WATER RESOURCES POLICY AND PLANNING:

TOWARDS ENVIRONMENTAL SUSTAINABILITY

ISPAN

IRRIGATION SUPPORT PROJECT
FOR ASIA AND THE NEAR EAST

Sponsored by the U.S. Agency for International Development

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SUMMARY

A study of the environmental sustainability of water development and use was conducted as one of a series of applied studies by ISPAN for the Bureau for Asia and the Near East. The study was undertaken in four medium-size cities and their surrounding agricultural areas. Information was collected on the extent to which water development and use were consistent with, or detrimental to, maintenance of the long-term adequacy and quality of water resources. It is hoped that conclusions drawn on some policy and planning measures will contribute to the environmental sustainability of future water-related programs and projects.

The Study

The purpose of the study was to examine how effectively water resources are used in selected case studies and to draw some conclusions on water sector policy-making and project planning to support environmental sustainability.

The study was environmentally oriented in addressing primarily the maintenance of the water resource, rather than the sustainability of the facilities to deliver and use water. Its focus was the concern implied by the Brundtland definition of sustainable development.[1]

Four medium-size cities in Asia and the Near East were selected for investigation. Each has an agricultural hinterland. The cities are:

- Fayoum, in Egypt, located in a topographic depression, so that none of the water conveyed from the Nile is returned; all of it accumulates in a saline lake or evaporates

- Beni Mellal, located near the Tadla irrigated area in Morocco, where the systems that bring in surface water have proved a magnet for explosive in-migration drawn by irrigated agriculture, urban and industrial development, and hydropower

- Faisalabad, the third largest city in Pakistan and a major industrial center with a poorly developed infrastructure, located in the Indus river basin, home of the largest irrigation system in the world

- Khon Kaen, located in seasonally water-short northeast Thailand, which has relatively well-developed water, wastewater, and other urban infrastructure systems.

The results of the field investigations were supplemented by knowledge gained from other recent ISPAN experience.

Primary Water Issues

In all four study areas and countries, water has been an important focus of economic development and donor assistance for many years. The water-related programs and projects generally have been beneficial. However, some important problems remain and in some instances have been aggravated by these interventions.

Direct evidence of the problems is seen in water quality degradation from pollution, actual or projected water shortage, and waterlogging and salinization caused by irrigation. These effects have actual or potential negative impacts on access to water, health, ecology, food production, and economic conditions. High rates of population growth compound the problems. The multiplicity of interests in water impedes efforts by governments to devise and implement solutions.

[1] "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Source: World Commission on Environment and Development, 1987, *Our Common Future.*)

The specific problems vary from case to case. In Fayoum, a serious issue is the accumulation of water and salt in Lake Qarun, where the level of salinity already exceeds that of the sea. Water is brought to Fayoum from the Nile system but not returned. Every drop brought to Fayoum, where some is used wastefully, is therefore a loss to the Nile system, where it would have been reused several times.

In Beni Mellal and Tadla, contamination of drinking water by human wastes and river pollution by industrial wastes are important problems. In the longer term, national water scarcity in Morocco may be reflected in Tadla because of in-migration from other areas.

Uncontrolled discharge of industrial and domestic wastewater into the water environment in Faisalabad puts the health of a large population at risk because of household use of polluted water and food chain contamination by hazardous substances. Nationally, the accumulation of water and salt in soils of the Indus basin must be reversed in order to maintain agricultural production.

Water pollution by industrial wastes and seasonal water shortages are priority issues in Khon Kaen. In all four locations, overuse of agricultural chemicals is a poorly quantified but potentially very serious health and ecological hazard.

By early next century, water shortage will be a serious national issue for Egypt, Morocco, and Pakistan. It is already a major problem for northeast Thailand. Conservation should therefore be a key element of water planning in all four countries. Nevertheless, water wastage is not adequately penalized in any of the cases.

Planning Deficiencies

Planning deficiencies were evident in several countries where projects have been implemented with little concern for protecting water resources. For example, irrigation systems, especially the older ones, have been installed without drainage systems, requiring expensive retrofitting to deal with waterlogging and salinization. Irrigation in Fayoum is causing excessive water loss for the country. Unlike in the Nile system as a whole, agricultural underdrainage in Fayoum, together with water wasted by farmers who do not need it, is not made available for reuse by being returned to the river but is lost by evaporation and the damaging enlargement of a salt lake.

There is no effective treatment of industrial wastes in the three cases where industrial development has taken place. In general, industrial wastes are allowed to mix with domestic sewage, thus preventing the use of effluent and sludge in agriculture. Pulp mill wastewater in Khon Kaen has apparently killed fish and denied farmers the use of water for irrigation during extreme seasonal shortages. Another common problem, even in donor-assisted programs and projects, is the combination of domestic sewage, industrial wastes, and stormwater in a single stream that adds to the volume of water polluted and to the costs of correction.

There are some examples of low-cost urban wastewater treatment in multistage stabilization lagoons, but most of the population in the four cities have no municipal sewage treatment facilities. In Beni Mellal, a very expensive activated sludge wastewater treatment plant lies idle because of the high cost of the electricity to operate it.

Waterborne and water-associated diseases are a hazard in several of the study areas, especially for periurban and rural residents. The cities have piped water systems, but many residents depend on polluted surface sources or wells contaminated by nearby latrine pits, especially when the water table is elevated by waterlogging. The incidence of diarrheal diseases is high. Water-associated diseases such as malaria are attacked mainly with biocides and drugs. The malaria program in Pakistan conducted with donor assistance since 1961 is an example. After three periods of temporary success, it has been foiled by the development of resistance to these substances, leaving the environment contaminated by DDT and malathion. Water management and behavioral control methods continue to be ignored.

The conservation and reuse of water form no part of sector policy or subsector programs and projects, in spite of growing water shortages exacerbated by pollution in all four cases. In addition, there are inadequate provisions for the control and monitoring of chemicals entering into water bodies.

In only one instance are the revenues adequate to cover the cost of providing urban water service. In none of the four cases does this apply to providing urban wastewater collection or irrigation water supplies.

At the planning stage of water development and water use programs and projects, the case studies show that the following substantive principles and measures should be considered to support environmental sustainability:

Resource availability and shortage:

- Conservation of water in all water subsectors through minimization of transmission losses and reduction of wastage by users
- Management of demand through water and wastewater pricing in proportion to volume and through the removal of subsidies on such factors as water for pumping
- Reuse of wastewater and sludge
- Conservation of energy, funds, and other resources used in water sector programs and projects
- Planning of new and rehabilitated irrigation facilities as parts of complete systems, including farmer needs, methods and rates of water application, delivery systems, drainage, operation and maintenance, and revenue generation
- Maintenance of base flows to support ecology and biodiversity, and the conduct of studies to quantify such needs

Water quality and health:

- Provision of drainage with irrigation systems and of sanitation and sewerage with urban water supply systems
- Giving high priority to the reduction of pollution by hazardous industrial and agricultural substances
- Separation of waste streams such as sewage, stormwater, and industrial wastes
- Provision of low-cost wastewater treatment for urban areas by the early acquisition of sites for lagoon systems and further demonstration use of artificial wetland systems
- Phased zero discharge systems for industrial wastes, beginning with hazardous components, and provision of separate recycling/disposal facilities for such components
- Location of industries to lessen the impacts of wastewater disposal on the water environment
- Use of water management and behavioral methods, as well as biocide-based techniques, to control water-related vector-borne disease
- Use of non-waterborne excreta disposal systems in water-short areas where conditions permit

Other case study conclusions include the importance of:

- Data collection programs directed towards the support of decisions and policies that must be made across the water sector, not limited to the interests of particular users
- Consideration of long-term trends well beyond the expected useful life of first-stage facilities in preparing feasibility evaluations of proposed projects

National or Basin-level Policies

None of the case study countries has an agency or process to devise policies that apply to all water subsectors, or to offer knowledgeable and independent environmental reviews of proposed water-related projects. There is a general reluctance to charge users the full capital and operating cost of water supply and wastewater disposal services, much less the opportunity cost of water with the intent of discouraging wasteful use. Environmentally sound policy decisions can only be assured if they are made by entities that are independent of particular water users.

Local conditions and needs vary and must affect the formulation of national or basinwide strategies. Nevertheless, there are certain features of an overall water policy framework that cannot be excluded it if is to support sustainable water development effectively. These include:

- Transparency and adequate feedback from all stakeholders, including the public, to ensure that the policy is acceptable
- A judicious combination of incentives and enforcement to protect water resources
- Procedures for drawing up rules and setting priorities and for resolving disputes
- Provisions for environmental assessments of all activities and projects affecting water

To ensure that water-related decisions are not biased, it is important to separate the power and authority of governance from the functions of providing water services and infrastructure. The countries studied illustrate the negative effects of not maintaining this separation. Irrigation systems have been planned and implemented without regard for the needs of users. Institutional barriers that inhibit cooperative action at the local level cannot be removed because they have been imposed by the national government. Service providers protected by government sponsorship are not accountable to their customers. Inappropriate or unnecessary facilities have been constructed, maintenance is poor, and operating procedures are unsuitable.

Environmental Assessments

Environmental assessments, now well recognized in many industrialized countries, are beginning to be adopted in some developing countries. More and more projects are being subjected to the process to ensure that they conform to standards of acceptability and sustainability.

However, many key decisions about water are made in conjunction with infrastructure investment decisions. Because these investments are frequently sponsored by government agencies, environmental assessments are generally treated as merely an aspect of preinvestment planning by or on behalf of the project sponsor or owner. Environmental assessments become searches for measures to mitigate environmental impacts and seldom seriously call into question the fundamental elements of projects.

Programs and projects for water infrastructure and use should be thoroughly assessed for potential environmental impacts at the planning stage before detailed designs have been drawn up (these can be assessed later), because once a project has found an interested funding source there is great pressure to proceed.

The criteria for conducting environmental assessments should be determined by an entity independent of the sponsoring or implementing organization. The results should also be approved or disapproved independently. Informed public opinion is vital in both the scoping and review of the assessments.

Donor Opportunities

International donors have both obligations and opportunities in relation to the maintenance of environmental sustainability in the water sector. Their obligations relate to the quality of interventions they make: to ensure that donor-financed programs and projects are at least environmentally benign. They also have opportunities to use their influence to promote both national and international efforts to encourage environmentally sustainable water development and use. To make the best use of these opportunities will require some new approaches by donors.

The critical strategic, policy, legal, and capability improvements that are needed will in many cases depend on longer-term, and more consultative and flexible, approaches than the traditional loan-project cycle allows. These improvements should provide frameworks for individual development projects, rather than being dependent upon such projects.

Country needs for donor assistance, therefore, include supplementing the project-by-project approach that relies heavily on loan covenants or institutional studies tacked onto infrastructure projects. Donors should support only environmentally sustainable water programs and projects, assist host countries to develop the right water policies and capabilities, and coordinate their efforts to prevent one donor from inadvertently undercutting the sustainability approach of another.

Towards Environmental Sustainability

The water resource constraints in these and many other countries will worsen. Donor support for development planning can contribute to environmental sustainability of water development and use. It cannot increase the supply of water. However, the institutional and procedural improvements suggested in the conclusions of this report should be beneficial and will certainly cost less than such supply-side devices as interbasin transfers or the desalinization of sea water, which some of the countries might eventually have to consider as well.

Better definitions of terms are needed for measurement of progress towards achievement of environmental sustainability. The Brundtland definition of sustainable development is indeterminate and can be regarded as unachievable, since it sets no limit on future needs. Definitions of the environmental sustainability of water development and the efficiency of water use are needed that, taken together, will embody the general sense of the Brundtland definition of sustainable development, provide a basis for measurement of performance, provide explicitly for both human and ecological needs, address both quantity and quality of water, and provide for preservation not only of the water resource but also of other related resources.

CONTENTS

PREFACE

This report on the environmental sustainability of water resources is based primarily on case studies of four secondary cities and their hinterlands in four countries. They are: Fayoum in middle Egypt, Beni Mellal and the Tadla irrigated area in central Morocco, Faisalabad in the Punjab province of Pakistan, and Khon Kaen in northeast Thailand.

The study was conducted by the Irrigation Support Project for Asia and the Near East (ISPAN), a water resources and water policy project sponsored by the Asia and Near East Bureau of the U.S. Agency for International Development, as one of a series of applied studies on water issues.

Four expatriate field investigators (Michael Colby, Richard English, William Jobin, and Bechir Rassas) worked in pairs with local experts in Egypt, Morocco, Pakistan, and Thailand for three weeks per country to collect and compile the case study data and findings. The experts were provided through Environmental Quality International in Cairo, the Institute of Agronomy and Veterinary Science Hassan II in Rabat, Enterprise & Development Consulting (Pvt.) Limited in Islamabad, and the Water Resources and Environmental Institute of Khon Kaen University. These consultants were: (in Egypt) Abdallah Bazaraa, Safwat El Mahdy Abdo, Abdel Aziz El Dakhakhni, Kamal Tolba Ewida, Fatma El Gohary, Soha A. Kader, and Diaa El Monayeri; (in Morocco) Abdelhafid Debbarh, Mohamed Daondi, Farouq Alioua, Khalid Khallayoune, and Ali Hammani; (in Pakistan) Nasir-ud-Din, Tariq Husain, Syed Ayub Qutub, and Najib Murtaza; and (in Thailand) Sanguan Patamatamkul, Wanpen Wirojanagud, Suparerk Sinsupen, and Sinee Chuangcharn.

The team made use of secondary data and rapid appraisal methods, including project documents, data and reports of international and national agencies, informant interviews, and field observations. The final report was prepared in the ISPAN Technical Support Center using supplementary information from other ISPAN experience in Asia and the Near East, particularly regarding institutional matters. Kathy Alison provided facilitation and review inputs.

The team is grateful to USAID mission officers, country officials, and informants for the cooperation and hospitality they offered to the field investigators; to Tracy Atwood, Herb Blank, and Tim Miller of the USAID Bureau for Asia and the Near East for reviewing drafts and providing many valuable suggestions; and to Gil Corey, Bill Easter, and Dennis Moran for their helpful comments. The authors clearly absolve these persons of any responsibility for the conclusions and opinions presented.

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INTRODUCTION

Background

For several decades, both donors and host countries in Asia and the Near East have been making extensive investments to develop or rehabilitate irrigation, potable water, and sanitation systems. Most of the irrigation systems have been completed, but potable water and sanitation systems continue to be a critical need, given the explosive growth of urban areas. Looked at broadly, infrastructure development has been reasonably successful. Agricultural production generally has kept pace with food requirements, and expanded water services for domestic use have supplied ever-increasing concentrations of people in the region.

However, this vast development has placed severe burdens on countries with limited financial resources. Governments in the region have often been unable to provide the institutional support to keep the systems in acceptable condition or provide adequate water-related services. As a result, they are attempting to transfer management and financial responsibilities for irrigation systems to users through turnover programs and are leaning towards privatization. While these approaches will create a broader base of stakeholders, they also are likely to mask some intractable problems rather than resolve them. Users are not necessarily better equipped than governments to deal with complex system management issues.

Furthermore, system development has been paralleled by markedly increased water demands. The last quarter of the twentieth century has witnessed a rapid growth in population, urbanization, and industrialization throughout much of the developing world, with corresponding pressures on natural resources and ecosystems, intensified competition for limited water resources for agriculture, municipal water supply and sanitation, industrial processing, and power generation, and concern for maintaining the quality of the water resource itself.

Typically, donors address water resources problems on a project-by-project basis, with each project sponsored by a single implementing agency that has a limited geographical and/or functional interest. However, the effects of overuse and pollution of water transcend such narrow boundaries, which although understandable in the context of a need for clearly defined targets, budgets, and schedules, are an impediment to overall resource management and can obscure the complexity of interrelationships in a basin or region.

Investments in system development have diminished over the past 5 to 10 years because of shrinking financial resources and a widespread consensus that most of the easier and more economically viable systems have already been completed. In irrigation, particularly, a pervasive concern that many of the systems have serious design flaws and cannot be managed efficiently is responsible for a dramatic shift in attention and funding towards making past investments sustainable.

Sustainability has been treated by donors and cooperating countries as maintaining the long-term viability of systems so that the delivery and use of water for a broad range of human requirements is ensured. Thus, strengthening the institutional infrastructure by enhancing public sector capacities, expanding financial responsibilities, and broadening user participation, has been seen as a means of sustaining the physical component of systems. But this emphasis on the delivery of services has often ignored concerns about the condition and availability of the resource itself. Many regions are suffering from water shortages, and the quality of the resource is being seriously degraded. It is likely that the next generation of development investments will focus much more strongly on environmental sustainability.

The environmental sustainability of water resources recognizes that water quantity and water quality are closely intertwined, since the degradation of the resource increases the cost of certain water uses, just as the need to use a more distant source would. Resource integrity requires controlled development and use, and the constant revision of what is considered adequate to meet present or future demands for water. National and regional priorities and conditions change, and the criteria for environmental sustainability will change correspondingly. There must be constant vigilance that the resource is neither misused nor mismanaged, and that water is not used in ways that damage or waste other resources. This is consonant but not identical with the Brundtland definition of sustainable development (World Commission on Environment and Development 1987).

Global Trends in Water Resources

The study highlights three significant global trends:

- Widespread water shortages
- Increasing competition among and within different sectors for limited resources
- Growing degradation of the quality of water resources

Water Shortages

The contention that the freshwater on the planet could support 10 times the present population if only it were properly distributed is fallacious for four reasons:

- Geographical, seasonal, and year-to-year fluctuations in precipitation contribute to wide variations in the levels of assured water resources, so that only about 35 percent of total runoff can be considered reliable.
- Compounding increased demand just from the magnitude of population growth is the per capita increase in consumption from the rapid urbanization in developing countries.
- The abstraction and use of the entire freshwater flow would be ecologically unsustainable because of damage that would result to natural habitats and to soil and water resources.
- Much of the world relies on flowing water to transport its domestic, industrial, and agricultural waste products, thereby reducing the supply of water of adequate quality for other beneficial uses.

Withdrawals accounted for only 23 percent of the reliably available resources six years ago; nearly 67 percent was dissipated uselessly in the form of flash floods. At current usage rates, there is at best enough water for one more doubling of the human population, which will occur in another 35 years. By 2030, taking into account potential water conservation, world freshwater needs will increase by about 60 percent (Seckler 1993).

In addition, urban domestic consumption rates are typically 5 to 10 times higher than rural rates because of easier access, losses in piped distribution systems, and the use of water to transport and assimilate wastes. Within the limitations imposed by supply or demand management programs, water withdrawals for domestic use are likely to increase more rapidly than population growth.

These estimates do not take into account the effects of human intervention on broad ecological processes involving such features as wetlands and intertidal zones. There is very limited understanding of how much water the ecosystem at large requires to sustain itself, and even of the hydrological system upon which human activity ultimately depends.

Competition for Water

For the majority of developing countries, agriculture continues to be the primary source of economic growth, the main sector of employment, the principal source of food, and the highest water consumer by a factor of at least five (see Table 1.1). Yet, environmental and development indicators alike suggest that the advances made in food production during the Green Revolution may not be sufficient in the face of current trends in population growth, despite donor and host government attempts to make improved agricultural technology, inputs, and practices widely available. For example:

- The area under irrigation doubled between 1950 and 1978, but since then has shrunk by 7 percent.
- The area planted with grain has remained the same since 1981.
- Since 1984, per capita grain production has fallen by approximately 1 percent per year (Brown 1993).

Rural poverty has persisted and in many areas has increased, despite a generation of programs to improve rural living standards. Many governments face the need to balance the cost of maintaining adequate water supplies for agriculture with the cost of providing potable water supplies, sewerage, and drainage for their growing urban populations.

Degraded Water Quality

Most water withdrawn for use from any surface or subsurface source and used is either returned to the usable system, as groundwater or surface flow, or lost to the atmosphere or to a salt sink, usually the sea. This process of partial return can repeat itself but, because of deteriorating water quality, not endlessly. Return flows of used water carry contaminants, some of which are biodegradable and are eventually rendered harmless by natural biochemical processes, but others, such as toxic wastes from industry, pesticides, and leached salts from agriculture, can be removed only with difficulty and at great expense.

When resource streams are mixed, for example, by combining storm flows with wastewater or by discharging industrial wastes into water bodies, too much reliance is placed on the assimilative capacity of the receiving waters, and wastewater treatment is made difficult and unnecessarily expensive. Such mixing also degrades a much greater quantity of freshwater. The assimilation of wastewater requires the maintenance of a clean base flow that can, through a combination of dilution and biodegradation, absorb a limited amount of contaminated wastewater without impairing the quality of the water resource for subsequent reuse.

Water Resources in Asia and the Near East

The Near East is one of the world's most extensive arid regions. Nearly three-quarters of the area from Morocco through Iraq has inadequate water and soils to support agricultural production. The total annual internal renewable water resources measure approximately 570 cubic kilometers, or 570 billion cubic meters (BCM), less than 2 percent of the world's annual runoff. A number of countries in the region face acute water stress.

By contrast, the countries of South and Southeast Asia have about 25 times the internal renewable water resources of the Near East, but nearly two-thirds of the water from the torrential monsoons that deposit the bulk of this resource is lost in flash floods. Fifteen percent of the 12,000 BCM per year of renewable water resources in South and Southeast Asia is now withdrawn for use. Although clearly not as stressed as the Near East, South Asia is at the point of confronting significant water management problems and prohibitive costs for developing new sources.

