2000. Extraction from the Delta and Valley aquifers will be increased from 2.6 to 4.9 billion m^3 by the year 2000.
4. Fresh water releases to the Sea for navigation during closure period will drop from 1.8 billion m^3 (1990) to 0.3 billion m^3 by the year 2000. The balance will be stored in Lake Burollus for future use.
5. Through water management and improvement of the irrigation systems, one billion m^3 could be saved annually by the year 2000.
6. The area expected to be reclaimed by the year 2000, based on available water resources, is 0.65 million hectares.

Table 4 summarizes the available and expected future water resources for Egypt for the years 1990 and 2000. Table 5 gives the present and future water demands. Figures 9 and 10 give a schematic representation of the water availaibility and use in 1990 and 2000 respectively.

It is worth mentioning that the Nile system below Aswan can be regarded as a basin with a single input from the High Aswan dam and with five outputs, except for the negligible groundwater flow in the Nubian sandstone deep aquifer. These outputs are:

— drainage to the Sea;
— non-consumptive use for inland navigation and regulations during closure period;
— evapo-transpiration;
— non-recoverable municipal and industrial consumption;
— evaporation.

Table 4

Present and Future Water Resources

Source	Quantity in billion m³ per year (1990)	(2000)
River Nile water	55.5	57.5*
Groundwater (Nile valley & delta)	2.6	4.9
Agricultural drainage water	4.7	7.0
Treated municipal sewage water	0.2	1.1
Water management conservation programs	—	1.0
Deep ground water (deserts)	0.5	2.5
Total	63.5	74.0

* After completion of the first stage of the Jonglei project.

Table 5

Present and Future Water Demands

Use	Quantity in billion m³ per year (1990)	(2000)
Irrigation	49.7	59.9*
Municipal Uses	3.1	3.1**
Industrial	4.6	6.1
Navigation & Regulation	1.8	0.3
Total	59.2	69.4

* Includes the irrigation requirements for an additional 0.65 million hectares to be reclaimed by the year 2000.
** Additional requirements for the year 2000 will be secured through reducing system losses from a present value of 50% to 20%.

Groundwater is also an integrated part of the system and should be looked at as a reservoir with negligible losses. When it fills, its higher water table provides for sub-irrigation of crops, pumping, or it spills into the drainage system and becomes available for downstream use.

Figure 9

Water Availability and Use in Egypt in 1990
(Billion m³/year)

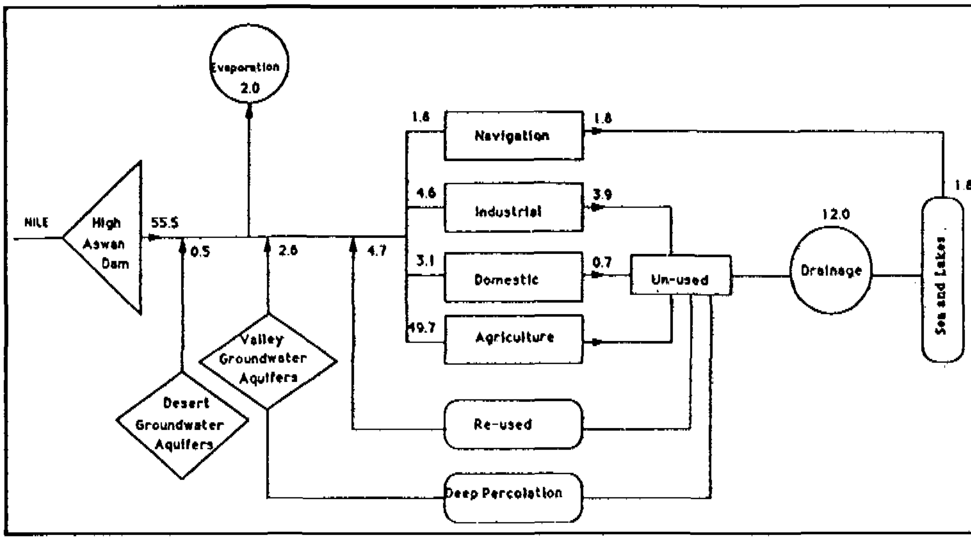
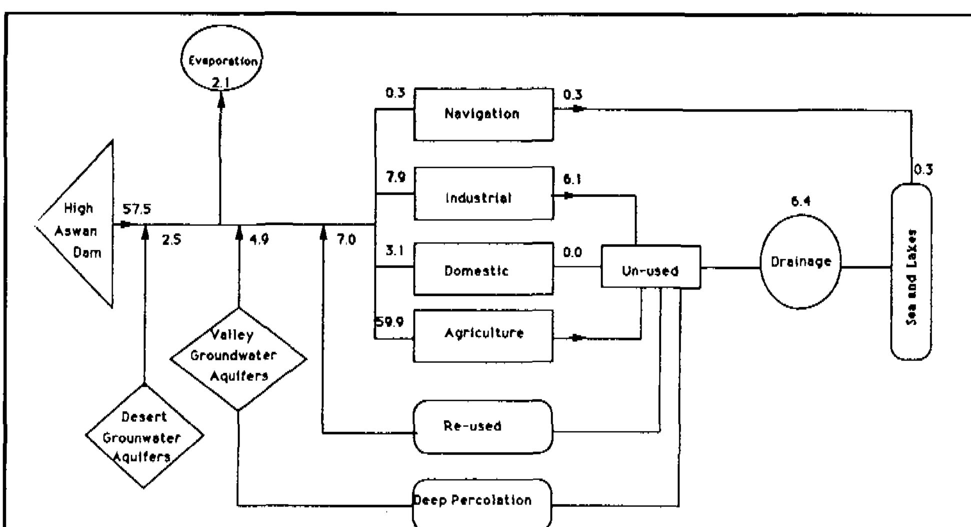


Figure 10

Water Availability and Use in Egypt in the Year 2000
(Billion m³/year)



These concepts make the interrelation of the different elements of the system very complicated. The exact contribution of each element is still not clear, nor is the impact of changes that will take place due to management programs and/or recycling activities.

The values of both supply and demand presented in Tables 4 and 5 show that Egypt has a spare capacity in the present system which will satisfy the demands up to the year 2000. Hence, water will not be a constraint to the anticipated land reclamation plan. However, it should be emphasized that the supply side is given under the assumptions that all the anticipated development projects will be completed as scheduled.

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Planification des ressources en eau au Maroc

DRISS MRIOUAH*

RÉSUMÉ

Situé à l'extrême nord-ouest du continent africain, le Maroc, dont la superficie est de 710 850 km², est caractérisé par un climat très varié allant du subhumide au nord, à aride au sud. De même, les ressources en eau sont caractérisées par une forte variabilité spatio-temporelle. Cette variabilité a nécessité, depuis longtemps, le recours à des techniques ingénieuses de mobilisation et d'utilisation des ressources en eau. Avec le développement socio-économique qu'a connu le pays, des techniques modernes sont actuellement utilisées aux côtés des techniques traditionnelles. De grands barrages de mobilisation et des canaux de transfert d'eau ont été construits permettant l'irrigation de grande envergure et l'approvisionnement en eau potable de la population du pays, évaluée actuellement à 25 millions d'habitants.

ABSTRACT

Situated at the extreme north-west of the African continent, Morocco, with an area of 710 850 km² has a variable climate ranging from sub-humid in the north to arid in the south. There are large variations, in time and space, in the available water resources. This variability has necessitated, since ancient times, ingenious techniques to extract and distribute the limited water resources. With the socio-economic development that the country has known, modern techniques are now used alongside traditional methods. Large storage dams and canals have been built, making possible large scale irrigation and water supply for the country's population, now estimated at 25 million inhabitants.

INTRODUCTION

Dans les régions telles que le Maroc à caractère aride et semi-aride, l'eau est un élément stratégique dont la disponibilité et la maîtrise de l'utilisation sont indispensables. Dans de nombreuses régions du monde, des exemples éloquents

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montrent qu'une bonne maîtrise de la gestion des ressources hydriques pouvait conduire à un essor remarquable de l'agriculture et constituer ainsi une courroie de transmission tant pour le développement économique que pour l'amélioration des conditions de vie des populations concernées.

Au Maroc, la rareté des ressources en eau a généralement déterminé une assez forte adaptation « spontanée » des structures socio-économiques d'utilisation de l'eau à composante agricole dominante, aux structures physiques des systèmes de ressource. Toutefois, l'évolution future tendancielle (urbanisation) ou volontariste (intensification de l'agriculture, industrialisation) des demandes en eau, entraîne une disjonction des champs d'utilisation traditionnelle des systèmes de ressources, nécessitant la mise en place des projets de transfert d'eau.

Partant de ces considérations, la planification et la gestion rigoureuse d'une ressource de plus en plus rare s'avèrent nécessaires pour asseoir une politique globale de mise en valeur des ressources en eau, dont l'objectif est le développement des ressources en eau au profit de la collectivité.

I. SITUATION GÉOGRAPHIQUE

Situé entre les 21^{e} et 36^{e} degrés de latitude Nord et les 1er et 17^{e} degrés de longitude Ouest à l'extrême nord-ouest du continent africain, le Maroc s'étend sur une superficie de 710 850 km^2. Projeté entre la Méditerranée et l'Atlantique, séparé de l'Europe par un détroit de 14 km, profondément enraciné au sud dans le continent africain, le Maroc appartient à la fois au monde méditerranéen, au monde océanique et au monde saharien.

Le Maroc se distingue à la fois par l'altitude élevée de ses montagnes et par la remarquable extension de ses plaines et plateaux. Le Haut Atlas occidental compte plusieurs sommets dépassant 4 000 mètres. Au nord, la chaîne du Rif, relativement peu élevée, est cependant une chaîne compliquée et contribue à l'isolement du littoral méditerranéen.

Le contact atlantique est sans doute l'élément le plus marquant. Le littoral est bordé de plaines basses où de plateaux peu élevés ne s'opposant à aucune pénétration des influences maritimes. Les vents humides se propagent facilement jusqu'au contact avec les chaînes montagneuses de l'Atlas permettant ainsi l'exploitation, loin dans l'intérieur, de vastes plaines fertiles.

Le climat qui règne dans le pays est extrêmement varié. Il est subhumide sur les régions côtières du Nord, semi-aride à sec sur les régions du Nord-Ouest et du Centre, et aride sur les régions rifaines-orientales et sud-atlasiques.

Devant cette diversité du climat, il est naturel que la pluviométrie soit très variable d'une région à une autre (carte n° 1).