Population growth and urbanization are the two most significant demographic developments affecting the quantity of water supplies. With an average annual growth rate of 3.6 percent, the population of the countries of the Near East is expected to double between 1990 and 2010 (USAID 1993). The growth rates in South Asian countries are substantially lower now, with a doubling of the population in perhaps 50

TABLE 1.1 – COMPARISON OF WATER REQUIREMENTS IN COUNTRIES OF THE NEAR EAST, SOUTH AND SOUTHEAST ASIA

	ANNUAL TOTAL WATER RESOURCES (cubic km)	ANNUAL WITHDRAWAL AS % OF TOTAL RESOURCES	ANNUAL PER CAPITA WITHDRAWAL (cu. meters)	WITHDRAWAL BY SECTOR (percent)		
				DOMESTIC	INDUSTRY	AGRICULTURE
NEAR EAST**	379	46	728	7	6	87
Algeria	18.4	16	161	22	4	74
Egypt	58.3	97	1202 +	7	5	88
Iran	117.5 *	39	1362	4	9	87
Iraq	100.0	43	4575	3	5	92
Israel	2.2	88	447	16	5	79
Jordan	1.1	41	173	29	6	65
Lebanon	4.0	16	271	11	4	85
Libya	0.7	404	623	15	10	75
Morocco	29.7	37	501 +	6	3	91
Oman	2.0	24	325	3	3	94
Saudi Arabia	2.2	164	255	45	8	47
Syria	36.5	9	449	7	10	83
Tunisia	4.3	53	325	13	7	80
Yemen	2.5	136	1167	5	2	93
SOUTH & SOUTHEAST ASIA**	10982	6	434	6	6	88
Afghanistan	50	52	1436	1	0	99
Bangladesh	2357	1	211	3	1	96
Bhutan	95 *	0	15	36	10	54
Cambodia	498 *	1	69	5	1	94
India	2085	18	612	3	4	93
Indonesia	2530	1	96	13	11	76
Laos	270 *	0	228	8	10	82
Malaysia	456	2	765	23	30	47
Myanmar	1082 *	0	103	7	3	90
Nepal	170	2	155	4	1	95
Pakistan	468	33	2053 +	1	1	98
Philippines	323	9	693	18	21	61
Sri Lanka	43	15	503	2	2	96
Thailand	179	18	599 +	4	6	90
Viet Nam	376 *	1	81	13	9	78

Source: WRI (1992:328–29). Countries in boldface are those facing conditions of water stress (percent withdrawn exceeds 20); a large part of India falls into this category, as does northeast Thailand.

* Annual internal renewable water resources only

** The listed countries only. Averages are weighted.

\+ Years to which data apply range from 1970 to 1987. For the case study countries, updating populations to 1992 yields the following per capita withdrawals (in cu.m.): Egypt 1,000; Morocco 440; Pakistan 1,240; Thailand 560.

years, but the total population of this region is already six times that of the Near East.

The population of urban areas in developing countries is expected to grow by 160 percent during this period (World Bank 1992), while rural settlement is expected to level off by the year 2015 in the Near East and South Asia. Because per capita water consumption is 10 times greater in urban than in rural areas, an expansion of the urban population of this magnitude will place enormous strains on water treatment, water supply, and wastewater disposal services.

Water development in Asia and the Near East has supported the demographic, economic, agricultural, and industrial changes that have taken place. It has also produced constraints on the future beneficial use of water resources. Future water development and use must avoid the mistakes of the past if the needs are to be satisfied. The negative effects of previous water-related activities include polluted water supplies, loss of wildlife habitats, depletion of aquifers, diversion of rivers away from populations needing the water, waterlogging and salinization of irrigated lands, and seawater intrusion into freshwater zones.

This study was undertaken to identify some lessons from the past to be observed when planning for the future.

Objectives of the Study

This study reflects the increasing concern of A.I.D. and other donors about the growing degradation of water resources in Asia and the Near East and seeks to:

- Assess how specific localities have developed and used their water resources and grappled with conflicting demands for water

- Draw conclusions of interest to governments and donors on some aspects of providing for environmental sustainability in water sector and water project planning

The Four Case Studies

The study draws lessons from four cases in Asia and the Near East. Each was specifically selected as a secondary city with an agricultural hinterland to obtain the benefits of experience in the development of water resources for combined urban, industrial, and agricultural requirements. The four cities were selected on the basis of their size, to make the effort manageable in the time available, and of the availability of data. They are:

- Fayoum, in Egypt, located in a topographic depression west of the Nile valley in middle Egypt. This is an arid area with annual rainfall of only 10 mm. About 30 percent of the land area is agricultural, 10 percent is settled, and the rest is desert. The population is 1.8 million. Most of the irrigation water conveyed from the Nile accumulates in a saline lake from which some evaporates.

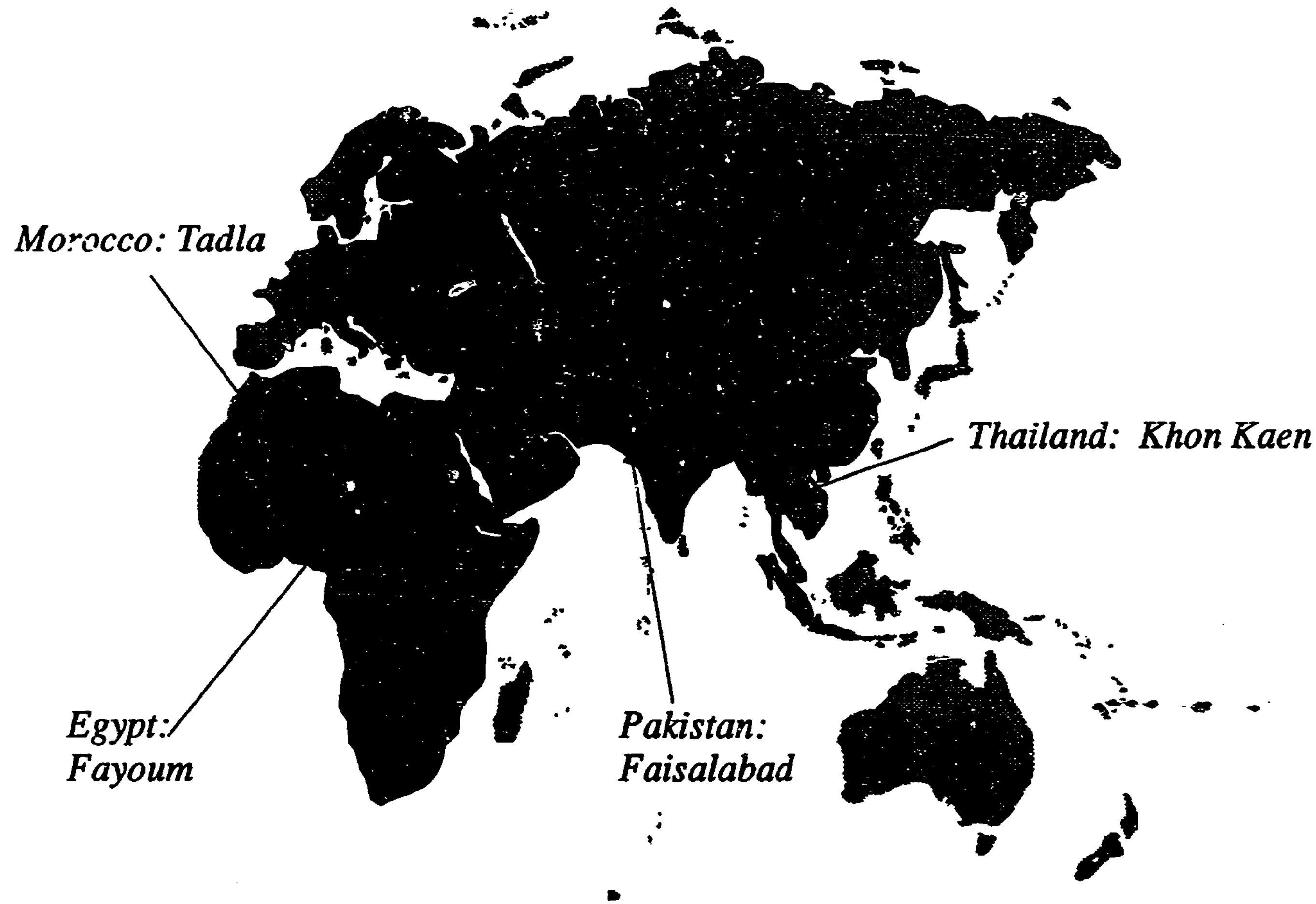
- Beni Mellal, located near the Tadla irrigated area in Morocco, where the systems that bring in surface water have proved a magnet for explosive in-migration based on irrigated agriculture, urban and industrial development, and hydropower. Beni Mellal and Tadla lie in the Oum Er R'bia basin and have a population of about 900,000. There is significant agriculture-based industry.

- Faisalabad, the third largest city in Pakistan and a major industrial center located in the Indus river basin, which has the largest irrigation system in the world. The Faisalabad district has a population of 6 million. The city is the largest studied, with a population of 2 million, and has poorly developed infrastructure and urban services.

- Khon Kaen, located in seasonally water-short northeast Thailand, with relatively well-developed water, wastewater, and other urban infrastructure systems. The city population is 135,000 and that of Khon Kaen province is 1.7 million. There is significant industrial activity.

Appendix A provides more information on each of the cases and Figure 1.1 shows where they are located.

FIGURE 1.1 - LOCATION OF FOUR CASE STUDIES IN THE NEAR EAST AND ASIA



2

WATER QUANTITY ISSUES

Overview

Many developing countries face the specter of water scarcity, created in part by explosive population growth and the concentration of people in urban areas, where per capita water demands are the highest. The shortage is exacerbated by the impact of pollution on available supplies.

Yet water allocation and consumption patterns generally do not reflect this scarcity. The maintenance of adequate water resources is threatened by demand growth that, although limited by the availability of funds for new and expanded facilities, tends to consume every drop of water that can economically be withdrawn. Competition for finite supplies continues and will increase, not only for municipal, industrial, and agricultural uses, but also for in-stream uses such as ecological maintenance, navigation, power generation, and recreation.

Inefficient municipal, industrial, and agricultural consumption is rife. Agriculture uses the most water and is apparently the least efficient. The case studies and the countries observed provided evidence of this inefficiency and of waterlogging of irrigated and downstream lands and water shortages. Table 2.1 rates the relative gravity of these problems in the four cities and countries.

Table 2.1
Water Quantity Issues Prioritized

	Fayoum EGYPT		Tadla MOROCCO		Faisalabad PAKISTAN		Khon Kaen THAILAND	
	Ctry	Case	Ctry	Case	Ctry	Case	Ctry	Case
Water Shortage	m	m	--	M	M	M	M	M
Inefficiency of Water Use	m	M	--	M	M	M	M	M
Waterlogging	M	M	--	M	M	m	m	m

M = major issue; m = minor issue; 0 = not an issue; -- = not studied; Ctry = country

Water Shortages

The four study areas are located in countries where the per capita amounts of water available per year range from 3,700 cubic meters in Pakistan to just over 1,000 cubic meters in Egypt (Figure 2.1). By the year 2020, population growth will have reduced those figures substantially, with the result that annual per capita

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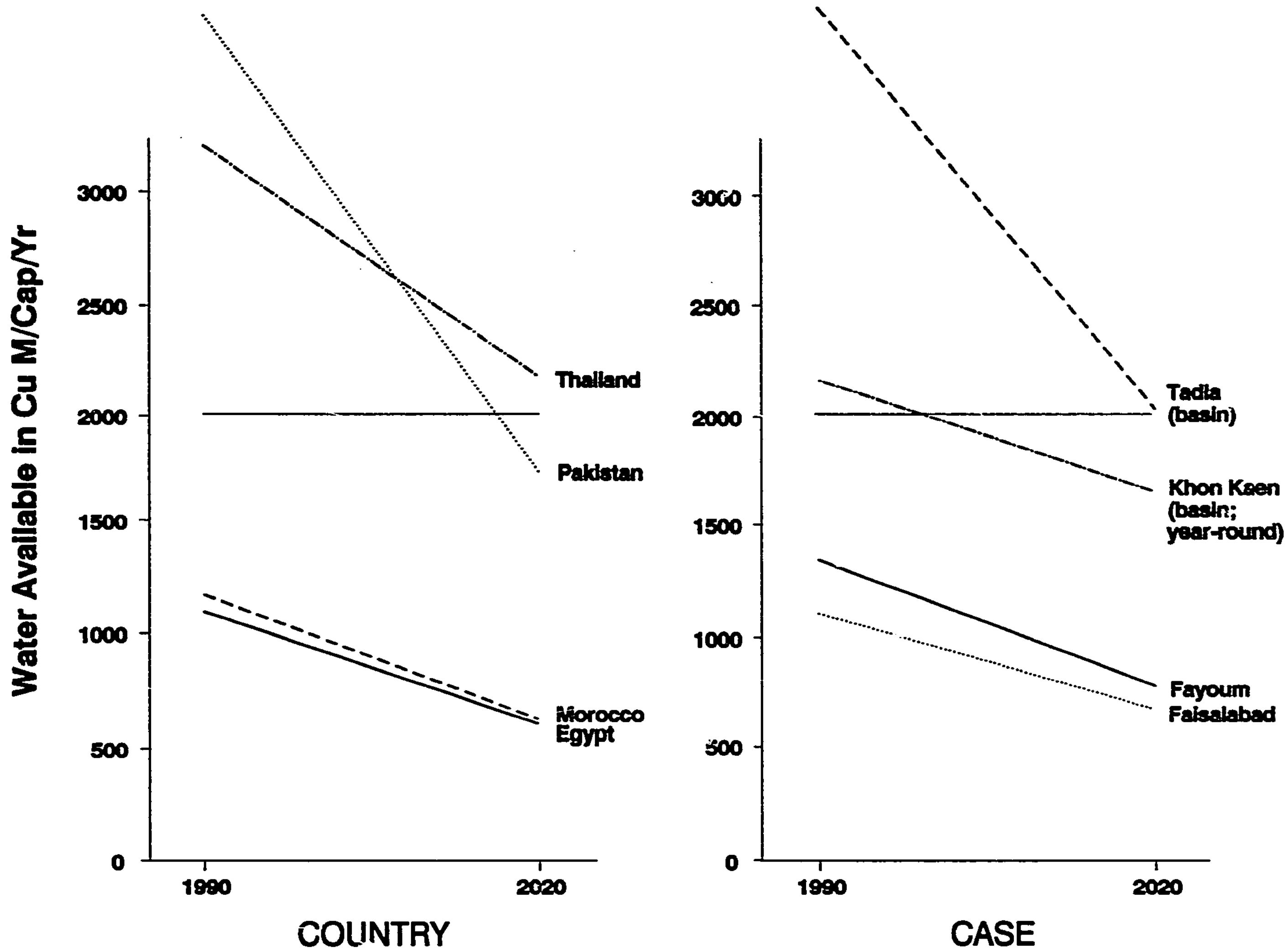
FIGURE 2.1 - WATER AVAILABILITY IN STUDY AREAS



Note: The 2,000 cu m/cap/yr line represents a widely accepted approximation of the threshold of water scarcity (see text) availability of water will be at or below 1,800 cubic meters in Pakistan and northeast Thailand and about 600 cubic meters in Egypt and Morocco. The rates of withdrawal range from one-third to almost 100 percent of the available water, taking into account multiple use through successive disposal and recapture. The figures do not give any indication of the allowance made, either in base flows or in wetland evaporative losses, to support ecological maintenance.

The accumulation of used water is a greater concern in Fayoum than water shortage. However, for Egypt as a whole, rapidly increasing population will create severe pressure on the water resource and competition among users. Fayoum gets its water from the Nile system, since local groundwater is saline. Agriculture accounts for over 95 percent of total water use. Two-thirds of this is estimated to be consumed as crop evapotranspiration, with losses of 3 percent by evaporation and 31 percent by drainage into saline Lake Qarun and Wadi Raiyan. Efforts are being made to reduce the drainage losses by extending the irrigated area. Seasonal variations in supply and the lack of incentives to value water are responsible for some conscious wastage. As the population expands, domestic and industrial water use may displace some irrigation use. The major problem in Fayoum is salt accumulation, unlike the problem in Egypt as a whole, for which freshwater to meet the needs of a burgeoning population will be the limiting factor on development. Because water used in Fayoum does not return to the Nile system, it has greatly reduced reuse potential compared with water that is used within the Nile basin. Five percent of the Nile flow is used by 3 percent of the national population in Fayoum.

In Tadla, the irrigated area is supplied with water from dams on the Oum Er R'bia and the El Abit river. The capacity of these systems exceeds the present demand but will be fully committed when another irrigated area is developed in a few years. A deficit is expected shortly after the year 2000. The supplies from these dams were severely depleted during a major drought in the early 1980s. The extent and quality of potential development are effectively constrained by the quantity of water introduced and how it is used.

Faisalabad is located in the Indus river basin, which has the largest irrigation system in the world. Annual withdrawals by the system already amount to 85 percent of the one-in-five-year low flow of the river and its tributaries. The government plans to increase this to 93 percent by 2020, mainly to extend irrigation to marginal lands. However, increases in nonirrigation demands between now and 2020 are likely to take up 75 percent of this increment. The per capita rate of water use for all purposes in Pakistan will be forced to decrease in inverse proportion to the population growth rate, which currently is 3.1 percent per year. This will require changes in demand and use patterns and will lead to water shortages before 2020 analogous to those now existing in Egypt (where annual per capita water use is now only 1,000 cubic meters). Inevitably there will be increasingly intense competition for water among agriculture and other uses around urban areas such as Faisalabad.

Seasonal water shortage is a serious issue in northeast Thailand. There is also an acute lack of good quality water in the Bangkok metropolitan area. In Khon Kaen, irrigation, currently covering 8 percent of the arable land, is limited not only by a shortage of water but also by the availability of nonfarm employment. Except in the city and some other communities, domestic water supplies depend mainly on rainwater harvested from roofs during the short wet season. Groundwater resources are generally insignificant in the northeast, although there is water- bearing alluvium near Khon Kaen. Water shortage is already a limiting factor in the development of this generally low-income area of Thailand. This year has seen a dryer than average wet season. Storage in the Ubolratana dam from May to October was the lowest in its 30 years of operation.

Calculations of water balances for the current situation and projections for the year 2010 or 2020 in the four study areas are presented in Table 2.2. The percentages of the freshwater supply currently being withdrawn are: 70 percent for Fayoum, 73 percent for Tadla, 90 percent for Faisalabad, and 61 percent for Khon Kaen, if drainage flows are deducted. These are year-round averages. The figure for Khon Kaen does not reflect the severity of the dry-season shortage.

TABLE 2.2 CASE WATER BALANCES

	Egypt Fayoum Governorate		**Morocco** Oum Er R'bia Watershed		**Pakistan** Faisalabad District		**Thailand** Lower Nam Phong Basin	
	1990	*2020*	1990	*2020*	1980	*2020*	1990	*2010*
Water (In Million m³):								
Supply								
Surface water	2,300	2,300	3,100	3,680	5,500	5,500	1,770	1,770
Groundwater	0	0	310	445	118	118		
Other								
Total	2,300	2,300	3,410	4,125	5,618	5,618	1,770	1,770
Demand								
Domestic (Rural + Urban)	57	*100*					38	*116*
Industrial	30	*60*					30	*106*
Domestic + Industrial			175	*587*	106	*300*		
Irrigation	1,518	*1,800*	2,210	*3,335*	4,956	*5,500*	1,004	*1,160*
Transfers			40	*296*				
Sanitary Discharge			63	*63*				
Total	1,605	*1,960*	2,488	*4,281*	5,062	*5,800*	1,072	*1,382*
Balance	695	*340*	922	*-156*	556	*-182*	698	*388*
Percent Used	70%	*85%*	73%	*104%*	90%	*103%*	61%	*78%*
							Khon Kaen Province	
Population (million):	1.70	*3.00*	0.89	*2.00*	5.00	*8.00*	1.68	*2.19*
Per capita water (m³/yr.):								
Supply	1,353	*767*	3,831	*2,063*	1,124	*702*	2,202	*1,689*
Demand	944	*653*	2,796	*2,141*	1,012	*725*	804	*807*

Notes:

1. Italics indicate estimates
2. For FAYOUM, irrigation drainage flow of 31% to lakes is subtracted from official Irrigation demand figure
3. For KHON KAEN, per capita supply & demand figures are for Khon Kaen province, not River basin; result is that demand is probably underestimated; also supply is very low in the dry season
4. Years (based on data available): Pakistan: 1980, 2020 Thailand: 1990, 2010 Egypt & Morocco: 1990, 2020

Water availability of 2,000 cubic meters per capita per year (indicated by the horizontal lines on Figure 2.1) is often considered the minimum below which a country is short of water. This standard of water scarcity applies well to countries with predominantly agricultural economies and subject to wide geographical or seasonal variations in supply that limit the effective capture of water. China (2,500), India (2,400), and Sri Lanka (2,500) have annual per capita supplies close to the standard. Countries with more serious shortages include Lebanon (1,600), Oman (1,400), and Jordan (250). By comparison, the figures for the United States and the United Kingdom are 9,900 and 2,100 respectively, the latter not reflecting overall scarcity because of the relative uniformity of supply and the limited use of water for agriculture.[2] Per capita withdrawals (water capture and use, as distinct from water availability) in the six Asian and Near East countries just mentioned range from 170 to 500 cubic meters per year, by comparison with which Pakistan's withdrawal of 1,240 cubic meters per capita per year (Table 1.1) is relatively high. In all four countries studied, however, new sources of supply are very limited, so per capita withdrawals will decrease rapidly, as indicated in Figure 2.1.

Conclusions on Water Shortages

Water availability will be the key to development in Egypt (although not in Fayoum), Tadla, and Khon Kaen, and potentially in Pakistan. Khon Kaen is already suffering from a severe seasonal water shortage. Egypt, Tadla, and Pakistan could have serious water deficits well before 2020, given the rates of population growth, and competition between urban/industrial and agricultural water demands will be acute. The year 2020 is only about one generation away and hardly too distant for sustainability planning; but longer projections were discouraged by the fact that accounting systems for water use are too imprecise even for current assessments, let alone future estimates.

There are four major problems affecting the accuracy of calculations of present and future water balances:

- Available data do not make clear distinctions between water withdrawal, use, reuse, and consumption.
- There is no acceptable way to account for the loss of water by quality degradation in the water balances.
- There is little acknowledgement of the water that the ecosystem at large needs to maintain the basic processes that support all life.
- Projections of future water demand are based on inadequate demographic information.

Information on water resource availability and use varies widely in completeness and reliability. One reason for the difficulty in obtaining and interpreting this information is that some very important parts of the water use cycle are not measurable except at the research level or by indirect means. Examples include seepage and evaporation losses, groundwater flows, evapotranspiration, irrigation water applications, and municipal water system losses. In addition, terms such as "use," "demand," "consumption," and "efficiency" are variously defined in different water subsectors.

The stochastic nature of the water cycle, and the daily, seasonal, and annual variability of surface water flows in particular, pose difficulties for water planners and managers, especially where almost the total available average flow is taken up to satisfy water demands, which are much more predictable than surface water resources. In some cases, low flow periods could affect users unequally, denying some of them any water at all.

These issues have implications for the development of information systems, and hence of management strategies and policies, for water, including maintaining the sustainability of the resource. The difficulties and costs of adequate data collection and management have tended to confine such activities to short bursts when water infrastructure pre-investment studies are being prepared.