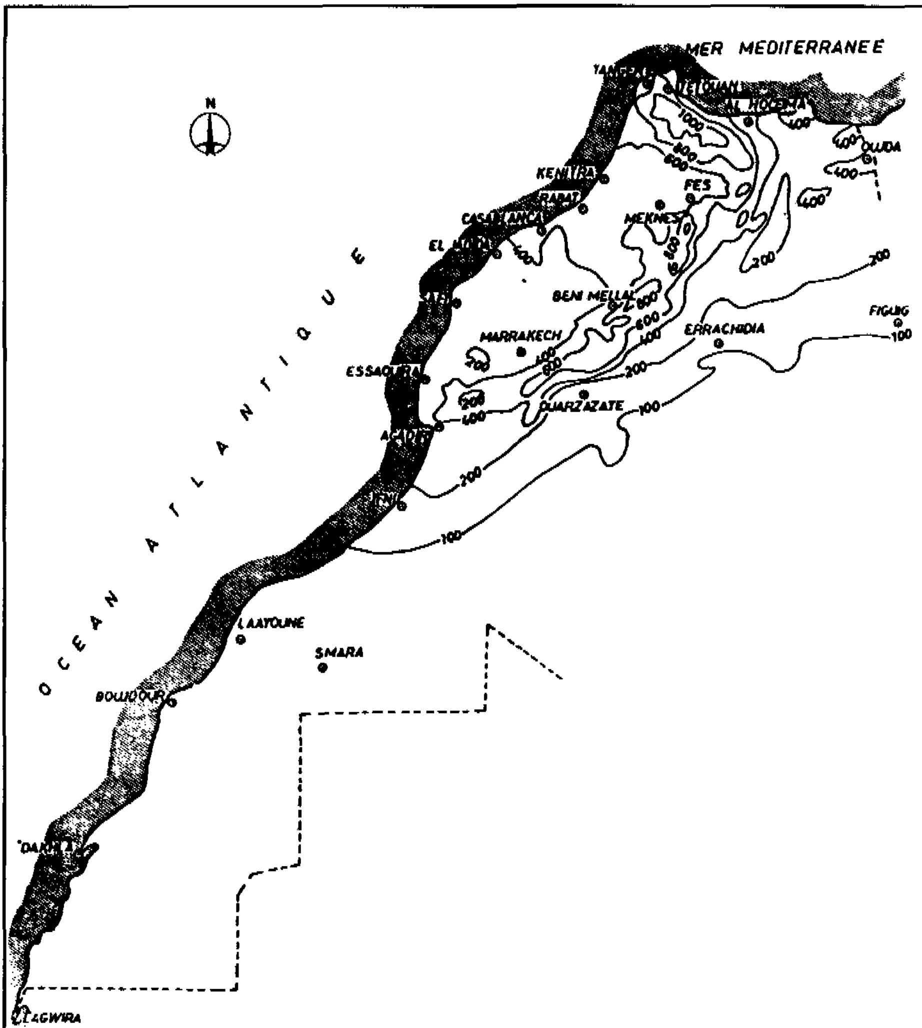
II. PLANIFICATION ET UTILISATION DE L'EAU AU MAROC

A. Ressources en eau

Bien que marqué par l'aridité de son climat, le Maroc dispose de richesses hydriques considérables jouant un rôle déterminant dans l'économie du pays. Cependant des contraintes naturelles importantes entravent la mise en valeur de ces ressources en eau :

Carte 1

Précipitations moyennes annuelles (mm)



— L'aridité du climat a pour conséquence des variations annuelles et interannuelles qui conditionnent l'*alimentation* naturelle des nappes souterraines et des cours d'eau. En particulier, les séquences d'années sèches plus ou moins longues sont fréquentes et font de ce phénomène une donnée de base de la problématique de l'eau au Maroc.

— La variabilité spatiale du climat se traduit par une disparité marquée de la disponibilité en eau entre les différentes régions. Ainsi la zone atlantique, limitée au nord par le Rif et à l'est et au sud par les chaînes de l'Atlas, renferme à elle seule près de 80 % des eaux de surface et plus de 70 % des eaux souterraines renouvelables. À l'encontre, les régions rifaines-orientales et sud-atlasiques renferment respectivement près de 18 % et 3 % des eaux de surface, et près de 14 % et 13 % des eaux souterraines.

Cette disparité dans la disponibilité en eau permet de distinguer trois grands domaines hydrauliques :

— un domaine atlantique comprenant l'ensemble des bassins hydrologiques situés au nord et à l'ouest de l'Atlas et débouchant à l'océan (carte n° 2). Cette zone comporte plus des deux tiers des ressources en eau mais se caractérise également par une population plus nombreuse, et par conséquent une importante concentration des activités économiques;
— un domaine rifain-oriental;
— un domaine sud-atlasique caractérisé par l'insuffisance de leurs ressources en eau face aux besoins exprimés;

En termes de planification de l'eau, le domaine atlantique bien que riche en eau est marqué également par une disparité entre ses zones nord et sud, ce qui nécessite une vision intégrée du développement des ressources en eau dans l'ensemble de la région.

Les autres domaines séparés physiquement du domaine atlantique par d'importantes chaînes de montagnes doivent compter avec leurs faibles ressources et s'accommoder des conditions naturelles défavorables en évitant d'en faire un frein au développement économique et social.

Le Maroc dispose de richesses hydriques évaluées en année normale à près de 150 milliards de m^3 de précipitations dont 30 milliards de m^3 contribuent à l'alimentation des eaux de surface et souterraines. De ces 30 milliards, plus de 20 milliards représentent le potentiel en eau de surface, dont 16 milliards de m^3 sont mobilisables dans des conditions techniques et économiques favorables. La répartition spatiale de ce potentiel est donnée dans le Tableau 1.

Une grande part de cette richesse naturelle est directement valorisée par l'agriculture pluviale, les pâturages et les forêts. Les écoulements superficiels et souterrains font l'objet d'aménagements permettant d'en maîtriser les flux pour en permettre une utilisation planifiée. À ces ressources renouvelables s'ajoutent les réserves en eau souterraines non renouvelables. Une planification correcte de l'eau ne peut donc s'envisager sans une vision globale prenant en compte l'ensemble des ressources en eau et des contraintes caractérisant l'expression de la demande en eau.

B. Demande en eau

Le Maroc connaît un accroissement rapide de la demande en eau consécutif à l'évolution démographique, à l'amélioration du niveau de vie et au développement économique et social. Cet accroissement de la demande en eau impose des efforts soutenus de l'aménagement de l'eau de plus en plus coûteux pour la collectivité. Ainsi un vaste programme de construction de grands barrages a été lancé par les pouvoirs publics donnant une impulsion nouvelle au développement des ressources en eau. Des projets intégrés ont vu le jour sur de vastes régions du territoire. Une répartition équilibrée des projets à travers le territoire national a traduit le souci des pouvoirs publics de promouvoir le développement régional.

Carte 2

Situation des bassins versants au Maroc

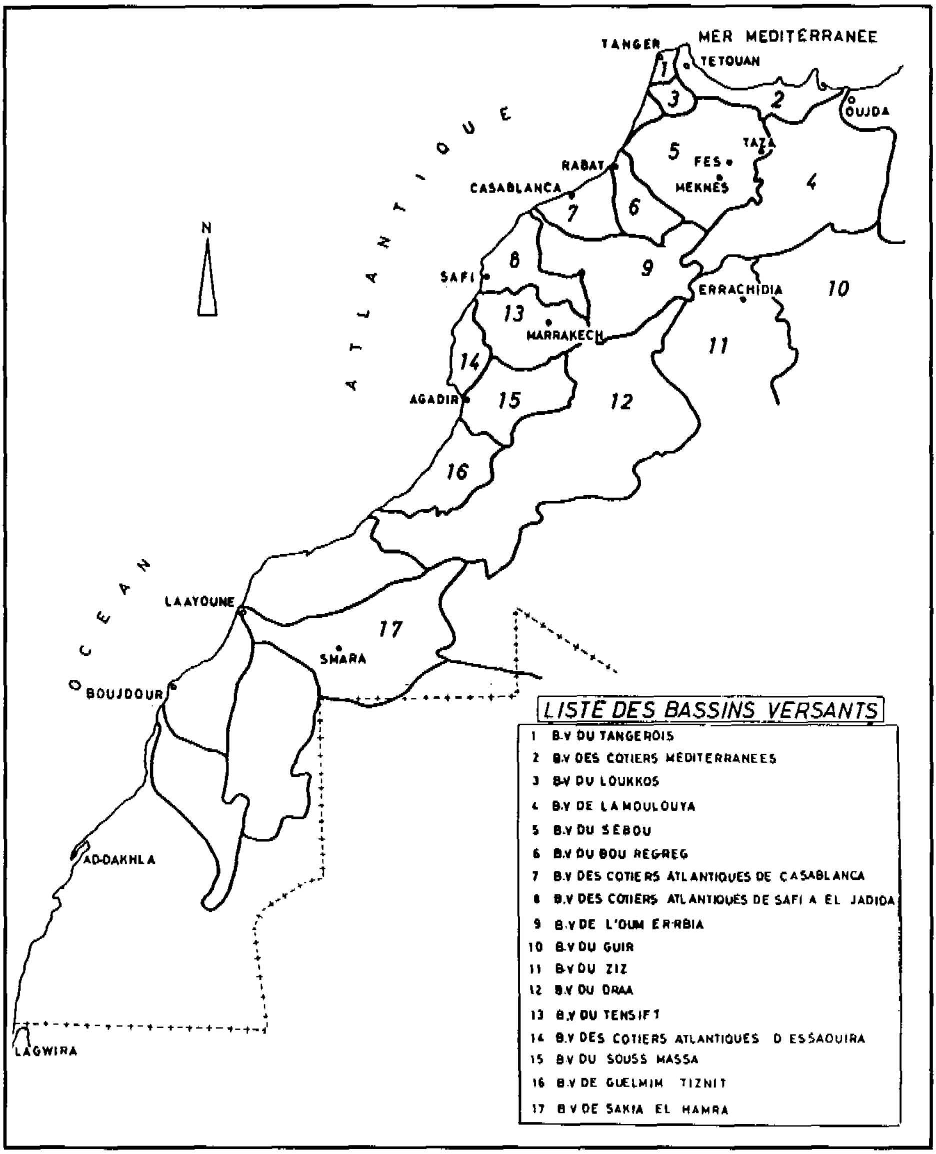


Tableau 1

Ressources en eaux superficielles du Maroc

Bassin versant	Superficie en km²	Pluviométrie moyenne (mm)	Apports moyens (Mm³/an)
Bassins rifins du Nord (1) + (2) + (3)*	20 600	680	4 170
Bassins atlantiques du Nord et Centre (5) + (6) + (7) + (8) + (9) + (13) + (14)*	132 500	520	11 280
Bassins sud atlasiques ouest (15) + (16)*	35 400	230	780
Bassins présahariens sud-atlasiques (10) + (11) + (12)* et reste	464 850	85	2 400
Bassins de l'Oriental (4)*	57 500	245	1 650
Ensemble du territoire	710 850	200	20 280

(*) Notation correspondant à celle de la carte n° 2

L'approvisionnement en eau des populations et des activités industrielles a été marqué par un développement sans précédent grâce au recours aux eaux de surface. La notion de solidarité entre régions riches et pauvres en eau s'est concrétisée par la réalisation de transfert massif d'eau. Enfin, la valorisation des potentialités hydroélectriques et les préoccupations de protection contre les inondations ont marqué les démarches de planification de l'eau.

On a ainsi assisté en fait à la naissance de la politique nationale de l'eau dans une phase marquée par l'intérêt prioritaire donné à la mobilisation. À ce jour, les recherches intensives d'eau souterraine et la réalisation de 35 grands barrages permettent de mobiliser plus du tiers des 30 milliards de m³ de ressources en eau renouvelables, contribuant de façon significative à l'essor économique et social du pays.

C. Planification de l'eau

La croissance continue de la demande en eau, la diversité des besoins et leurs interactions éventuelles, le renchérissement des coûts d'aménagement et la complexité des problèmes de gestion de l'eau dans leur ensemble nécessitent des démarches rationnelles pour faciliter le processus de prise de décision. Une planification rigoureuse intégrant l'ensemble des ressources en eau et les contraintes caractérisant l'expression de la demande a été poursuivie. En effet, compte tenu des durées relativement longues de mise en œuvre des projets hydrauliques, le processus de planification doit être consolidé et élargi à l'ensemble des aspects en rapport avec le développement des ressources.

L'expérience en cours vise à doter à court terme le pays d'un plan national de l'eau prenant en compte les priorités régionales et nationales. L'enjeu est effectivement de taille si l'on se rappelle qu'à l'horizon 2000 les projections d'utilisation de l'eau prévoient une demande globale de l'ordre de 15 milliards de m^3 dont 2 milliards de m^3 pour l'eau potable et 13 milliards de m^3 pour l'irrigation de 1 500 000 ha environ.

Le véritable processus de planification de l'eau a démarré au début des années 1980 par le lancement des études de plans directeurs d'aménagement des différents bassins du pays. C'est la première fois que des études de planification d'une telle envergure sont conduites. Auparavant, deux études de plans directeurs ont été réalisées et ont concerné, la première en 1963 le bassin du Sebou (39 000 km^2), et la seconde en 1975 le bassin de l'Oum Er Rbia (36 000 km^2).

L'évolution de la demande en eau constatée entre 1960 et 1980 impose que les études menées actuellement définissent des schémas d'aménagement à même de rechercher un équilibre inter-régional dans la répartition des ressources en eau. Ainsi les transferts d'eau du nord vers le sud, soumis à une forte pression de la demande en eau, deviennent une composante de plans directeurs proposés, lesquels plans tiennent compte également de la protection de l'environnement.

Au delà de la satisfaction des besoins en eau envisagée, l'intérêt de la démarche de planification poursuivie est d'être également un moyen efficace de concrétisation de l'effort de développement commun grâce à la solidarité régionale et nationale en matière d'eau qui pourrait aussi être instaurée.

De même, on peut espérer pour autant que les problèmes techniques et économiques du développement de l'eau soient résolus, et que la mer joue également un rôle dominant dans la politique nationale de l'eau. Les régions côtières traditionnellement importatrices d'eau pourraient devenir autonomes, voire exportatrices d'eau, et donner ainsi une nouvelle dimension à l'eau dans l'organisation du territoire national.

III. AMÉNAGEMENTS EN ZONES ARIDES AU MAROC

Au Maroc, les zones situées au sud de la chaîne de l'Atlas sont arides et leur aridité s'accentue au fur et à mesure qu'on se déplace vers le sud où le climat saharien règne. Ces zones sont caractérisées par la faiblesse, ou l'inexistence, des ressources en eau de surface régularisées. Les crues constituent la majeure partie sinon la totalité des apports des cours d'eau. Le régime hydrologique est tel que les débits sont nuls plusieurs mois dans l'année.

La faiblesse de ces ressources et leur caractère éphémère et aléatoire ont été à la base de développement de techniques susceptibles de mobiliser le maximum des ressources en eau. Ces techniques vont des plus simples, nécessitant des moyens modestes, aux plus sophistiquées et plus coûteuses, mettant en jeu de véritables aménagements de mobilisation et de transfert d'eau.

Dans ce qui suit, on présentera les efforts accomplis par le Maroc dans ces régions déshéritées caractérisées par des bilans hydriques plus ou moins déficitaires.

A. UTILISATION DES EAUX SUPERFICIELLES : ÉPANDAGES DE CRUES

Depuis plusieurs siècles, l'aridité et la semi-aridité qui règnent sur une partie importante du Maroc ont été à l'origine de l'utilisation des ressources en eau superficielle par des systèmes ingénieux constitués de prise au fil de l'eau et d'épandages de crues.

La technique d'épandage des crues consiste à faire profiter l'agriculture des eaux de crues aléatoires. Cette pratique a toujours suscité l'intérêt des habitants, dans la mesure où elle ne nécessite pas des techniques sophistiquées pour sa mise en œuvre. Il s'agit d'ouvrages traditionnels ou modernes permettant, tout en laissant passer les pointes de crues à caractère dangereux et destructeur, de dériver les décrues vers un canal tête-morte qui débouche sur les zones d'épandages plus ou moins aménagées. Ces barrages de dérivation jouent un rôle très important dans le développement des ressources en eau de ces régions. Ainsi des surfaces très importantes sont mises en valeur grâce à ces techniques qui ont fait l'objet d'amélioration dans leur conception et leur réalisation.

En effet, si ces ouvrages continuent à bénéficier des efforts accomplis par les agriculteurs qui, au début de chaque saison, construisent ou réparent les barrages endommagés par les crues passées, il n'en demeure pas moins que l'État a consenti des efforts importants depuis plusieurs décennies, témoignant ainsi de l'intérêt de ces ouvrages.

La technique des épandages de crues est utilisée au Maroc dans l'ensemble du bassin sud-atlasique et permet de procurer des avantages forts importants sur les plans agricole, social et environnemental : affectation mieux équilibrée des eaux des crues entre l'amont et l'aval, augmentation de la production agricole, meilleure alimentation des nappes souterraines. Ainsi, on dénombre plusieurs dizaines de barrages de dérivation dans ces bassins, dont pas moins de 10 dans le seul bassin du Rhéris, principal affluent du Ziz. La vocation locale de ces barrages s'est élargie en vue de permettre un transfert à l'intérieur du bassin vers des zones appelées à un développement plus poussé : c'est le cas de la plaine de Tafilalet, située en aval du bassin du Ziz, et qui bénéficie actuellement des eaux de l'Oued Rheris grâce à la réalisation, en 1986, d'un aménagement comportant un barrage de dérivation et d'un canal de transfert. Ainsi, près de 15 millions de mètres cubes par an (Mm^3/an) peuvent être transférés au lieu de se perdre vers le désert sans aucune utilisation.

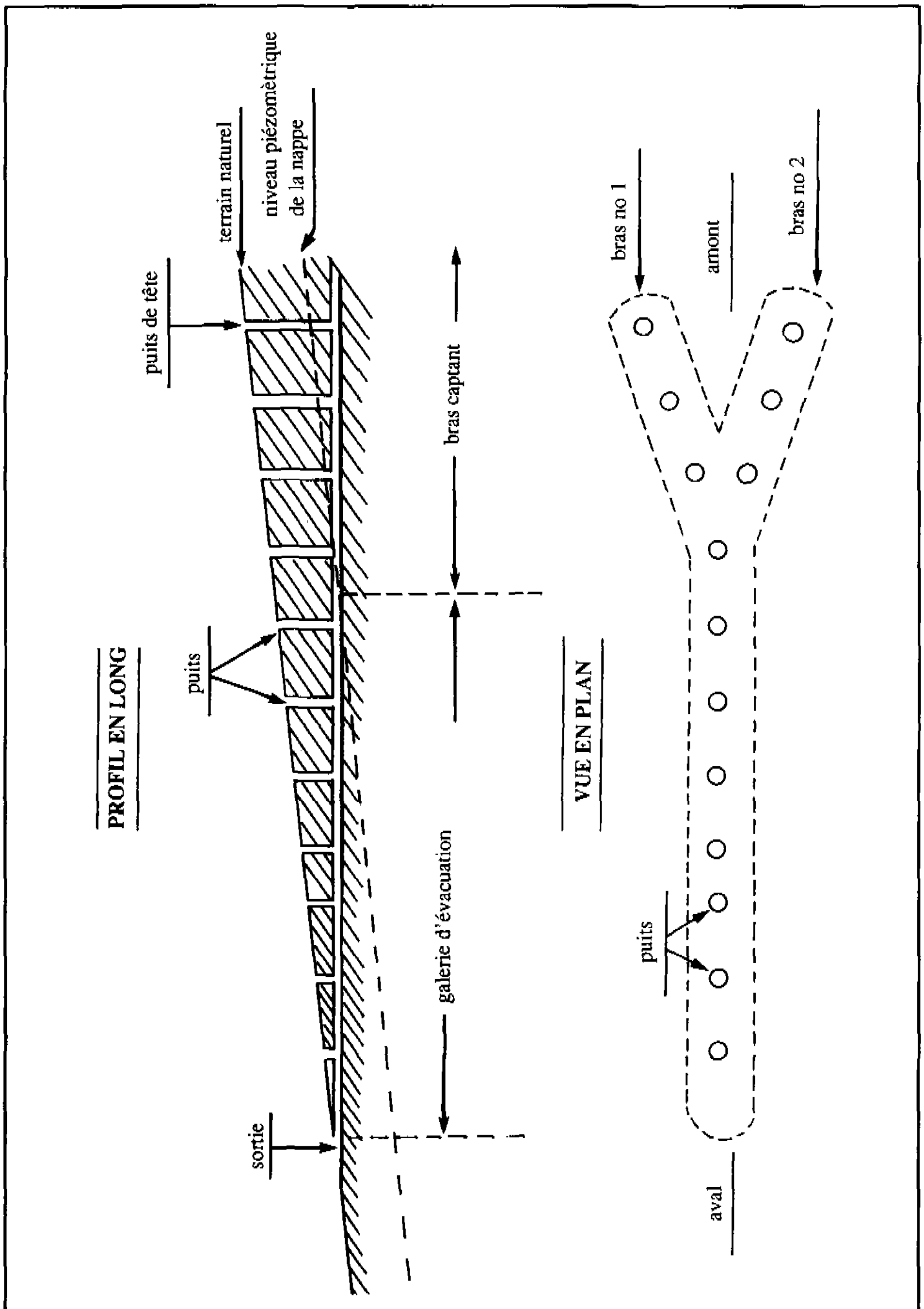
B. UTILISATION DES EAUX SOUTERRAINES : SYSTÈMES DE RHETTARAS

Depuis plusieurs siècles, l'aridité des espaces occupés par les populations ont été à l'origine de l'installation de systèmes de galeries souterraines qui drainent les eaux captées dans la nappe phréatique. Elles sont par là-même conduites au point d'utilisation et ce, au moyen d'une pente régulière inférieure à la pente générale du sol. Cette technique de captage des eaux aurait pris naissance en Asie, où ce système, très répandu, représente un véritable patrimoine hydraulique encore utilisé de nos jours. Elle fut introduite au Maroc au cours des premiers siècles de l'Islam, et elle est très répandue dans le Haouz de Marrakech qui est une vaste dépression alluviale de 6 000 km^2 située entre le Haut Atlas au sud et les Jbilet au nord.

La réalité physique de cette région du Maroc et la rigueur du climat qui y règne ont lié étroitement le développement de l'agriculture aux techniques de la maîtrise de l'eau. C'est dans ce cadre rural et contrasté, mais à vocation agro-pastorale, que les habitants de la zone du Haouz ont développé depuis des siècles, par leur savoir-faire et leur génie, tout un arsenal de procédés de mobilisation, de stockage et de distribution de l'eau, celle-ci ayant presque toujours été une matière de première nécessité inégalement répartie.

Figure 1

Système de Rhettara



Ainsi, plus de 650 Rhettaras, drainant les eaux de la nappe phréatique, ont été réalisées dans les différentes parties de cette région, totalisant une longueur de 700 km et mobilisant un débit de plus de 5 000 l/s, soit 70 % des prélèvements de la nappe. La première Rhettara a été réalisée vers 1071 et l'effort de leur réalisation a été continue pendant des siècles.

La technique de ces Rhettaras consiste au creusement d'une canalisation souterraine à l'aide d'une série de puits distants de 20 à 25 m (Fig. 1). Les puits servent à l'évacuation des terrassements et à l'aération au moment de la construction, ainsi qu'à l'entretien durant le fonctionnement. Les tracés sont généralement simples, rectilignes ou sinueux. Le drain a pour fonction de créer une dépression et une collecte latérale des eaux, et sa longueur est directement liée au niveau piézométrique par rapport au sol, à la pente du terrain naturel et à la pente du drain.

En ce qui concerne la situation actuelle, l'exploitation des eaux souterraines par ce procédé a permis incontestablement la mise en valeur dans le Haouz d'une superficie de 20 000 hectares. La péриclination de cette technique coïncide avec l'apparition du pompage à cause des inconvénients, tels que les gros frais de première installation, l'entretien coûteux, la grande servitude de passage et la grande occupation au sol. Actuellement, quelques Rhettaras d'État ou privées sont encore entretenues, mais leur débit diminue au fil des ans à cause de la baisse de la nappe sous l'effet de la sécheresse qu'a connu le pays entre 1980 et 1985.