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[2] These supply figures, taken from *World Resources* (WRI 1992), include internal resources and flows from other countries, reduced by flows to other countries.

Efficiency of Water Use

Growing water shortages in three of the study areas (Tadla, Faisalabad, and Khon Kaen) and in all four countries emphasize the need to improve the efficiency of water delivery and use.

The case studies confirm that the reuse occurring naturally in many irrigation systems indicates that the overall efficiency of use can be quite high if recounting of reused water is permitted. On the other hand, the fact that water abstractions amount to 97 percent of the reusable resource in Egypt cannot be taken to show that the limit of possible reuse is being approached. There is no limit except that set by deteriorating water quality. The relatively high overall efficiency of water use by agriculture in basins where seepage is not entirely lost suggests that the efficiency of urban and industrial water delivery and use, and not only that of irrigation, should be improved. The term "efficiency" is not commonly used in the municipal and industrial water subsectors, however; "unaccounted-for water" (or "non-revenue water") expresses the municipal equivalent of water loss during delivery for irrigation, except that it also includes meter underregistration as a "loss." Losses after the customer's supply has been metered are handled with varying degrees of vigor by different municipal water systems. They are as difficult to measure in domestic as in irrigation systems (see Appendix B).

Local Versus Areawide Irrigation Efficiency

Irrigation efficiency is both low and highly variable in the four cases studied. High variability is attributable to the spatial and seasonal distribution of water discussed below. Efficiency in the Nong Wai irrigation project in Khon Kaen is estimated at only 30 percent, whereas in Fayoum it is estimated at 60 to 70 percent. However, both on-farm efficiency and regional efficiency within the Fayoum basin are highly variable. On-farm inefficiency may be masking water reuse and trading between farms.

Poor efficiency is the result not only of technological factors but also of inadequate system management and wasteful use of water. In Fayoum, for instance, basin irrigation is used on most of the agricultural land, followed by furrow irrigation. The leveling of the basins and the maintenance of the furrow gradients are generally inadequate. Farmers apply unnecessarily large quantities of water so that higher areas can be covered. Similarly, since the fixed weekly rotation of deliveries takes no account of the amount of water used, farmers take as much water as they can. The resultant overirrigation not only wastes water but also causes waterlogging, increases salt accumulation, and has negative effects on plant growth and yield.

It is estimated that agriculture accounts for about 90 percent of the water used in developing countries, while its efficiency of use (evapotranspiration divided by the amount applied) is usually somewhere between 30 and 60 percent of that amount. The difference can be ascribed to waste. Agriculture is generally considered the least economically efficient user of water in terms of its contribution to GDP per unit of water applied. Thus, it is easy to conclude that even small gains in physical and economic efficiency could release substantial amounts of water for domestic and industrial use and thereby improve the general welfare.

When total plant evapotranspiration is divided by the sum of irrigation water withdrawals to arrive at an estimate of efficiency, the implicit assumption is that seepage below the root zone is lost to the system. In fact, most of the "lost" water is often recovered. In Egypt, a little over 20 percent of the Nile flow reaches the Mediterranean, and the rest is used several times over. There are plans to capture half of what is now discharged to the sea. In Faisalabad, farmers have come to rely on tubewells that tap the shallow groundwater seeping from canals and other improperly maintained irrigation structures in an approach known as conjunctive use. As has been demonstrated elsewhere (Seckler 1993), a single farm might be using water inefficiently, but an entire irrigated valley might be much more efficient because of the reuse of water. This process (depending on water quality changes) can repeat itself any number of times.

The four case studies do suggest, however, that irrigation efficiency can be significantly increased through improvements in land leveling and farm ditches, drip irrigation, and conjunctive use of groundwater and water from gravity systems. Other equally important options that might contribute to increased reuse, for example, have not been adequately evaluated.

Technological solutions to irrigation inefficiencies have fallen short of success. As the evaluation report of USAID's Command Water Management Project in Pakistan notes: "At present, poor management causes the greatest losses in Pakistan's irrigation systems." In particular, indifference to service and the exclusion of users from decision-making have combined to foster widespread alienation and a distrust of civil authority. The result is a system that neither delivers service nor recovers its cost.

In many instances, wasteful on-farm water management practices are followed, not because of technical difficulties or ignorance, but simply because they are more convenient or even more economical. Because the price of water is lower than the cost of the labor and equipment needed to manage it better, farmers have little or no incentive to practice water conservation.

The four case studies indicate that water pricing is not being used to induce better on-farm water management and reduce water losses. Paying the full opportunity cost of water would give farmers a strong incentive to invest in proper maintenance for more efficient water use, and would also provide water management agencies with the revenue for adequate maintenance of the distribution systems.

Substantial water savings in the urban areas of the four countries are possible by curbing losses from system leaks, on-premises wastage, and wastage at uncontrolled community taps. Some of the leakage and wastage is lost to evaporation, some seeps into the ground, and some can be recovered downstream but at a significant cost in wasted pumping and treatment. The rehabilitation of the infrastructure, especially the replacement of faulty service connections, which are often a major source of leakage, may be needed along with institutional strengthening and demand management programs. Similar considerations apply also to irrigation water management. Water in many urban areas is a cheap commodity and many users are careless about the amount they use or waste. Accurate meter reading, regular billing and collection, and public education campaigns to stress the importance of water conservation are some effective mechanisms for improving urban water use efficiency.

Ecological Base Flow Need

The countries studied seem to assume that it is appropriate to capture every available drop of water for consumption. In fact, apparent inefficiencies in water use in agriculture actually provide a base flow that sustains the larger ecosystem directly or indirectly supporting all forms of life. This base flow should not be regarded as a water loss, and studies to estimate the minimum volume of water needed to sustain ecological needs should be vigorously pursued.

Some important functions of base flow are: the water to leach accumulating salts away from the soil surface; the seaward flow in coastal aquifers to prevent salt water intrusion; and the river flows to maintain fisheries and their vital estuarine nurseries. Other examples are water for nutrient and mineral cycling, for flushing and assimilating biodegradable wastes, and for vegetative ground cover to prevent soil erosion and ensure retention of rainwater.

Water Allocation and Delivery

A well-managed irrigation system optimizes both the spatial and temporal distribution of water to boost agricultural production, ensure equity, and minimize adverse environmental effects. A major objective of irrigation management in the four cases studied is to provide the right amount of water at the right time to match plant requirements in all canal commands throughout the year. However, there are obstacles to the distribution of water by area and season that have yet to be eliminated.

Distribution by Area

The Fayoum irrigation system was designed to distribute water according to crop needs. In practice, this has not happened. Some of the main canal areas receive more water per crop-acre than others. Head-end farmers along one of two main canals receive more water than tail-end farmers, leaving downstream areas underirrigated and vulnerable to salinization of the topsoil. In addition, good quality drainage water is dumped into the desert, where it evaporates in Wadi El-Raiyan. Depriving downstream farmers of their fair share of water reduces farm profitability by limiting crop selection and yields. The recent liberalization freeing farmers from prescribed cropping patterns will exacerbate these difficulties in the absence of a water pricing policy based on the true value of water.

As in Fayoum, the irrigation system in Tadla was designed to meet the water requirements of a mandatory cropping pattern geared to a national food production drive. The water schedule was based on standard system flow rates and crop rotations. However, farmers abandoned the prescribed cropping pattern, and a system to provide schedules of gate settings was introduced. Allocations were based on the farmers' requests for water up to available system capacity. The severe shortages caused by the drought that started in 1981 significantly altered the distribution policy of the regional water agency for Tadla. Under the new policy, upper limits are placed on the quantities of water farmers can order, based on weekly estimates of water requirements for those crops specified in the fixed rotation. The amount allocated to each farmer is calculated as the maximum area approved for each eligible crop times a predetermined crop water demand times the number of days in the rotation.

As part of its structural adjustment program, Morocco has eliminated the mandatory cropping pattern and liberalized agricultural producer prices and marketing activities. However, these reforms have yet to be reflected in the water agency's allocation policy. Despite the elimination of the mandatory cropping pattern, eligible crops and the maximum area allocated to each of them are still the criteria for water allocation.

To improve efficiency, water allocation must consider the implications of crop liberalization and other market-oriented policies. As a result of liberalization, farmers are likely to grow a wider variety of crops and crop combinations that will require a flexible and reliable water delivery schedule. A steady flow of water for a predetermined time is no longer adequate. The most effective interventions would be based on the premise that farmers should set the cropping pattern and that their informed participation should guide water allocation. Just as farmers must be made to understand the technical limitations of the hydraulic system, water allocation policies of management agencies should respond directly to farmers' needs.

A basinwide management plan that takes into account the basin's ecological balance is necessary to reduce waterlogging, salinization, and leaching, and to increase crop productivity.

Seasonal Distribution

Seasonal distribution is a problem in Fayoum and especially in Khon Kaen, plagued by alternating periods of flooding and prolonged dry weather.

Excess supply in Fayoum during the spring, autumn, and winter can be easily controlled by reducing the intake at Lahun and operating the Abu Shuquq spillway to divert excess water back into the Nile. This will require smoother and more timely communications with the irrigation department in Beni Suef, which controls flows to Fayoum at Lahun. The canal telemetry system installed under USAID's Irrigation Management Systems Project should facilitate these two adjustments.

Relieving shortages during the summer will be harder, involving the reuse of drainage water, closer monitoring of cropping patterns, and greater irrigation efficiency, particularly at the upper end of the Fayoum basin. Although reuse of drainage water may increase overall system efficiency, it will exacerbate soil salinization in Fayoum, already a problem.

Irrigation development and efficiency in northeast Thailand are affected by unfavorable physical conditions, especially the erratic pattern of rainfall and large seasonal fluctuations in the natural watercourses. The region's rolling hills form a number of small watersheds that drain consecutively into the Chi, Mun, and Mekong rivers. In addition, the basins are underlaid with impermeable rock that causes intense surface runoff and rapid rise and recession of stream flow during rainstorms, conditions that are aggravated by deforestation and improper cultivation practices. Consequently, the monsoon rains bring widespread flooding that occasionally causes severe crop damage, while the dry season often brings water shortages.

In the 1950s and 1960s, the Royal Irrigation Department built over 200 small-to-medium irrigation projects in the northeast, with small dams to regulate seasonal stream flow variations. In addition, it has built thousands of small weirs in the upper watersheds over the past decade to store water.

While this has helped to expand dry season irrigation, seasonal drought remains a primary concern for water resource management agencies in northeast Thailand. Expanding municipal and industrial demands compete not only with agriculture but also with the domestic requirements of the rural population, which must rely primarily, and in some cases solely, on roof water harvested in the monsoon season to provide drinking water through the eight-month dry season.

Conclusions on Efficiency of Water Use

The need to make less water go further emphasizes the importance of reducing demands and reusing water successively for multiple purposes. Agriculture has frequently been targeted for prime attention because it uses water so inefficiently. Yet the way in which irrigation efficiency is computed counts agricultural drainage and aquifer recharge as though they were real losses. In fact, they are not necessarily so unless the quality of water has made them unusable. Similarly, but on a lesser scale, while losses from urban and industrial water systems certainly denote unnecessary costs to the system owners, the amounts lost may or may not be significant for sustainability.

Losses, by evaporation, pollution, and to salt sinks, should be the real targets of demand management and efficiency-of-use improvement programs in all components of the water sector. Typical points in municipal, industrial, and irrigation systems at which flows are best monitored and where conservation is feasible are indicated in Appendix B. Both delivery/distribution systems and the farms and premises where water is used provide opportunities for conservation. In addition, where treated urban wastewater is to be reused, losses can be reduced by controlling sewer leakage and, in coastal areas, preventing sewer infiltration by saline water.

Actions to reduce losses affect various beneficiaries. System owners, whose revenues depend on water delivered and whose costs depend on water supplied, gain financially. However, as discussed above, the impact of loss reduction on the sustainability of the resource is influenced by the extent to which water lost to the facility is also lost to the resource. Since no water basin is a completely closed system, some part of facility and user losses will necessarily be lost to the resource. But conservation requires a basinwide analysis, covering the full spectrum of interests, and must take into account factors that do not concern the owners and operators of delivery systems. Such factors may include the needs of other users, the need to maintain base flows, and economic issues of no consequence to a particular supplier. Therefore, while water conservation benefits the revenues of water suppliers, it may be needed more urgently as a strategy for developing and protecting the resource, if water is scarce.

Waterlogging

Waterlogging is a problem wherever large surface-water irrigation systems have been installed without adequate drainage. It is serious in three of the case study areas—Fayoum, Tadla, and Faisalabad—and elsewhere in Egypt, Morocco, and Pakistan.

Observations on Waterlogging

Making allowance for losses by evaporation, one-fifth of the water introduced into the Fayoum depression eventually remains in Lake Qarun, whose level is rising, and one-tenth drains into a wadi where it evaporates. The highly saline water in the lake extends back under the surrounding lands, creating serious problems for the farmers. In some places near Fayoum, pumps are being used to lower the water table; elsewhere in Egypt, a very large World Bank tile drainage project is in operation.

In Morocco prior to 1938, the depth of the water table in the Beni Amir irrigated area in Tadla varied between 50 meters upstream and 15 meters downstream. Leakage from the earth distribution canal network and excessive irrigation have caused a significant rise in the water table since 1974. After the introduction of irrigation in 1954, the water table in the eastern part of the Beni Moussa region began to rise rapidly and reached the soil surface in many places. Significant salt accumulations occurred in the parts of the two irrigated areas where the water table depth is less than 1.5 meters.

The situation improved markedly during the droughts of 1979-84 and 1992-93 because of the droughts themselves and a growing number of privately constructed irrigation wells. The combined efforts of the public sector and the farmers have had some effect in controlling groundwater accumulation. The public sector provided improved surface drainage and installed large-capacity low-lift pumping stations to return excess water to the canals, either for reuse or for discharge into the drains leading to Oued Oum Er R'bia. Private pumping of water from the shallow wells since 1985 has lowered the water table to a satisfactory level and developed a system of conjunctive use that has improved the flexibility and timeliness of irrigation even in years when water has not been in short supply.

When the Lower Chenab canal and its Jangh, Rakh, and Lower Gugera branches were constructed in Faisalabad in 1894, the water table was about 15 meters below the surface. When Pakistan's enormous gravity-fed irrigation system was constructed in the early 1900s, the groundwater table was still deep and in dynamic equilibrium over most of the Indus basin.

With seepage from persistent and widespread application of water by border and flood irrigation methods, and because of leakage from the canals, the water table rose steadily. By the late 1930s and early 1940s, it had almost reached the surface in many areas. Capillary evaporation from the high water table led to the accumulation of salts in the upper soil stratum and salinity in the crop root zones. These problems are typical of many areas of Punjab and Sindh provinces, where, by the early 1960s, waterlogging and salinity were acute. In Punjab alone, 14 percent of the total canal-irrigated area had fallen out of production, 17 percent was in an advanced stage of deterioration, and 50 percent of the province was affected to some degree. About 70,000 acres were being lost each year.

The installation of over 2,000 deep wells under a series of Salinity Control and Reclamation Projects (SCARPs), starting in 1960, lowered the water table to about 5 meters below ground level by 1970. The pumping costs are partly built into the user charges paid by farmers.

Conclusions on Waterlogging

The extent and severity of waterlogging depend on the amount of water applied and the availability of gravity drainage. Where gradients for gravity drainage are not available, waterlogging can be reduced at substantial costs by pumped drainage. If such costs are incurred by corrective measures after the event, it is very difficult to introduce them into farmers' decisions on the amounts of water to use.

This study has reinforced the idea that the construction of new irrigation schemes and the upgrading or rehabilitation of existing schemes should include provisions to control excessive application and to remove used water or make it available for reuse.

3

WATER QUALITY ISSUES

Overview

In most developing countries, water quality degradation seriously endangers the sustainability of the freshwater resource. It renders water unsuitable for certain uses, adds to the cost of treatment for other uses, destroys habitats, and introduces carcinogens and toxic substances into the food chain. Contamination of aquifers or lake sediments can damage these water bodies for very long periods.

Along with saline agricultural drainage, the wastes from exploding populations and from accompanying industrial and agricultural expansion are the primary causes of the widespread impairment of water quality observed in the four countries. By design or by accident, most of these wastes have been diluted with clean water in poorly designed and unregulated systems, thereby contaminating large volumes of water. Contaminated water has actual or potential negative impacts on downstream uses, health, aquatic and marine ecology, and economic activity. Attempts to remedy the problems have failed largely because they were based on inappropriate technology and planning.

Not all of these problems were observed in all four cases nor were they of equal significance where they were noted. Table 3.1 summarizes the relative importance of four factors affecting water quality in the four cases studied.

Table 3.1
Water Quality Issues Prioritized

	Fayoum EGYPT		Tadla MOROCCO		Faisalabad PAKISTAN		Khon Kaen THAILAND	
	Ctry	Case	Ctry	Case	Ctry	Case	Ctry	Case
Sanitation & Sewerage	M	M	--	M	M	M	M	M
Industrial Wastes	M	0	--	M	M	M	M	M
Salinity	M	M	--	M	M	M	m	m
Agricultural Chemicals	m	m	--	M	M	M	--	m

M = major issue; m = minor issue; 0 = not an issue; -- = not studied; Ctry = country

Sanitation and Sewerage

In the four countries, the practice of discharging urban and industrial wastes into natural streams or watercourses has caused major damage to aquatic, estuarine, and marine ecosystems. This happens in many other countries where this practice is followed, but it is especially destructive in these four during the long dry seasons when flows are very low in some of the watercourses.

Sanitation and Sewerage Deficiencies

Poor sanitation is a severe threat to public health in all four case study areas, especially for the rural and poorer urban residents who lack a piped water supply and safe excreta disposal facilities. In Egypt, for example, about 80 percent of the urban population are reported to have basic latrine or sewer services, although this may be an overestimate, whereas only 25 percent of the rural population have latrine facilities and only 5 to 6 percent have sewer connections. Untreated or inadequately treated sewage is a major contributor to the waterborne pathogen/parasite problem (causing typhoid and diarrheal diseases, for example).

In Thailand and Egypt, the dry season is severe, lasting about 250 days in Thailand and bringing virtually no rain in Egypt. In Morocco and Pakistan, the dry season is not so severe, but river flows are reduced by upstream interruptions or diversions for power and irrigation. In all four cases, there is virtually no flow in some natural streams for part of the year. Discharge of sewage under such conditions eliminates fish life and destroys the value of the water resource. Even in the Nile water system, fecal coliform levels typically average 1,500 to 2,000 per 100 milliliters, far exceeding normal standards for treatable drinking water. In Faisalabad, the problem is exacerbated by the large number of industrial discharges, many of them containing toxic materials.

Fayoum City has a sewerage network and a secondary treatment plant discharging into a drain that flows into Lake Qarun. The effluent is said to violate Egyptian standards and the plant is overloaded and only partially operable. Sewage flows are expected to increase by about 50 percent by the year 2000. Until very recently, virtually no sewerage system existed in rural Fayoum. Collection and small treatment facilities have recently been built in two villages and a third is being constructed under the USAID-funded Provincial Cities Project. Ten to 15 villages have sewerage systems discharging untreated wastes. About three-quarters of the population depend on on-site disposal in simple soakaways, many of which actually overflow into irrigation canals or drains. This causes a problem where tail-end canals are used for drinking water. Private vacuum trucks also empty latrine pits and discharge the contents into drainage channels.

In Tadla, there are two sewerage systems with sewage treatment plants, for Beni Mellal and Khenifra. The larger system, for Beni Mellal, has a modern activated sludge plant with provisions for drying the sludge and discharging the treated water directly into the drainage system so it can flow to Oued Oum Er R'bia. The activated sludge process requires a great deal of energy and will be expensive to operate. The plant cost US$6 million and the line of credit was exceeded several times. The final overruns were so large that bringing power from the electrical grid to the plant would have added considerable additional debt. For these reasons, the municipality of Beni Mellal refuses to accept responsibility for the plant despite the serious environmental and health risks posed by overflowing sewage. The much smaller plant upstream of the Kasba Tadla dam at Khenifra is a simple lagoon that relies on algae, sunlight, and a long detention time to render the sewage less offensive.

Pakistan generates 40,000 wet tons of excreta per day, or 15 million tons a year, virtually all of which is discharged untreated. In rural areas, an estimated 80 percent is deposited in fields; in urban areas, 5[illegible] percent is disposed of in sewers and open drains. The remainder is deposited on the roadside or incorporated into solid waste. The prevalence of untreated human waste results in pathogenic contamination of food and water through irrigation of garden crops, airborne dust, cross contamination of water mains by sewers, and human handling. Sixty percent of all deaths below the age of five and 33 percent of all adult deaths are attributed to waterborne disease.

Wastewater in Faisalabad is collected by sewers and drains, many of which are inadequate and/or require repairs. They collect domestic and industrial discharges and storm flows and, in some cases, agricultural drainage. The combined wastewater flows into natural depressions that serve as drainage courses discharging into the Chenab and Ravi rivers. The wastewater is not treated.

Water samples collected from dug wells and hand pumps in Faisalabad and other large cities in Pakistan reveal that 70 percent are contaminated by sewage organisms. The water in the aquifer beneath Faisalabad, while vulnerable to wastewater contamination, is in general not potable because of its salinity. Surface water quality in rural areas varies according to source (stream, canal, or pond), distance from dumping points, and dilution capacity. Actual wastewater flows and the quality of wastewater and receiving waters are not monitored.

The conditions in Faisalabad, where 300 industries have separate pipes discharging into streams and drains, illustrate the great complexity, cost, and difficulty of implementing a pollution control policy based either on effluent standards or receiving-water quality standards. Each one would require thorough sampling and analysis before standards could be set and enforced. Ongoing monitoring would be needed. The staff and facilities for this are not available.

As of January 1993, the Environmental Health Division Center in Khon Kaen calculated that 86 percent of the province's rural population had latrine facilities, and 46 percent had adequate sewage treatment. These figures were each up about 2 percent over 1992. The city of Khon Kaen received priority in the Regional Cities Development Project (UNDP 1983), funded in part by the World Bank, for the construction of intercepting sewers and a stabilization pond system designed to serve 118,000 people. It is a combined sewer system, carrying both wastewater and stormwater. The stabilization pond treatment facility, covering 19 hectares, went into operation in 1989. It consists of two large facultative ponds and three smaller maturation ponds, providing a retention period of about 12 days for wastewater to move through the entire process. It cost about US$1 million to construct, has a current capacity of 25 million liters per day (Mld), which is about two-thirds of the city's discharge, and requires only four persons to operate and maintain it. The processed wastewater is discharged into a large nearby wetland lagoon/lake system that previously received the sewage untreated. The improvement in the water quality of the lake has brought attendant benefits for fisheries and recreational uses.