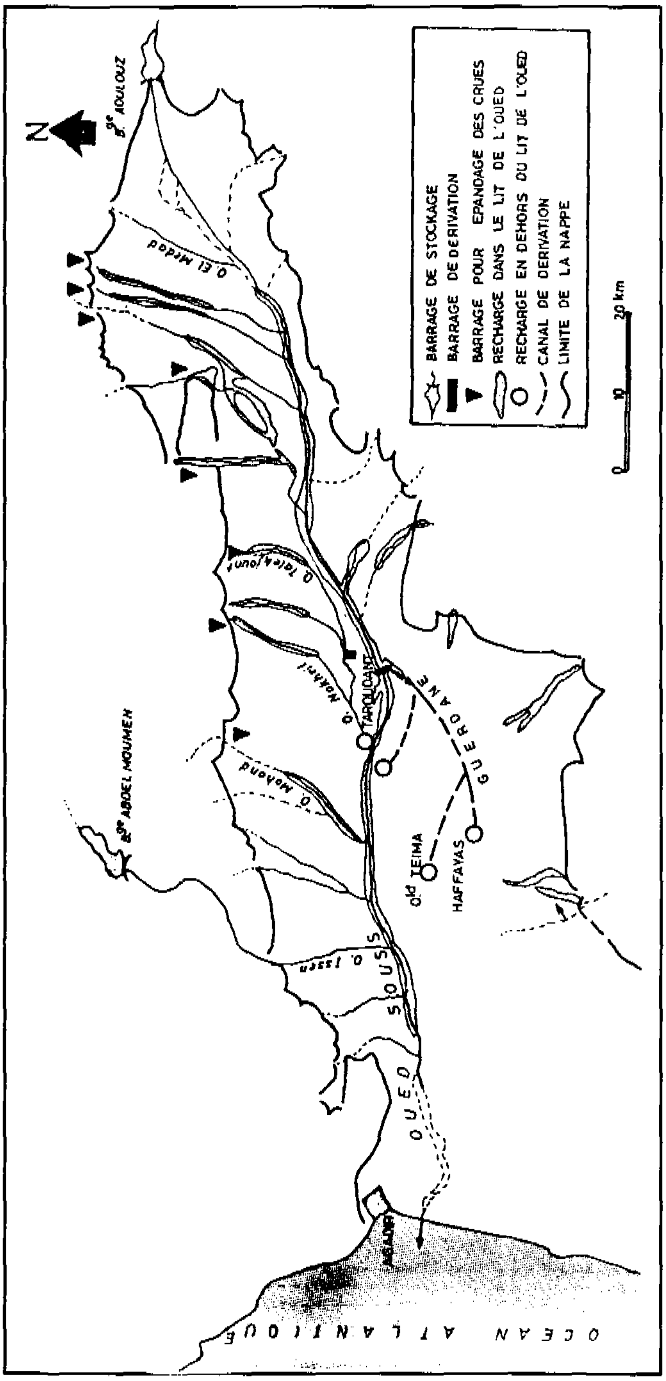
Bien que l'utilisation de cette technique soit actuellement en voie de disparition, il reste cependant l'œuvre qui témoigne de l'exploitation et de l'aménagement des eaux souterraines de manière très précoce dans cette région du Maroc.

C. TECHNIQUES MODERNES

1. *Cas du bassin du Souss (carte n^{0} 3)*

Les moyens traditionnels mis en œuvre au fil des temps ne permettent plus de faire face aux besoins en continuelle croissance des régions arides. Des efforts importants ont été accomplis par l'État en vue de maximiser l'utilisation de l'eau dans les régions fortement handicapées par la rareté de la ressource qui ont subi également le contrecoup de la sécheresse des dernières années. En plus des efforts dans la mobilisation, traduits par la construction de barrages de régularisation forts importants et par le creusement de puits et forages, il y a eu recours à une politique de gestion intégrée et rationnelle des eaux superficielles et souterraines. L'exemple type au Maroc de cette politique est celui constitué par l'aménagement du bassin du Souss qui s'étend sur 16 000 km^2 et est situé dans une zone où la pluviométrie moyenne annuelle est de l'ordre de 250 mm.

Ce bassin contient une plaine fertile sur une superficie de 4 000 km^2. Le développement de l'agriculture irriguée sur la base d'une mobilisation des eaux superficielles saisonnières (épandages de crues) ou semi-pérennes (résurgences, Rhettaras) est très ancien. Mais, depuis 1940, s'est développé un secteur irrigué moderne grâce à la mobilisation des eaux souterraines. Ce développement de l'irrigation s'est accompagné d'une baisse importante des niveaux d'eau de la nappe, ce qui a obligé les agriculteurs à recourir à des investissements très coûteux pour approfondir leurs puits ou réaliser de nouveaux forages. La sécheresse qu'a connue



Carte 3
Gestion intégrée des eaux du bassin du Souss

la région depuis 1970 a aggravé cette situation. Ainsi, de 1960 à 1986, près de quatre milliards de m^3 ont été déstockés sur les réserves, ce qui a entraîné une baisse de niveau d'eau allant jusqu'à 40 m par endroit. Devant cette situation, il n'est guère de solution que de chercher un moyen pour compenser les déstockages de la nappe. Le régime hydrologique de l'Oued Souss et la nature du lit de l'oued ne favorisent pas une infiltration naturelle à même de compenser le déficit de la nappe.

La manière la plus judicieuse de résorber ce déficit de la nappe, évalué en 1986 à 260 Mm^3/an, est de récupérer une partie des fuites en mer, grâce notamment à un barrage situé à l'entrée de l'Oued Souss dans la plaine. Ce barrage, mis en service en 1991, permet avec tout le dispositif de recharge complémentaire qui lui est associé :

— d'étaler suffisamment les crues pour maximiser les infiltrations de l'eau dans le lit de l'oued et donc de contribuer à rétablir l'équilibre de l'exploitation de la nappe;
— de régulariser l'écoulement des bassins à l'aval permettant l'infiltration d'une partie de leurs eaux de crue dans le lit de l'oued.

Cet aménagement fonctionnera, après son achèvement selon des règles de gestion judicieusement étudiées, de telle manière à maximiser l'infiltration. Une étude approfondie sur les capacités d'infiltration de l'Oued Souss et sur les règles de gestion du barrage a été menée.

Parallèlement aux efforts de mobilisation, la valorisation maximale de l'eau a été fortement recherchée dans cette région par l'adoption de techniques modernes économes d'eau : pratique des cultures sous serres (cultures, bananières, floriculture, maraîchage) et systèmes de centres pivots.

En fait, le barrage d'Aoulouz, original dans son genre, tant par les fonctions qui lui sont attribuées que par le procédé de sa construction, est destiné à l'agriculture irriguée par pompage. Il constitue de ce fait un exemple type au monde de gestion intégrée eaux de surface-eau souterraine.

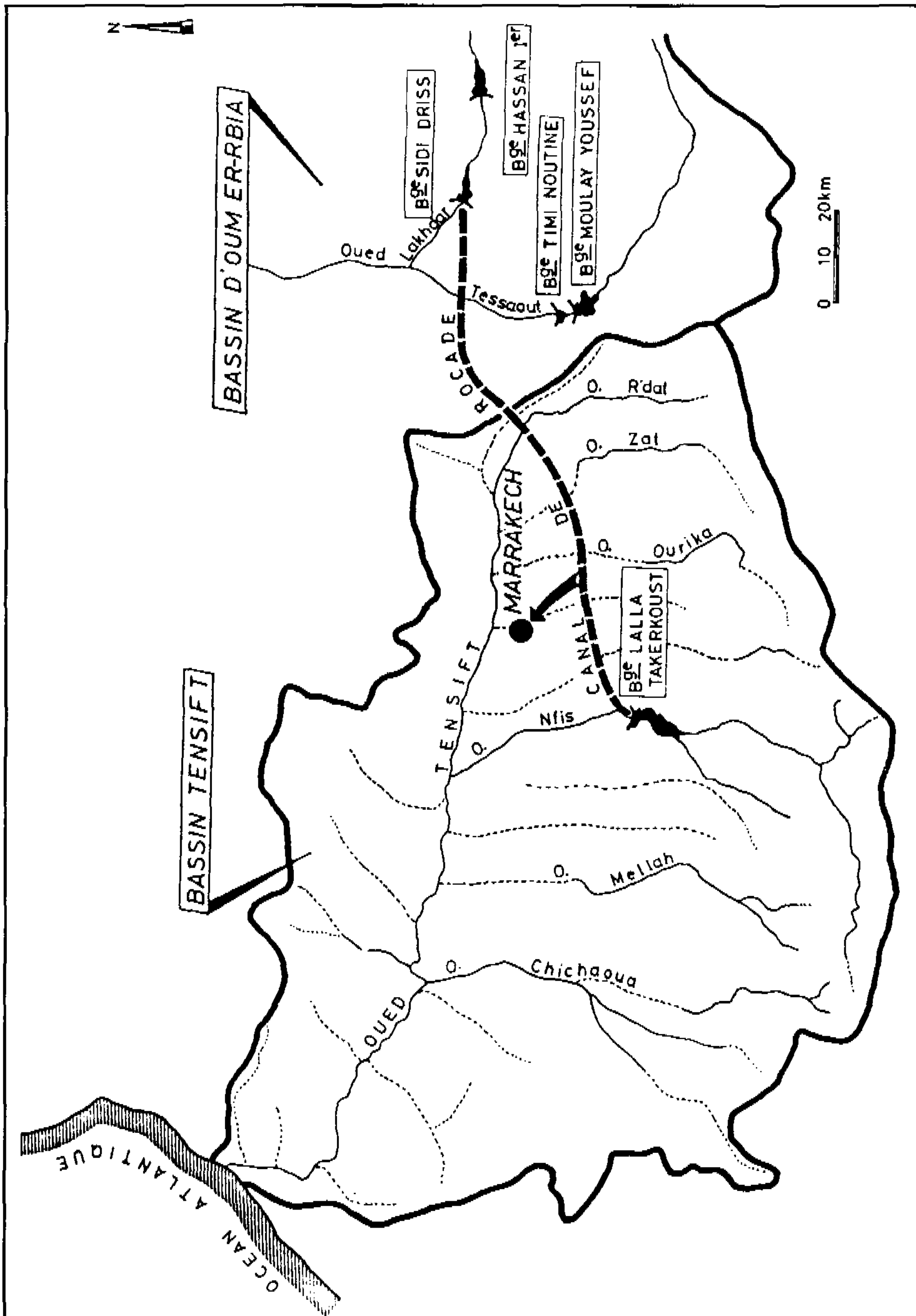
De par sa fonction, ce barrage permettra de reconstituer à travers la maîtrise des crues :

— un régime hydrologique plus régulier permettant un meilleur usage de l'eau en aval;
— l'équilibre des écosystèmes en aval fortement perturbé par le déstockage de la nappe du Souss.

2. *Cas du bassin du Tensift (carte n° 4)*

Les systèmes traditionnels de mobilisation des ressources en eau développés dans le Haouz ne permettaient plus de faire face aux importants besoins d'irrigation de la région. Malgré un barrage construit en 1929 régularisant près de 80 Mm^3/an, un important déficit subsistait. Ce déficit ne pourrait être résorbé que par le recours à des ressources extérieures au bassin, celles de l'Oum Er Rbia situé au nord.

Ainsi un projet de transfert d'un volume d'eau de 300 Mm^3/an a été réalisé. Ce projet comporte le complexe de barrage Hassan 1[er]-Sidi Idriss, édifié sur l'Oued Lakhdar, principal affluent de l'Oued Oum Er Rbia, et un canal de rocade permettant



Carte 4

Transfert d'eau interbassin

ce transfert sur une distance de 120 km. Le volume transféré permet l'irrigation de 35 400 ha dans la plaine du Haouz et l'alimentation en eau potable de la ville de Marrakech à raison de 40 Mm^3/an.

Cet aménagement est l'exemple type de la solidarité nationale en faveur d'une région pauvre en ressources en eau et permet également d'instaurer l'équilibre régional en matière de répartition des richesses hydriques du pays.

CONCLUSION

Dans un contexte de rareté des ressources en eau, l'utilisation de tous les moyens de leur mobilisation est nécessaire. C'est ainsi que les techniques d'épandage de crues et les Rhettaras sont utilisées depuis des siècles pour l'utilisation des eaux de surface et la mobilisation des eaux souterraines.

Devant cette rareté et étant donné l'évolution de la demande en eau, le Maroc s'est engagé dans un processus de planification visant à rechercher un meilleur usage de l'eau. Les premières études de planification ont été lancées en 1963 et ont concerné le bassin versant du Sebou. À partir de 1980, une série d'études de planification à l'échelle de l'ensemble des bassins versants du Royaume a été entreprise par le pouvoir public dans le but de préparer le plan national de l'eau. Ce plan devant définir les schémas de développement des ressources en eau afin de faire face à la demande en eau, qui sera en l'an 2020 de l'ordre de 10 milliards de m^3, dont 2,5 milliards de m^3 pour le secteur de l'eau potable et industrielle.

Water Resources Management in the Semi-Arid Regions of Nigeria

LEKAN OYEBANDE*
and
IDOWU BALOGUN**

ABSTRACT

Northern Nigeria forms part of the semi-arid region of Africa known as the Sahel. This article outlines climate and water resources (ground and surface waters) of the region. The need for water storage is stressed and water management strategies, both present and proposed, are considered. Interbasin water transfer schemes are outlined. The need for integrated planning is emphasized for a sustainable level of water resources development.

RÉSUMÉ

Le Nord du Nigéria fait partie d'une région semi-aride de l'Afrique que l'on appelle le Sahel. Après une brève description des conditions climatiques et des ressources en eau (souterraines et de surface) de la région, les auteurs mettent l'accent sur un certain nombre de mesures susceptibles d'assurer un développement durable des ressources en eau: construction de réservoirs, stratégies de gestion à court et à long terme, planification intégrée et partage des eaux internationales.

INTRODUCTION

Politically, northern Nigeria consists of the eleven northern states: Sokoto, Katsina, Kano, Borno, Gongola, Bauchi, Benue, Plateau, Kaduna, Niger and Kwara. The southern boundary of this political entity coincides roughly with Lat. 7°N in the east up to River Niger and with Lat. 8°N west of the River Niger.

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In terms of climatic and ecological zoning, northern Nigeria is covered by three broad zones: Guinea Savanna, Sudan Savanna and the Sahel. Figure 1 shows these zones in relation to the mean annual isohyets. The typical mean annual number of rainy days in the two savanna zones ranges from 75 to 115, while for the Sahel it is between 55 and 65 days. The present extent of the Sahel has likely exceeded the area shown in Figure 1. Much of the north-central and north-eastern areas have experienced typical Sahelian climate during the last 15 years or more, and the resulting prolonged desiccation has produced Sahelian ecological conditions. Using trend analysis to supplement the long-term means of rainfall, Jensen (1990) noted that rainfall decreased sharply during 1960-83 in the Sudan and northern Guinea Savanna at an average rate of about 10 mm/yr (Figure 2). This rate of decrease has been interpreted to correspond to an average southward progression of the agroecological zones by about 33 km per decade while the start of the growing season in the central parts has been delayed by about 10 days per decade.

Figure 1

Ecological Zones and Annual Isohyetals (mm)

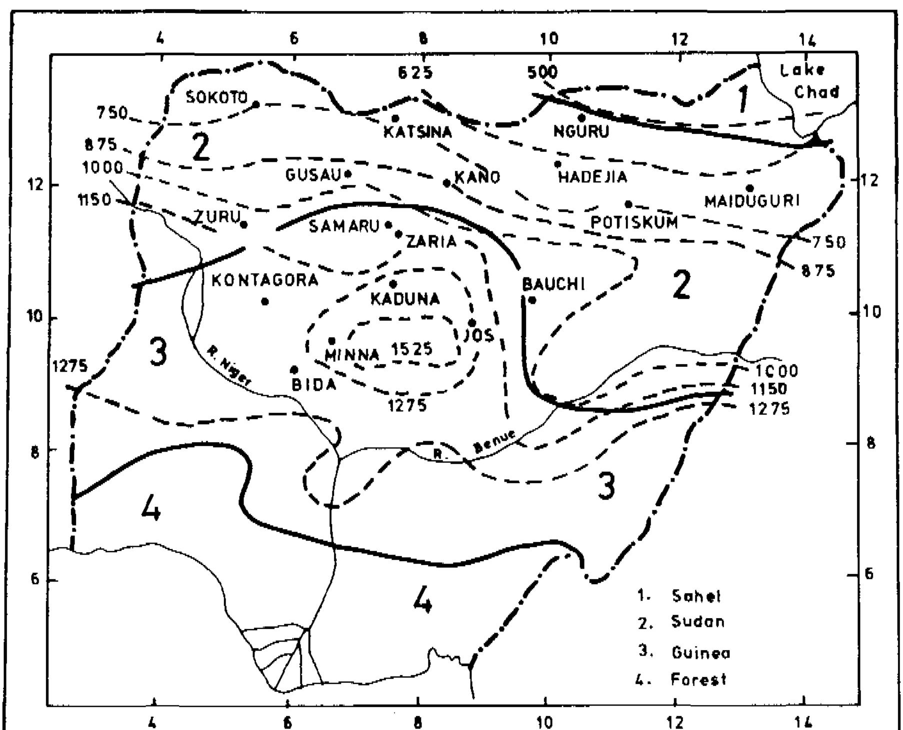
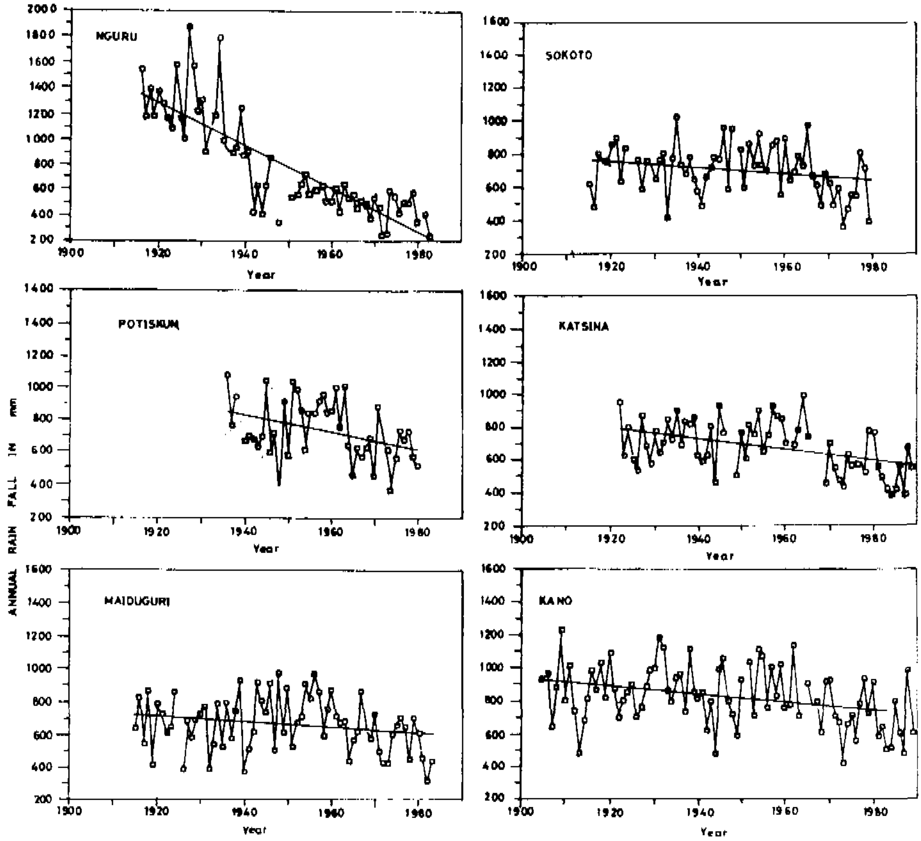


Figure 2

Annual Mean and Trends of Rainfall at Selected Stations of the Sudano-Sahelian Zone (SSZ)



The Sahel with the northern Sudan zone is a semi-arid region and is currently studied intensively under the appellation "Sudano-Sahelian zone" (SSZ). It is indeed part of the larger SSZ of Africa that has been described as a large area covering semi-arid and tropical wet-dry regions of the sub-Saharan Africa.

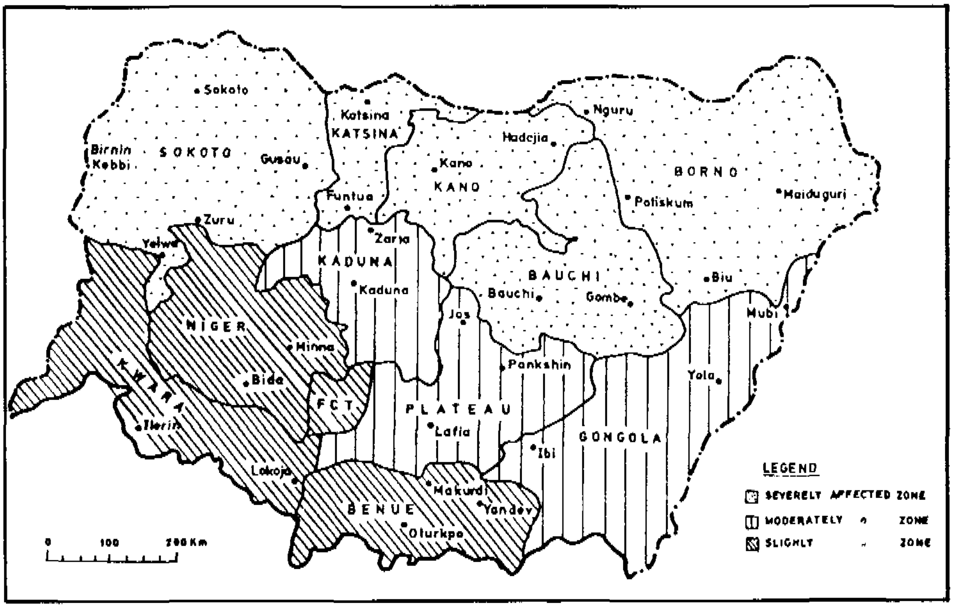
The semi-arid zone or SSZ of northern Nigeria is approximately bounded by latitude 11°N and 13°N and by longitude 4° and 15°E (Kowal and Knabe, 1972). The land area covered is 26 160 km^2 or 28% of Nigeria's total land area, including large portions of Borno, Katsina, Kano and Sokoto States (Figure 3).

I. CLIMATE

Rainfall in the semi-arid regions of northern Nigeria is low and highly variable with the bulk of total annual rainfall occurring in 5 to 10 high-volume, high-intensity

Figure 3

Desertification in the Northern States of Nigeria



showers that lead to considerable flood flows. In absolute terms, Ojanuga (1987) also reported that mean annual rainfall ranges from less than 508 mm in the driest part to 1 016 mm in the wettest.