Septic tanks and cesspools are common in Khon Kaen as well; many now overflow into the sewer system. Several interceptor drains and sewer mains continue to be added to the system. The budget for the sewerage system under the current five-year plan, 1992 to 1996, includes US$3.5 million for road and drain improvements and US$2.5 million for sewer mains. The treatment plant was designed with the expectation that it would eventually have to be expanded by 14 Mld to cover the entire population of the city and anticipated future demand. This expansion is not scheduled for implementation in the near future, however.

Currently, there is no sewerage/wastewater tariff in Khon Kaen or in Thailand. Residents do pay for piped water, but wastewater is managed by a different agency that does not share the revenues. Since wastewater flow is proportional to water consumption, a progressive sewerage fee tied to water consumption would simultaneously serve to encourage water conservation, reduce the additional treatment capacity requirements, and contribute to the financing of system expansion.

The Khon Kaen municipality's sewage treatment system appears to be working reasonably well and could serve as a model for other small and medium-size cities. Additional training of operational personnel would be beneficial. Industries connected to the system will add toxic and carcinogenic substances to the effluent and sludge, impairing these for reuse by agriculture. Including storm runoff with the domestic/sanitary flows is less critical than it would have been because of the storage capacity provided. However, it is likely to lead to storm overflows in the collection system.

Efforts Towards Improved Sanitation and Sewerage

A wastewater treatment plant in Fayoum is currently being expanded. Elsewhere in Egypt, wastewater treatment plants for rural towns are being given a high priority. The National Organization for Potable Water Supply and Sanitary Drainage (NOPWASD) plans to build eight, with capacities of up to 20 Mld each, in the coming decade. An experiment with constructed wetlands sewage treatment systems is underway in

Damietta (Lake Manzala). The results of this experiment should be carefully monitored, as this technology offers the potential for major savings in village-level sewage management.

The technology used in the treatment plant for Beni Mellal is inappropriate because of its huge capital and expected operating costs. Multistage stabilization ponds would have been much cheaper. They do require more land than activated sludge plants, but have minimal power requirements, are much simpler to operate, and incur significantly lower capital costs, assuming the land can be obtained for a reasonable price. A disadvantage is the increased loss of water by evaporation from the large surface area. Several small lagoons on the fringes of the urban area of Beni Mellal would have facilitated the use of settled, stabilized sludge as soil conditioner.

While multistage stabilization lagoon systems are well understood, artificial wetlands as a means of treatment are still being studied (for example, in Damietta, Egypt). A long-standing example of large-scale application of sewage to pasture land is the Werribee Farms complex in Melbourne, Australia. With proper safeguards, multistage lagoon effluent from which helminths have been removed is appropriate for agricultural use but may require wet-season disposal facilities. Land is a critical factor, and early allocation or acquisition of this component is important, especially when high-technology treatment of urban wastewater is not a practicable alternative.

A donor-supported master plan for sewerage system expansion and improvement that continues the current combined sewer arrangement is underway in Faisalabad. Pakistan's Seventh Five-Year Plan provides for 100 percent sewerage service for major cities, including Faisalabad, by 1995 but does not provide for wastewater treatment, presumably in part because of the high cost and disappointing performance of the treatment plants in Karachi and Islamabad.

In spite of the need for long-range water conservation, utility-oriented short-term economic analysis in many cases tends to support disposal rather than conservation and resource recovery options. Alexandria, Egypt, and Karachi, Pakistan, are examples of the selection of marine disposal over land application and resource recovery. In both cases, long-term analysis based on the true value of water and other recoverable resources might have yielded a different recommendation. However, simple recovery systems are less appropriate for coastal than for inland cities where pumping is not required. Wastewater from some very large cities, including Mexico City and Melbourne, Australia, is entirely reused for irrigated farming after minimal or no treatment with no discharge to natural water courses except during rainstorms. In such cases emphasis is placed on safe farming practices and crop selection to obviate health hazards.

One policy option for the reduction of pollution by urban and industrial wastewater is a requirement that permits no discharges whatever. This is the ultimate stage of a wastewater reclamation policy. There are few examples of such zero discharge policies in developing countries and none in the case study areas, although Sudan is reported to have one. This is an alternative to following the course of water pollution policies as they evolved in the U.S. and other industrialized countries. The application, by stages, of treatment or effluent quality standards, receiving water standards, and best available treatment requirements has highlighted the conflict between water quality improvement and enforceability. But all stages assumed that disposal is the ultimate objective. Enormous sums have been expended on systems that only with great difficulty and expense can now be converted to water reclamation. The technical, infrastructure, administrative, and legal costs of implementing and enforcing each of these evolving policies are prohibitive. Recently, however, some states such as Florida, where water is recognized as a precious resource, have enacted and are enforcing zero discharge laws, which should be an attractive option for water-short developing countries, especially in dealing with industrial wastewater.

Conclusions on Sanitation and Sewerage

Multiple domestic use of groundwater creates health problems in rural areas, where excreta are disposed of in pits that are either simple latrines or cesspools. When the water table rises to the level of these pits, it provides a direct hydraulic connection with wells used for drinking water, and the resultant contamination can cause outbreaks of waterborne diseases such as cholera and typhoid. In Tadla, the child mortality rate has risen in years when the water table is highest. Under such circumstances, piped water supported by sanitation improvements should be considered, depending on the interest and willingness of householders to pay for such systems.

An important factor contributing to both high urban water demand and water quality damage in the four case studies is the practice of using clean water for transporting feces, urine, and industrial wastes to water bodies distant from residential areas. Most industrial societies consider that the convenience of this method for system users justifies the waste of both clean water and of human excreta as fertilizer. This costly disposal and the subsequent treatment of these mixed resource streams are not a rational solution for developing countries where water is scarce, agriculture is the main economic activity, farmers cannot easily afford synthetic fertilizers, and the costs of treating drinking water and collected wastewater are major economic burdens.

Separating human wastes from domestic wastewater for disposal conserves water and permits on-site treatment and reuse of human wastes, which are also resources. This solution could have been applied, for example, in Tadla at some point before householders had made financial and amenity commitments to transporting wastes by water. However, where there are multistory dwellings and people are already culturally or financially committed to waterborne systems, this alternative is not practicable.

For simplicity and to minimize collection costs, combined sewerage systems have been developed in all four cities to carry wastewater and rainwater runoff. This is the case even for the proposed donor-supported facilities in Tadla and Faisalabad. This combination of clean water and wastewater, besides violating ecological planning principles, necessitates very large sewers and treatment plants to handle the unusually large flows from storms. Except where rainfall is negligible, as in Egypt, this short-term expedient will create long-term problems and costs of overflow management and increased wastewater treatment capacity.

Conventional wastewater management favors disposal over reuse, a tendency that is changing in water-short countries as the impact of water on economic development and the quality of life becomes more apparent. National strategies to maximize reuse must emphasize separation at waste sources and a reduction of contaminant discharges to facilitate the reclamation of wastewater.

Industrial Wastes

Industrial activity encouraged by government is increasing in many developing countries, and so is the use of toxic and carcinogenic materials. Unless these materials are reused or separately disposed of, they find their way into wastewater streams and hence into freshwater bodies. There, together with other industrial wastes, they endanger human health by contaminating drinking water and the food chain, add to the costs of other water users, and damage ecological resources such as wildlife habitats.

Industrial Waste Pollution

Tadla, Faisalabad, and Khon Kaen all have large industrial plants that discharge inadequately treated wastewater into watercourses with almost no base flow except sewage. This turns these watercourses primarily into wastewater channels and completely destroys their ecology.

Fayoum is mainly an agricultural region, with no heavy industries and few industrial effluents to contaminate the water. Nonetheless, heavy metals have accumulated in the waters and fish of the Wadi El-Raiyan lakes, probably from impurities in fertilizers and from one tannery.

In Tadla, wastewater from four sugar beet mills and tanneries in Beni Mellal affect a limited area downstream. The sugar beet mills have gone a long way towards reducing water consumption and waste, and reusing solid wastes for animal feed and other agricultural uses. However, even the waste remaining is too much for the drains and canals to assimilate. Since the irrigation authorities are convinced that the chemicals used to clean the mills at the beginning of the milling season are toxic to fish and crops, the effluent is not used for agricultural purposes, although normally sugar beet wastes are mostly natural organic material.

There are over 100 industries in Faisalabad led by textile manufacturing and finishing (including dyeing and sizing). Industry has grown rapidly in the past few decades, both in the number and diversity of mills and in the size of individual plants. Approximately 70 percent of all industrial wastewater is generated by textile plants, followed by the food processing industry, especially vegetable and cotton seed oil plants. Major drains in Faisalabad carry almost all of the city's domestic and commercial sewage, as well as wastewater from industries, to the rivers. The aquifer beneath Faisalabad is vulnerable to surface spills and other infiltration of polluting substances but is used only by industry, apart from portions that are replenished by seepage of freshwater from the irrigation canals. Industrial contamination, especially by heavy metals, has begun to appear in water, soil, and biota. Careful analysis for industrial solvents and other dangerous organic compounds has not yet been undertaken but the contamination is probably increasing, especially in the vicinity of metal finishing industries.

Until recently, industrial production in Thailand was concentrated in Bangkok, with the lowest generation of hazardous waste coming from the northeast region (Engineering Science Inc. et al. 1989). Pollution will continue to be heavy in Bangkok for the foreseeable future, but there are signs that it is growing in other areas, especially since the government now promotes industrial development through financial incentives for industrial estates. The above-referenced study evaluated the environmental risk associated with various types of hazardous wastes, and the cost-effectiveness of treating them in the context of Thailand. It found that the highest priority for risk reduction should be the treatment (or retention) of heavy metal sludges and solids. A distant second should be photographic chemical wastes, followed by alkaline wastes, acid wastes, and infectious wastes. In Khon Kaen, the largest industries are agriculture-based and include pulp, sugar beet, whisky, textiles, food canning, and soft drinks.

In Khon Kaen, massive fish kills were ascribed to accidental spills of molasses from sugar mills and also to paper mill discharges that have not been specifically identified. The principal paper mill had an activated sludge treatment system, so it appears unlikely that excessive organic loading caused the fish kills.

Efforts Towards Control of Industrial Pollution

In Tadla, industrial development has been guided by zoning and the creation of well-defined industrial parks. The zoning laws have been strictly followed because the major industries are the property of the Ministry of Industries. In Faisalabad, by contrast, industries have started up in residential areas and on good agricultural land around the city without control. There are no zoning restrictions and no permits, enforcement, or other regulations.
Neither in Tadla, Faisalabad, nor Khon Kaen, have industries been located so as to minimize the impacts of their wastewater discharges.

Although regulation would appear to be simple for the two or three industrial installations in Tadla, since they are government owned, economy has outweighed environment as a priority. There is no monitoring or regulation of the discharges even though they are believed to be toxic. There is a plan to connect the tanneries to the Beni Mellal city sewers so that their wastes can pass to the activated sludge treatment plant. This could seriously disrupt the biological processes in the plant and also pose a health hazard if either the sludge or final effluent is used for agricultural purposes. Tannery wastes usually contain toxic chromium salts and other compounds that cannot be removed by conventional processes. Thus, pollution reduction would be greater if the tanneries treated their own wastes instead of discharging them into the sewer system.

There are virtually no controls on industrial waste emissions in Pakistan. A recent survey of 100 hazardous chemical factories showed that only three in the whole country treated their wastes to acceptable standards. Perhaps the greatest concern is that toxic materials in industrial wastes discharged into shallow groundwater may remain there for decades.

In preparation for the implementation of the sewage and drainage components of its master plan, the Faisalabad Water and Sanitation Agency (WASA) has prepared an inventory of over 300 factories or establishments that discharged wastes into the water resources of Faisalabad district in 1993. The only wastewater treatment measures that any industries have adopted to date are the installation of bar screens/strainers on their drains or sewers to reduce blockage, or interceptor pits to prevent grit from entering sewers. All industries surveyed discharge wastewater into sewers or public drains. The industrial and other wastes degrade the quality of receiving waters, including the groundwater.

The primary government response to the problems of industrial and domestic pollution has been the creation of the Environmental Protection Agency at national, provincial, and local levels. The EPA has only barely begun to function almost 10 years after its creation. A legal framework for controlling water pollution in its modern form does not exist in Pakistan and comprehensive guidelines have not yet been established. The Pakistan Environmental Protection Ordinance (PEPO) promulgated in 1983 is concerned more with the control of air pollution than other aspects of environmental protection. To date, PEPO has not been effectively implemented because the government has yet to delegate the necessary powers to the provincial EPAs.

The WASA wastewater master plan proposes general measures that encourage industries to reduce their waste production, recycle valuable resources, and eliminate toxic materials from their discharges. The plan also proposes the establishment of separate industrial wastewater treatment plants in areas of the city where industries are concentrated. However, not all Faisalabad's industries are located in these areas, so that many will still be connected to the sewers that flow to the urban sewage treatment plants. The master plan's sewerage component utilizes the natural drainage channels and streams that existed before the city developed. After heavy rains the sewers will thus mix rainwater runoff with industrial and domestic wastewater flows. Although the sewers are designed to take fairly large storm runoffs, there will inevitably be frequent overflows as the city grows and sewage will back up into streets and residential areas.

Faisalabad does not have the staff and facilities to monitor compliance with any discharge or other industrial wastewater requirements. The government is overwhelmed by the number of industries it is supposed to regulate. In the 10 years since Pakistan established its water pollution program, it has provided Faisalabad with a single person who has no laboratory or stream simulation abilities to develop the water quality program.

Until 1992, Thailand's water pollution control system relied exclusively on the establishment of concentration-based effluent standards. This does not promote water conservation or guarantee ambient water quality. The solution frequently is merely to dilute the effluent with more water. In addition, Thailand has not had the resources to enforce compliance with even these standards. The year 1992, however, saw the passage of two major environmental laws, the Industry Act and the Water Quality Control and Promotion Act, which created an environment fund financed by pollution fees collected from industry.

Since 1988, the Thai government has initiated the construction of a total of four hazardous waste treatment plants, the second of which is expected to commence operation in 1993. New industries are encouraged to site themselves in industrial estates, which have wastewater collection and treatment systems.

Conclusions on Industrial Wastewater

The situations studied are typical of newly industrializing developing countries, where governments that recognize the need for reducing industrial pollution do not have the clear policies and administrative machinery to act decisively and also are aware of the real or perceived unacceptably high cost to industry. While an important missing element sometimes is a suitable statute, also frequently lacking is a management strategy that includes adequate incentive, enforcement, and data collection mechanisms and information.

Solutions to industrial waste pollution include zoning, in-factory process changes to minimize waste production, waste recycling and water conservation, on-site wastewater treatment, and the retention and reuse or separate disposal of concentrated, toxic, oily, or carcinogenic waste substances. This is facilitated by the provision of separate plants for the treatment of hazardous wastes, as is being done in Thailand. Effective solutions must consider not only the technology and costs of the intended methods and processes but also the feasibility and costs of monitoring and control systems. There must be the political will to reduce pollution through incentives and technical assistance on the one hand, and enforcement plus disincentives on the other.

The traditional option of allowing industrial wastes into urban sewer systems has not solved the problem and has made proper treatment and disposal of municipal sewage much more difficult and expensive. It also has prevented beneficial reuse of sewage solids for agriculture, and is becoming less sustainable as more synthetic compounds are used in industrial processes. Toxic industrial materials often interfere with biological activity in treatment systems for domestic wastes. In addition, this option requires environmental agencies to maintain large technical staffs, sophisticated laboratories, and frequent and detailed sampling programs for the industrial discharges. None of the countries studied has or can afford these facilities, suggesting the wisdom of introducing zero discharge policies in phases.

Zero discharge programs are a manageable way of monitoring and enforcing industrial wastewater pollution reduction. A zero discharge program sets a final date for the elimination of each category of discharge. Separate facilities are set up for the collection and reclamation or destruction of hazardous materials, and occasional inspection ensures that the discharge has in fact been eliminated. This makes it possible for citizens' groups as well as government agencies to assist in monitoring and enforcement. For industries, it also places the financial responsibility where it belongs, on the polluter. Hazardous raw materials for which effective substitutes are available need to be banned and technical assistance in waste minimization is also needed.

Salinity

The effect of waterlogging, described in the previous chapter, is compounded in three of the four cases by the related problem of increasing salinity. Salinization is caused by a combination of leaching of soil salts and evaporative concentration of salts in water. It affects both surface water and groundwater, reduces or destroys the productivity of irrigated or waterlogged soils, and damages fisheries.

The Problem of Salinization

Salinity buildup has been going on in Fayoum for the past 30 years. The salinity of Lake Qarun is higher than that of sea water and, as no salt leaves the lake naturally, is expected to increase continuously. The rising levels of the lake, and hence of the saline groundwater, are putting arable land progressively out of production.

In Tadla, a rising water table and increasing salinity have affected certain crops and reduced the general productivity of the soil. The salinity of groundwater is also believed to be correlated with the high prevalence of hypertension and kidney failure in the region of Beni Amir, the northern portion of the Tadla area. The deep alluvial soils in the Faisalabad area were saline long before the introduction of irrigation. The application of irrigation water for cultivation has raised the water table and brought the salts to the soil surface, with adverse effects on crop yields and vegetation. In desperation, farmers have resorted to stripping away the topsoil and in the process have removed much of the fertile soil as well.

The SCARP program, described in the discussion of waterlogging, lowered the water table but did not solve the problem of salt left in the soil by evaporation of irrigation water. In some cases, deeper saline groundwater, drawn into wells whose zones of influence extended beyond the freshwater layer, increased the salinity of the water discharged into the canals and subsequently reused downstream. Most of these wells were closed down, but private wells in the lower part of the system have contributed highly saline agricultural drainage to the waterways. Horizontal tile drain systems with pumped discharges have been installed more recently. However, no economically feasible way has been found to evacuate saline water from the upper parts of the basin to the sea. Saline soils remain a problem throughout the Punjab, especially in areas where irrigation water is insufficient to leach salts from the fields and where the water table remains high. Salt also continues to accumulate in the groundwater because of the lack of adequate drainage to carry away irrigation water.

Increased salinization of soils or surface water is not a major problem in Khon Kaen at the present time, since seasonal saturation of soils by the monsoon rains and relatively good drainage have served to retard the upward capillary movement of salts to the surface. Nevertheless, salinization is expected to become a significant issue with time. Several environmental effects associated with salinity are, however, apparent in Tadla, Faisalabad, and Fayoum.

Efforts Towards Control of Salinity

Several responses to salinity buildup were detected in the case studies. In Fayoum, pumped drainage systems have been installed to lower the water table. In Tadla, a switch has been made to crops more tolerant of salt, especially in the portions of the irrigated area most affected.

New dams proposed above Kasba Tadla should reduce the salinity in the irrigation canals simply by dilution, if this additional water is less saline than the groundwater. The added flow would also help to leach some of the accumulated salts to the drainage system. However, a general and more sustainable approach for reduction of salinity in the water table would be to design the new dams for selective withdrawal or bypassing of the most saline waters, and dilution of first flush saline waves with the sweeter water of the flow during the later part of the rainy season. Management of salt deposits in the upper watershed would also be a sustainable way of preventing salinity from entering the irrigation system.

In Punjab, the deep tubewells installed in large numbers under the SCARP program started in 1960 had lowered the water table to about five meters below the surface by 1970. But some of these wells were claimed to have extracted highly saline water and thereby contributed to a general increase in the concentrations of salts in irrigation drains and natural watercourses. The underdrain system being installed by the Fourth Drainage Project in Pakistan appears to be a more successful approach to controlling waterlogging and salinity, for it offers the future hope of easy recycling of sweet drainage water, once sufficient salts have been removed from the upper soil profile by coordinated leaching programs. Nevertheless, the system requires large equipment and fuel expenditures to install the drains, and continued energy expenditures to pump the drainage water from the sumps back to the irrigation channels.

Conclusions on Salinity

The basic principles of irrigation system design to minimize salt accumulation are well known. They include reducing on-farm evaporative losses, providing sufficient water to leach salts out of the root zone, and providing drainage to lower the water table sufficiently to prevent capillary evaporation. They have frequently not been followed because of both the cost of providing and operating drainage and a public works approach that separates the delivery systems from farmers and their use of irrigation water.

Planners must recognize that an irrigation system does not end at the offtake gate. The delivery system and its operation and maintenance, the farmers and their holdings and actions, and the drainage system and its operations are all part of a single endeavor that can be designed to prevent destructive salinization as long as an ultimate salt sink is economically accessible.

Agricultural Chemicals

Public health threats from agricultural chemicals can arise from lack of precautions during application, daily contact by the rural population with drainage canals, drinking of contaminated groundwater, and the accumulation of residues in the food chain. Environmental damage can accrue from eutrophication of water bodies due to excess fertilizer runoff, and from inadvertent destruction of pollinators and other useful organisms such as those that serve as natural controls on pests.

Pesticide and Fertilizer Pollution of Water

While agricultural chemicals were not the worst water quality problem in any of the cases studied, they were of significance in Fayoum, Tadla, and Faisalabad.

The environmental effects of excessive application of agricultural chemicals is best illustrated in Egypt. The need to compensate for the alluvial deposits now retained at the Aswan High Dam has required a significant increase in the use of chemical fertilizers throughout the country. Increased demand has been met through both construction of new fertilizer factories and larger imports. A program of fertilizer subsidies encouraged higher application rates than in most developing countries, and even many developed countries.

A similar subsidy program led to excessive use of pesticides. In Fayoum, approximately half a million tons of a wide range of pesticides have been applied over the last 30 years. In 1991-92, for instance, more than 80 types of pesticides were distributed by the

Ministry of Agriculture. Herbicides were used until 1991 to clear canals of clogging weed growth stimulated by fertilizer runoff, and biocides were used to kill the snails that transmit bilharzia. Egypt has recently made major progress towards a more environmentally sustainable use of agrochemicals by reducing subsidies.

In Tadla, observed concentrations of nitrates in the groundwater were well above levels considered dangerous, and constitute a severe threat to children who drink the water. Anemia of unknown origin, unofficially attributed to high nitrate concentrations in drinking water, is common among children coming to the Beni Mellal hospital from rural areas.