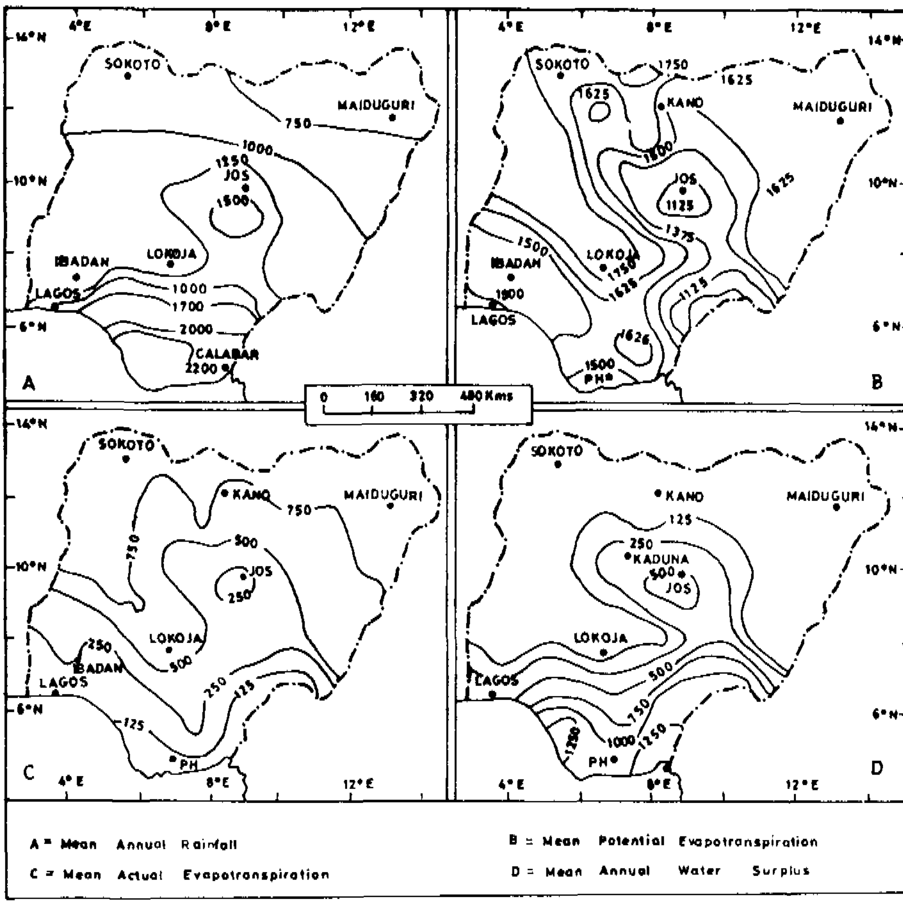
Rainfall distribution in this part of northern Nigeria has given rise to three distinct seasons (Virmani, 1991). These are:

— a dry season of 100 to 200 days during which temperature and saturation deficit are high, available soil moisture is low, and crop production is impossible without irrigation;
— a rainy season of 60 to 210 days at the beginning of which temperature and saturation deficit decrease and rainfed agriculture is feasible; and
— a dry post-rainy season when temperatures decrease and limited crop production is possible on stored soil moisture.

The mean temperature in the semi-arid regions of northern Nigeria is between 26°C and 28°C. A high soil temperature combines with an equally high air temperature to create high evaporative demand. The potential evapotranspiration as a consequence, can be as high as 3-5 mm/day during the rainy season, and exceeds rainfall for about eight months annually. A considerable part of the semi-arid regions of Nigeria receives an average of only 300-650 mm/yr, while experiencing a potential evapotranspiration that is as high as 3 500 mm for the same period.

Northern Nigeria, particularly the semi-arid regions, has one of the most severe climates in the world. Figure 4 shows the distribution of some water balance

Figure 4
Distribution of Some Water Balance Components in Nigeria (in mm)

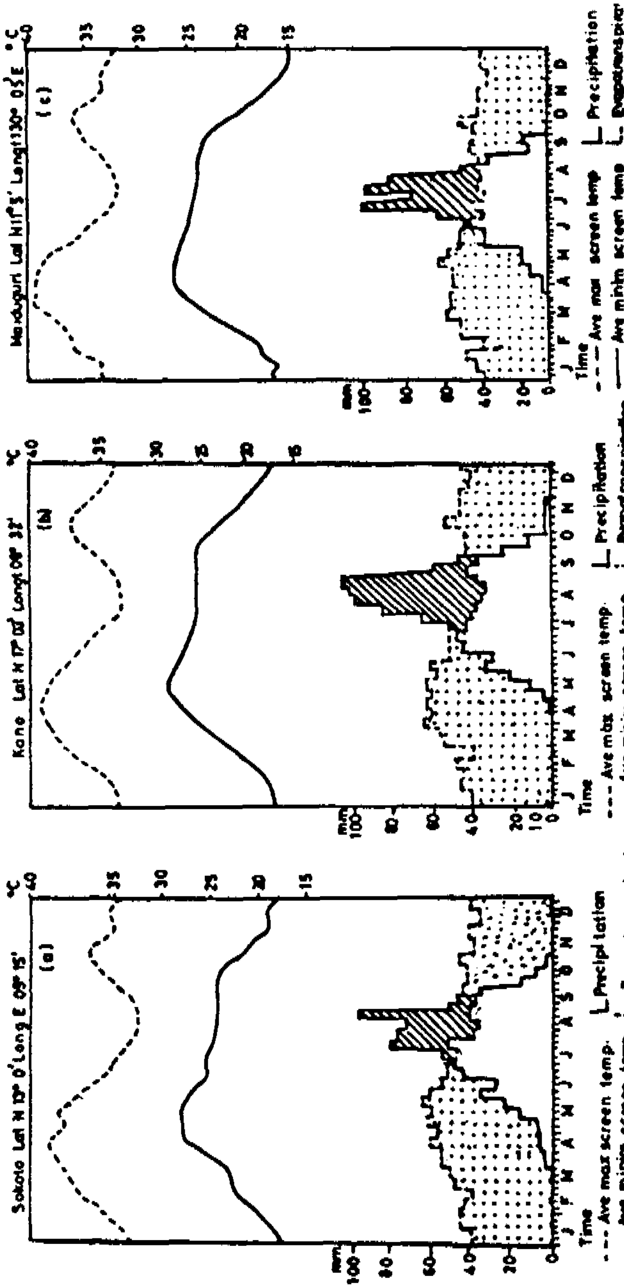


components in Nigeria while Figure 5 also includes similar climatic information for Sokoto, Kano and Maiduguri which are fairly typical of the patterns in the semi-arid regions.

Even in the relatively wetter southern regions where rainfall averages about 1 110 mm annually, the problem for human settlement and particularly agriculture has been that of the seasonal distribution of rainfall (Sivakumar and Wallace, 1991), and the rate at which it is lost by evaporation. While evapotranspiration in some temperate environments and in the humid tropics constitutes only a small fraction of annual rainfall, its contribution towards annual water deficit in the semi-arid regions assumes greater prominence. The natural climatic vagaries and extremes of these areas, coupled with land use and water management that is not environmentally friendly, have resulted in the recurrence of droughts, progressive desertification, soil erosion and consequent crop failures as well as declining soil fertility.

Figure 5

Climatological graphs for Sokoto, Kano and Maiduguri



The incidence of the natural hazards has had such undesirable effects as loss of lives and property, diminished land productivity, declining national incomes and decreasing per capita food production. This has culminated in hunger and poverty being endemic in the region. The situation has been so bad that the region is viewed as being a highly fragile land resource and environment (ICRISAT, 1989). Figure 6 shows the severity of one of the natural hazards to which the entire Nigerian environment is susceptible, i.e. soil erosion. In terms of magnitude, the northern parts of Nigeria experience soil loss of between 4 352 and 14 592 tons/km^2/year with the semi-arid region recording an upper level range of 10 752 to 14 592 tons/km^2/year. The wind erosion that is a common feature of Sokoto State has made shifting of roads mandatory while also constituting a menace to the farmer during the planting season.

II. MAJOR SURFACE WATER RESOURCES

Figure 7 shows the surface water sources of the semi-arid zones of northern Nigeria. These include Lake Chad and the Rivers Hadejia, Jama'are, Yobe, Rima Sokoto, Kano and Gongola.

A. LAKE CHAD

The hydrological basin of Lake Chad is a vast area, roughly circular and covering an area approximately 2 million km^2 in extent. Its conventional area, however, is about 0.43 million km^2. One quarter of the watershed area of Lake Chad is within Nigeria.

The surface water supplies, apart from rainfall over the area, are derived from the rivers which drain the hydrological basin. Annual rainfall ranges from 1 600 mm in the south to less than 200 mm in the semi-desert areas of the north.

Lake Chad is about 282 m above sea level, though it is not the lowest part of the hydrological basin. This large expanse of fresh water has a surface area that has varied between 13 000 and 23 000 km^2 since the turn of the century. The variation has been due to the corresponding fluctuations in climate with its adverse effect on the Chari River which accounts for more than 90% of the surface inflow into the lake.

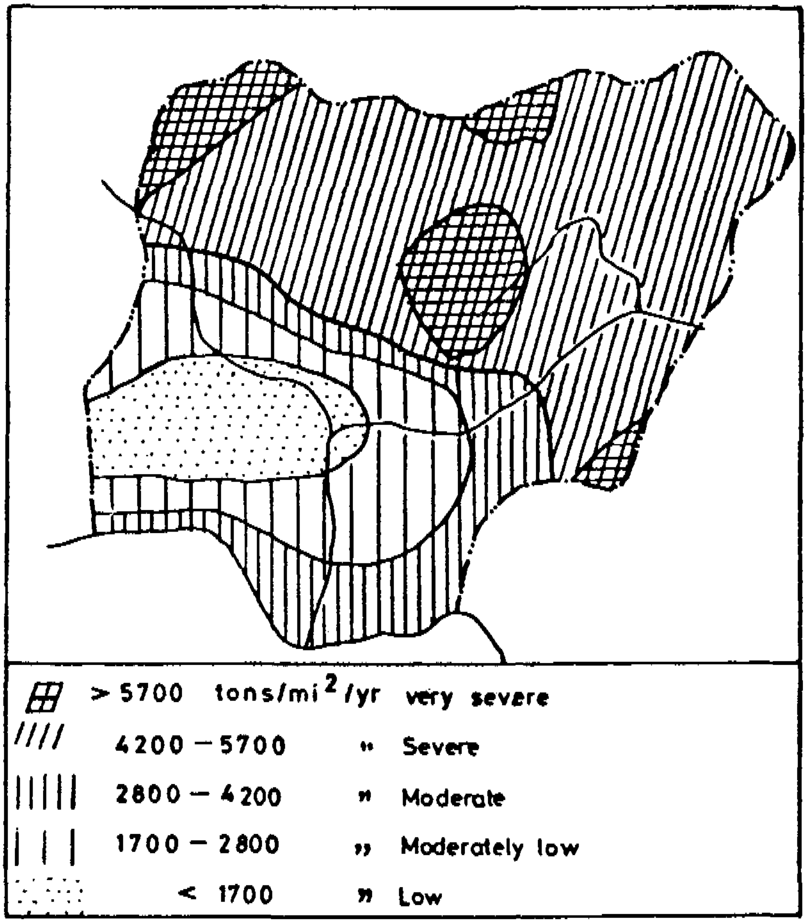
The lake, despite its vast areal extent, is an extremely shallow body of water with depths of between 1.5 and 5.0 m, with an extreme depth of 6.0 m in the south-east polder region. Over the last 100 years, records show that there have been four major periods of extreme low levels. The depth was less than 2.5 m at Boldune gauging station in 1907-1908, 1914-1916, 1942-1943, and especially recently in 1971-73. Correspondingly, the lake has recorded fluctuating water volumes that spanned an all-time high of $100 \times 10^9 m^3$ and a low of $20 \times 10^9 m^3$.

The river systems that contribute to the waters of Lake Chad can be broadly grouped into (1) those that drain areas which lie outside Nigeria and its borders, and (2) catchment areas which lie wholly or mainly within Nigeria's borders.

The second group will be the focus of this present paper. The Lake Chad river systems that lie wholly or mainly within the Nigerian border are the Ebeji (22 640 km^2 catchment), Yedseram (16 320 km^2), Ngadda (14 400 km^2), Gubio (26 580 km^2) and Yobe rivers.