The amount of biocides used in the Faisalabad district has increased steadily since the Green Revolution of the 1960s. Since 1980, the amount of pesticides used in the Punjab has increased over six times. In addition, large amounts of DDT and malathion were used throughout the district under the malaria control program from 1960 to 1992. Traces of malathion and other biocides are appearing in food, groundwater, and aquatic habitats in the Punjab and Sindh provinces.

Conclusions on Agricultural Chemicals

There is very limited evidence of actual levels and effects of pesticides in the study cases and countries. Epidemiological studies elsewhere indicate that, while there appears to be good reason for concern about both acute and delayed effects of pesticides, there is limited direct evidence linking specific pesticides to specific long-term outcomes (Hoover and Blair 1991; Sharp et al. 1986). The greatest risks are to those using, inhaling, or handling pesticides, and possibly to persons eating fruit or vegetables treated with certain insecticides.

Cancer hazards, reproductive hazards, and neurotoxic hazards due to pesticides are subjects of extensive study but must be assumed to exist, even for indirect exposure through contaminated water. It is very important that levels of contamination be monitored.

In the absence of effective means of directly controlling the use of pesticides and fertilizers, an important step is the elimination of incentives for overuse. Incentive structures must be reviewed, and direct and indirect subsidies for fertilizers and pesticides gradually eliminated. Price policy reforms should be supported by agricultural research and extension programs to promote profitable and ecologically sound farming techniques like integrated pest management and such basic crop management practices as staggered planting, intercropping, and varied crop spacing. These measures should be accompanied by the development and improvement of pest-resistant crop varieties, the investigation of biological pest control methods, and the identification of pesticides and techniques of pesticide use with minimal impact on humans and the local agro-ecosystems.

In the longer term, it is important that the distribution and use of pesticides, and their movement through the agro-ecosystem and water bodies, should be monitored through data collection and information management systems.

4

ENVIRONMENTAL AND INSTITUTIONAL ISSUES

Overview

Quantity and quality are the most basic features of the water resource affecting environmental sustainability, since they offer direct evidence of its availability, particularly for human abstractive use. Flowing from these features are five issues that are important in the cases studied: water-related health problems, ecosystems and biodiversity, planning for long-term trends, institutional constraints, and water pricing. Table 4.1 presents the relative importance of these issues in the four cases studied.

Table 4.1
Environmental and Institutional Issues Prioritized

	Fayoum EGYPT		Tadla MOROCCO		Faisalabad PAKISTAN		Khon Kaen THAILAND	
	Ctry	Case	Ctry	Case	Ctry	Case	Ctry	Case
Water-related Health Problems	M	M	--	m	M	M	m	m
Ecosystems and Biodiversity	m	M	--	0	M	M	m	M
Planning for Long-term Trends	M	M	--	m	M	m	M	M
Institutional Constraints	m	m	m	m	M	M	M	M
Water Pricing	M	M	--	M	M	m	M	m

M = major issue; m = minor issue; 0 = not an issue; -- = not studied; Ctry = country

Water-related Health Problems

Waterborne diseases from the ingestion of food or water contaminated by excreta are a serious problem in each study area. Of lesser severity are water-associated diseases, primarily vector-borne diseases such as malaria and bilharzia.

Waterborne Diseases

Waterborne diseases are the most serious health issue in Fayoum, which has child mortality and crude death rates higher than the Egyptian average.

In Tadla, diarrheal diseases are a growing problem, primarily because of the rapid increase in population and the high water table. Periodic outbreaks of cholera have occurred in recent years in the waterlogged areas, and the general incidence of typhoid, hepatitis, and other severe diarrheal diseases is high in children. The public health authorities report seasonal diarrheal disease epidemics in years when the water table is high, a phenomenon explained by the fact that as the water table rises to the level of rural latrine pits or cesspools, it provides a direct hydraulic connection with the nearby wells used for drinking water.

Sixty percent of all deaths below the age of five and 33 percent of all adult deaths in Pakistan are attributable to waterborne disease. Much of the drinking water supply is contaminated—in rural areas, because of polluted sources, storage in contaminated vessels, and poor handling; in the cities, because of leaking sewers, reverse pressure during supply interruption in water mains, and faulty underground tanks.

The province and the municipality of Khon Kaen have made major progress in the past decade in providing good quality drinking water in rural and urban areas, in handling urban sewage, and in public health education. Gastrointestinal diseases related to water quality and sanitation have declined as a result of these programs.

Water-associated Vector-borne Diseases

Control programs for vector-borne diseases in all four countries emphasize new drugs, biocides, and vaccines, to the neglect of environmental management and community-based preventive measures.

Encephalitis is much more common in Fayoum than in the rest of Egypt. Bilharzia infection rates, comparable with the rest of Egypt, are declining through the treatment of patients.

Tadla has had the highest incidence of bilharzia for any city of its size in Morocco since irrigation was introduced in the area. Although by 1990 this had abated substantially through the use of biocides in selected snail habitats, infection still occurs and could increase if snail control is relaxed.

In Pakistan, the incidence of malaria is strongly related to waterlogging and ponding of abstracted groundwater. Internationally assisted control programs, conducted in phases since the early 1960s, have failed because the mosquitoes and the parasite have developed resistance to the biocides and drugs used. The residual effect is an environment containing large amounts of harmful DDT and malathion.

The national government has passed up simple preventive measures such as careful management of groundwater, drainage and filling of mosquito habitats, use of fish to control mosquito larvae, and screening of sleeping areas. Had they chosen these measures, the biocides and drugs could have been kept in reserve for the epidemics that follow flooding.

Dengue is believed to occur in Khon Kaen and in some rural areas in Thailand. It can be controlled by keeping domestic roofwater jars covered to prevent mosquitoes from breeding in them (Strickman et al. 1991). No malaria was reported in the province. Liver flukes, most likely from eating raw fish, are still a problem. As a whole, water-related public health concerns are declining in Khon Kaen.

Ecosystems and Biodiversity

An ecological water buffer is the margin of water needed to maintain the larger ecosystem supporting human and other life. Withdrawals of irrigation water in the four countries are uniformly high, but 40 to 70 percent is returned to the ecosystems, via surface drainage or seepage into aquifers, for local or downstream reuse. An undetermined portion of this water is used by each ecosystem in several nonconsumptive but productive ways, such as supporting fisheries, assimilating human wastes, recycling nutrients, and retarding salt water intrusion in coastal zones.

The four cases reveal that the importance of a water buffer has not been adequately recognized in planning. In Egypt, the regulation of the Nile flood by the construction of the Aswan dam has offered a more predictable supply of irrigation water, but it has caused the loss of millions of tons of fertile silt. New health threats from disease vectors have emerged. Ecological cycles and community structures have been altered. Fayoum, a small-scale version of the Nile watershed itself, presents some of these same problems, such as salt water intrusion from the lake, on a reduced scale. The increasing salinity of the lake, which already exceeds that of sea water, is severely reducing fish stocks.

In Morocco, new dams or diversions have restricted base flows and other conditions needed to protect and maintain fisheries and other aquatic and nonaquatic populations, thus reducing the environmental sustainability of irrigated perimeters developed and expanded downstream. Suitable habitats can be developed in the large reservoirs by analyzing their annual fluctuation patterns and developing operating guidelines to protect the maximum numbers of species.

In Pakistan, the extensive Indus river irrigation system, by diverting normal river flows into irrigation canals, has reduced fish and aquatic mammal populations and threatens the ecology of the coastal zones. A major threat is to wetlands, especially the mangroves of the coastal zones, which face serious damage from existing and planned irrigation. Inland freshwater bodies are also threatened by saline effluent and agrochemicals. Biodiversity in arable areas will suffer if plans for improving watercourse delivery and on-farm application efficiency are implemented without regard for maintaining wildlife habitats and organic processes in soils.

Biodiversity in Thailand's Khon Kaen province has already been greatly reduced by centuries of extensive land use and harvesting of every available food resource. Little macro-wildlife remains in the region. The growing use of biocides will exacerbate this problem, wiping out beneficial, if often nearly invisible, organisms for short-term gains against pests. Research into, and implementation of, integrated pest management techniques, particularly for rice paddies, may be useful countermeasures.

Planning for Long-term Trends

It is evident that future needs and conditions have not figured adequately in strategies and project designs. In Tadla, no realistic population projections to reflect the magnet effect of the development program have been made. In most cases, changes in economic, social, and physical conditions likely to have a severe impact on the sustainability of water use and on development decisions have been ignored.

The most important trend of all is population growth, especially in Pakistan and Egypt, as well as in Tadla. It is a trend that must be taken into consideration in water sector planning. In addition, however, if not controlled, population growth threatens to make the best planning irrelevant.

Other long-term trends noted in the field studies but not adequately reflected in water sector planning include the effects of changing sediment loads and energy trends.

Effects of Changing Sediment Loads

Indiscriminate clearing of forest land in a watershed upsets the natural modulation of water flows that forest cover provides, causing greater extremes of both drought and flood. Deforestation also results in upland soil erosion that exacerbates the siltation of irrigation conveyance and control structures and the sedimentation of reservoirs. This is a serious impediment to water conservation and efficient management in Faisalabad and Khon Kaen, and is a long-term international issue for Egypt and the Nile.

Future water sector planning in Egypt must allow for the siltation of the Aswan reservoir. Between the completion of the dam in 1964 and the complete filling of the reservoir in 1976, measurements and calculations showed that only about 7 percent of the storage capacity had been lost, giving the reservoir an estimated life of about 300 years. However, the projection was an underestimate because it ignored the considerable amount of sediment moving in the bed load of the Nile, and the temporary trapping of sediment in new dams upstream on the Atbara and Blue Nile in Sudan. These dams were constructed at the same time as the Aswan dam. The normal load to be expected in the Aswan reservoir when the two upstream dams start passing sediment will probably be more than twice the amount observed during the past two decades, indicating a life for the reservoir of about 150 years instead of 300 years. The dam on the Atbara filled with sediment in 1990, and the Roseires dam has already lost its dead storage space.

With the dual effects of rapid population growth and decreasing reservoir capacity, Egypt faces a rapidly declining supply of water per capita. Since water from the Nile is essential for agriculture, this decrease will be disastrous. Silt control in the upper catchment should be an international concern of the highest priority.

In Pakistan, there has been a steady decline in the storage capacity of the main reservoirs of the Indus system because of heavy sediment loads in the upper portions of the rivers. This decline can be expected to reduce the regulation capability of the reservoirs and hence to decrease water for irrigation.

In Thailand, forest cover in Khon Kaen province has declined by nearly 60 percent over the last 20 years as farmers have harvested timber and bamboo for expanding industrial markets, and cleared land for upland production of cash crops like cassava and sugar cane. Khon Kaen's many small- and medium-size reservoirs are particularly vulnerable to sedimentation, and the resulting reduction in their storage capacity has hampered the ability of farmers and the Royal Irrigation Department to regulate irrigation supplies. Lower flows during the dry season affect water quality, raising the costs of treating water for drinking. Furthermore, the reduction in both the quality and quantity of river flows harms fish and other aquatic life.

These examples illustrate the importance of linkages between water management and land management, linkages that have not been adequately recognized in water sector planning.

Energy Trends

The loss of reservoir capacity through siltation will have a significant impact on hydroelectric generation in Egypt, Morocco, and Pakistan. Because the prime sites for generation have already been developed and new reservoirs are unlikely because of their disruptive effects on human settlements and ecological systems, these countries have little scope for hydroelectric power expansion. This prospect, combined with the unrealistically low energy prices prevailing, indicate an uncertain future for many water schemes utilizing pumps and other electrical equipment. A sustainable solution will require prices that reflect the true value of energy and strenuous efforts to reduce sedimentation in reservoirs.

There are also indications that subsidized energy prices are responsible for the inappropriate designs, heavily dependent on electricity, of donor-supported urban water supply and sewage treatment systems in Faisalabad and Tadla. Adequate consideration of future trends in power supply at the planning stage probably would have modified these designs.

Institutional Constraints

Institutional constraints include the performance and capacity of environmental and water management institutions, the effectiveness and appropriateness of legislation and regulations to govern resource development and use, the adequacy of information systems, and planning for the long term.

The Weakness of Environmental Institutions

As competing demands for water resources have proliferated, so have the agencies responsible for subsector water management. At the national and provincial levels in the four nations observed, there are agencies with jurisdiction over surface water resources, groundwater resources, water use for energy generation, municipal water treatment and supply, rural water treatment and supply, navigation, fisheries, public health, and water quality.

The weakest of these agencies commonly are those charged with protecting natural resources, including water. They have little authority to carry out their mandates, are poorly staffed and equipped to enforce compliance with quality standards and pollution prevention regulations, and are powerless to require and approve environmental assessments of water-related developments. Water resource development and service delivery or sponsoring agencies often have responsibility for enforcing their own, albeit weak, regulatory statutes.

The Separation of Water Management Responsibilities

Each agency with planning or implementation responsibilities is granted nominal water policy and oversight authority. This not only weakens the agency's accountability to its customers, but also prevents coherent policy development and implementation across all water subsectors. Policies reflect the entrenched interests of agencies and their constituencies, and ultimately lose sight of the unitary nature of water resources and the interrelationship of alternative uses. Thailand offers the most extreme example of this proliferation of bureaucracy, with eight national ministries, 30 agencies or departments, and 20 committees with shared and overlapping responsibility for water resource management and development.

None of the four countries has a comprehensive mechanism for making and implementing water policy. In some, cabinet level councils rely on line agencies to recommend and implement policy decisions. In others, basin-level authorities influenced by user groups have a strong hand in planning. Generally, there is little consideration of issues outside the purview of each agency that makes and implements de facto water policy in isolation.

The deficiencies in policy-making and planning for the water sector in the four countries are marked by the absence of:

- Clear and well-understood legal principles
- Trained multidisciplinary professionals (not necessarily part of the bureaucratic establishment) to consider the full range of issues on the basis of adequate data
- Input from well-informed water users and the public before decisions are made
- Decision-makers who are accountable to the public and whose powers transcend the narrow interests of subsectors and agencies
- Fair appeal and adjudication processes
- Adequate promotional and enforcement capabilities

Training and Outreach for Government, Industry, and NGOs

One of the most effective investments that donors and host governments can make to strengthen environmental institutions is to support staff training and public outreach. Officials at even the highest levels in most developing countries have only a limited appreciation of environmental issues and the requirements for environmentally sustainable natural resource management. Many of the environmental agencies are staffed by veterans of traditional line departments such as public works, fisheries, forestry, and public health, who could profit from new insights.

The case studies indicate that industry and trade associations such as Faisalabad's textile manufacturers' association and Tadla's olive growers' association play no part in the management of water resources, pollution control, or water conservation.

As in many of the industrialized nations, the most vocal groups demanding government action on environmental issues are private voluntary organizations. The success of such groups in articulating popular concern in Thailand over the environmental impact of water resource development suggests the power of grassroots activism. Incorporating these organizations into outreach and awareness programs would raise the profile of environmental issues and encourage greater public participation in confronting them.

Deficiencies in Legislation and Regulations

Deficiencies in the legal and regulatory framework vary by country in the four case studies. In Egypt, eight laws pertaining to water quality and wastewater discharges have been passed since 1962. The Ministry of Public Works and Water Resources is responsible for issuing discharge licenses, monitoring discharges, collecting pollution fees, and enforcing the statutes. Tariffs and fines are supposed to fund enforcement but few fines have ever been collected.

In Pakistan, there is no modern legal framework for controlling water pollution and no comprehensive guidelines have yet been drawn up. The Pakistan Environmental Protection Ordinance, passed in 1983, is concerned mainly with air pollution but has hardly been enforced. There are virtually no controls on industrial waste emissions, as borne out by a recent national survey of 100 hazardous chemical industries that showed only three treated their wastes to acceptable standards.

Until 1992, Thailand's water pollution controls relied exclusively on concentration-based effluent standards, resulting at best in the application of end-of-pipe treatment that did not promote water conservation or guarantee ambient water quality. But even these standards were not enforced for want of the requisite resources. The new, more market-oriented, strategy will use pollution charges to stimulate reduction of pollution sources via process and technology changes. This strategy was launched in 1992 with the passage of two major environmental laws that established an environment fund supported by pollution fees from industry.

These examples from the four countries illustrate three broad conclusions:

- Appropriate legislation and regulations are a key component to environmentally sustainable water development and management, but they need to be based on a strategy that recognizes the difficulties and constraints and is supported by political will.
- Inadequate enforcement of environmental legislation remains a major deficiency. In some cases it can be ascribed to unrealistic legislation, in others to the fact that environmental agencies have only nominal responsibility and a limited executive function, or that responsibilities for water management are dispersed among too many agencies with their own mandates and ambitions. Enhancing the status and capability of environmental agencies and improving interagency coordination will ensure more sustainable protection of water resources and the environment.
- To be effective, water quality protection laws need to be realistic. Sanctions should be commensurate with the environmental damage inflicted. Industries unable to invest immediately in new technologies or pay for cleaner products should be aided by phased implementation of the law. In all cases, legislation and regulations should be simple, transparent, easy to apply, and adapted to local conditions.

Inadequate Information Systems

Adequate environmental information is a prerequisite for strategic as well as project-level development planning. Research related to water resources in all four of the cases studied is at an early stage. There are few studies on anything other than the effect of salinity in the agricultural drainage systems. The environmental effects of pesticides have been evaluated in only one country and that with a very limited number of observations. Safer application of fertilizers and pesticides requires more investigation and management information systems linked to international agencies with experience in the toxicity of these chemicals. Such systems would facilitate wise policy decisions affecting the use of agrochemicals.

Regular data collection on water quality and water uses, a common databank, and improved data analysis would provide invaluable information. The experience of the industrialized countries in developing indicators of ecosystem health could be incorporated and adapted to local conditions. Compatible procedures and methodologies, the spacial distribution of data collection, frequency of sampling, and methods of using data in environmental planning are other fields that could be developed. Strengthened national environmental agencies could be instrumental in coordinating data collection, implementing systematic and uniform monitoring, stimulating information sharing, and ensuring the acceptability of new water developments and uses.

Water Pricing

Water Pricing Policies

In water development and management, engineering solutions alone are unlikely to conserve an increasingly scarce resource without realistic water pricing. Suitable pricing is essential to recover the cost of service.

The four case studies indicate that current on-farm water management practices in many instances have led to conscious waste, not because of technical difficulties or ignorance, but simply because such practices appear more convenient or even more economical. Since the price of water is less than the cost of labor and equipment needed to conserve it, farmers have little incentive to avoid overirrigation and practice conservation.

Morocco is demonstrating that movement toward a market approach is feasible under some circumstances. The Agricultural Investment Code (AIC) calls for full recovery of operation and maintenance costs and up to 40 percent of initial investment costs. Water rates have three components: a volume-based charge to cover operating costs and 10 percent of investment costs, a volume-based pumping charge to cover energy costs, and a land betterment levy to cover 30 percent of initial investment costs. Charges are differentiated by region and are periodically updated to cover inflation. There are plans to increase water charges and improve collection rates.

Substantial water savings in the four countries are also possible in urban areas through more appropriate water pricing. Water in urban areas is still a cheap commodity, and most users do not pay for the actual amount they use. Two effective mechanisms for encouraging the efficient use of water in all its subsectors are to raise user charges and enforce collection according to the level of consumption.

Other Resource Price Distortions

Just as a better pricing policy can improve water use efficiency, so also reestablishing the link between water pollutants and their cost as a factor of production can improve water quality. The case study of Egypt illustrates how price distortions can be corrected.

A policy to enforce the responsible application of agrochemicals is expected to substantially reduce the wasteful use of fertilizer and pesticides. It will be supported by the reform of the economic policy framework and incentive structure to bring about the gradual elimination of the implicit energy subsidy for fertilizers and the continued reduction of the direct subsidy for pesticides.

Studies by Egypt's Water Pollution Control Department of the National Research Center suggest that pollution in most industries is a consequence of inefficient production methods, driven in part by subsidized energy prices. Reducing energy subsidies will be an important step towards reducing industrial pollution.

5

WATER POLICY IMPLICATIONS

Program and Project Planning

The study has revealed some deficiencies in the planning of water subsector programs and projects. It also suggests some principles that should be considered at the planning stage.

Planning Deficiencies

All four study locations suffer from some degree of water shortage and water pollution, and three now face or have had waterlogging and salinization problems. All four have taken major steps in water development and water-related activity, some since the last century, others more recently. With a few exceptions, these steps have met their objectives. Nevertheless, there are observed deficiencies affecting environmental sustainability. These include:

- Failure to use low-cost technologies and minimize energy needs
- Combining wastewater streams
- Irrigation systems without drainage
- Lack of incentives to conserve and reuse water in all subsectors, not just agriculture
- Failure to monitor or control the use of agrochemicals
- Failure to consider the interactions among these and other water issues

Of the many water development and water-related activities observed, only two have proved unsuccessful: an activated sludge wastewater treatment plant that the intended owning and operating authority has declined to accept because of its very high operating cost; and a sequence of malaria control programs, based on the use of biocides and drugs, which has been abandoned because of the development of resistance.

In almost every case, however, it appears that programs and projects would have profited from better planning and design, especially if there had been suitable water policies to provide a framework for program or project planning.

Important project planning or design deficiencies are clearly apparent in retrospect and should have been avoided. One of the most important oversights is the failure to provide affordable and effective wastewater treatment, or in some cases even to allocate the land needed for treatment. The acquisition of land for low-cost lagoon or land treatment near growing urban areas, if not taken care of at an early stage, can become so expensive that it precludes the use of such methods.

The inclusion of industrial wastes in collected urban sewage often makes the treated sludge, and even the effluent, unusable for agriculture. In spite of this, separate management of industrial wastes has not been incorporated into urban wastewater planning. Even where urban land use planning, including industrial siting, has received some attention, the mitigation or control of water pollution does not seem to have been an important objective, even though zoning can reduce the effects of industrial wastes and the cost of managing them.

Other planning and design deficiencies include the failure to use integrated vector management, including water management, in dealing with malaria, and the well-known failure to provide for drainage in irrigation projects, with the result that waterlogging and salinization later become the focus of corrective measures.

A major shortcoming is the omission of such water-saving features as water charges that link user costs to water demands the reuse of reclaimed wastewater that is safe for agricultural or other purposes, and programs to minimize water losses. In addition, there is an erroneous assumption that all renewable water resources are available for abstraction without regard to the needs of ecological maintenance, wastewater assimilation, and prevention of saline intrusion in coastal areas.

Many other planning and design features in the case study areas appear to be questionable, but it is not possible to take definitive positions on them without more detailed study. They do, however, suggest issues that should be considered carefully in all future planning for water-short, low-income countries with environmental health and ecological maintenance problems. Examples are the inappropriateness of combined sewers, which tend to lead to overflows and increase treatment costs, and the use of a waterborne wastewater conveyance itself when there are more suitable alternatives for some water-short rural and periurban communities.

Planning Principles

The case studies and other available information show that the following substantive principles and measures should be considered at the planning stage of water development and use programs and projects to support environmental sustainability:

Resource availability and shortage:

- Conservation of water in all water subsectors through minimization of transmission losses and reduction of wastage by users
- Management of demand through water and wastewater pricing in proportion to volume and through the removal of subsidies on such factors as energy for pumping
- Reuse of wastewater and sludge
- Conservation of energy, funds, and other resources used in water sector programs and projects
- Planning of new and rehabilitated irrigation facilities as components of complete systems, including farmer needs, methods and rates of water application, delivery systems, drainage, operation and maintenance, and revenue generation
- Maintenance of base flows to support ecology and biodiversity, and the conduct of studies to quantify such needs

Water quality and health:

- Provision of drainage with irrigation systems and of sanitation and sewerage with urban water supply systems
- Giving high priority to the reduction of pollution by hazardous industrial and agricultural substances
- Separation of waste streams of domestic sewage, stormwater, and industrial wastes
- Provision for low-cost wastewater treatment for urban areas by the early acquisition of sites for lagoon systems and further demonstration use of artificial wetland systems
- Phased zero discharge systems for industrial wastes, beginning with hazardous components, and provision of separate recycling/disposal facilities for such components
- Location of industries to lessen the impacts of wastewater disposal on the water environment

- Use of water management and behavioral methods, as well as biocide-based techniques, to control water-related vector-borne disease

- Use of non-waterborne excreta disposal systems in water-short areas where conditions permit

Other conclusions include the importance of:

- Data collection programs directed towards the support of decisions and policies that must be made across the water sector, not limited to the interests of particular users

- Consideration of long-term trends well beyond the expected useful life of first-stage facilities in preparing feasibility evaluations of proposed projects

Water Sector Policies

While all four countries have policies relating to water, they are not adequate for good governance of the sector. Good water policies may differ among countries, but some sound principles for policy-making apply universally.

Policy Shortcomings

The inadequacy of, or failure to implement, water policies has had several significant consequences, not only for water development that has already taken place, but also for broad unresolved issues. Examples of the former are infrastructure facility decisions that are questionable on the basis of water and energy conservation or pollution mitigation but were made because of jurisdictional barriers between water subsector organizations.

The consequences of ineffective policies on problem resolution are most evident in industrial pollution control and in tracking and control of the use of agrochemicals. Significant progress in environmental management is being made in only one country where, for example, voluntary environmental organizations are becoming active and separate hazardous industrial waste treatment or recycling facilities are being introduced. In one other study country, new legislation to empower environmental management is being considered.

Improved Policy Development

The water sector is very complex and variable, as are the organizational and institutional arrangements to manage it. Effective policies do not appear by effortless inspiration or simple transfer between countries. In general, they result from the careful study of options across the spectrum of sector components and water uses. In the following section, the term "governance" denotes the sponsorship and development of broad strategies and the adoption and application of policies based on them. It does not include the provision of infrastructure or services, even when government agencies are responsible for them.

The Issue of Governance

The four countries have institutional difficulties in dealing with water sector problems. While the private sector has contributed to these problems and a lack of funds limits improvement, the boundaries defined by these two constraints are in many cases untested because of inertia or indecision in governance.

Inertia and indecision are the result of: the conflicting interests among agencies having water-related responsibilities and between these agencies and the private sector; lack of transparency and unwillingness to permit public participation in the consideration of water issues; fear on the part of policymakers and regulators that control of water pollution will have unacceptably high costs to industry and others; and lack of reliable data on which to base sound water sector decisions.

These concerns are general and understandable for most countries, not just the four being studied. A common contributing cause is that water usually is one of many concerns for government agencies and other entities. If they do focus on water, their jurisdictions and interests are generally limited. The question therefore is this: In the context of firmly based divergent interests both inside and outside of governments, is it possible to generalize about actions that constitute good governance in support of environmentally sustainable water use and development?

This study and other ISPAN experience in these and other Asian and Near East countries suggest that there are two levels at which appropriate decisions must be made: the national or basin level and the program or project level. National or basinwide policies establish the procedures and criteria for the development, screening, and approval of infrastructure and service programs and projects. At each level, it is critical that the necessary information is available, that all stakeholders are heard, that environmental and water resource sustainability issues are examined openly, and that decisions are made or approved by an impartial process or entity. Based on these principles, some generalizations have been made about elements of good water sector governance.

National or Basin-level Policies

While decisions should not have to await the preparation of overall water strategies and policies, they will be more sound if such strategies and policies exist. In addition, policy development will be most even-handed when it is not associated with the evaluation of a specific proposal or the interests of a particular water user. National or basinwide strategies and related policies will depend, among other factors, on the national philosophy of governance. They may be situated at any point on a continuum between largely diagnostic and prescriptive planning at one extreme and broad legal principles requiring case-by-case interpretation at the other.

Regardless of the philosophy, however, there are several criteria that water policies should meet and that should guide the process by which they are developed, if they are to provide good sector governance in the long term. These criteria include:

- Adequate data for decision-making
- Transparency and adequate feedback from all stakeholders, including the public, to ensure policies are acceptable
- Judicious combination of incentives and enforcement to protect water resources
- Procedures for setting priorities and standards, and for resolving disputes
- Provision for environmental assessments of all activities and projects affecting the water resource
- Flexibility to accommodate changing needs and conditions
- Provisions to minimize bias and promote equity

Good sector governance requires the separation of the power and authority of governance from the functions and interests of those who provide water services and infrastructure. The study countries illustrate the negative effects of not maintaining this separation. Irrigation systems have been planned and implemented with little regard for the needs of users. Institutional barriers that inhibit cooperative action at the local level cannot be removed because they have been imposed by the government. Service providers protected by government sponsorship have made decisions to further their own interests because they are not accountable to their customers. Inappropriate or unnecessary facilities have been constructed, maintenance is poor, and operating procedures are unsuitable.

The Environmental Assessment

At the program or project level, the coordination of development and use proposals for all water subsectors is vital before they are implemented.

As a tool to achieve this, the environmental assessment, already well recognized in many industrialized countries, is beginning to be adopted in some developing countries as well, in part because of the efforts of donors like USAID and the World Bank. More and more projects are being subjected to the process to ensure that they meet acceptable standards and will be sustainable.

However, many key decisions about water are made in conjunction with infrastructure investment decisions. Because these investments are frequently sponsored by government agencies, the environmental assessment is generally treated as merely an aspect of preinvestment planning by or on behalf of the project owner or a sponsoring ministry. It becomes a search for measures to mitigate environmental impact and seldom seriously calls into question the fundamental elements of a project or program. It tends to sidestep consideration of whether a project or program should proceed at all, or be subject to major reorientation for reasons of environmental sustainability. In addition, environmental impact evaluations are frequently postponed until the project implementation stage when commitment to the project or program may be irrevocable.

Most projects are not expected to require major revisions as a result of environmental assessments. However, some of those reviewed during the case studies probably would have been changed significantly had thorough environmental assessments using full data been conducted. The recommendations of planners and designers may very well have been different with the prospect of an environmental assessment ahead.

Projects for water infrastructure and use should be thoroughly evaluated at the planning stage before detailed designs have been drawn up (these can be assessed later), because once a project has found an interested funding source there is great pressure to proceed.

The criteria for conducting environmental assessments should be determined by an entity independent of the sponsoring or implementing organization. Decisions based on the results of the assessments should also be made independently. Informed public opinion is essential in both the scoping and review of these assessments.

Donor Opportunities

In addition to their obligation to support only environmentally sustainable water programs and projects, donors have an opportunity to help governments to develop and apply sectorwide strategies and policies to support sustainability.

The health and ecological implications of the uncontrolled use of water are now so great that new approaches by international donor agencies are warranted. The piecemeal approaches that have tended to rely heavily on covenants or institutional studies tacked onto loan or grant programs are no longer adequate. Such devices seldom have more than a limited effect, given the concerns and difficulties of governments.

Furthermore, decision-making on water use must at all costs avoid a bias in favor of agencies or subsectors that happen to be ready to make investments, even if their programs and projects have health-oriented or environmental goals.

An essential component of sector planning and policy development is interagency and public participation. Such participation is essential for the sound development of the broad analytical frameworks for policy analysis and planning recommended by the World Bank (1993) and for the appropriate scoping, conduct, and application of environmental assessments.

Donors should support only environmentally sustainable water programs and projects, assist host countries to develop the right water policies and capabilities, and coordinate their efforts to prevent one donor from inadvertently undercutting the sustainability approach of another.

Support for Sustainable Interventions

Environmental sustainability, while not readily measurable, is a familiar concept and goal for international donors. Both governments and donors generally intend to maintain the adequacy of resources but are often faced with the need to make decisions with inadequate data. Donors can assist governments to decide what data are needed as a basis for decision-making. They can also influence host country governments in other beneficial ways, for instance by advocating access for interest groups and transparency when water programs are being formulated, and by providing examples, data, and expertise. Donors can help governments at the project identification stage to reach an awareness of water sustainability issues that have not previously been seriously considered and assist in ensuring that the appropriate principles are applied in program and project planning.

They can also provide impetus to governments in introducing suitable planning processes and in upgrading their capabilities for water program and project planning. Pending the development of suitable water sector policies and planning principles by governments, donors can encourage the use of appropriate donor-provided planning principles and methods for interventions that they are being asked to support. Such planning principles might include those listed above in section 5.1. Related planning processes should where appropriate include both public participation(includingdemand-based decision-making) and adequate environmental review.

Assistance with Policy Development

Policy dialogue between governments and donors that have established influential host-country relationships can be a major force in the general promotion of environmental sustainability. Such dialogue may frequently need to include joint undertaking of sector-wide strategic studies on the basis of which appropriate policies should be adopted. These studies may need to be preceded by assistance in the planning or execution of data collection and management.

Policy development and implementation guidance will generally need to be provided as grant assistance because governments are reluctant to borrow internationally for purposes other than infrastructure development. In order to prevent bias from influencing the results, policy assistance should preferably be independent of loan or other assistance to any individual facility owner or service provider.

Technical assistance is hemmed in by difficulties, not the least of which is the limited availability of donor grant funding. The weakness of agencies nominally responsible for environmental management in standing up to agencies that support the interests of industrial groups is another difficulty. Donors are also uneasy with programs whose timeframes do not offer the promise of early results or which do not fit readily into conventional donor project cycles. Associated with this is the difficulty donors have in setting up programs that do not have a preconceived course of action and end-results fully identified in advance.

The development and initial implementation of sector policies involve data collection, problem/issue definition, organizational and strategic planning, policy formulation, interagency discussion and consensus-building, public/NGO participation, and field testing. Governments may need donor assistance with many of these steps. The typical donor project cycle of five to seven years is not long enough to provide adequately for sustained input to this process.

The two key requirements to ensure the effectiveness of donor assistance in improving governance in the water sector are:

- A long-term partnership between the host country and one or more donors that sets out to achieve water sector environmental sustainability, and recognizes that policies and strategies must evolve in response to experience gained, lessons learned, and changing perceptions.

- An understanding among donors that they will all be sensitive to environmental sustainability in defining the objectives and conditions of grant and loan assistance projects for water infrastructure investment, water development, and water use.

Donor Coordination

Donor coordination in providing for the water sector is of paramount importance. Without it, any donor offering low-interest or grant funding of capital projects, and ignoring the need for environmental or water management, is likely to undercut others who have serious concerns and try to persuade the host government to provide such management. However, it is essential that coordination of donor programs should not usurp host government responsibility for policies, programs, and priorities.

Towards Environmental Sustainability of Water Resources

The four case studies illustrate environmental sustainability problems of various degrees of severity that could probably have been found elsewhere. As the basis for the conclusions drawn in this report, the results have been supplemented by ISPAN's experience in other countries in Asia and the Near East.

The water resource constraints in these and many other countries will worsen. In most water-short developing countries, water crises are approaching much faster than is implied by global population and water use trends. Donor support for development planning to achieve environmental sustainability can ease the impending crises, helping to alleviate water shortages and pollution. It cannot increase the supply of water. The institutional and procedural improvements suggested in the conclusions will be far less expensive than such supply-side measures as interbasin transfer of water or desalinization of sea water. Such measures might eventually be needed in some countries, but the improvements proposed are a worthwhile first line of action towards long-term stability.

Better definitions of terms are needed for measurement of progress towards achievement of environmental sustainability. The Brundtland definition of sustainable development, by referring to future needs, is indeterminate, and can be regarded as unachievable, since it sets no limit on future needs. While efficiency of water use is generally understood as requiring minimization of losses and wastage, it is clearly defined only in the irrigation subsector. Even that definition does not completely isolate losses and wastage. Sectorwide definitions of the environmental sustainability of water development and efficiency of water use and/or other appropriate terms are needed that, taken together, will embody the general sense of the Brundtland definition of sustainable development, provide a basis for measurement of performance, provide explicitly for both human and ecological needs, address both quantity and quality of water, and provide for preservation not only of the water resource but also of other resources that support water development and use.

BIBLIOGRAPHY

APHA, ASCE, AWWA, WPCF.
1981. *Glossary: Water and Wastewater Control Engineering.*

Brown, Lester, et al.
1993. *State of the World 1993.* New York: Norton.

Caldwell, Lynton K. (editor).
1988. *Perspectives on Ecosystem Management for the Great Lakes.* Albany: SUNY Press.

A reader on an ecological systems approach to water basin management that draws on the lessons of shared U.S.-Canadian experience.

Clarke, Robin.
1993. *Water: The International Crisis.* Cambridge: MIT Press.

Colby, Michael E.
1990/1991. "Environmental Management in Development: The Evolution of Paradigms." World Bank Discussion Paper No. 80 (1990) or *Ecological Economics* 3(1991): 193-213. Washington, D.C.: World Bank.

A paper explaining five worldviews of the relationship between ecology and economics, and their strategic implications for planning sustainable development.

Costanza, R., B.G. Norton, B.D. Haskell (editors).
1992. *Ecosystem Health: New Goals for Environmental Management.* Island Press.

Daly, Herman E. and John B. Cobb, Jr.
1989. *For the Common Good.* Boston: Beacon Press.

A major treatise on what is required to redirect economies toward sustaining communities and the environment.

De Zulueta, J., S.M. Mujtaba, and I.H. Shah.
1980. "Malaria Control and Long-term Periodicity of the Disease in Pakistan." *Transactions of the Royal Society of Tropical Medicine and Hygiene.* Vol. 74, No. 5: 624-632.

Engineering Science Inc., Thai DCI Co. Ltd., and System Engineering Co. Ltd. 1989. "National Hazardous Waste Management Volume 2." Report submitted to the Office of the National Environment Board, Bangkok, Thailand.

Food and Agriculture Organization.
1990. *An International Action Programme on Water and Sustainable Agricultural Development: A Strategy for the Implementation of the Mar del Plata Action Plan for the 1990s.* Rome: Food and Agriculture Organization of the United Nations.

Fredericksen, Harald D.
1992. "Water Resource Institutions: Some Principles and Practices." World Bank Technical Paper. Washington, D.C.: World Bank.

Hardin, Garrett.
1968. "The Tragedy of the Commons." *Science* 162: 1243-8.

This paper discusses the process by which unpriced, unowned resources ("common property") are almost inevitably driven to extreme scarcity, and the economic disruption that follows.

Herbert, Frank.
1965, 1984. *Dune.* New York: Putnam.

Winner of both the Nebula and Hugo Awards, the first of a series of six novels about [illegible]ing an understanding of the interactions between ecology, governance, philosophy, and religion to transform an arid planet into a more habitable, moist climate.

Hoover, Robert N., and Aaron Blair.
1991. "Pesticides and Cancer." *Cancer Prevention: An International Journal.* February: 1-11.

Hunter, J., L. Rey, K.Y. Chu, E.O. Adekolu-John, and K.E. Mott. 1993. "Parasitic Diseases in Water Resources Development." Geneva: World Health Organization.

Kalbermatten, J.M., D.S. Julius, C.G. Gunnerson, and D.D. Mara. 1982. "Appropriate Sanitation Alternatives: A Planning and Design Manual." *World Bank Studies in Water Supply and Sanitation Volume 2.* London: Johns Hopkins University Press.

Obeng, L.A. and F.W. Wright.
1987. "Integrated Resource Recovery: The Co-composting of Domestic Solid and Human Wastes." Project Management Report Number 7. United Nations Development Programme. *Also* World Bank Technical Paper 57. Washington, D.C.: World Bank.

Panayatou, Theodore.
1992. *Green Markets: The Economics of Sustainable Development.* San Francisco: ICS Press.

Rogers, Peter.
1992. "Comprehensive Water Resources Management: A Concept Paper." Policy Research Working Paper No. WPS 879. Washington, D.C.: World Bank.

Seckler, David.
1993. "Designing Water Resource Strategies for the Twenty-first Century." Center for Economic Policy Studies Discussion Paper No. 16. Arlington, Va.: Winrock International Institute for Agricultural Development.

This paper discusses the limited feasible gains from water conservation, especially in "closed" systems where water is reused several times. It concludes that the world will need to develop about 60 percent more water by the year 2030.

Sharp, Dan S., Brenda Eskenazi, Robert Harrison, Peter Callas, and Allan H. Smith. 1986. "Delayed Health Hazards of Pesticide Exposure." *Annual Review of Public Health.* 7:441-71.

Strickman, D., P. Kittayapong, B. Innis, and R. Wannapong. 1991. "Focality of Dengue Transmission in Rural Thai Villages and Proposals for Community Based Vector Control." Abstract 402, Proceedings of December 1991 Annual Meeting, Boston, American Society of Tropical Medicine and Hygiene.

United Nations Development Programme (UNDP).
1983. "Feasibility Studies for Regional Cities Development, Final Report, Volume 3—Khon Kaen." Kingdom of Thailand Ministry of Interior and United Nations Development Programme.

U.S. Agency for International Development (USAID).
1993. "Water Resources Action Plan for the Near East: Background, Issues, and Options." Washington, D.C.: U.S. Agency for International Development, Bureau for the Near East.

U.S. Geological Survey.
1986. "Estimated Use of Water in the United States in 1985." Washington, D.C.: U.S.G.S. Circular 1004.

Includes a glossary of water-use terminology that is updated every five years.

Vitousek, P. M., P.R. Ehrlich, A.H. Ehrlich, and P.A. Matson. 1986. "Human Appropriation of the Products of Photosynthesis." *BioScience* 34: 368-373.

Estimates the total amount of the planet's primary (plant) productivity that is being consumed by humans, and raises questions about what the ecological limits to such appropriation might be.

World Bank.

1991. "Environmental Assessment Sourcebook. 3 Volumes." World Bank Technical Paper Number 139. Washington, D.C.: World Bank.

1992. *World Development Report 1992: Development and the Environment.* New York: Oxford University Press.

1993. "Water Resources Management." A World Bank Policy Paper. Washington, D.C.: World Bank.

World Commission on Environment and Development.

1987. *Our Common Future.* Oxford: Oxford University Press.

World Resources Institute.

1992. *World Resources: 1992-93.* New York: Oxford University Press.

Appendix A

OVERVIEW OF CASE STUDIES

Fayoum, Egypt

The Fayoum governorate is located west of the Nile valley in middle Egypt in an extremely arid region with an average annual rainfall of only 10 mm (Figure A.1). It covers an area of about 4,578 km^2 and is part of a circular 12,000 km^2 natural depression with well-defined boundaries.

The National Context

Egypt has a land area of about 1 million km^2, of which less than 3 percent is cultivated. The rest is desert. Most of the population of 57 million lives within 10 km of the Nile or on its delta on the Mediterranean; 38 percent of the population is estimated to be settled in urban areas. At the current 2.5 percent rate of growth per year, the population could reach 70 million by 2000 and at least 86 million by 2025. The Nile is the principal source of freshwater for agricultural, domestic, and industrial uses. Annual per capita water use is estimated at 1,000 m^3. Table 1.1 of the report provides estimates of water use by sector.

The Nile Waters Agreement with Sudan and other upstream countries provides Egypt with an average of 55.5 BCM of water per year released from the Aswan High Dam. Groundwater abstraction in the Nile valley and delta currently is 2.6 BCM per year, and this must be recharged from the river flow. About 97 percent of the water in the Nile is used; only 1.7 BCM per year flows into the Mediterranean. A further 12.3 BCM per year of used water (mainly excess irrigation water) flows out through drains, mostly into the Mediterranean and the delta lakes.

Irrigation canals are the principal means of water delivery in the cultivated lands of the Nile valley and delta. Egypt's growing water requirements could increase by 20 to 25 percent in all sectors by 2000, especially if the government succeeds in reclaiming another 2 million acres of desert for agriculture. The rapid population growth, combined with the limit on water available from the Nile, will thus cause a rapid decline in the per capita national supply of water. Except to the extent that reuse can be increased, the per capita rate of abstraction of water will decrease in inverse proportion to population growth.

Population and Settlement

The population of the Fayoum governorate, three-quarters of whom live in rural areas, is estimated at 1.8 million, approximately 3 percent of the national total. Fayoum city has nearly 250,000 inhabitants, and four smaller cities another 150,000. Each city has several satellite villages. Including their farmland, these villages have an average population density of 1000 people per km^2. Population growth has slowed somewhat from an annual rate of 3.6 percent in 1960 to about 2 percent today, but the total population of the governorate is still expected to exceed 2 million by 2000 and could reach 3 million by 2020.

About 30 percent of the land area of the governorate is agricultural, 10 percent is occupied by infrastructure and human settlements, and the rest is desert. There is relatively little industry.

Water Resources and Issues

The sole source of Fayoum's surface water is an irrigation canal network with an offtake on the Nile. This network dates from 1869, when the Ibrahimiyah canal was added from an offtake higher up the river to increase flows into the Bahr Yousef, which supplies the central and northern parts of the basin. Drainage from this system is directed to a natural depression to form Lake Qarun. The supply for the governorate's potable water treatment plants comes from an intake

FIGURE A.1 - EGYPT AND FAYOUM

near the point at which the Bahr Yousef enters Fayoum. The quality of this water is relatively good. The Bahr Hassan Wasef canal was added in 1905 to supplement water supplies in the southwestern area. More recently, a tunnel was installed to drain excess water from the southwestern part of the basin to form two artificial lakes in the adjacent Wadi El-Raiyan district, which is uncultivable desert. All agricultural runoff and domestic/industrial wastewater drain into Lake Qarun and these two artificial lakes. The lakes have no outlets. Groundwater in Fayoum is saline and is not exploited.