Figure 6

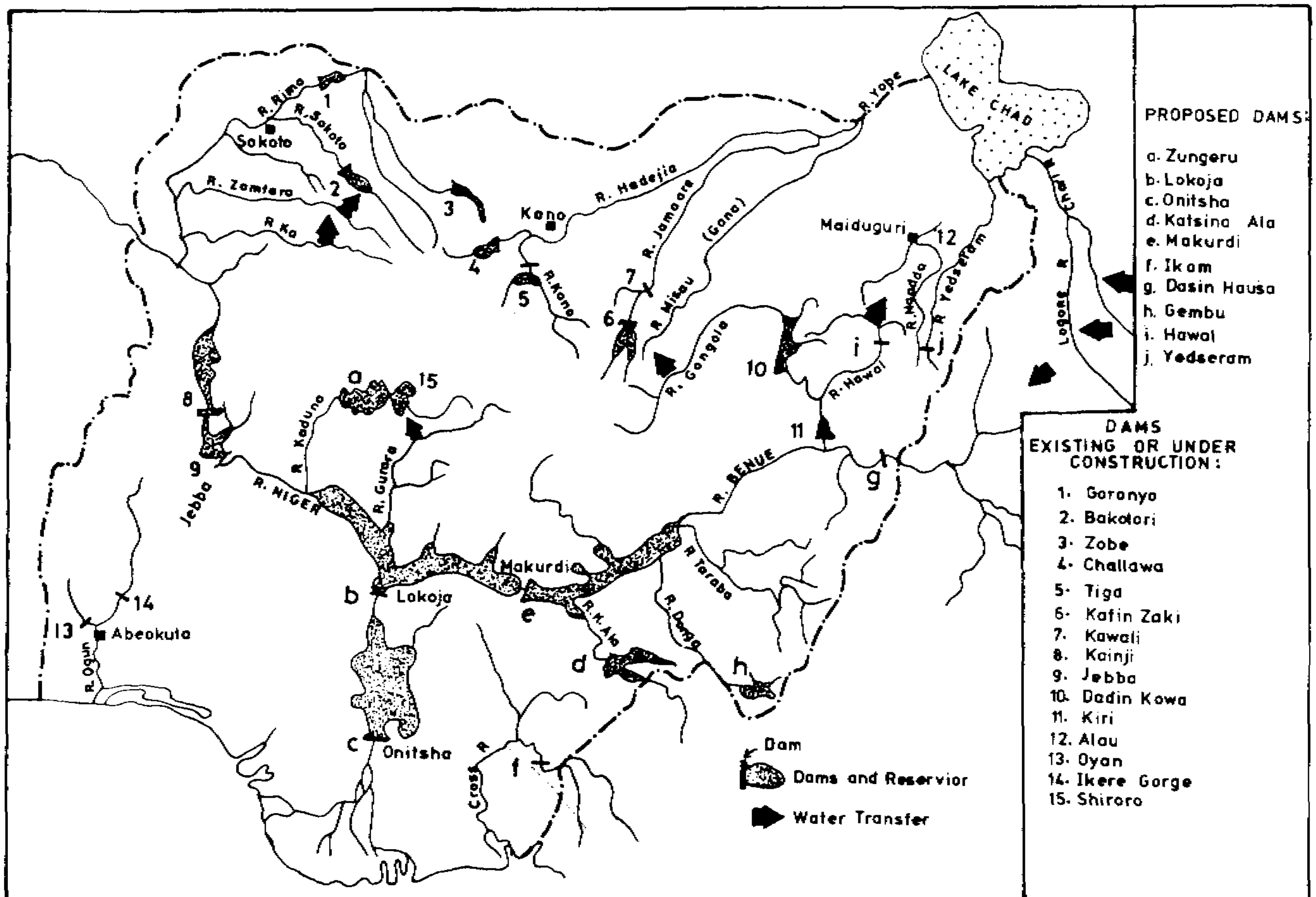
Erosional Hazards in Nigeria



The Kamodogu-Yobe river system covers 147 848 km^2 an area of great diversity. The Yobe river system empties into northern Nigeria. It is made up of three main rivers: the Hadejia, and the Jama'are that contribute 40% and 51% of its flow respectively, and the Misau. The Hadejia with a mean annual flow of 1.9 x 10^9m^3 (at Wudil) is formed by the confluence of the Challawa and Kano rivers. In contrast to the Hadejia, the Jama'are has a fairly well defined channel over most of the Chad lowlands and has an annual flow of about 5.34 $\times$ 10^9m^3. The Misau River rises north of Bauchi and flows northeast to join the Yobe River at a point 128 km from Lake Chad. Average annual rainfall varies from 760 to over 1 200 mm and the coefficient

Figure 7

Major Dam Storages and Interbasin Water Transfer



of runoff ranges from 7 to 22%. Evapotranspiration accounts for most of the water losses in the Yobe system, with a small but significant portion of surface runoff infiltrating and contributing to groundwater accretion.

B. Sokoto-Rima Basin

The rivers in the Sokoto Basin generally have their sources in the Basement Complex from which 80% of the basin's runoff is derived due to a geology that inhibits infiltration. Table 1 is a summary of the average annual flow at some hydrological stations for the period April 1964 to March 1970, while Table 2 shows evapotranspiration in the Sokoto Basin for the same period. The mean annual precipitation over the area is 837 mm while mean potential evapotranspiration varied between 2 086 and 2 185 mm/yr. Actual evapotranspiration annually decreased from 900 mm in the south to 600 mm in the northern part of the state with a mean of 752 mm. This gives an effective precipitation of 82 mm/yr.

Table 1

Run-off at Selected Gauging Stations in the Sokoto Basin

River	Station	Catchment Area (km^2)	Av. annual runoff ($\times 10^6 m^3$)	Depth over catchment area (mm)	Geology at Station
Sokoto	Gusau	2 662	397	149	Basement Complex
Sokoto	Bakolori	4 800	573	119	Basement Complex
Sokoto	Gidan Doka	12 590	739	59	Rima Group
Rima	Sabo Birni	19 590	885	45	Gundumi Formation
Zamfara	Anka	4 134	554	134	Basement Complex
Zamfara	Kalgo	16 708	1 173	70	Gwandu Formation
Gawaon Daji	Sanyinam Daji	3 942	16 433	4.2	Gwandu Formation

Source: Oteze, 1989.

Table 3 shows surface water balance for the Rima Group of Sokoto State and it can be seen that outflow in three of the rivers is greater than inflow for the period. Only the Rima Valley retains part of the inflow into the area.

C. The Need for Water Storage

The drought events that took immense toll on both human and material resources of the semi-arid region of northern Nigeria have been highlighted

Table 2

Evapotranspiration in the Sokoto Basin (1964-1970)

Location	Mean Annual Air Temperature (0°C)	Potential Evapotranspiration		Actual Evapotranspiration (mm)	
		From Evaporimeter (mm)	From Turc's Formula (mm)	By Turc's Formula from Evaporimeter (mm)	From Turc's Potential Evapotranspiration (mm)
Sabon Bini	30.18	2185	2428	606	610
Kware	27.97	2126	2093	634	633
Gusau	27.35	2086	2006	860	855
Birnin Kebbi	27.75	2151	2062	847	841
Gummi	31.00		2560	902	931

Source: Oteze, 1989.

Table 3

Surface Water Balance for the Rima Group Area (April 1964 — March 1970)

River	Inflow ($\times 10^6 m^3/yr$)	Outflow ($\times 10^6 m^3/yr$)	Difference ($\times 10^6 m^3/yr$)
Sokoto	656.03	738.8	82.77 (loss)
Rima	1217.29	817.03	400.26 (gain)
Zamfara	1038.80	1088.40	49.8 (loss)
Gawon Culbi	6.5	14.1	7.6 (loss)
Total	2918.41	2658.33	260.08 (gain)

Source: Oteze, (1989).

(e.g. Oyebande, 1991; Oyebande and Balogun, 1990). The causal factors included low rainfall, excessive atmospheric and soil temperature that led to very high evapotranspiration, and unavailability of adequate managerial skill to cope with the hazard. Among the proven combative measures put forward to check not only drought and desertification but other natural hazards, is the storage of water during the periods of adequate quantity for use during periods of scarcity. The need for water storage through dam construction is particularly relevant in a semi-arid environment with characteristic inclement climate and high variability of rainfall. This variability of rainfall and streamflows precludes direct abstraction of water from the rivers and requires storage in adequately designed impoundments.

A study of drought effects on some otherwise reliable surface water sources in the semi-arid region after a drought spell was undertaken. The observations were made in December 1984 on some rivers and reservoirs in Borno, Kano, Kaduna and Sokoto States. In some cases rivers did not flow at all. This was particularly true of

Borno State where Rivers Komodogu, Gana, Ngadda, and Yedscram dried up. Even the only natural surface water reservoir that traditionally offered succour during the dry season, i.e. Lake Chad, also shrank to an all time minimum. The conclusion of the Committee that undertook the tour of the Sadano-Sahelian region was that dam construction alleviated the severity of both drought and desertification in most of the areas visited. Water resources conserved in this way enhance the development of hydro-power generation, water supply for industrial, domestic and agricultural purposes, navigation, flood control and aesthetic and recreational uses in the semi-arid environment.

Table 4 shows that 79% of the dams have water supply components while 33% have irrigation largely as one of the uses to which the stored water will be put. Four percent of the dams have hydro-electric power generation consideration; fisheries is undertaken in 29% of the selected dams; while only 16% have built-in provisions for recreation. All the dams, however, contribute towards flood mitigation. Other positive aspects of flow regulation by dams include possible groundwater level stabilization, throughout the general area of the reservoir, improved minimum flow and utilisation as a water source for interbasin water transfers from water surplus to water deficit areas. High evaporation rates ranging from 1 000 to 2 500 mm, however, deplete the storage each year leading to water losses to the tune of hundreds of million cubic metres depending on the surface areas of the man-made lakes.

Table 4

Uses of Selected Dams Projects in Nigeria

Purpose of Dam	# of Dams	% of Total in Sample
Water Supply (S)	21	40
Irrigation (I)	2	6
S, I, R	2	6
S, I, R, F	2	4
S, I, F	2	4
S, I	7	13
S, R	1	2
S, R, F	2	4
S, F	2	4
S, H	1	2
I, F	7	13
I, H	1	2
TOTAL	52	100

Source: Oyebande, 1989.

R = Recreation, F = Fisheries, H = Hydro-electric power

One of the structures that plays a prominent role in water resources development in the semi-arid regions of northern Nigeria is the Tiga Dam that regulates flow in the Kano River. It has a capacity of $2.0 \times 10^9 m^3$ and is used for the Kano River and the Hadejia Irrigation Projects. Since its construction some measures have been taken to ensure its safety and to increase the benefits derivable from its waters. In

1989, the emergency spillway was widened from 100 m to 300 m and was lowered by 3.5 m below the concrete spillway to allow more spillage. This modification has had the effect of reducing the storage capacity of the dam by 600 $\times$ $10^6 m^3$ or about 70% of the current average annual flow of Gashua at Yobe. Downstream areas will thus be more extensively inundated. This means that the Hadejia-Nguru Lake and surrounding *fadamas*, or wetlands, will be adequately fed by floods. The extent of the wetlands progressively decreased from 3 265 km^2 in 1950 through 2 350 km^2 in 1969 to 700 km^2 in 1987. It was less than 300 km^2 during the drought of 1984. The decrease is attributable to both the effects of Tiga dam regulation since 1974 and to the recurrent drought.

III. GROUNDWATER RESOURCES

One of the factors responsible for the low surface water consumption in most parts of northern Nigeria is the overconcentration on groundwater development. In Borno State, for example, multitudinous wells of varying but shallow depths are concentrated in both rural and urban areas where the Borno State Water Board particularly stresses groundwater development. As of 1987, over 170 boreholes were functional, serving a majority of the urban and suburban populace and having a daily yield of over 100 million litres. It is in only about 10% of the State Water Schemes that alternative surface schemes were being initiated. Except for areas near Lake Chad which draw their water for irrigated agriculture from the lake, other areas rely heavily on groundwater. Over-exploitation of the middle and lower aquifers in the vicinity of large population centres such as Maiduguri has, however, caused much concern and has underlined the importance of developing a conservation policy which restricts as much as possible groundwater extraction to safe yields. Fortunately, there are plans to augment existing schemes by supplementing them with water from surface sources.

In Sokoto State, the situation is similar to Borno State. In the fadamas (wetlands) over 5 000 tube wells have been sunk to an average depth of 12-15 metres for both irrigation purposes and water supply to surrounding villages.

In two other northern states (Niger and Kwara), the siting of the new Federal Capital Territory and several large scale agricultural projects in the area, together with recurrent droughts since 1968, have led to a greater emphasis being placed on the exploitation of groundwater for diverse uses. Numerous boreholes have been drilled under various water supply schemes. Examples of projects that have been executed or are still being executed in the area are the National Borehole Program (NBHP), UNICEF Rural Water and Sanitation (RUWATSAN), Directorate of Food, Roads and Rural Infrastructure (DFRRI), Kwara State Utilities Board (KSUB), and the Niger State Water Board (NSWB).

Borehole yields are low to moderate and rarely exceed 20 m^3/hr. In some cases boreholes have been abandoned due to unacceptably low yields under 1 m^3/hr. With an annual mean rainfall of 1 200 mm, 90% of which is lost through evapotranspiration, an annual mean groundwater recharge of about 135 $\times$ $10^6 m^3$ was estimated (Kehinde and Loehnert, 1989) for this central area of Nigeria. This is in spite of the depth to water rarely exceeding 50 m in unconfined aquifers.

The need to reduce the excessive reliance on groundwater sources in the face of unknown and unpredictable replenishment through surface sources has been stressed. For example, though the annual recharges of the two main aquifers in the Maastrichtian Rima Group of Sokoto Basin (the Wurno and Taloka Formations) have been found to be approximately 4.26 $\times$ 10^6m^3 and 73 $\times$ 10^6m^3, respectively, with corresponding storages of 400 $\times$ 10^6m^3 and 2.12 $\times$ 10^7m^3, using them for large irrigation water supply will result in the "dead" storage being reduced (Oteze, 1989) by mining as the "safe" yield is exceeded.

IV. WATER MANAGEMENT STRATEGIES

A. WETLAND UTILIZATION

Land that is flooded during the wet season is referred to as *fadama* in Hausa language. In terms of areal extent, the FAO (1976) estimated that the fadamas account for 66 million hectares of the entire land area constituting the humid tropics. They occupy 9% of Africa's land area, while in Nigeria, 7% (66 000 km^2) is found to be fadamas. In the northern part of Nigeria, they also cover 5 to 7% of the land area and the proportion increases towards the south (Singh, 1982).

The characteristic harsh climate and the frequency of drought and desertification in the semi-arid region of northern Nigeria have underlined the potential of the fadamas in diverse areas. As a consequence, states that are particularly affected by the inclement climate have come to regard the fadamas located within their borders as life-lines. It is not unusual, therefore, to find the greatest agricultural activities on an all-year basis confined to the fadamas. In Sokoto State, for example, though both irrigated and rainfed agriculture were practised, the latter was more developed in the fadamas. Better soil moisture regimes, availability of water for supplementary irrigation and more fertile soils are the factors responsible for the higher and sustainable agricultural productivity of the fadamas. Productivity would be four to five times that of cultivated upland, as they have an extended growing season that spans several months after the cessation of the rains in the semi-arid regions of northern Nigeria.

Fadamas are characterized by high water tables which result from flooding by rivers as they flow in their flood plains. Among the important fadamas in the semi-arid regions of northern Nigeria are those formed by the Sokoto-Rima. For instance, the area south-east of Moriki-Fokku line that is the source of the Sokoto and Rima rivers and their tributaries is characterized by an impermeable basement complex which creates a quick run-off. The area north of this line has more permeable sedimentary soils that allow some infiltration. The rivers form diverse flood plains that are waterlogged for varying periods of the year. In 1969, the FAO stated that of the 600 000 hectares irrigable land found in Sokoto State, only 160 000 hectares are of upland soils. The remaining 440 000 hectares, or 73%, are fadamas found mainly in the Sokoto-Rima flood plains. A lower figure of 300 000 hectares was, however, given by the World Bank in 1981.

The fadamas formed on the flood plains of the Sokoto-Rima river system have been inventoried and classified into major, intermediate and minor types based on the potentials for shallow groundwater development. Table 5 presents the extent and location of each category.

Table 5

Classes, Area and Flood Plains of Fadamas of Sokoto State

Class	Estimated Area (10^3 hectares)	Flood Plains
Major Fadamas	178	Sokoto/Rima
Intermediate	52	Sokoto, Zamfara, Bunsuru, Gulbinka
Minor	50	Sokoto, Zamfara, Sheila, Kondawa, Gulbinka, among others
Total	280	

The major fadamas found in the Sokoto-Rima floodplains have the highest water yield with storage coefficients of between 10^{-1} and 5×10^{3}. They comprise unconfined and semi-confined aquifers with water levels fluctuating from 0.2 to 0.8 m.

Apart from the benefits derivable from the Sokoto-Rima fadamas for water supply on a year-round basis, recession farming is also practised. At the peak of the rainy season, excess water tolerant crops are cultivated in the fadamas, the main types being rice and sugar cane. As the dry season approaches and water recedes to a point where only the perennial fadamas and the valley bottom are still water logged, the parts of the fadamas thus drained are put to other crops. The major crops favoured in the recession farming are millet, sorghum, cowpea, onions, as sole cropping or multiple cropping. At the peak of the dry season, only sugarcane is found under cultivation in small areas of the fadamas.

B. Interbasin Water Transfers

Interbasin water transfers occur when surface water (especially river flow) is channelled from a basin where a surplus exists to another where it is deficient. The transfer is effected by means of pipes, tunnels, canals, or natural river courses which convey the water from intermediate storages by gravity or pumping.

Available hydrological records suggest that since 1968 there has been a distinct regional trend in sharply reduced run-off in the river systems of northern Nigeria. The vagaries of climate in this part of the country were accentuated by the droughts of 1970-73 and 1983-85. Desertification on a large scale has also been experienced in the region, as land areas engulfed by sand dunes increase and move southward annually at a steady pace.

The characteristic harshness of the climate in the semi-arid part of northern Nigeria has been made more severe by recent natural hazards. If the trend continues, the low runoff or inflow will have an adverse effect on the performance of existing impoundments such as the Tiga, Bakolori, Goronyo and Zobe dams. In most cases, the identified irrigable land resources cannot be effectively irrigated with the available surface water resources. If the extensive irrigation development in the drought-prone areas is to be promoted, then water must be imported from water surplus basins further south.

Table 6 shows the internal interbasin water transfer schemes proposed by the Federal Department of Water Resources (now Federal Ministry of Water Resources) in order to ameliorate the effects of drought and desertification in the semi-arid environments of northern Nigeria.

Finally, a regional water transfer scheme between Zaire-Chad-Niger (ZCN) has been proposed to convey the excess and "wasted" waters of the Zaire River which are presently emptied into the ocean, to the dry, drought, and desertification-prone areas of northern Nigeria and central Africa. It is estimated that the Zaire River discharges as much as 70 000 m^3/s annually into the ocean. Part of this amount (20%) according to Umolu and Oke (1986), which is twice the mean annual flow of the Niger, could be transferred into Lake Chad and thence to the Niger River. In doing this, the need to be cautious has already been emphasized (Oyebande and Balogun, 1991).

Table 6

Interbasin Transfer Projects

	Name of Project	Exporting Basin/River	Importing Basin/River	Volume of Transfer (Mm^3)	No. of Reservoirs	Approximate Length (km) and Means	Potential Uses of Transfer
1.	Dindima	Gongola	Misau	1 064	1 or 2	62, Tunnel	Irrigation
2.	Zamfara	Zamfara and Ka	Sokoto	730	2 or 4	87, Tunnel/ Canal	Irrigation and Water Supply
3.	Hawal	Hawal	Ngadda	300	2	50, Canal/ Pipe	Irrigation and Water Supply
4.	Gurara	Gurara	Kaduna	1 300	1	30, Tunnel/ Canal	Irrigation and Hydropower
5.	Mada	Mada	Katagun	300	1	100, Canal	Irrigation and Water Supply
6.	Tum (Alternative to Hawal)	Tum	Yedseram	300	1	25, Tunnel/ Pipe	Irrigation

CONCLUSION

The lack of adequate and environmentally sound water resources management in Third World countries in general, coupled with inclement climate in the semi-arid regions of northern Nigeria serves to aggravate the occurrence of some natural hazards. The most prominent of these hazards include drought, desertification and soil erosion by water and wind. The role played by low and unevenly distributed rainfall in curtailing the effectiveness of developmental efforts is a major factor in the area.

Dams and their associated reservoirs have been identified as a valuable instrument for conserving the water of the rivers whose regimes are too variable for direct abstraction. These impoundments have been and are being used in northern Nigeria to provide vital water supplies for agricultural and other needs. The high evaporation rates from these reservoirs, however, pose serious problems.

Population pressure has also induced the exploitation of groundwater sources particularly in and around most urban centres in the region. Because information needed for sustainable development of the groundwater resources is not available, they have been over-exploited in a number of cases in semi-arid northern Nigeria.

The fadamas have immense potential as a water utilization strategy for providing food and water supplies. However, if the water is tapped excessively through the construction of wells and boreholes, this vital resource may cease to be renewable and an ecological imbalance may result.

In order to attain a sustainable level of water resources development, certain strategies must be adopted. These include interbasin water transfer from more humid areas with proven long-term surplus to the semi-arid parts where water deficit is chronic. The transfer may be internal or external. Indeed transfer from outside Nigeria appears to be imperative in the long run. The ameliorating influence that the fadamas have must be fully recognized and understood. This is achievable through articulated and well-conducted research into the peculiarities inherent in these natural environments. The areas to be studied must of necessity include soil water balances through which the complex interrelations between climate and the environment can be thoroughly understood.

Since the strength of any research lies solely in the timely application of the findings, a coordinated and prompt implementation of results of studies should replace the existing attitude of decision makers. Policy options that aim at making the users bear a reasonable portion of the cost of water supply must be considered in order to reduce wasteful use and reduce the dependence on the fast diminishing resources of governments.

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Revue canadienne d'études du développement

Published by / Publié par

THE INSTITUTE FOR INTERNATIONAL DEVELOPMENT AND CO-OPERATION
L'INSTITUT DE DÉVELOPPEMENT INTERNATIONAL ET DE COOPÉRATION

At present, an increasing number of countries in arid zones (Middle East, Maghreb, Sahel) are approaching the limits of their available water resources. There is a need to address this problem with comprehensive data and analysis of the situation, workable management principles and innovative technological approaches, as well as case history experiences from some countries in the region.

This publication, which is one of the resulting activities of IWRA's Seventh World Water Congress held in Rabat during May, 1991, is an important background handbook to assist decison makers in planning national and regional programs. It could serve also as a reference for those attending regional meetings in preparation for the Global Environment Conference in Rio de Janeiro in 1992.

À l'heure actuelle, un nombre croissant de pays du Moyen Orient, du Maghreb et du Sahel arrivent aux limites de leurs ressources en eau. Devant cette situation, il est urgent de faire l'analyse de la situation et l'étude des programmes mis en oeuvre dans la région avant de mettre en place de nouvelles technologies ainsi que des méthodes de gestion durable.

C'est ce que propose le présent ouvrage, qui est une des résultantes des activités de la Septième conférence annuelle de l'Association internationale des ressources en eau qui a eu lieu à Rabat en mai 1991. Il s'agit donc d'un ouvrage de base important qui sera d'une grande utilité aux décideurs lors de la planification de programmes régionaux et nationaux sur la question, tout comme à ceux qui assisteront aux réunions régionales précédant la Conférence globale sur l'Environnement de Rio en 1992.

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