Withdrawals of water in Egypt total about 97 percent of the flow of the Nile, virtually Egypt's sole source of freshwater. This includes re-withdrawal of return flows, so there is no implication that there is an upper limit of 100 percent or any other figure. The projected population increase is expected to add at least 60 percent to the demand for water services by 2020. Water scarcity in Egypt is already a concern and can be expected to become critical. Since it is highly unlikely that the gross water supply will increase, gains in the efficiency of water use and in the extent of reuse will be essential to sustaining the population's needs in the not-too-distant future. Since water transferred from the Nile to Fayoum cannot economically be reused, this transfer can be regarded as detracting from the overall efficiency of national water use.

In Fayoum, there are major deficiencies in the spatial and seasonal distribution of irrigation water and in the efficiency of water use. Excessive leakage and low pressure are common in the domestic water distribution system.

The main environmental effects of irrigation water management are waterlogging, salinization, and contamination by agricultural chemicals. Some heavy metals are also found, probably from fertilizer impurities.

Until very recently, rural Fayoum had virtually no sewerage system. About three-quarters of the population depend on on-site disposal in simple soakaways, many of which overflow into irrigation drains or canals.

Waterborne diseases are the most serious health issue in Fayoum, which has child mortality and crude death rates higher than the national average. Encephalitis is much more common than in the rest of the country. Malaria and bilharzia infection rates are comparable with the rest of Egypt, though they appear to be gradually declining through treatment rather than the control of vectors.

Lake Qarun's fish production has been declining steadily over the past three decades because of increased salinity from inflowing agricultural drainage water.

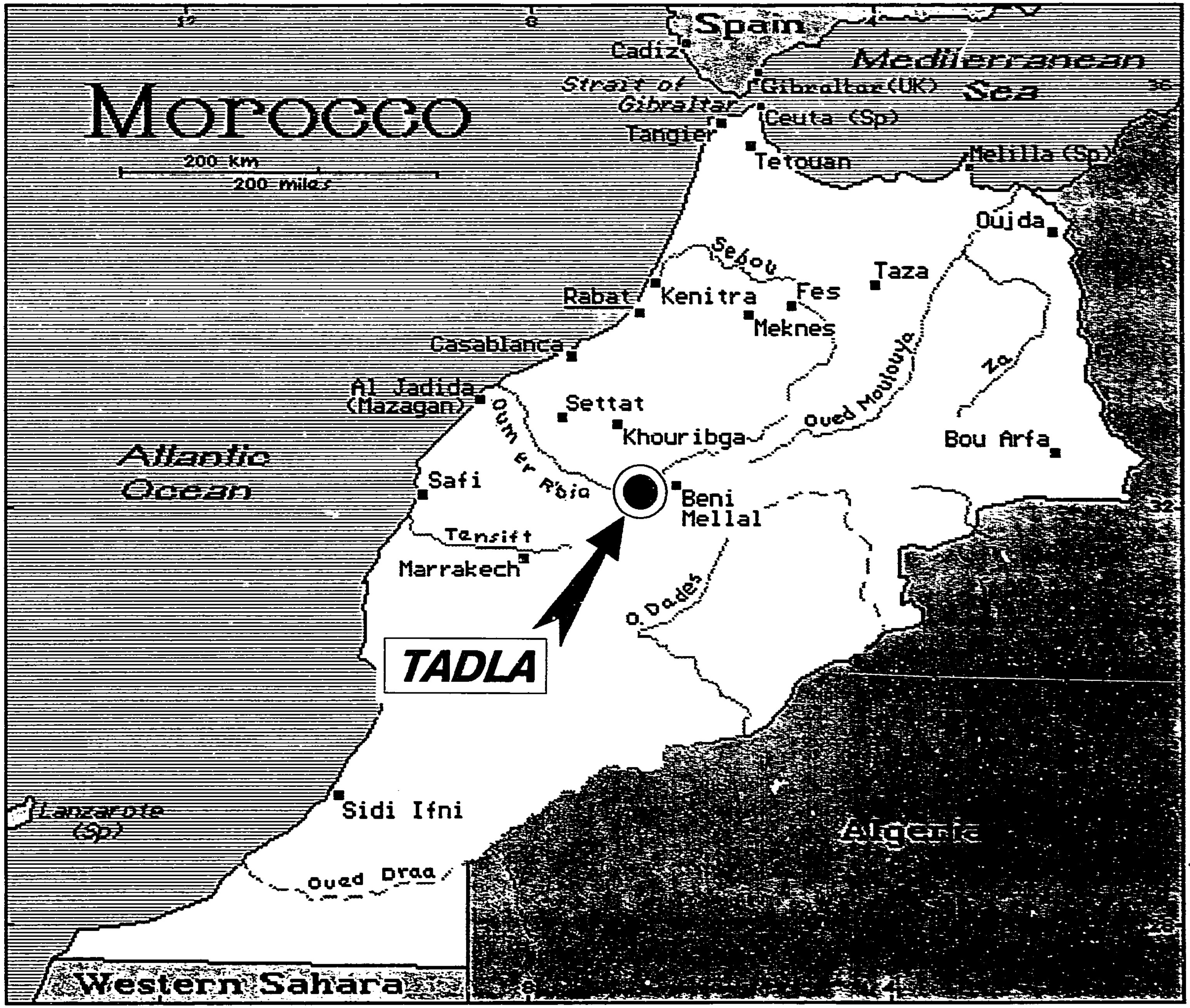
Responsibilities for water management in Fayoum and Egypt are dispersed among several ministries and line agencies, each with its own activities, mandate, and jurisdiction. The Egyptian Environmental Affairs Agency (EEAA) was established in 1982 under the Ministry of Cabinet Affairs to improve environmental planning and coordination. However, EEAA has had only nominal responsibility and a limited executive function. The passage of pending legislation to enhance EEAA's status and capability will be an important step toward the sustainable protection of water resources and the environment.

Tadla, Morocco

Tadla lies in the Oum Er R'bia river basin, one of the most important in Morocco (Figure A.2). Development of water resources has greatly increased economic activity, especially sugar and cattle production, in the Tadla plain.

The National Context

Morocco has a land area of approximately 459,000 km^2, of which only 8.3 million ha, or 18 percent, is arable and only 6.7 million ha is now under cultivation. The population of 25 million is concentrated in the northern and coastal areas of the country, and 45 percent is estimated to be settled in urban areas. The population growth rate has been



Boundaries shown are not necessarily authoritative

FIGURE A.2 - MOROCCO AND TADLA

declining in recent years and is now 2.4 percent per year, which will double the population by 2020.

Morocco has a Mediterranean climate, with arid to semiarid conditions over most of the country. Average annual precipitation ranges between 300 mm and 900 mm. Most of the country's rivers are intermittent watercourses, with dry periods during the spring and summer. Two-thirds of Morocco's water withdrawals of 11 BCM per year are derived from surface water sources and one-third from groundwater sources. Ninety-five percent of surface water and 85 percent of groundwater withdrawn are used for irrigation. Annual per capita water use in Morocco is estimated at 501 m^3.

The Government of Morocco has for several years been mobilizing water resources under the "one-dam-per-year" development program that has resulted in the construction of major structures and hill dams and in the extension of irrigated areas. It plans to further increase land area under irrigation from 830,000 ha to at least 1 million ha by the year 2000.

In urban areas, about 75 percent of the population have a piped water supply and 50 percent have connections to a sewer system. The other 50 percent rely on on-site disposal systems, mainly septic tanks. In rural areas, only 4 percent of the population have individual house connections, and another 30 percent have access to public standpipes and wells. The rest depend on surface water and private wells that are potential sources of waterborne diseases.

Population and Settlement

The Tadla irrigated area coincides roughly with the province of Beni Mellal, which had a population of 900,000 in 1992. The population projected for 2020 is about 2 million, excluding those likely to migrate into the province. The population density of Beni Mellal province was 100 persons per km^2 in 1992 and is projected to increase to over 200 persons per km^2 by 2020.

Recent migration figures show that the population is increasing faster than previously estimated. The Tadla area is a magnet for people from the surrounding provinces attracted by employment opportunities offered by sugar beet processing, olive oil production, and a tannery. Tadla is a prosperous and successful agricultural community, and its problems spring primarily from rapid population growth and improper water management.

Water Resources and Issues

Tadla is divided into two subperimeters by the Oum Er Rbia river. The Beni Amir subperimeter on the right bank has 27,500 ha of agricultural land irrigated from the Kasba Tadla diversion dam upstream. The Beni Moussa subperimeter to the south on the left bank covers 69,500 ha of agricultural land irrigated from dams on the El Abid river. An additional 5,000 ha are irrigated in small perimeters and 12,000 ha are irrigated by groundwater.

A hydroelectric dam at Bin el Ouidane discharges to a smaller diversion dam that passes the flow to tunnels under the Atlas Mountains and then to penstocks leading to another hydroelectric installation at the southern edge of the Beni Moussa subperimeter. Irrigation canals lead the water discharged from the turbines at this point to the subperimeter.

The irrigation system in Tadla includes 200 km of main canals, 360 km of primary and secondary canals, and 1,800 km of tertiary canals, all lined with concrete. Drainage is provided by a network of 1,700 km of surface drains.

The watershed suffered severe droughts in the early 1980s and continues to experience depressed rainfall. The two main storage dams in the basin were at less than 20 percent of capacity in June 1993.

Waterlogging from excessive irrigation and contamination of surface water by surface salts, agrochemicals, and agroindustrial discharge are major problems in midvalley and downstream from Beni Mellal. Pollution of surface waters by urban sewage is serious and is especially pronounced in the areas downstream from Khenifra, Kasbat Tadla, Beni Mellal, and Azemmour. A $6 million activated sludge wastewater treatment plant for Beni Mellal lies idle. The municipality will not accept and operate the plant because of its high power demand. Drinking water supplies in rural areas are contaminated because of the high water table and the proximity of shallow wells and septic systems.

Although the present systems provide enough water for all sectors, the development of another irrigated perimeter near Doukkala within a few years is expected to cause a deficit in the basin by 2000.

In Tadla, diarrheal diseases are a growing problem, caused primarily by the rapid increase in population and the high water table. Periodic outbreaks of cholera have occurred in recent years in the waterlogged areas, and the general incidence of hepatitis, typhoid, and other diarrheal diseases is unacceptably high in children. The public health authorities report seasonal outbreaks of cholera and typhoid in years when the water table is high. As the water table rises to the level of the pits, either simple latrines or cesspools, in which people generally dispose of their excreta, it provides a direct hydraulic connection with the nearby wells used for drinking water.

Tadla has had by far the highest incidence of bilharzia in any large area of Morocco since the development of irrigation in the area. In 1982, a survey of over half the rural households in Tadla by the Ministry of Health indicated that 19 percent of the people examined were passing the eggs of the bilharzia parasite in their urine. In 1990, only 155 cases of bilharzia were detected by urine examinations, but the infection still occurs and could increase if snail control is relaxed. Current control practice affects only a few of the snail habitats, and the snails could return in force if repeated biocide applications are interrupted.

Water management in Morocco's irrigated perimeters is carried out by the Ministry of Agriculture and Agrarian Reform through its regional agricultural development offices, the *Offices Régionaux de Mise en Valeur Agricole* (ORMVAs).

Water supply and sanitation for Beni Mellal, the provincial capital, are managed by the National Office of Potable Water and the Municipal Engineer's office. The only functioning environmental agency in the Tadla area is the environmental division of the ORMVA. National monitoring of water quality is conducted by the Administration de l'Hydraulique's water quality division in Rabat.

Faisalabad, Pakistan

Faisalabad district is a 535,000 ha jurisdiction situated in the center of Punjab province between the Ravi and Chenab rivers (Figure A.3). It is the most populous district of the province, accounting for nearly 10 percent of Punjab's 60 million people. Since the end of World War II and Pakistan's independence from British colonial rule, Faisalabad city has grown steadily as Pakistan's preeminent textile manufacturing center, with related enterprises such as dyeing and finishing, to become the third most populous city in the country after Karachi and Lahore.

In addition, Faisalabad is home to Pakistan's largest ink and vegetable oil manufacturers. In the early 1960s, cotton production in the district declined as a result of increased waterlogging and salinity, and cotton gave way to more diversified agriculture during the Green Revolution.

National Context

Less than 40 percent of Pakistan's land area of 804,000 km^2 is suitable for agriculture and approximately 16.2 million ha are under irrigated cultivation. With an annual population growth rate of 3.1 percent, the population of 122 million is expected to double by 2020. The climate is arid or semiarid and large areas of the country are sparsely populated. Thirty-two percent of the population is estimated to be settled in urban areas.

Pakistan relies on irrigation from the Indus and its tributaries for more than 90 percent of its food and fibre production. The river basin spans nearly two-thirds of the country and is home to the largest irrigation network in the world. It drains 945,000 sq km, of which 530,000 sq km lie within Pakistan.

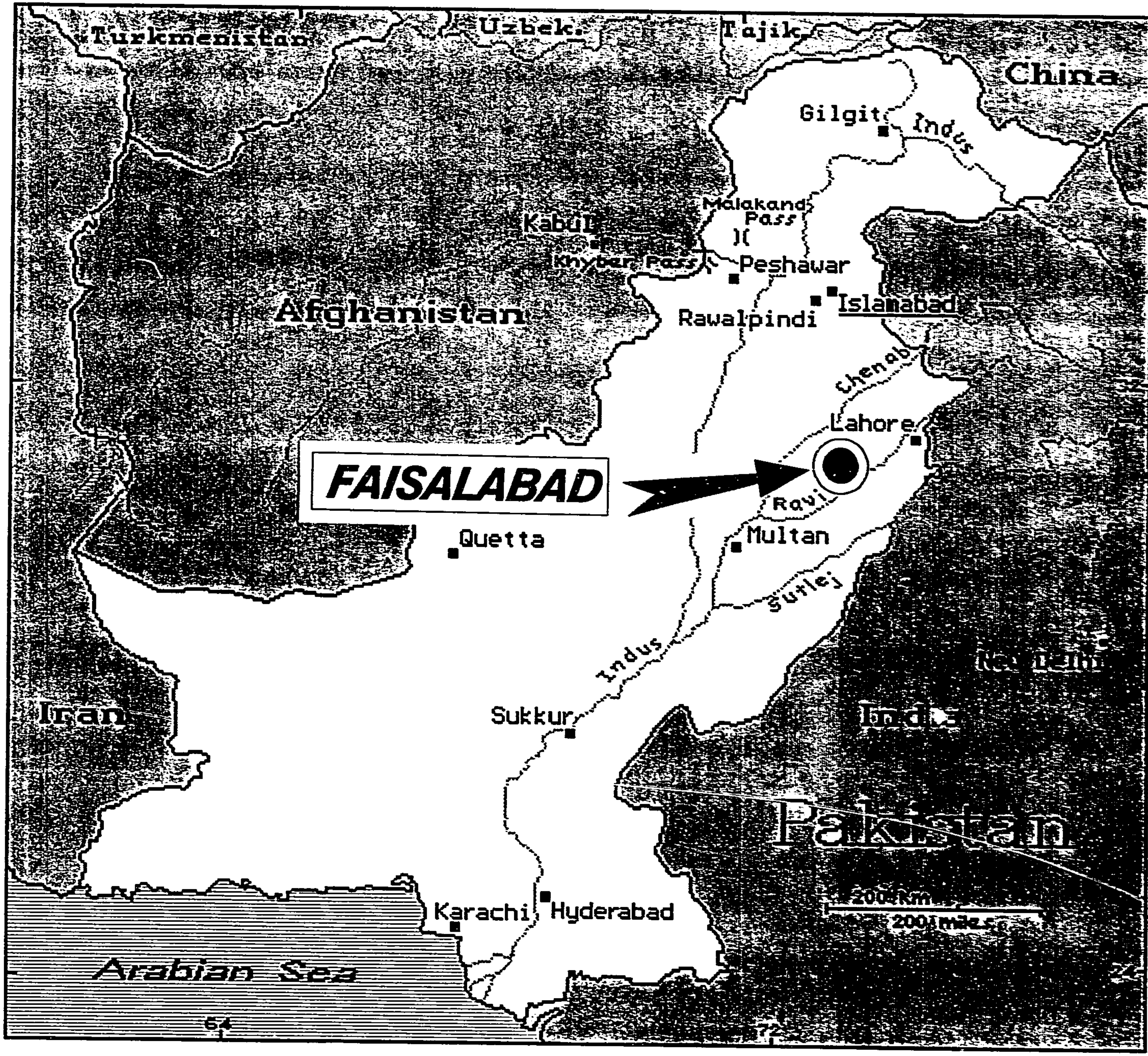


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FIGURE A.3 - PAKISTAN AND FAISALABAD

Nearly 95 percent of the flow in the Indus is used for irrigation, about 4 percent is diverted for municipal water supply and domestic consumption, and 1 percent is withdrawn for industrial purposes. Annual per capita consumption of water in Pakistan is estimated at 2,053 m^3.

Water Supply

The average annual inflow of the Indus into Pakistan is 170 BCM; it drops below 150 BCM once in five years. Approximately 128 BCM are already diverted at canal heads. Groundwater is a secondary resource, derived from surface water percolation. Of the annual recharge of groundwater, estimated at 57 BCM, more than 50 BCM are drawn up by tubewells and used; most of the unused recharge is saline.

Withdrawals have increased from 74 BCM to 128 BCM in the last three decades, thanks to projects under the Indus Basin Works Program supported by massive funding from the World Bank, USAID, and other donors. The Government of Pakistan plans to increase extraction to 140 BCM before 2020 to irrigate marginal lands. Undoubtedly, coastal mangrove swamps already under stress from reduced freshwater inflows, and shrimp fisheries that depend on the swamps, will be seriously damaged.

A water supply and sanitation sector study financed by the Asian Development Bank estimates that 80 percent of Pakistan's urban dwellers have access to piped water and 52 percent have access to sewerage, but that water supplies are delivered irregularly, for an average of 6 hours per day. The amount of nonrevenue (unaccounted-for) water in many systems is as high as 50 percent.

Although 70 percent of urban dwellers have access to a toilet, the treatment and safe disposal of wastewater are often deficient.

Water Resources and Issues

Each year, 123 BCM of water are diverted into the irrigation network. Of this amount, 96 BCM are available at the heads of watercourses. It has been estimated that up to 65 percent of all irrigation water is lost in conveyance because of evaporation, seepage, and poor management, leaving less than 30 percent for application to crops. Pakistan's groundwater table has risen by an average of 15 to 25 cm per year since construction of the canal system began in the nineteenth century. The adverse environmental impacts of surface irrigation are evident in widespread waterlogging and salinization, loss of forest cover, and decreased biodiversity.

The rural population of Faisalabad district draws irrigation water from the Jhang, Gugera, and Rakh branches of the Lower Chenab canal. Because the groundwater in 75 percent of the district is brackish, rural populations take drinking water from shallow wells located near irrigation watercourses in order to capture seepage. Over the past 20 years, the Public Health and Engineering Department has developed a network of shallow tubewells and canal water sedimentation/sand filtration facilities to meet the growing potable water requirements of smaller cities and towns throughout the district.

Until 1992, Faisalabad city relied on the Rakh branch for its drinking water supply. But as the demand rose with the expanding population, the Faisalabad Development Authority embarked on a massive scheme to pump potable water to the city from a tubewell field 30 km to the northwest on the banks of the Chenab.

Much of the drinking water in Pakistan becomes contaminated before end-use. In the rural areas, contamination arises from polluted sources, storage in contaminated vessels, and poor handling. In the cities, leaking sewers, low pressure in water mains during supply intermission, and faulty underground tanks account for poor water quality. Sixty percent of all deaths below the age of five and 33 percent of all adult deaths are attributable to waterborne disease.

Malaria is again becoming a scourge. New drugs and biocides had an enormous appeal for public health authorities seeking to control malaria in the tropics from the 1950s because the initial application of these substances gave dramatic results. Pakistan's malaria eradication campaign, begun in 1961 and based solely on the spraying of houses with DDT, succeeded in reducing the annual number of cases in rural areas from 7 million to 10,000 by 1967. When the campaign collapsed by 1971 because of widespread resistance of the malaria mosquito to DDT, a total of 23,000 metric tons of DDT had been sprayed.

By 1972, the annual number of malaria cases had risen to 10 million. Instead of returning to the drainage programs successfully used against the malaria mosquito in the early part of the century, the public health authorities turned to the newer biocides, including BHC and malathion, in areas where DDT resistance was emerging. They also added the widespread use of chloroquine for treating persons at risk from malaria. DDT was used intermittently until 1983, when it was completely replaced by malathion. By 1992, malaria control was a failure; donors no longer contributed biocides and drugs to the program. As a result, malaria is again rampant.

Pakistan was never able to sustain the program alone. It was supported largely by donors and their national commercial interests, which encouraged the use of these synthetic chemicals. USAID gave $144 million to the program from 1963, most of it in the form of biocides such as DDT and malathion.

Despite the availability of simple preventive measures such as bed nets, drainage and filling of mosquito habitats, use of fish to control mosquito larvae, and screening of sleeping areas, the public health authorities have not added these methods to their strategy. If they had, the biocides and drugs could have been kept in reserve for the epidemics that follow large-scale flooding.

No effective wastewater treatment is provided for any of the 300 industries in Faisalabad. The provincial environmental authority has one person with no effective resources to control industrial waste pollution.

Khon Kaen, Thailand

The northeastern province of Khon Kaen, with a population of nearly 1.7 million, is Thailand's fifth most populous province (after Bangkok and three other northeastern provinces: Nakhon Ratchasima, Ubon Ratchathani, and Udon Thani). Khon Kaen city (see Figure A.4), the capital of the province, is located 360 km northeast of Bangkok on the "Freedom Highway" (Highway 2) and the rail line that links all the region's major cities.

Khon Kaen municipality has an area of approximately 46 sq. km. The municipality and its environs have grown rapidly since the 1960s with the development of agroindustry, light manufacturing, public administration, and the service sector. With an estimated 1993 population of 135,000, Khon Kaen is Thailand's sixth largest city.

Despite more than three decades of public sector investment in irrigation infrastructure, only 8 percent of the province's arable land is served by a perennial system and water use efficiency on that land is poor. Agriculture is still dominated by subsistence production of rice, both the glutinous and nonglutinous varieties, during the wet season. Cash crops such as cassava, sugar cane, kenaf (a fibre plant used for paper pulp), and soybeans are cultivated on upland farm holdings. The steady growth in wages for off-farm employment within the region has discouraged farmer investment in dry season cultivation of food crops, even in irrigated areas.

National Context

Thailand has a total land area of 513,000 km^2, 47 percent of which was agricultural as of 1986. Forest cover has diminished to less than 20 percent of the country's land area.

Thailand's population grew rapidly from 17.4 million in 1950 to 47 million in 1980, and surpassed 58 million in 1992, yielding an average density of 113.5 persons per km^2. Though the annual growth rate has declined considerably over the past decade to 1.4 percent, the total population is still expected to reach

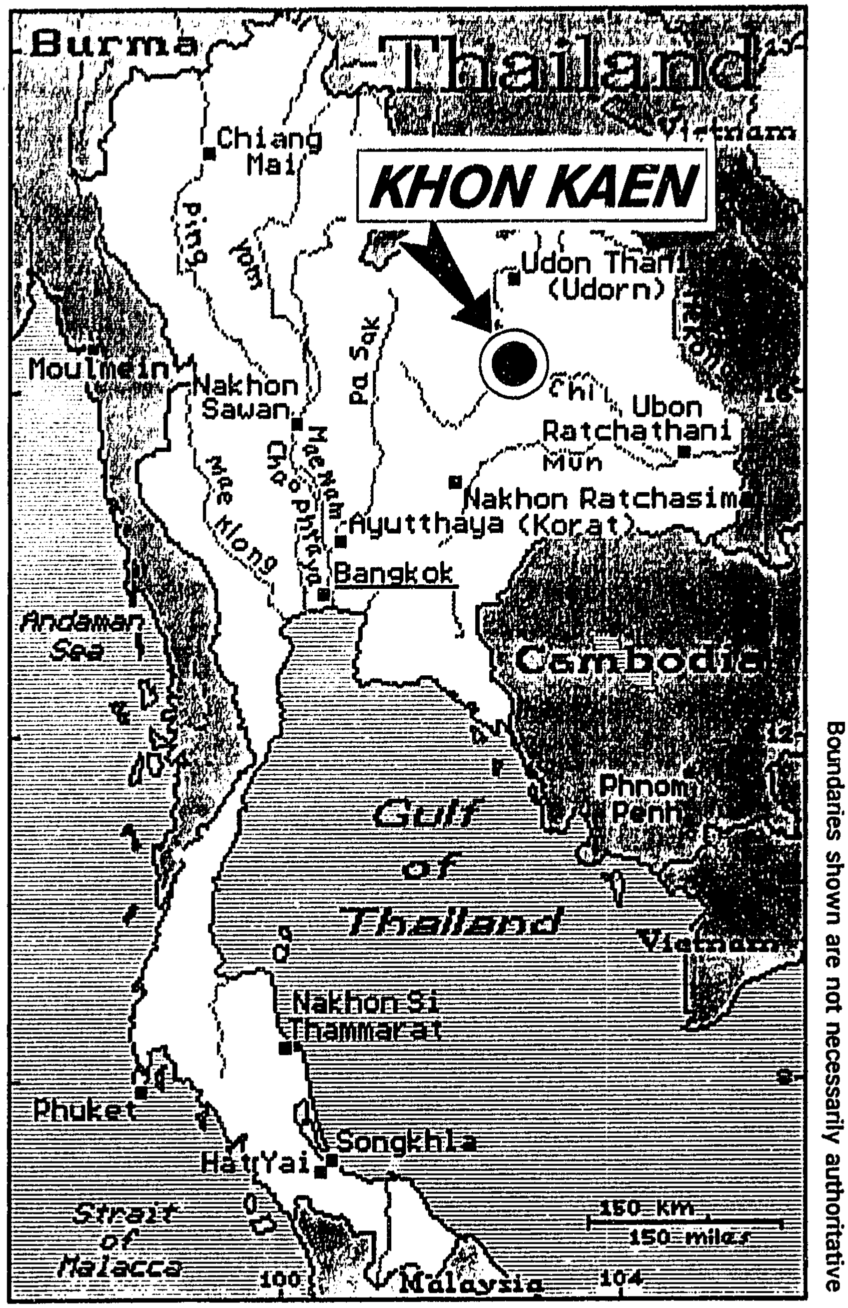

FIGURE A.4 - THAILAND AND KHON KAEN

70 million by 2010, with almost all of the increase occurring in urban areas. Rural areas may even decline in population after 2010.

Thailand has a tropical monsoon climate. The northern, northeastern, and central regions receive some 85 percent of their rainfall during the southwest monsoon season from May to October. Mean annual rainfall ranges from about 1,100 mm in parts of the north and northeast to over 2,000 mm in the south. Wet season rainfall is generally adequate for rice cultivation, but irrigation is usually required for dry season crops, except in the south. Total rainfall amounts to about 800 BCM per year.

The past 35 years have seen Thailand's irrigated land almost triple, from 1.4 million ha in 1958 to 4 million ha today. As of 1987, three-quarters of this area was served by large irrigation schemes (covering more than 20,000 ha), although the 1980s saw an emphasis on small- and medium-scale irrigation projects, particularly in the northeast.

The seasonal distribution of rainfall causes a marked difference between wet and dry season flows. The Royal Thai Government has constructed hundreds of dams and reservoirs in recent decades to regulate flows and reduce flooding, and to capture a greater portion of the runoff for productive purposes. Most of Thailand's usable groundwater occurs in the Chao Phraya floodplain. Most of the northeast is poorly endowed with good quality groundwater outside of narrow riverine alluvial zones.

The Regional Context

In contrast to the rest of Thailand, the northeast is classified as a semiarid tropical agricultural region. Its longer dry season, combined with wide variations in the amount and timing of rainfall from year to year, makes agriculture dependent upon irrigation for much of the region. Nevertheless, at present, of the 9 million ha cultivated, only 8 percent is irrigated by some form of public or private system. Because of limited water supplies, no more than 20 percent of the agricultural land in the northeast is potentially irrigable.

While the water supply would be adequate to meet current demand were it uniformly distributed and available throughout the year, there are localized shortages in many areas of the northeast, especially during the dry season.

In Thailand, domestic/municipal water in urban areas is usually piped from water treatment plants, while water in rural areas comes from rainwater jars, shallow or deep wells, manmade ponds, or rivers and streams. Water use ranges from 50 liters per person per day in rural areas to several times that figure in urban areas with piped water connections.

In Thailand, agriculture accounts for 90 percent or more of water consumption. However, the efficiency of water use (evapotranspiration divided by water supplied) in Thai irrigation is understood to be only 30 percent. Industry uses 6 percent (with the demand increasing rapidly) and domestic use accounts for 4 percent of water withdrawal. About 85 percent of the water used for industrial purposes is believed to become polluted wastewater.

Groundwater has been heavily exploited for domestic and industrial purposes in the Bangkok metropolitan area, and also in other urban and some rural areas. Extraction around Bangkok was estimated to exceed the estimated safe level by at least 0.5 million m^3 per day in 1986, and has not declined. As a result, land in the Bangkok region is subsiding, in some places at a rate of 10 cm per year. Saltwater intrusion is also a growing threat as a result of this unsustainable rate of exploitation. Consequently, the Bangkok Metropolitan Waterworks Authority is now making plans for a large diversion from the Mae Klong river, 100 km to the west, to quench Bangkok's ever-increasing domestic and industrial thirst.

Water Resources and Issues

In the early 1980s, Khon Kaen was selected by the government as the northeastern municipality to receive assistance under the Regional Cities Development program, which provided funds for municipal water and sewage system development with the help of multilateral donors.

It is estimated that almost 61 percent of the flow of the Nam Phong river in Khon Kaen province is being withdrawn now. Overall per capita water availability has declined by 35 percent in the past 20 years. Continued growth in industrial and domestic demand can be expected to exacerbate the situation.

The city's potable water system is owned and operated by the Provincial Waterworks Authority, which estimates that unaccounted-for water amounts to about 52 percent. Wastewater from Khon Kaen is now treated in a multistage stabilization lagoon system, which has improved water quality in the lake that receives the discharge. Fees are charged for water supply but not for wastewater disposal, the costs of which are borne by the municipality. Industries in and near Khon Kaen include pulp and sugar mills and other agriculture-related industries, and light industries including metal finishing. The river is sampled only three times per year at four stations.

In Khon Kaen province, the most pressing water resource conflict arises from industrial wastes, both treated and untreated, that contaminate the Nam Phong river. Negative environmental impacts of contamination increase during the dry season, when flows are insufficient to assimilate wastes effectively. The possible long-term effects such as bio-accumulation of toxic elements are undetermined at this point, but kills of fish and other aquatic life are becoming increasingly common, and farmers fear their crops are suffering from degraded water quality. This highlights an important relationship between water quality and quantity.

The province and the municipality of Khon Kaen have made major progress in the past decade in providing high-quality drinking water (both rural and urban), handling urban sewage, and promoting public health education. Gastrointestinal diseases related to water quality and sanitation have declined as a result of these programs.

Dengue haemorrhagic fever was reported in Khon Kaen, albeit without reliable statistics of its prevalence. It is known to be on the rise in some rural areas of Thailand, but can be prevented by keeping domestic water jars covered to prevent mosquitoes from breeding in them (Strickman et al. 1991). No malaria was reported in the province. Liver flukes, most likely from eating raw fish, are still a problem. As a whole, water-related public health concerns appear to be declining in Khon Kaen.

Deforestation ranks as a significant constraint to conservation and efficient management of water. Forest cover in Khon Kaen province has declined by nearly 60 percent over the last 20 years. This upsets the natural modulation of water flows, resulting in greater extremes during times of both drought and flood. It also increases upland soil erosion and exacerbates siltation of irrigation water conveyances and control structures, as well as sedimentation of reservoirs.

Water management is very complicated in Thailand. Eight national ministries, over 30 agencies and departments, and some 20 committees share some responsibility for various aspects of management and development. The agencies mainly responsible report to the Ministries of Interior and Agriculture and Cooperatives. There is a National Environment Board under the Ministry of Science, Technology, and Environment that collects data and establishes standards but does not directly review the programs or projects of other agencies.

Summary of Basic Data

Table A.1 summarizes basic water-related information on the four study areas and countries.

Table A.1
Summary of Basic Data

	Fayoum	Beni-Mellal Tadla	Faisalabad	Khon Kaen
Population: Urban	0.4	0.3	2.0	0.2
Total	1.8	1.2	6.0	1.7
Area Irrigated (sq km)	1,300	1,140	4,470	503
Water Supplied (BCM/yr)	2.3	3.4	6.0	1.03
Water Supplied (cu m/sq m/yr)	1.37	2.3	1.3	2.0
Water Supplied (cu m/cap/yr)	1,280	2,830	1,000	609
	Egypt	**Morocco**	**Pakistan**	**Thailand**
Population (million)	56	25	125	58
Water Available (BCM/yr)	58	30	468	179
Water Available (cu m/cap/yr)	1,040	1,200	3,700	3,100
Percent Abstracted	97	37	33	18
Water Abstracted (cu m/cap/yr)	1,000	440	1,240	560

Appendix B

SUBSECTOR WATER CONSERVATION AND EFFICIENCY

Water subsectors differ in their use of water, their opportunities for conservation, and even their terminology.

Figures B.1, B.2, and B.3 present simplified cycles of typical water use by the municipal, industrial, and irrigation water subsectors, respectively, showing points where water is beneficially used or lost, where conservation is possible, and where flows can be measured or accurately estimated.

Except in industrial use, the points where water can be conserved do not always correspond with those where flows can be readily measured. In consequence, the recoveries from such conservation measures as reduced delivery/distribution system leakage, or reduced wastage by customers, may not be immediately quantifiable and may take time to show up as increased water availability.

Efficiency means the ratio of output to input. For water use, this can be taken to mean the ratio of water that is beneficially used to the demand, where the difference between the two amounts includes leakage and wastage. Beneficial use has no agreed definition; demand is the amount taken by customers from the delivery system. The only water subsector that has a clear measure for efficiency (and hence for beneficial use) is agriculture, where it is reckoned as evapotranspiration divided by demand. Beneficial use is thus equated with evapotranspiration, which may include some unproductive loss by evaporation, depending on the method of application. The level of evapotranspiration that corresponds to the optimum level for plant growth is readily estimated and is usually used as the numerator of the ratio. Since this may exceed the amount actually evapotranspired, it tends to overstate beneficial use and the efficiency of use. On the other hand, this approach treats all seepage as a loss even though some seepage is essential to prevent salt accumulation.

Urban and industrial systems, however, have no agreed way to measure the efficiency of water use, although here also efficiency implies minimizing wastage and losses. Even in irrigation, efficiency has a different significance according to whether it applies to an individual farm or a basin. Reuse gives a basinwide system greater efficiency than the individual farms in the basin.

Consumptive use (or water consumption) refers to both beneficial and wasteful uses that prevent water from returning to the resource. It involves water quality to the extent that water lost to a salt sink, or to a water body too polluted to be usable, can be regarded as having been consumed. There is no general consensus on whether the definition covers water contaminated before it returns to the resource, even if this renders the resource unusable for some purposes. In the urban water subsector, consumption is sometimes taken to mean beneficial or conscious use (that is, excluding what is lost through dripping taps or overflowing cisterns), or water that is discharged after use to the sewer. Therefore, while consumptive use is a useful term for overall resource management in the absence of pollution, it is not helpful in water subsectors that want to distinguish between beneficial use and combined wastage and leakage.

Even within subsectors, conservation opportunities are not limited to the nonbeneficial part of demand, since consumers can use less than optimum amounts of water for plant growth, change to crops that need less water, alter their personal water-use habits, or install domestic water-saving devices. Therefore, while efficiency is a useful notion that implies effective use and loss reduction, it is not a universally definable goal or a generally valid quantitative measure of performance in water conservation.

Efficiency of water delivery, meaning the quantity of water delivered to customers in relation to the quantity entering the system, indicates the effectiveness of the delivery system but gives no indication of the nature, destination, or effects of the losses. The converse—unaccounted-for or nonrevenue water--in the municipal water subsector relates facility losses plus meter underregistration to water entering the system, and is generally used to measure the performance of distribution systems, including customer metering.

There is a need for agreed measures of performance in reducing water losses and wastage both in delivery systems and on users' farms and premises. These should be applicable or comparable in all water subsectors.

FIGURE B.1 - ILLUSTRATIVE SIMPLIFIED MUNICIPAL WATER CYCLE

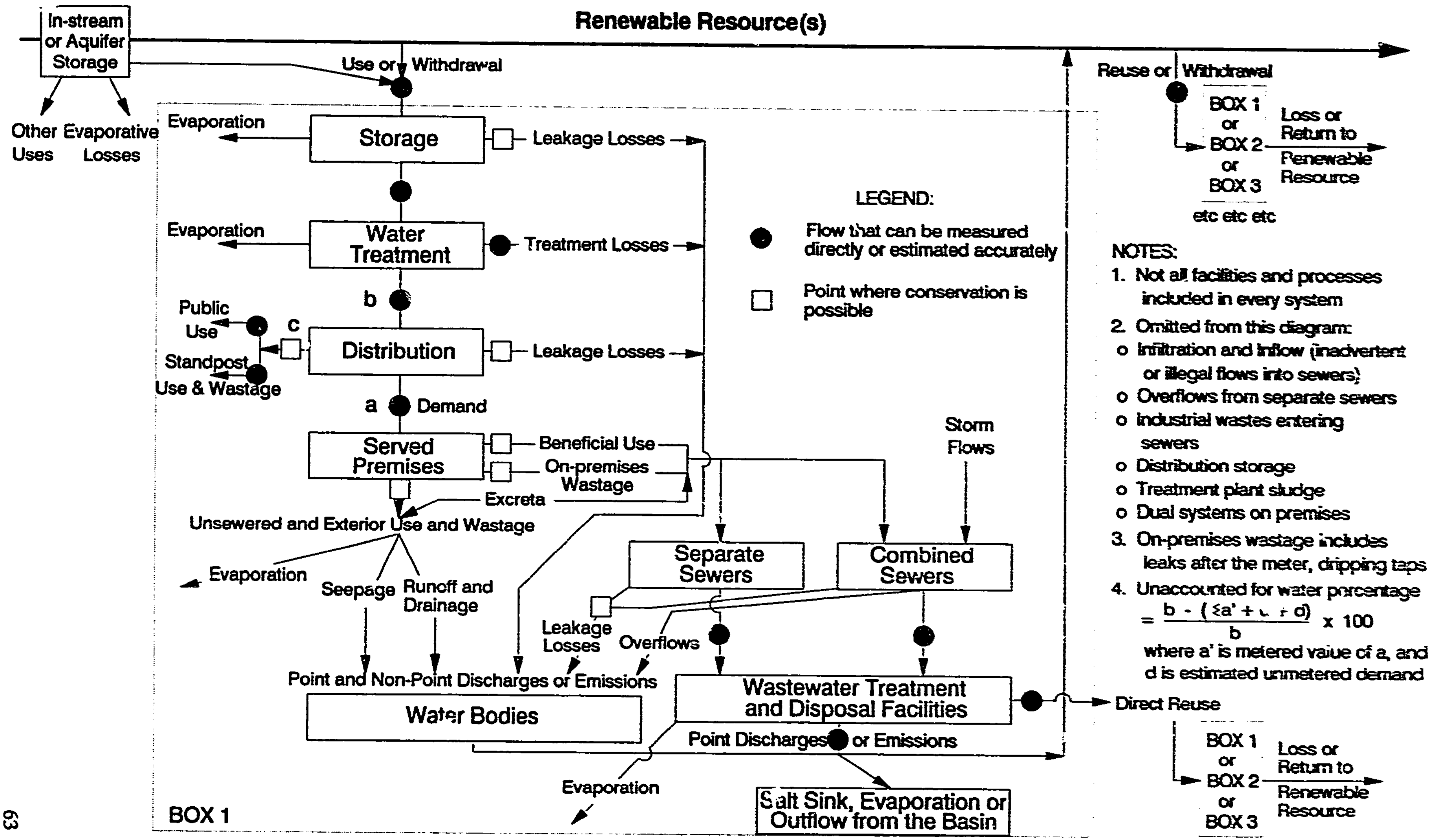

FIGURE B.2 - ILLUSTRATIVE SIMPLIFIED INDUSTRIAL WATER CYCLE

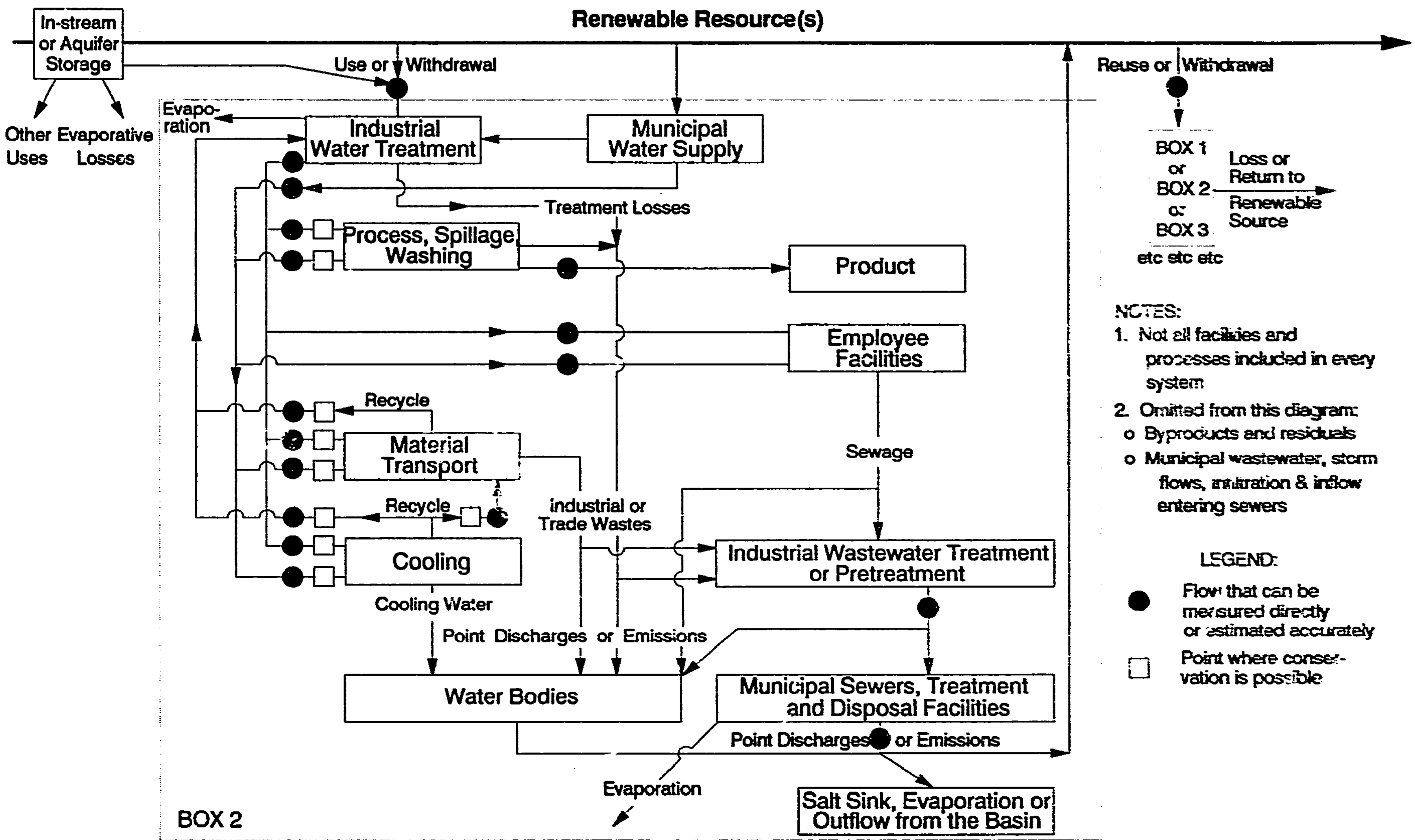

FIGURE B.3 - ILLUSTRATIVE SIMPLIFIED IRRIGATION WATER CYCLE